Colorado River Conversations Project
Scenario Planning Workshop Series Final Report

June 2020

Organized by the Center for Climate Adaptation Science and Solutions and Martin & McCoy LLC

Center for **Climate Adaptation Science** and **Solutions**

MARTIN & McCOY

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I. Progress Report Overview

This document summarizes three Scenario Planning workshops that were held as part of the Colorado River Conversations Project, funded by the Walton Family Foundation. This final report includes a concise overview of the purpose, summary, analytical methodology, and next steps of the workshop series. The agendas, participants, discussion summary notes, and outputs of the workshops are presented sequentially in the Appendices.

II. Purpose of the Scenario Planning Workshop Series

The overarching goal of the three scenarios workshops was to explore the areas of uncertainty outside the parameters of most planning discussions. For example, what are plausible black swan events that could occur within the context of extreme climate conditions? This may include a future that includes prolonged and severe drought, megafloods, and other social, economic, environmental, and governance extremes. The aim was to collectively co-create a broad set of scientifically supported "what if" storylines that explore the implications of low probability/high consequence climate events, as well as a range of other drivers that influence risk.

III. Summary of Workshops

The three workshops were held over 10 months and designed to progressively evolve the conversation from an initial brainstorm of drivers to a final discussion of low-regret solutions and next steps (Table 1). All three workshops were attended by roughly 30 people representing interests across the seven basin states.

Table 1. CRC Scenario Planning Workshops

	Date	*Location*	*Objectives*
Phase 1	June 2019	Boulder, Colorado	Set the context Identify and rank "nightmare" drivers Select plausible low probability/high consequence scenarios, in the context of extreme drought and catastrophic floods
Phase 2	October 2019	Tucson, Arizona	Present detailed scenarios Brainstorm impacts (e.g. legal/political, governance, ecological, physical, social, and economic) across the Basin
Phase 3	April 2020	Virtual	Identify common solutions that address multiple challenges Focus on pathways to build more robust systems Describe useful ideas and research paths forward, specific to themes that are common to many different futures

The first workshop, held in June 2019 in Boulder, Colorado, focused on identifying plausible low probability/high consequence disruptive socio-economic and water management events within the context of extreme drought and catastrophic floods. The workshop agenda extended beyond the traditional planning parameters and offered water managers the space to consider the uncomfortable extremes that keep them up at night and may be outside the capacity of a utility or agency to absorb or discuss. Over the course of the day, the workshop participants identified a list of future climate scenarios, a list of "nightmare" drivers, and developed preliminary storylines.

Eight storylines were then developed to a) reflect climate change drivers and other "nightmare" drivers and b) provide a description of the hypothetical future created by a climate driver and two additional drivers

(e.g. governance, economics, the economy, etc.). The storylines outline a qualitative description of the future, as well as evidence supporting the trajectory of three drivers derived from current scientific literature, historical precedent, and current conditions.

The second workshop was held in Tucson, Arizona from October 30-31, 2019, and was designed to a) present detailed scenarios and b) discuss the implications of each storyline. To identify and discuss the impacts from each storyline, workshop participants broke into two groups, with each group focusing on four storylines over the course of the workshop. Six categories of impacts helped to guide the discussion and included implications to: Legal/Political, Governance, Ecological Risks and Conditions, Economics, Social, and Physical Conditions throughout the Basin. Following the break-out sessions, the group concluded the workshop with a high-level brainstorm discussion about next steps. The group identified several ideas to continue the discussion, including finalizing the storylines, considering what direction to take the process, and developing summary materials for the workshops thus far.

The third and final workshop was held on April 6-7, 2020 and identified common solutions across four storylines (condensed from the eight by the CRC project team). While the original project plan only called for two workshops, participants were very engaged in the process and requested a third workshop to build on the momentum and discuss low-regret, broadly applicable solutions. Due to the COVID-19 pandemic, the workshop was held remotely via Zoom and included breakout groups and online polling to facilitate an interactive discussion (Figure 1). For each storyline, participants discussed solutions that would mitigate the impacts of each storyline, as well as trade-offs around the benefits and/or challenges of each solution. Then, participants considered common solutions across storylines. Finally, participants prioritized these common solutions and elaborated on each. The final workshop closed with a discussion of paths forward, including specific opportunities for collaboration, to continue the conversation.

The approach for the Colorado River Conversations Project overall and the Scenario Planning workshops in particular has been co-developed with an Advisory Committee (see Appendix A). The committee's input in designing the overall approach and throughout the course of the project was been essential. With the committee's help, the project team convened a group of people that represented high level players in all seven basin states, including water utilities, agriculture, water user associations, academia, NGO's, tribes and Mexican representatives. In most cases, participants were influential staff rather than the highest-level negotiators for each state. With few exceptions, the project received high levels of interest and support. The project team is very grateful for a partnership with Daryl Vigil and Matt McKinney, who assisted the project in connecting and building relationships with tribes in the basin.

Figure 1. Photo of some participants during the most recent Scenario Planning Workshop, held remotely in April 2020.

IV. Analytical Methodology

Scenario planning allows managers to strategically envision an assortment of possible futures that highlight key areas of uncertainty, as well as identify broad options for living within those areas of uncertainty. These futures may be near-term and simple (e.g., What happens if there is very high rainfall in the spring on top of heavy snowpack? What if several years of extreme drought begin when reservoir levels are already very low?), or they may be long-term and complex, addressing highly uncertain interactions (e.g., What if over the next 50 years precipitation extremes increase while the budget for flood/river management is cut in half?) (Moore et al. 2013).

Scenario planning is not a means of predicting the future, but rather is a systematic way of bracketing uncertainty (Figure 2) (Moore et al. 2013). The involvement and contributions of diverse participants is key to creating a shared understanding of risks, trade-offs, and possible management actions. In developing scenarios around climate change and other stresses, the process offers a way to articulate the potential consequences of uncertainty in a way that empowers decision makers to prepare and respond.

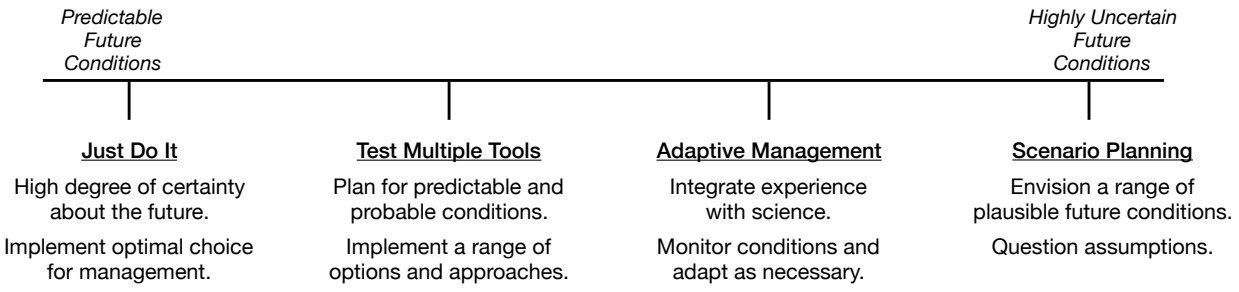

Figure 2. Role of Scenario Planning in Management Responses (adapted from Moore et al. 2013)

The Intergovernmental Panel on Climate Change (IPCC) definition of scenario is a "plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of

assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline" (IPCC 2008).

These futures can integrate a range of conditions, including historically average projections, extremes, and low probability but highly disruptive events. Qualitative data can be used, including popular opinions about climate change or political leadership, as well as quantitative data, such as climate information. Future planning horizons may also vary to encompass both short- and long- term projections.

There are numerous different and quite effective methodologies for scenario planning. The project team worked with Ralph Marra, of Southwest Water Resources Consulting, a well-known scenario planning expert, used materials from the University of Arizona webpage on Scenario Planning for Climate Adaptation (https://www.adaptationscenarios.org/) and drew specifically upon three primary sources of information (listed in the Citation section) to craft the methodology for this two-part workshop. In the following section, the scenario planning process is broken down into six steps that were conducted in order, over the course of the three workshops (Figure 3). Additional definitions can be found in the Glossary of Terms in Appendix B.

Steps 1-3 were completed at the first scenario planning workshop in Boulder in June 2019. The agenda for this first workshop is presented in Appendix C and participants in the first workshop are presented in Appendix D. Step 4 was completed in summer and fall 2019. Step 5 occurred at the second scenario workshop in Tucson in October. Step 6 occurred in April 2020 at the third workshop held over Zoom.

Figure 3. Colorado River Conversations Project Scenario Planning Approach

Step 1: Setting the Context

This scenario planning process began by defining an overarching planning goal, workshop goals, the geographic scope, and the planning horizon. For the Colorado River Conversations Project, the overarching goal of the scenarios workshops was to explore the areas of uncertainty outside the parameters of most planning discussions. Specifically, an emphasis was placed on identifying low-probability but nonetheless plausible black swan events that could occur within the context of extreme climate conditions (Figure 2). The first workshop focused on identifying various combination of drivers that could cause a significant disruption in conditions within the basin. The geographic scope of the Project includes the entire basin within the U.S. and Mexico including tribal nations. The planning horizon extends through about 2050 to incorporate the near-term renegotiation effort, as well as longer-term management conditions under new guidelines.

Figure 4. Scope of Scenario Planning Workshop

Step 2: Identification of Drivers

Step two in scenario planning focused on 1) developing a list of possible drivers and 2) identifying the trend, possible impacts, or disruptor for each driver. A driver, or driver of change, is something that influences a plausible future and is distinct enough to determine the potential impact it will have on that future. Drivers of change can cause one or many disruptions which can lead to unprecedented extreme outcomes.

Extreme drought and flooding are the key master drivers and may include changes in future temperatures, precipitation, and drought frequency and severity. Therefore, the first discussion of drivers focused on identifying plausible climate extremes as the master variable in the system.

The relationship between changing climate conditions and shifts in water supplies is not the only influential trigger for potentially disruptive future conditions. Other drivers are important to consider as well, such as changes in demands, supply augmentation, technology, land use planning, energy availability and costs, water law issues, governance, and regulations (Stratus Consulting and Denver Water 2015). The summary of notes from the full workshop discussion are presented in Appendix E, and the final set of drivers that were developed at the June 2019 workshop are presented in Appendix F.

Step 3: Choose Scenarios

Scenarios are plausible futures that help envision and evaluate the outcomes of potential decisions in the context of different sets of background conditions. In this case, "plausible" is contextualized and defined by the participants. Importantly, this approach to scenario planning is only useful if the storylines themselves are legitimately plausible (and/or conceivably possible, even with a very low probability) to the participants. In this approach, the storylines should ideally be very different from one another and should consider relatively well-known trends or threshold-type drivers.

To develop the scenarios, participants chose three of the identified important drivers and mapped them using three axes as shown in Figure 3. From the intersection of the three drivers, eight possible future scenarios can be named and described within the axes. The final step of the June 2019 workshop was to select which of the future scenarios to develop further into storylines. The complete set of storyline matrices that were developed at the June 2019 workshop are presented in Appendix G.

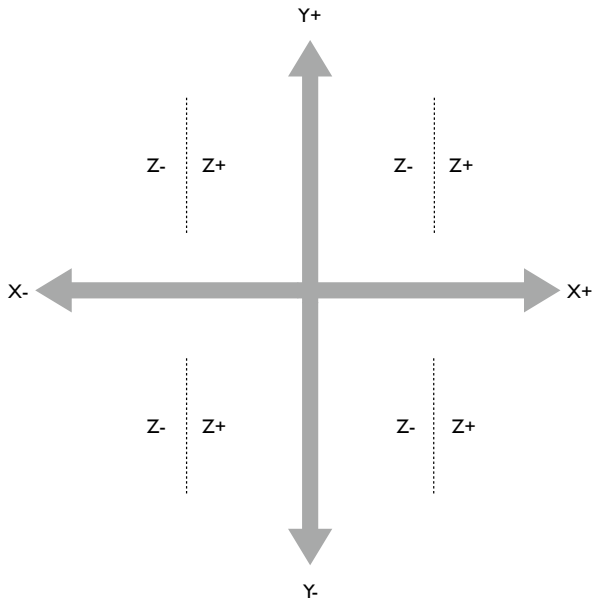

Figure 5. Three-Dimensional Matrix for Organizing Drivers into Scenarios (adapted from Southwest Water Resources Consulting)

Step 4: Develop Details about the Scenario Storylines

Following the workshop, the eight selected scenarios were developed from the foundation of intersecting drivers that were selected by the participants. For each scenario, an overarching storyline was developed to paint a more accessible picture of future conditions, and each was given a name. Current scientific literature and historic evidence of the proposed future conditions was used to set a scientific context for those conditions. Background evidence and/or trend information was provided for each of the three drivers, including a range of recent climate studies. A citation list was provided for the literature referenced. Each of the eight storylines are presented in full in Appendix H.

Step 5: Impacts of Scenarios

At the October workshop, six categories of impacts were discussed for each of the storylines:

- Legal/Political
- Governance
- Ecological
- Physical
- Social
- Economics

The agenda for the October workshop is presented in Appendix I, and the list of participants is presented in Appendix J. The full list of impacts that were identified and discussed at the October 2019 workshop are presented in Appendix K, and the summary of the concluding discussion is presented in Appendix L.

Step 6: Identify Common Solutions

Following the second workshop, the project team re-configured the original eight storylines into four storylines and included their associated impacts. These four storylines highlighted the full range of drivers developed in the scenario planning process and each one pointed to a distinct and different future. The

goals of Workshop #3 included developing common themes that could be found in most (if not all) of the four storylines, identifying directions for low-regret strategic solutions, and describing useful ideas and pathways forward. The agenda for the third and final workshop is presented in Appendix M, and the list of participants is presented in Appendix N. The four storylines and impacts are presented in full in Appendix O and a summary of the solutions and concluding discussion is presented in Appendix P.

V. Concluding Thoughts and Insights

There is a strong sense among the project team and the participants that this project has opened up a new set of conversations and essentially given "permission" to start engaging in difficult discussions about very low probability but high consequence futures that responsible water managers need to at least acknowledge are possible. In reality, this project has been more successful than expected, in part because of the enthusiastic engagement of highly influential players in the Colorado River basin.

Over the course of the three workshops, it became increasingly clear that when given a creative, safe space, people are not only willing, but also eager, to engage in unsettling and challenging conversations. Throughout the process, participants acknowledged the range and level of risk to water supplies and discussed new ideas for actions, if taken now, to reduce risk. Individually and collectively, participants were ready to step into a courageous and creative conversation about uncertainty, and ways they could work together to prepare for unexpected future events. In addition, the group acknowledge that a diversity of perspectives, needs, and values is essential to create a well-rounded way of knowing the river and managing water.

The evaluation forms reflected the many practical reasons for being part of these discussions, and a number of participants have mentioned how much they learned by considering the intersection of social and natural issues in new ways and from varying perspectives. The overall project has received public accolades in at least three major venues: the Boulder Martz conference in June, the Water Education Foundation conference in Santa Fe, and the Colorado River Water Users Association meeting in Las Vegas.

VI. References

IPCC – Intergovernmental Panel on Climate Change – Fourth Assessment Report (2008). Glossary. Climate Change 2007: Synthesis Report. IPCC Press. Accessed November 19, 2012 http://www.ipcc.ch/publications_and_data/ar4/syr/en/annexes.html.

Moore, S.S., N.E. Seavy, and M. Gerhart. 2013. Scenario planning for climate change adaptation: A guidance for resource managers. Point Blue Conservation Science and California Coastal Conservancy.

Southwest Water Resources Consulting (https://swrcscenarios.com/) and conversations with principle, Ralph Marra (April-May 2019).

Stratus Consulting and Denver Water. 2015. Embracing Uncertainty: A Case Study Examination of How Climate Change is Shifting Water Utility Planning.

VII. List of Appendices

Overarching Documents

Appendix A Advisory Committee Members
Appendix B Glossary of Terms

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Appendix C Agenda
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Appendix E Summary Notes
Appendix F Full Set of Drivers
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Appendix M Agenda
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Appendix O Four Storylines Discussed in Workshop #3
Appendix P Summary of Solutions and Concluding Discussion

Appendix A – Advisory Committee Members

Mike Connor – WilmerHale
Jennifer Gimbel – Colorado State University
Chris Harris - Colorado River Board of California
Laurna Kaatz - Denver Water
Vineetha Kartha - Arizona Department of Water Resources
Eric Kuhn - Retired Water Manager and Author
Jennifer Pitt - National Audubon Society
Jack Schmidt - Utah State University
Seth Shanahan - Southern Nevada Water Authority
Brad Udall - Colorado State University
Darryl Vigil - Jicarilla Apache Nation
Steve Wolff - Wyoming State Engineer's Office

Appendix B – Glossary of Terms

Drivers – Something that influences a plausible future and is distinct enough to determine the impact it will have on that future. The words "factors," "trends," "forces," "variables," and "drivers of change" are used variously to indicate the same concept in the scenario planning literature. This report uses the term drivers of change, or drivers.

Process – Something that takes place over a long period of time, defined in terms of years, decades, or centuries.

Event – An occurrence with a duration in shorter terms, such as hours or days.

Plausible – A highly situational condition that is defined by the participants in scenario planning. Notably, scenario planning in only as useful as the scenarios are plausible to the participants.

Scenarios – Plausible futures that help envision and evaluate the outcomes of potential decisions in the context of different sets of background conditions.

Uncertainty – The extent to which something is unknown because of:

- Lack of information
- Disagreement about how to interpret
- Ambiguous definitions
- Lack of understanding of underlying processes
- Errors in observation
- Lack of Model Skill

Appendix C – Agenda: Workshop #1

Colorado River Basin Conversations – Scenario Planning Workshop
June 5, 2019

Purpose

The overarching goal of the two scenarios workshops is to explore the areas of uncertainty outside the parameters of most planning discussions. For example, what are plausible black swan events that could occur within the context of extreme climate conditions? This may include a future that includes extreme drought, megafloods, and other social, economic, environmental, and governance extremes. The aim is to collectively co-create a broad set of scientifically supported "what if" scenarios that explore the implications of low probability/high consequence climate events, as well as a range of other drivers that influence risk.

The goal of the first workshop focuses on identifying various combination of drivers that could cause a significant phase shift in conditions within the basin. The geographic scope of the full project includes the entire basin within the U.S., Mexico, and tribal nations. The planning horizon extends through about 2050 to incorporate the near-term renegotiation effort, as well as longer-term management conditions under new guidelines.

Agenda

8:30 – 9:00	Registration and Breakfast
9:00 – 9:15	Welcome
9:15 – 10:15	Introductions
10:15 – 10:30	Overview of the Day
10:30 – 10:50	Break
10:50 – 12:00	Full Group Discussion – Defining Wet and Dry Extremes
12:00 – 12:50	Lunch
12:50 – 2:40	Full Group Discussion – What Keeps You Up at Night?
2:40 – 3:00	Break
3:00 – 4:00	Breakout Discussion – Develop Storylines
4:00 – 4:10	Transition
4:10 – 4:50	Full Group Discussion – Reporting on Storylines
4:50 – 5:15	Wrap-Up and Next Steps

Appendix D – Participants: Workshop #1

Participants

Homey Bon, Comisión Nacional del Agua
Bidtah Becker, Navajo Nation
Peter Culp, Culp & Kelly
Aaron Derwingson, The Nature Conservancy
Tom Davis, Yuma County Water Users Association
John Fleck, University of New Mexico
Terry Fulp, Bureau of Reclamation
Jennifer Gimbel, Colorado State University
Chris Harris, Colorado River Board of California
Mark Harris, Grand Valley Water Users Association
Carly Jerla, Bureau of Reclamation
Laurna Kaatz, Denver Water
Jamie Kelley, Mohave County
Eric Kuhn, Author
Jeff Lukas, Western Water Assessment
Mohammed Mahmoud, Central Arizona Project
Clayton Palmer, WAPA
Jennifer Pitt, National Audubon
Jack Schmidt, University of Utah
Seth Shanahan, Southern Arizona Water Association
Rebecca Smith, Bureau of Reclamation
Tim Thomure, Tucson Water
John Weisheit, Living Rivers
Steve Wolff, Wyoming State Engineer's Office

Project Team

Kathy Jacobs, University of Arizona
Andrea Gerlak, University of Arizona
Season Martin, Martin & McCoy
Amy McCoy, Martin & McCoy
Mira Theilmann, University of Arizona
Amanda Leinberger, University of Arizona
Mariana Rivera-Torres, University of Arizona

Appendix E – Meeting Notes: Workshop #1

Morning Introduction: Scenario Planning Effort Context

This effort is intended to broaden the set of future conditions that people are thinking about as they initiate the discussions of the 2026 guidelines. The focus is on high impact, low probability events that could "break the system" or at least be very challenging to address. We will be considering the drivers of change, including both climate change and a range of other issues that could cause "black swan" events. We are not looking at scenarios from the perspective of the planning for the future of individual organizations, rather looking at the basin as a whole and developing scenarios that could be useful for states, utilities, NGOs or organizations to consider within their own processes. Our intent is to develop around 5 "storylines" associated with the intersection of climate and other drivers as fodder for discussion at the next scenario planning meeting at the end of October. The linkages between the drivers, crossing thresholds/tipping points, and how much change we are prepared for will affect the degree of disruption. We are focused on "out-of-the-box" thinking.

Defining Wet and Dry Extremes Discussion

The purpose of this discussion is thinking about climate and defining the areas outside of the comfort zone, including the parameters and definitions of extremes that we might need to be prepared for. In the context of considering extreme flooding, it is worth looking at paleoclimate records and what types of floods have been recorded in the past. Of the 14 known floods in the last 4,500 years that exceeded anything in the gauged record, the largest was more than twice the size of the largest recorded flood (O'Connor et al 1994).

Metrics of flood events to be considered in our storylines include duration, location, frequency, and volume.

There is evidence that climate change has altered the relationship between precipitation and runoff, and therefore we need to look beyond the historic record when thinking about the distribution of events in the basin. This is different from simply looking at statistical outliers from the past. No one is denying the existence of the past events, the real question is whether future extremes will be significantly different from those in the past. There is strong evidence that climate change will increase the magnitude of the variability, and that increased temperatures will enhance drying.

If we agree to use climate as an axis in each of our storylines, the question is how extreme the ends of the axis should be? The largest measured drought and flood? The largest droughts and floods reconstructed using paleo data? The physics of the system is changing, therefore extremes may change.

We should contextualize these events within current infrastructure capability to handle extremes and the understand the importance of initial conditions (eg, how full the reservoirs are) in terms of how that affects the system. Timing of events is crucial, and the location of the flood is also a major consideration (Figure 1).

Figure 1. Lake Powell at Total Capacity in 1980 (Bureau of Reclamation)

Risk tolerance of managers is also a consideration – if they are willing to bet that extreme events will not happen, it is important that they understand the consequences of that position. What are the potential institutional and economic feedback loops and consequences? For example, there are managers issuing power contracts that are 40-yr contracts who may not have the bandwidth to think beyond the changes in precipitation and temperature.

Scenarios can include definitions of the drivers of the wet/dry cycle of extreme events? We can identify the straightforward ones, e.g. magnitude and duration, but may also need to consider stacking those events/consequences. All of these issues will be covered in story lines.

Swing from big flood to drought could be very quick, which has additional ramifications. This timing of swings needs to be considered in the story line. The capacities of the lakes Powell and Mead can quickly drop (as we have seen recently) and back to back events, can put major stress on the system (Figure 2).

Low flow conditions have been documented in terms of tree rings but not the impact of increased temperatures (Figure 3).

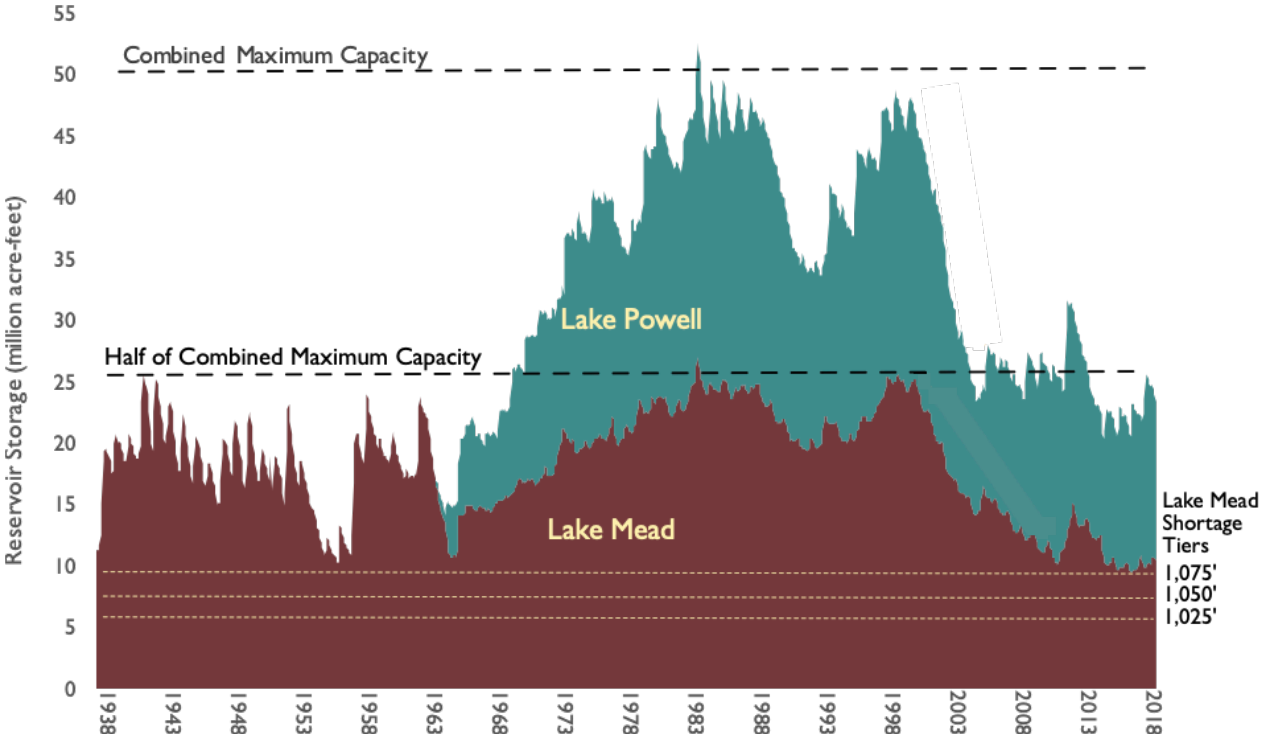

Figure 2. Combined Storage for Lake Powell and Lake Mead 1938-2018 (adapted from US Bureau of Reclamation)

Reconstruction	Calibration period	Reconstruction period	Long-term (1568-1961) mean flow, MAF	Mean flow, late 1500s drought (1579-1600), MAF
Stockton and Jacoby (1976)	1914-1961	1520-1961	13.4	11.1
Michaelsen et al. (1990)	1906-1962	1568-1962	13.8	10.6
Hidalgo et al. (2000)	1914-1962	1493-1962	13.0	9.1
Woodhouse et al. (2006) (Lees-A)	1906-1995	1490-1997	14.7	12.9
Meko et al. (2007)	1906-2004	762-2005	14.7	12.8

Figure 3. Recent streamflow reconstructions that present a range of long-term and drought-era flows (adapted from www.treeflow.info)

Brad Udall suggested in a previous meeting that we could define scenarios in terms of the annual water availability, eg 12 MAF vs 16 MAF, instead of focusing explicitly on the drivers that got us to those levels. Or, the discussion can be much more specific about location of floods and droughts, where and why they occurred.

The impact of rising temperatures due to climate change should be taken into account because of the very robust evidence that ongoing warming will occur. Based on the work of Udall and Overpeck and Connie Woodhouse, temperature is expected to have a big impact on runoff volumes as well as other implications for demand, evaporation and transpiration. There is evidence that this is already happening in the Upper Basin.

Some around the table are interested in the health of the river, as opposed to talking only about the interests of consumptive users. A simplified approach ignores some of these other uses of the river. It is agreed that these other components of conversation are crucial.

Is it possible to manage flood and drought at same time? The system needs both, whether or not in same storyline. The storylines must be distinct so that solutions can be developed from these storylines. Because initial conditions are critical for the basin, want storylines with different initial conditions. Could also consider an augmentation storyline if that seems important to the group, though our focus is not on the solutions side of this.

Suggested climate axes:

1. Wet and Dry Swings: Rapid hydrologic swings, with wet/dry timing and variability unpredictable, considering stacking of events
2. Shock Events: Looking at 1 year/short term extreme events (consider conditions of atmosphere changing these shocking events)
3. Multiple year events - Wet/dry continuum with longer (5-year plus) cycles
4. Vegetation disturbance (eg massive wildfires) leading to changes in flows (seasonality, water availability, sediment, species loss, etc)
5. Geographically segregated scenarios. When talking about biodiversity of the river, eg the CR Delta vs. the Yampa river, hard to compare the implications. For example, a possible scenario is we turn off the snow melt systems in the southern part of the upper basin and turn on snowmelt in northern portion. This scenario upends how the state of Colorado gets water, Wyoming becomes the water czar! Monsoon seasons could also intensify or turn off. These options will affect sedimentation into Lake Powell, change the fish species, potentially affect power production. In some geographies, this change in supplies could dampen or amplify the ends of the spectrum.
6. Dam loss: Can we assume Reclamation will just 'take care of' extreme flood events? Obviously they work to protect structures, it is their job, but almost lost Glen Canyon Dam in 1983. Dam loss can be at one end of the "flooding" option.
7. Groundwater storage, long term implications of changes in groundwater, demand/supply feedback loop needs to be included. For example, 90 MAF were pumped out of the Central Valley of CA during the recent drought, will take centuries to recover. Groundwater could be a separate axis from other climate/hydrology considerations. Massive drying could result in large die-off of biodiversity => groundwater dependent riparian systems etc. and broad consideration is important in group discussion.
8. Snowmelt dominated vs rain dominated system changes

Clarification on the timing of our assumptions for these scenarios: think about a 50-yr time frame rather than 30-yrs, more useful to decision-makers and will allow future climate regimes to be more visible.

Overall Summary of Climate Discussion

We will refine details in each scenario:

- Include: location, duration, frequency, intensity, timing, and context

Scenarios

- Wet-dry swings
- Short-duration super intense system shock
- Long-duration year events
    - Multiple dry/wet years in a row
- Atmospheric patterns
    - WY water Czar (turn off the snowmelt system in the south part of the upper basin and turn on the snowmelt runoff in the northern part of the system
    - Monsoon turn off across the region
    - Flip from snowmelt dominated system to rainfall dominated
    - Climate change related process changes (runoff efficiency)- push us to the extremes
- Flooding:
    - Historical: 1983/1984 flooding
    - Historical: twice the largest gauged flood
        - Two types flood:
            - Snow melts: April-July
            - Historical long gage: 1984
- Drought:
    - Historical mirror 50-year drought in the 1500s
    - Historical: 1992-2002 drought

Citations

Hidalgo H.G., T.C. Piechota, and J.A. Dracup. 2000. Alternative principal components regression procedures for dendrohydrologic reconstructions. Water Resources Research 36(11): 3241-9.

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Stockton, C.W., and G.C. Jacoby. 1976. Long-term surface-water supply and streamflow trends in the Upper Colorado River basin based on tree-ring analyses. Lake Powell Research Project Bulletin 18: 1-70.

Woodhouse, C.A., S.T. Gray, and D.M. Meko. 2006. Updated streamflow reconstructions for the Upper Colorado River basin. Water Resources Research 42, W05415, doi:10.1029/2005WR004455.

Appendix F – Full List of Drivers from Workshop #1

Over 70 distinct "nightmares" were shared during the "What Keeps You Up at Night" discussion. The project team rolled up these "nightmares" into a categorized list of approximately 35 drivers that are presented in the Storyline Workbook document. The list below presents each nightmare that was mentioned at the workshop.

1. Climatic
    A. Wet to dry swings – two, three, four years broken up by a couple of really wet years
    B. Short-duration super intense system shock:
        a. Wicked wet year
        b. Devastating dry year
    C. Long-duration events
        a. Multiple dry years in a row
        b. Multiple wet years in a row
    D. WY water czar - Turn off the snowmelt systems in the southern part of the upper basin and turn on the snowmelt runoff in the northern part of the system
    E. Monsoons turn off across the region – impacts sedimentation and groundwater recharge
    F. Flip from snowmelt dominated system to rainfall dominated
    G. Climate change related process changes (e.g. runoff efficiency)

2. Governance
    A. Broken governance structure: Reduction of civility and capacity to collaborate, Erosion of trust to the point that there is none, Past investments in the law of the river will erode
    B. No one acts but for meeting their legal responsibilities
    C. Leadership and process capacity significantly declines
    D. Collapse of the law of the river / Inability to administer water according to law of the river (e.g. DCP)
    E. Governance doesn't move fast enough to keep up with the problems
    F. Increasing complexity in the system without an adaptive governance system to support that complexity
    G. Federal takeover of the system (e.g. Australia) / The federal role is diminished or is eliminated
    H. Implementation of ESA erodes the law of the river

3. Ecological
    A. Hitting biological tipping points (e.g. loss of primary systems, movement of species)
    B. Prospect of landscape scale wildfire
    C. Loss of ecosystem values that are linked to healthy functioning rivers
    D. Broad social memory loss of ecosystems (we don't remember what they used to be)
    E. No goals for ecosystems, preserve vs restore

4. Legal
    A. Interstate litigation
    B. Loss of ESA law and protections for species

5. Economic
    A. Investments won't get made because of uncertainty / Failure to invest in infrastructure to prepare for uncertainty
    B. Transition away from electrical central station service – decreased need for hydropower
    C. Economic recession/prosperity / Total economic collapse
    D. Significant difference in economic prosperity in rural and urban areas / Systematic under investment in rural areas
    E. Behavioral and economic shifts are not dependent water availability/conditions
    F. Economic/demographic shifts causes dramatic changes to water supply needs
    G. Changes in global trading patterns – changes in demand for crops grown in the basin
    H. Changes in tourism
    I. Tribes don't see the full value of the water rights that have been settled or quantified
    J. Infrastructure being built doesn't work economically
    K. No incentives to save this place
    L. Exponential growth of the wealth inequality gap

6. Social
    A. Inclusivity increases / Arc towards exclusion and cruelty / Movement to try to "protect our own"
    B. Continued population growth in the southwest
    C. Lack of new/younger generation working in the system / Changing social views about the West and natural resources – younger generation lack of interest in the West / Decline in younger generations in agriculture and loss of history
    D. Narrative failure from historic norm
    E. Dangers of large populations when put under stress
    F. Loss of societal license to manage problems and implement solutions
    G. Lack of crisis
    H. Continued divergence between land use and water supply planning
    I. Depopulation of rural America, best and brightest are leaving
    J. Loss of cultural and language diversity
    K. Poor people are left behind
    L. Let's move to Mars movement
    M. Acceptance of science and facts
    N. Massive population movements across states/countries
    O. Loss of power in connecting and understanding

7. Political
    A. Elected political won't choose the sustainable path / Continued hardening of positions causing deadlock / Individual political agendas overtake the collaborative foundation
    B. Relationship between MX and US disintegrates / Changes in leadership in MX and US

8. Physical
    A. Major infrastructure failure (e.g. dams, irrigation delivery systems)
    B. Water quality significantly declines
    C. Speed of change radically increases

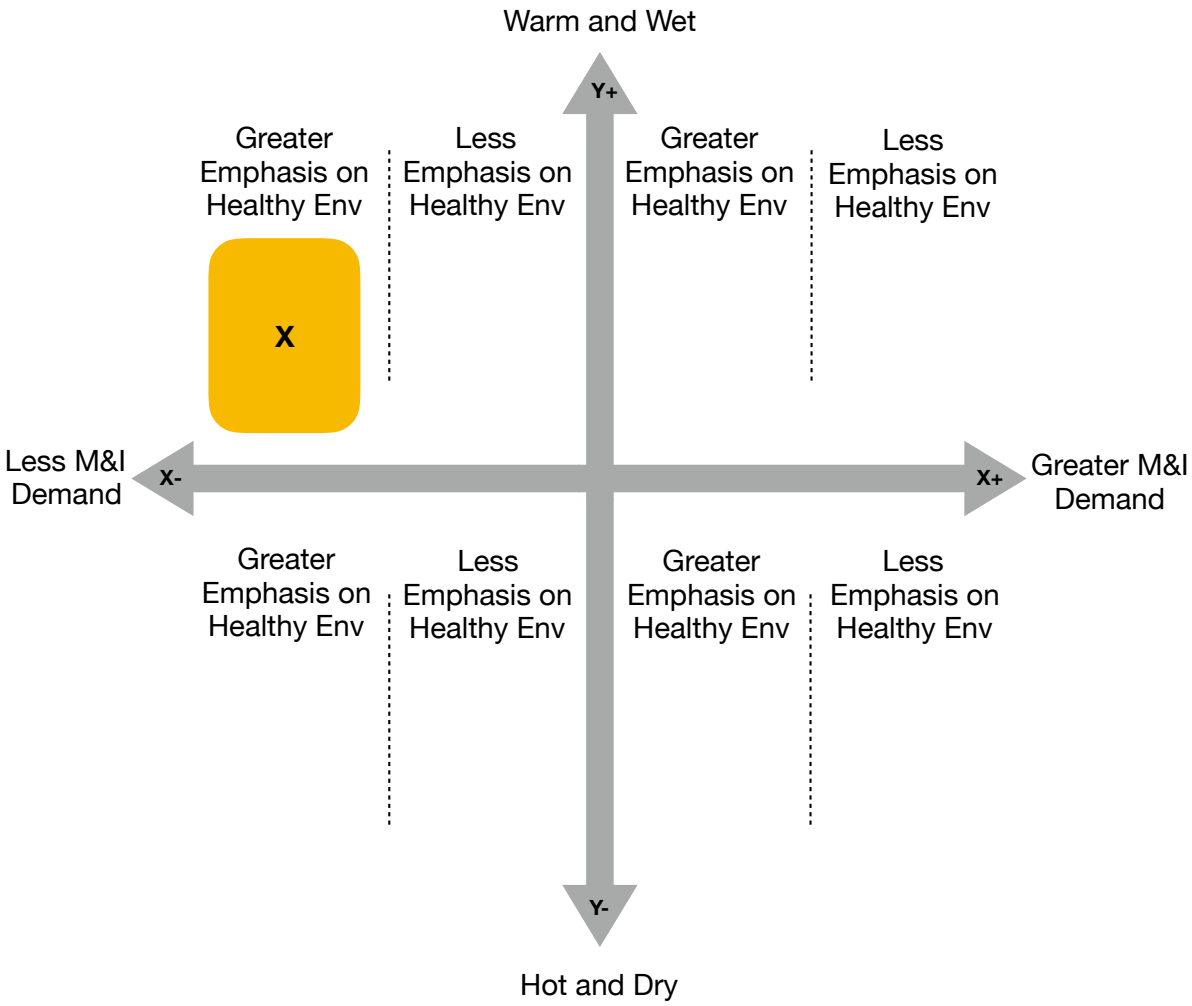
D. Increased reliance on the Colorado River System because of collapse of other systems (e.g. collapse of State Water Project/Central Valley Project, failure of Orville) / Perfect storm of all vulnerabilities at the same time within Colorado River system and in connected systems
E. Large scale movement of water from Colorado River Basin to Central Valley or other connected land bases
F. Salton Sea is not solved
G. Significant loss of farm ground or disconnection btw land and water
H. Massive water reallocation of water to growing population centers/ Moving water out of agriculture into municipal and industrial use
I. Groundwater and aquifers crash
J. Deliveries of water to Mexico are no longer hitting average targets

9. Other
   A. Technological advancements
   B. Increased investment in science leading to better understanding of the system

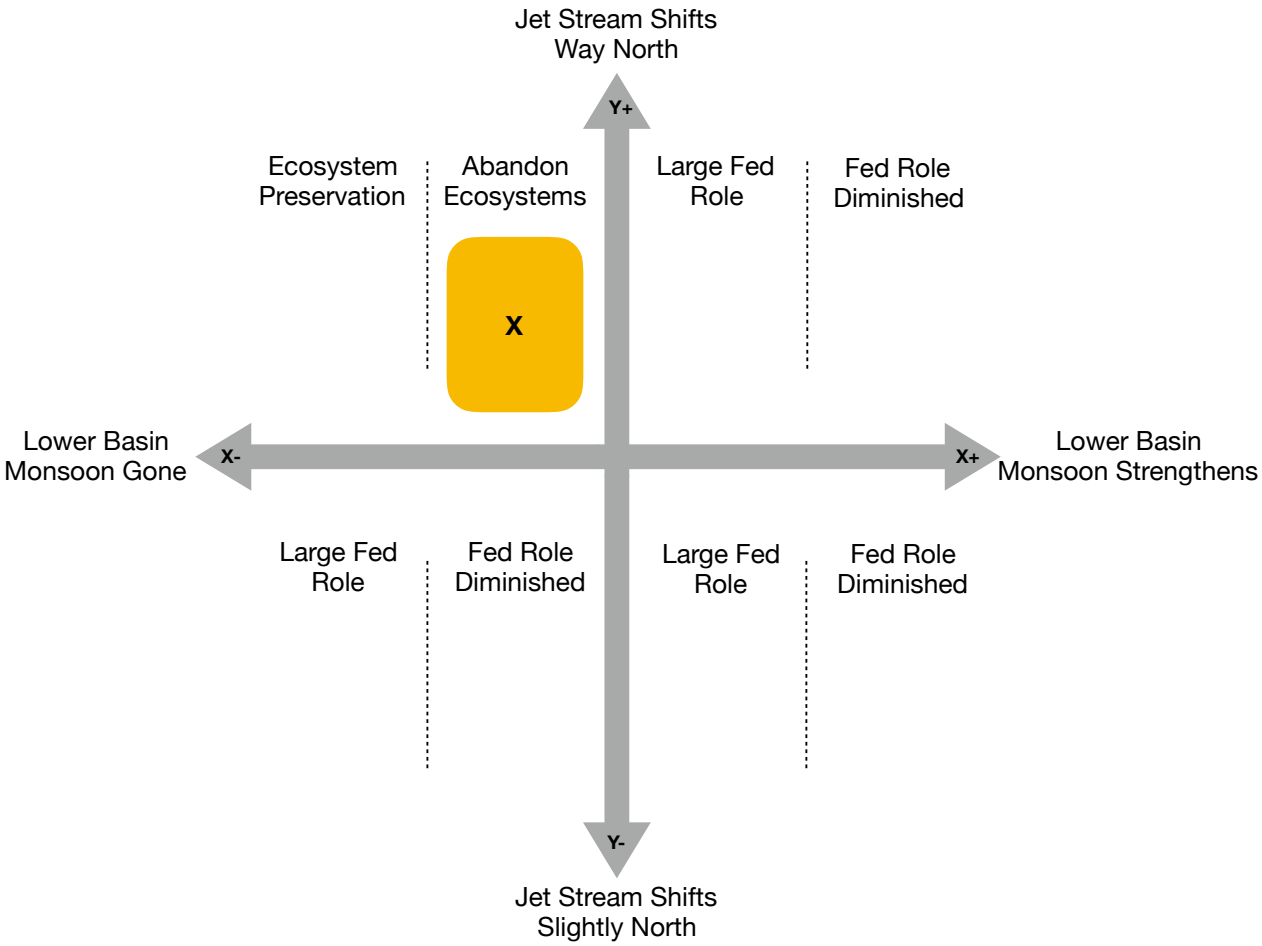
Appendix G – Scenario/Storylines from Workshop #1

During the June 5th meeting, four groups developed several matrixes that were distilled down to 3-5 storylines. Each matrix and the recommended scenario/storylines from each group are presented below. The yellow boxes indicate the workshop scenarios that were the foundation of the final eight storylines.

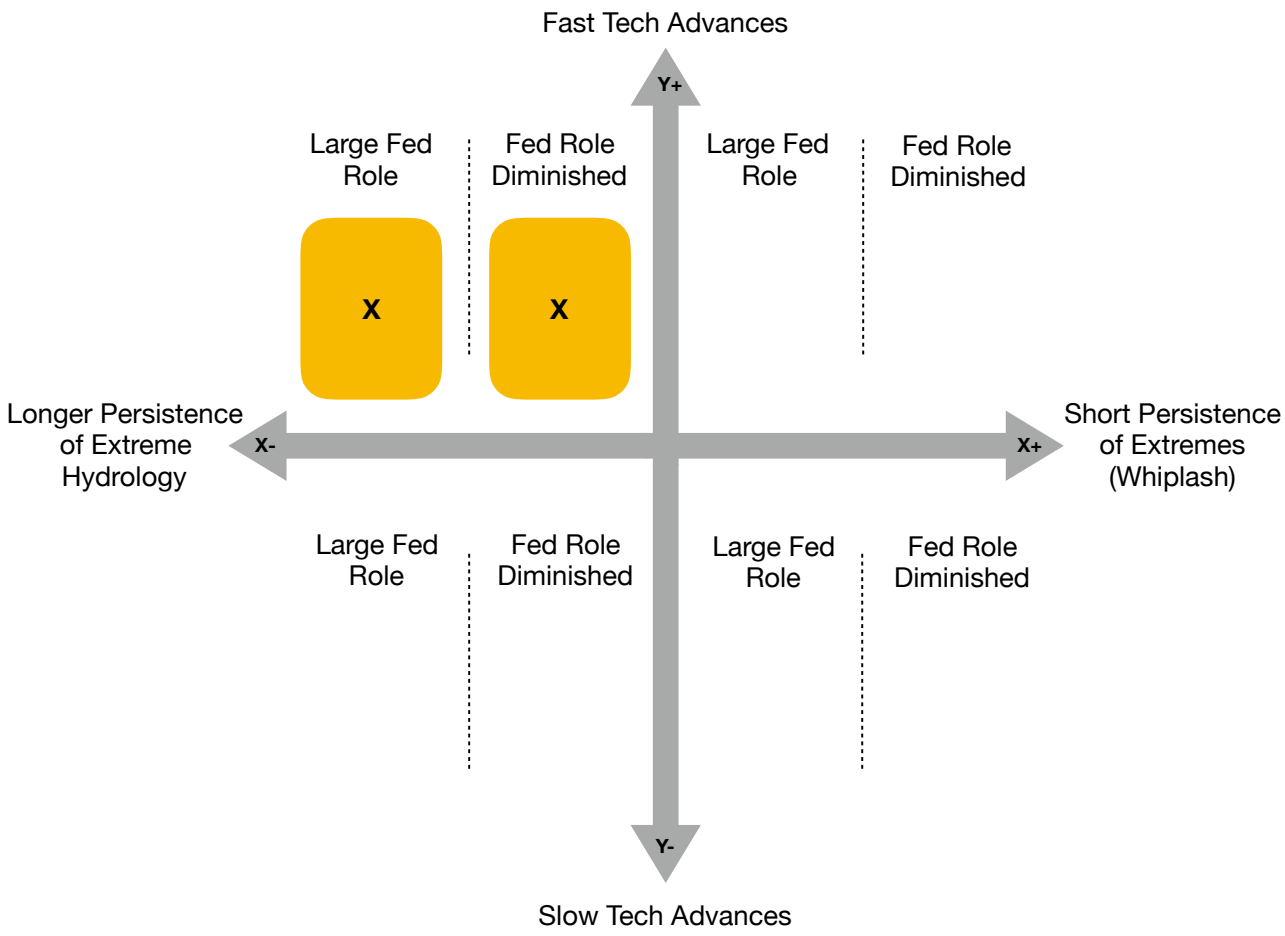
Group 1 - Matrix #1



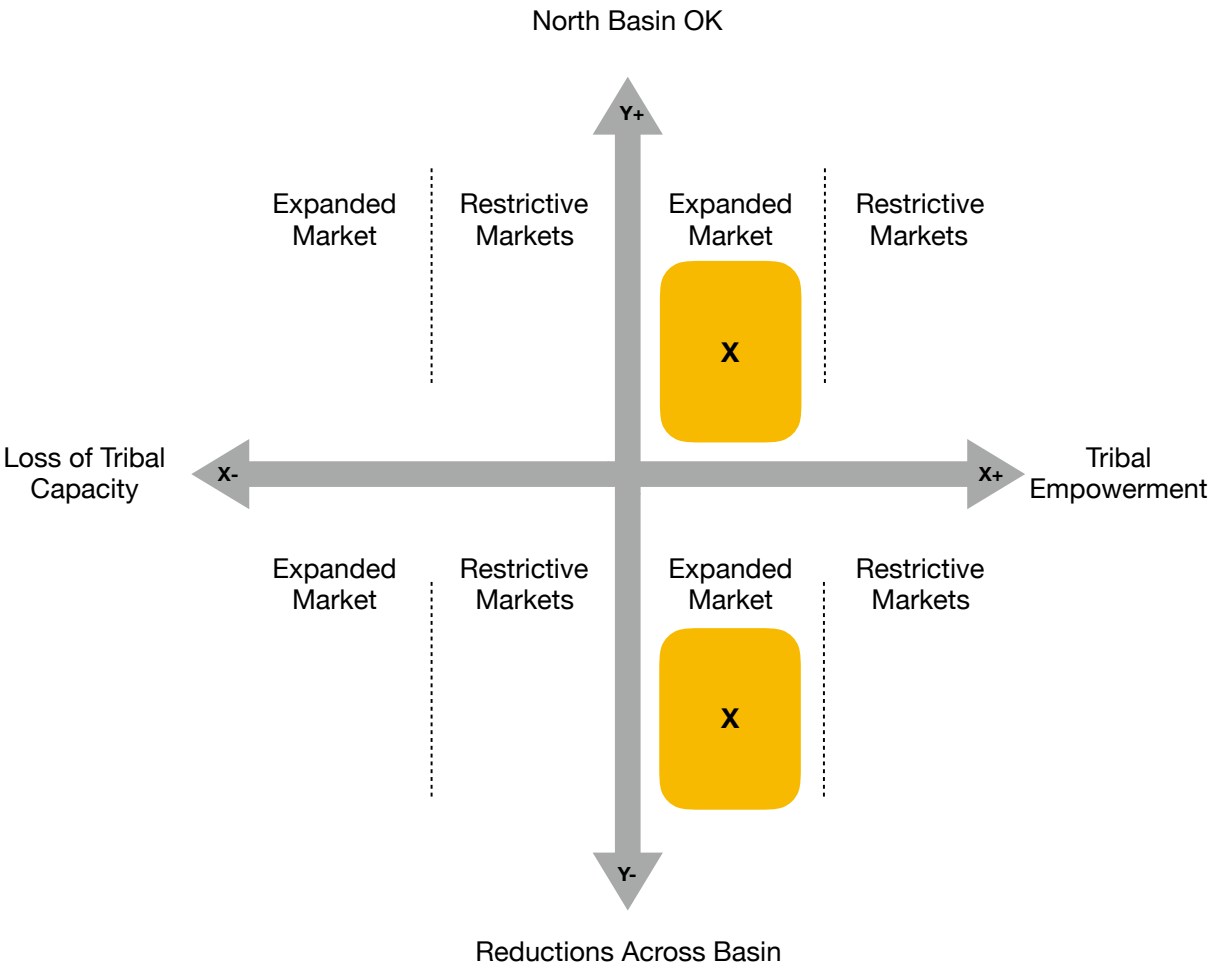
Group 1 - Matrix #2



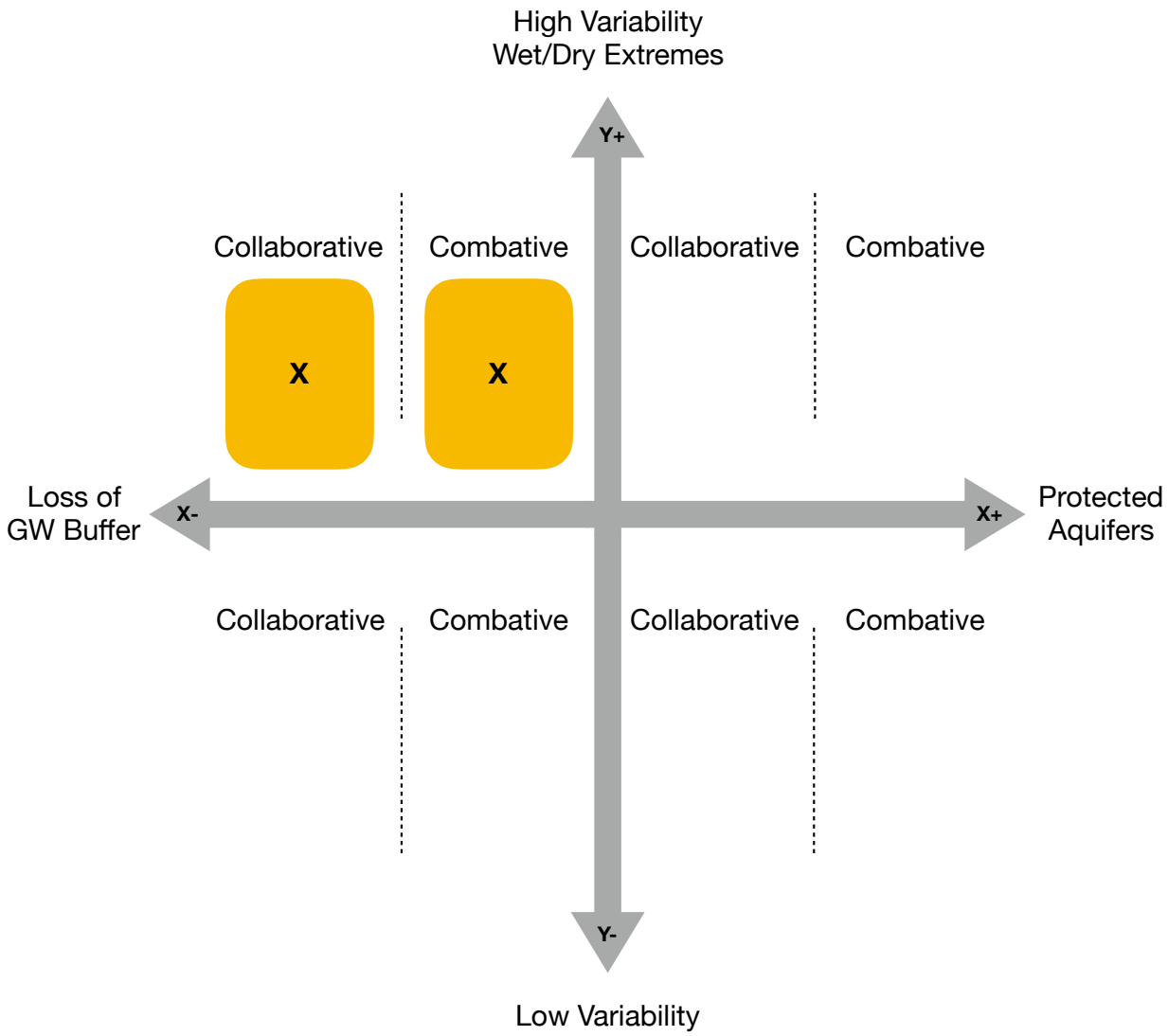
Group 1 - Matrix #3



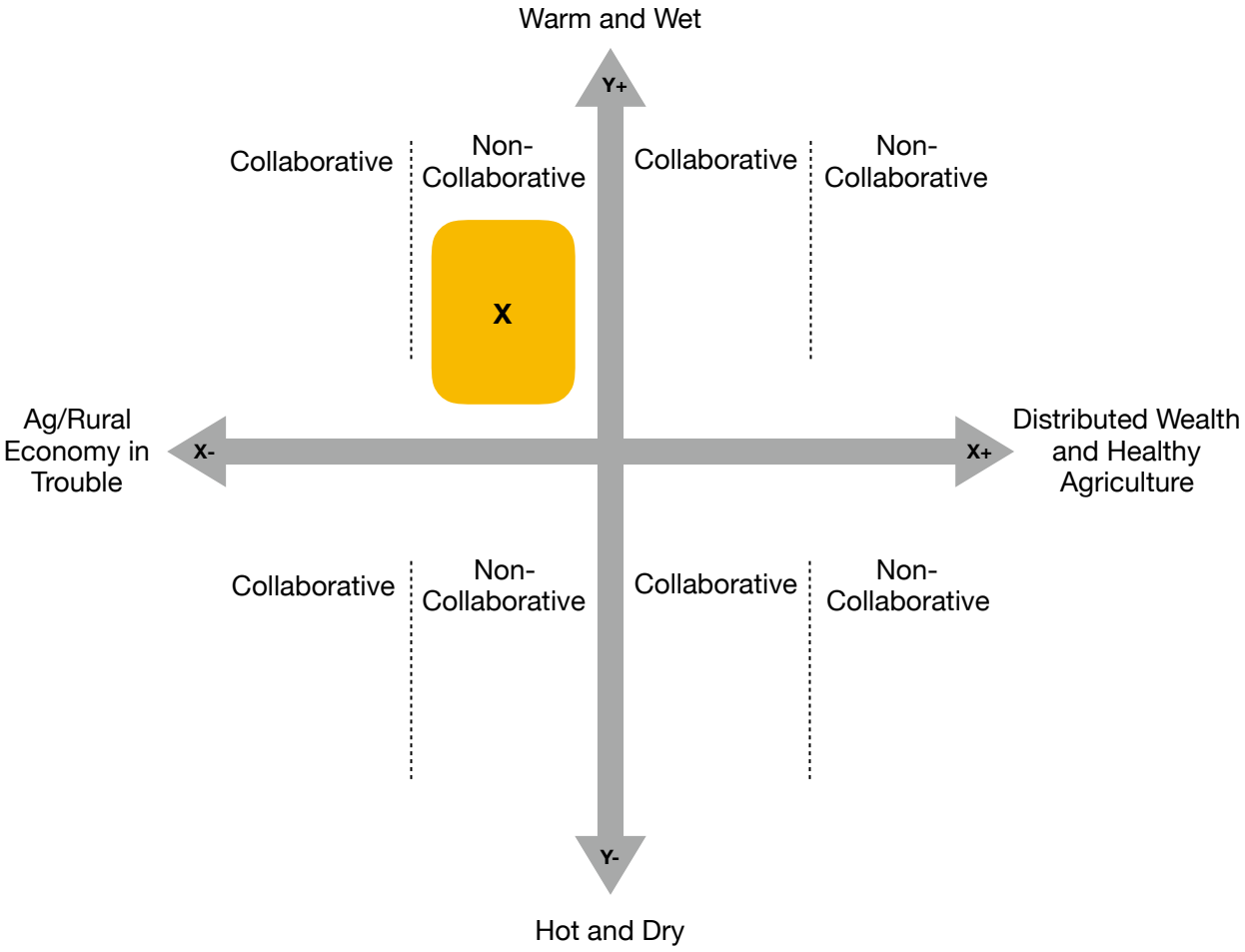
Group 2 - Matrix #1



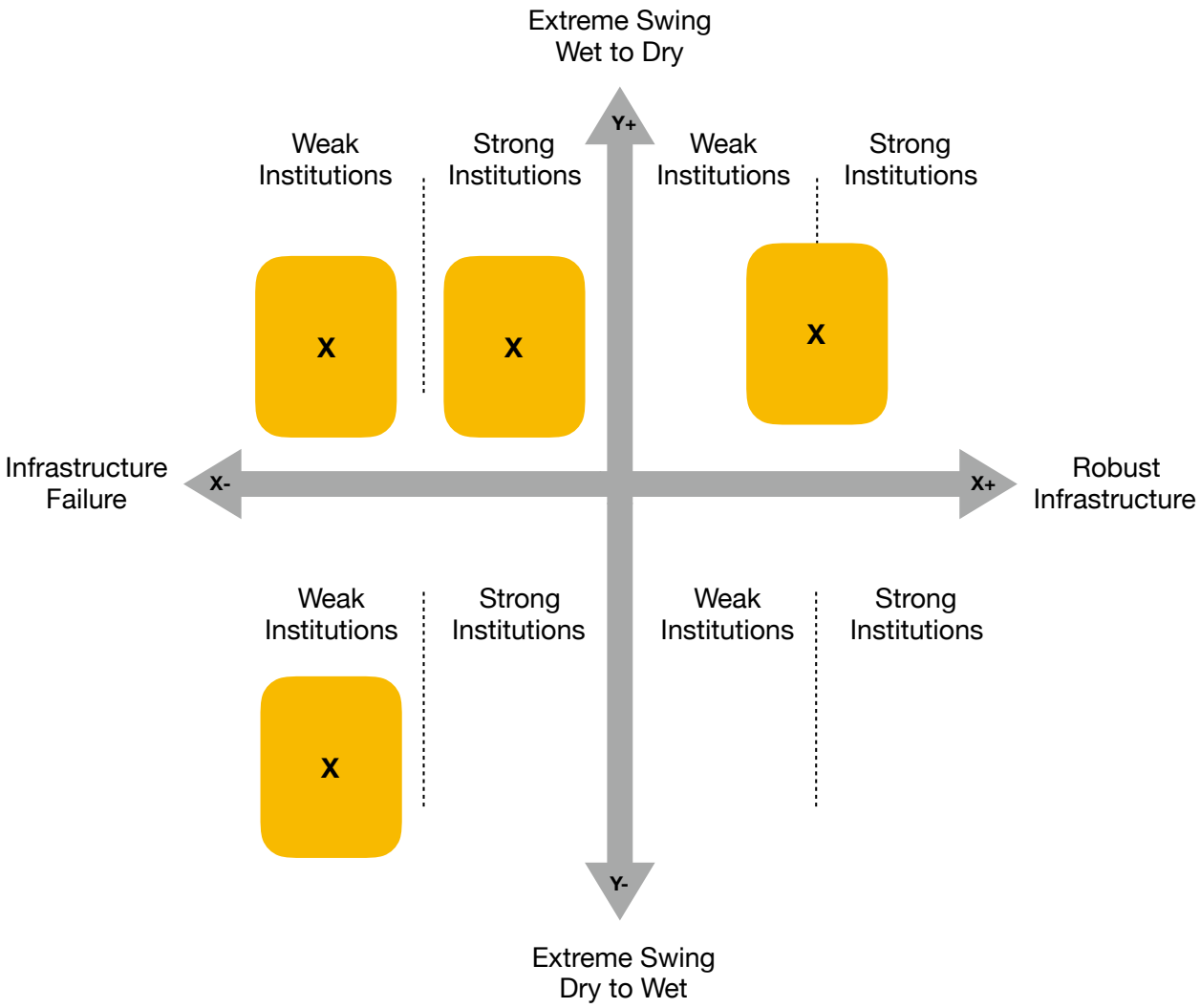
Group 2 - Matrix #2



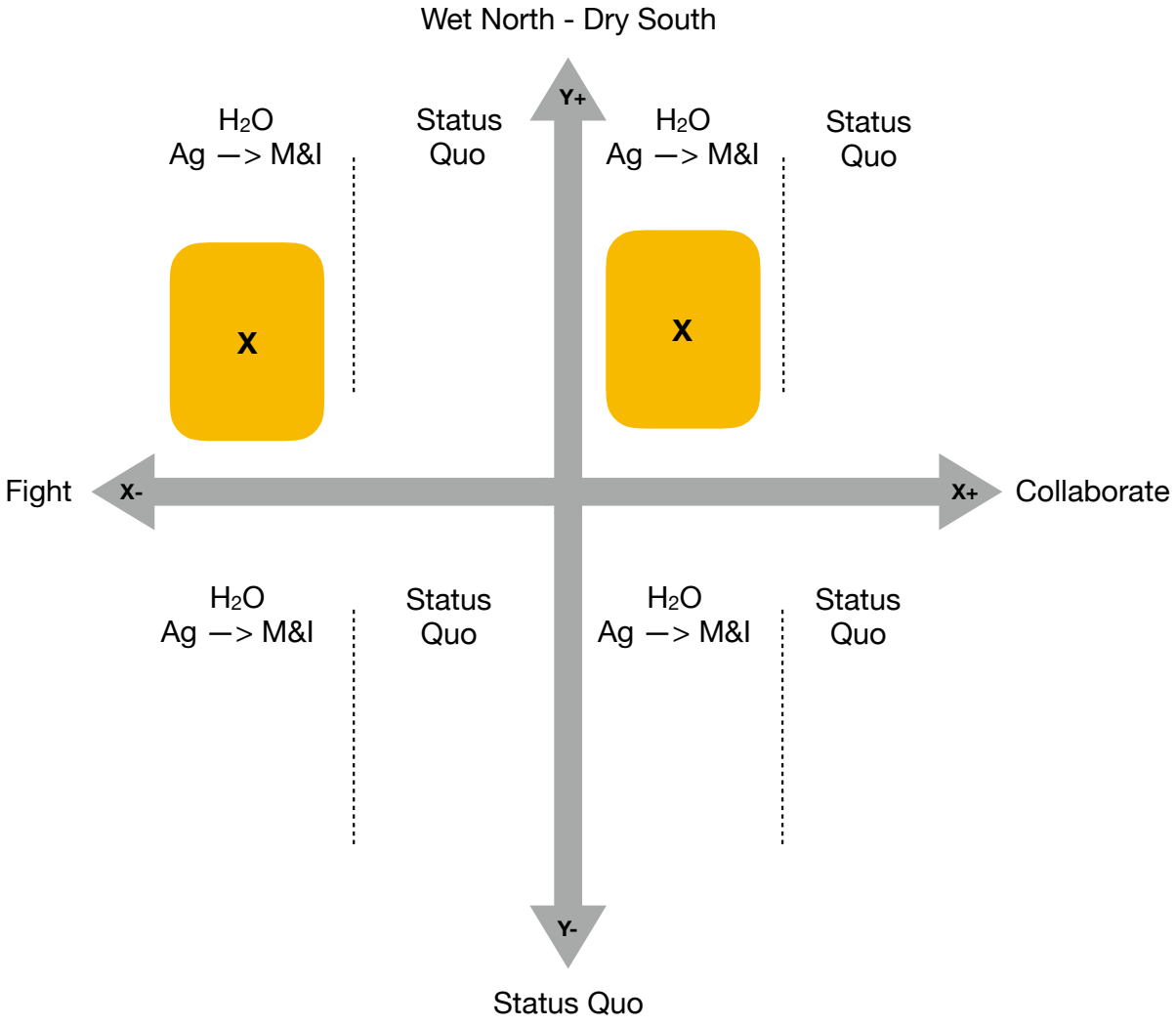
Group 2 - Matrix #3



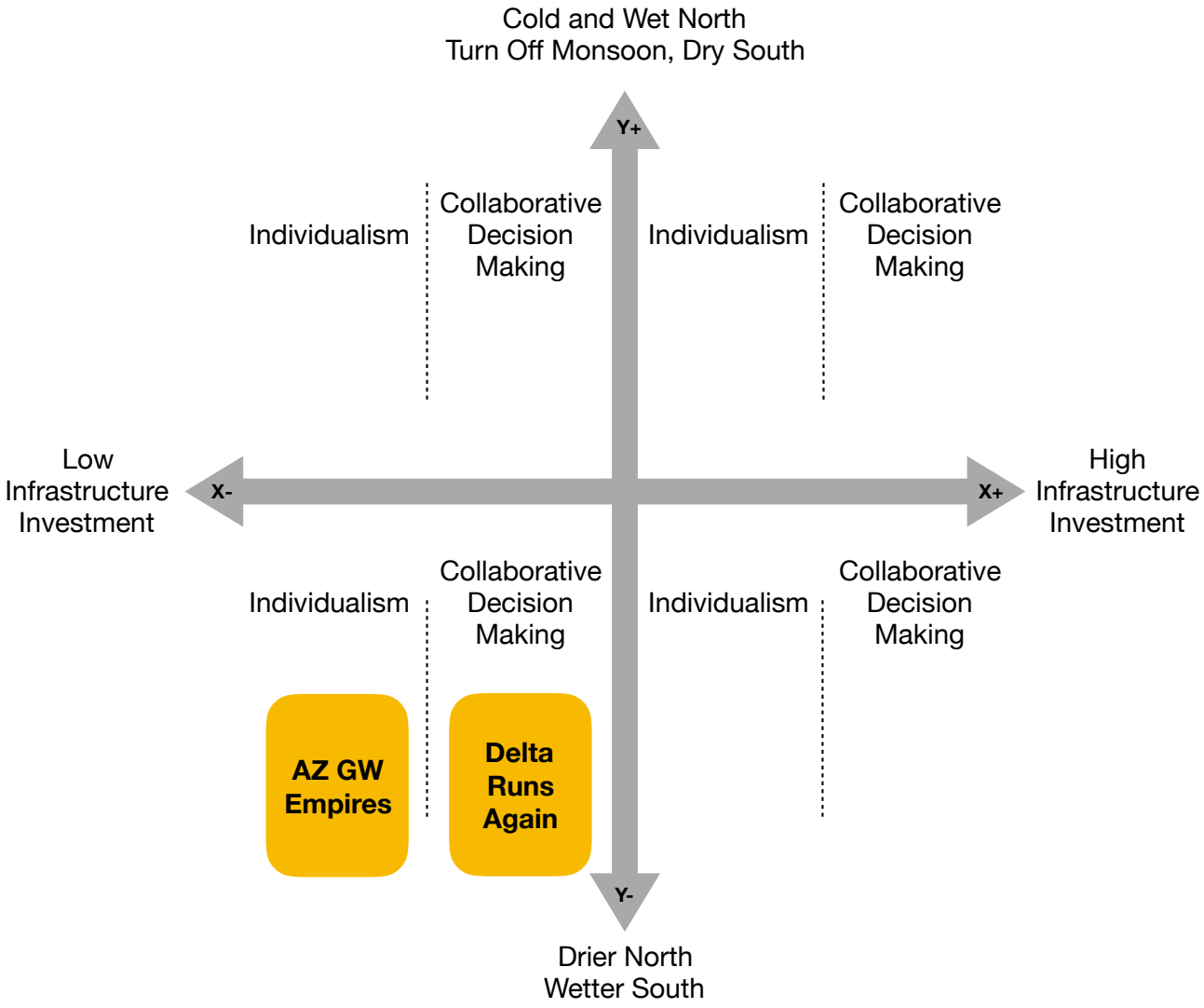
Group 3 - Matrix #1



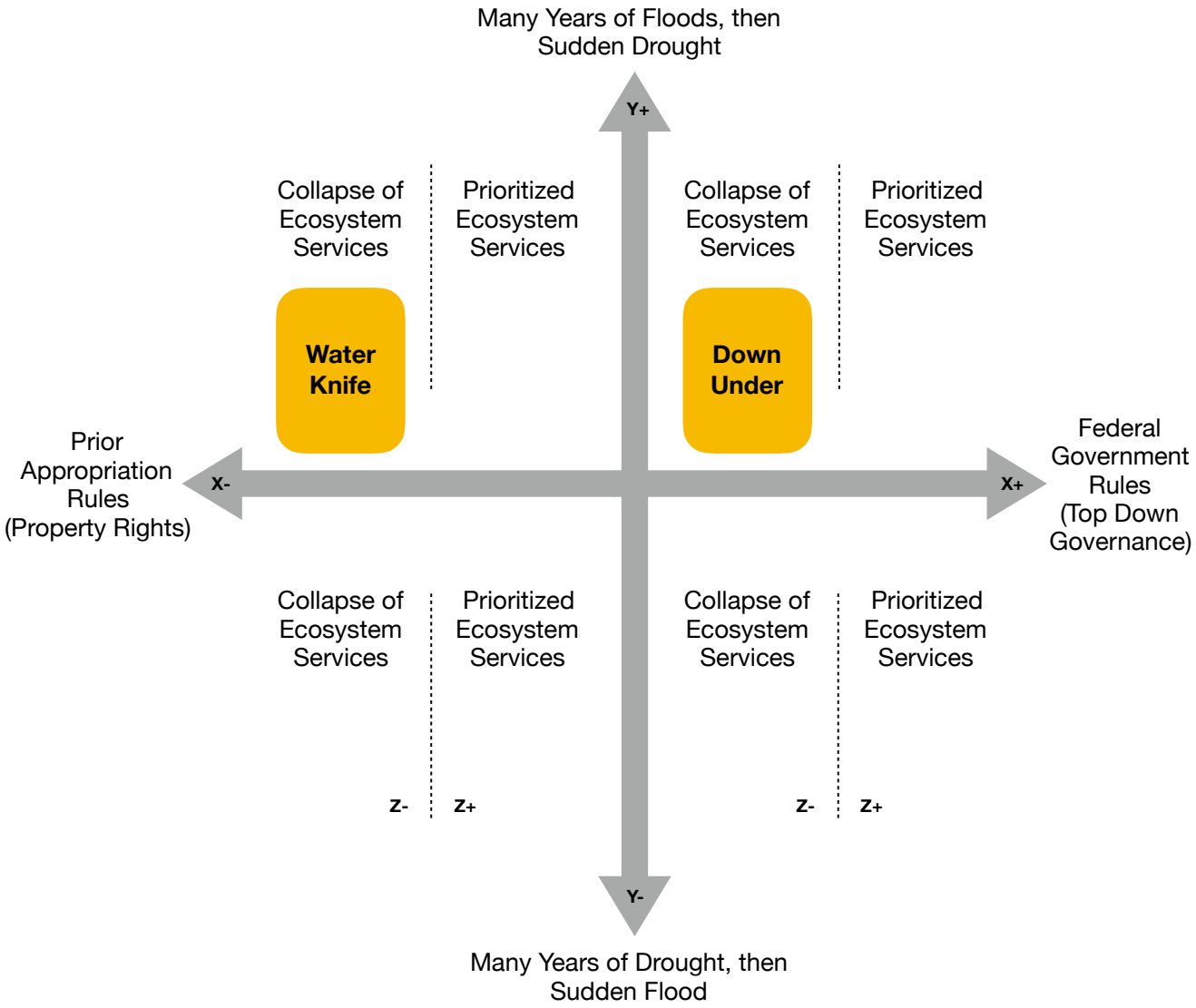
Group 3 - Matrix #2



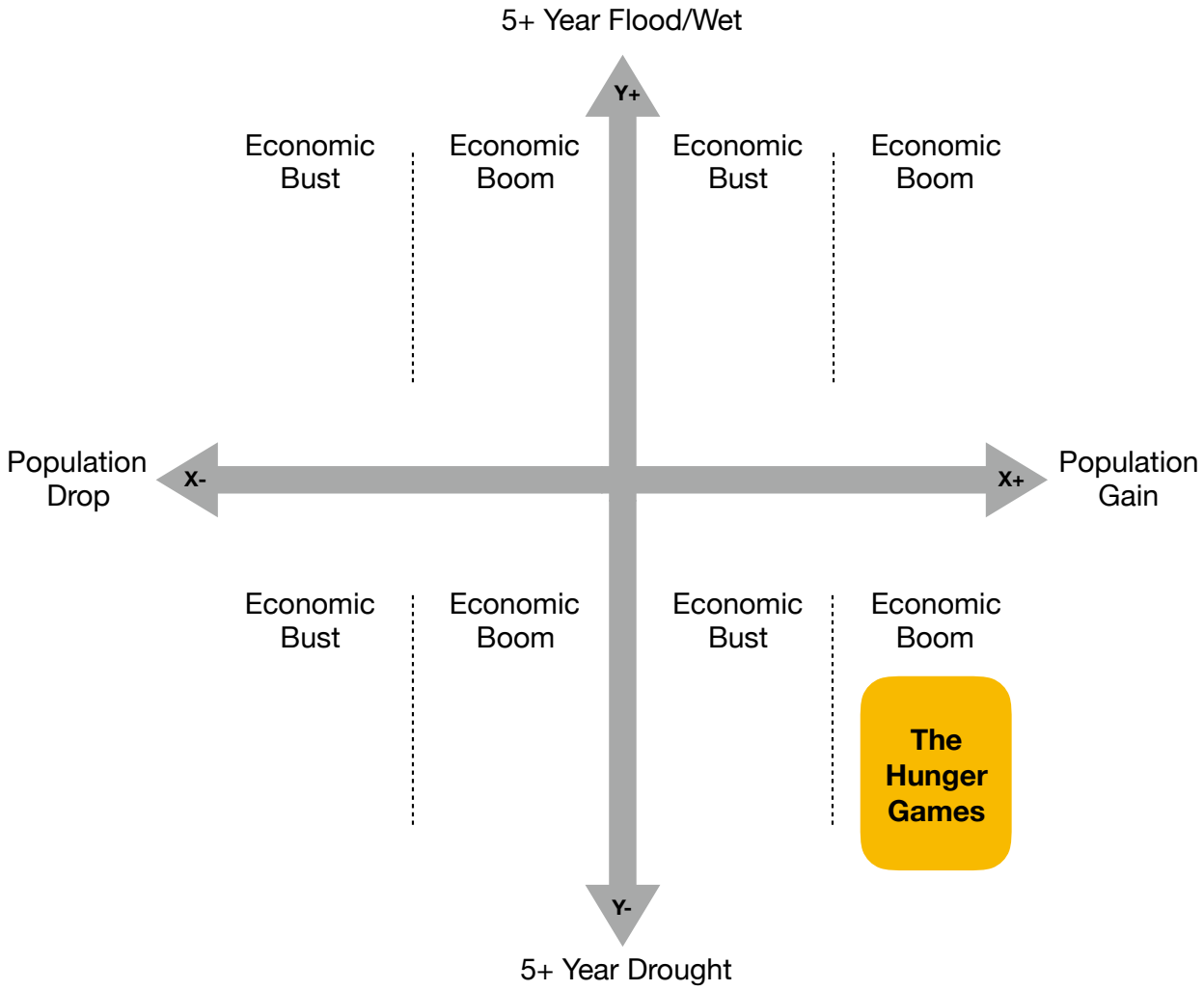
Group 4 - Matrix #1



Group 4 - Matrix #2



Group 4 - Matrix #3



Appendix H – Final Storylines for Workshop #2

1. Caught Off Guard

Wet -> Dry Swing, Governance Failure, Infrastructure Failure

A rapid shift from normal to above average precipitation, to basin-wide dry conditions, including low snow pack and below normal monsoons. Wet conditions have diminished a sense of urgency and attention to drought responses and both governance and infrastructure are unprepared for sudden and extreme dry conditions. Litigation rules the day.

2. Dig it Deeper

No Monsoon, Aquifer Crash, Increased Tribal Engagement in Lower Basin

Persistently poor monsoon seasons diminish surface water resources and the Lower Basin turns to groundwater. Aquifers crash and water deliveries are further curtailed, while high priority tribal water remains available. Demand for water rapidly increases.

3. Unfair and Arid

Long Duration Dry, Increased Wealth Gap, Decrease Inclusivity

Basin-wide dry conditions continue unabated. The wealth gap widens and those with economic resources can either escape or adapt to unfavorable conditions, while those with limited economic resources are increasingly affected by harsh climate conditions and excluded from decision-making processes.

4. Sad Skiers

Snow –> Rain, Low Environmental Values, Decrease in Recreational Economy

Overall drying conditions reduce snowpack, shifting to a precipitation dominated water supply. Environmental values are not prioritized within water and land management decisions, and the recreational economy is commensurately reduced.

5. Water on the Move

Wet to Dry, Increase in Markets, Increased Tribal Engagement in the Upper Basin

Precipitation steadily declines and markets increase in response to regional scarcity. In the Upper Basin, tribes increase participation in emerging markets. Speculators drive water prices sky-high.

6. Disaster Strikes

Short System Shock (Wet/Dry), Collapse of CA Water Systems, Bad Economy

A sudden and drastic shift to very dry conditions places immediate stress on California water supplies and infrastructure, which causes negative economic responses.

7. Rural Revival

Long Duration Dry, Transition from Global to Local Economies, Rural Ag Investment

Dry conditions slowly and steadily worsen, while unstable global markets shift focus to local economies that are bolstered by durable investments in rural agriculture.

8. Flood Gates

Dry -> Wet Swing, Technological Advances Enhance Supply, US-Mexico Collaboration

A sudden and unexpected shift moves the regional focus from dry to wet conditions. This shift runs in parallel to technological investments in supply efficiency and in effective and committed US-Mexico collaboration.

Appendix I – Agenda: Workshop #2

Purpose

The Colorado River Conversations Project is envisioned to help build broad, interdisciplinary support and a science foundation for the upcoming renegotiations of the 2007 Colorado River Interim Guidelines. The overall objective of this project is to expand the parameters of the conversation about future conditions in the Colorado River Basin. This will take place over the course of three linked events, including two workshops.

This second workshop is designed to a) present detailed scenarios, b) discuss the implications of each storyline, and c) explore options for participants to apply the scenarios within their work and moving forward towards the start of the renegotiation of the basin guidelines.

Wednesday, October 30, 2019

12:45 – 1:00	Registration and Coffee
1:00 – 1:15	Welcome, Review of First Workshop, and Overview of Workshop Goals
1:15 – 2:00	Introductions and Reflections on the First Scenarios Workshop and Conference
2:00 – 2:30	Presentation on Storylines Content
2:30 – 2:45	Break and Transition to Breakout Groups
2:45 – 4:00	Breakout Groups: Discussion of Impacts for Storylines 1-4
4:00 – 5:00	Full Group: Discussion of Impacts for Storylines 1-4
5:00 – 5:10	Wrap-up and Review of Agenda for Next Day
6:00	Depart for Dinner. Hosts will provide rides from hotel at 6:00 PM as needed, and return to hotel at the end of the dinner. Participants are welcome to use Uber/Lyft, if necessary.

Thursday, October 31, 2019

8:00 – 8:30	Doors Open and Breakfast
8:30 – 9:30	Breakout Groups: Discussion of Impacts for Storylines 5-8
9:30 – 9:45	Break and Transition Back to Full Group
9:45 – 10:45	Full Group: Discussion of Impacts for Storylines 5-8
10:45 – 12:00	Discussion of Lessons Learned, Next Steps, and Wrap-Up
	Evaluation forms due – will be your ticket for lunch!

Appendix J – Participants: Workshop #2

Participants

Peter Culp, Culp & Kelly
Tom Davis, Yuma County Water Users Association
Carolyn Enquist, University of Arizona
Nadia Hardjadinata, Metropolitan Water District
Chris Harris, Colorado River Board of California
Mark Harris, Grand Valley Water Users Association
Taylor Hawes, The Nature Conservancy
Laurna Kaatz, Denver Water
Vineetha Kartha, Arizona Department of Water Resources
Jamie Kelley, Mohave County
Eric Kuhn, Author
Jeff Lukas, Western Water Assessment
Mohammed Mahmoud, Central Arizona Project
Jennifer Pitt, National Audubon
Jim Prairie, Bureau of Reclamation
Jack Schmidt, University of Utah
Seth Shanahan, Southern Arizona Water Association
Rebecca Smith, Bureau of Reclamation
Tim Thomure, Tucson Water
Crystal Tulley-Cordova, Navajo Nation
Brad Udall, Colorado State University
John Weisheit, Living Rivers
Steve Wolff, Wyoming State Engineer's Office

Project Team

Kathy Jacobs, University of Arizona
Andrea Gerlak, University of Arizona
Season Martin, Martin & McCoy
Amy McCoy, Martin & McCoy
Mira Theilmann, University of Arizona
Amanda Leinberger, University of Arizona
Mariana Rivera-Torres, University of Arizona

Appendix K – Storyline Impacts

Caught Off Guard

Legal/Political	**Governance** - Governance failure makes it difficult to solve problems - Inability to enforce existing laws - Funding becomes a source of conflict and uncertainty, no big pots of government funding available
Ecological - Initial releases from damaged reservoirs inundates rivers, but natural flow regime quickly breaks down - In the Lower Basin, almost all streams are dry and/or have been converted to canals to prevent leakage - Higher fire risk - Erosion of environmental protection mechanisms	**Physical** - Dam Failure (Orville Dam serves as a good example) - Spillway and emergency spillway damaged and lost - Flood control limitations - No supply resilience because of storage limitations - Flooding damages other aspect of delivery infrastructure, so capacity to divert flood waters and reservoir releases is limited
Social - Adversarial process forming (higher priority vs. low priority) - Communities closer to the river will try to maximize allocations - Inability to solve future problems – litigation becomes main conflict resolution tool - Upper basin cannot meet lower basin needs, which is uncharted territory - Day zero: - Tucson (10-20 year window) - Salt Lake City - Northern front range - Water for drinking not agriculture - Nevada: they are probably safe-> Las Vegas best prepared for water reuse. - Mexico: Tijuana, Tecate, and Ensenada – limited supplies	**Economic** - Population growth would decrease - Cities cannot support population refugee situation - Local market collapse: market cannot deal with circumstance or prices escalate - Augmentation options would be regional and dependent on access to funding - Southern California would be dependent on desalinization

Water on the Move

Legal/Political - Investment in areas with high priority water rights - Speculative water investors - Increased quantification of water - Environmental and recreational interests at the table	Governance - Tribes transact in water - LB/AZ relax on development restrictions - During dry period, tribes can play their hand as they wish and are highly engaged in governance actions
Ecological - Increase 1-2 degrees in temperature - Precipitation enough to overcome decrease in run-off from higher temperatures - Increase in wildfire risk - Delta revives during wet period - Equalization blows Grand Canyon sediments	Physical - Increase in reservoir levels, then rapid drop - UB feels hydrologic drought immediately - Lag in impacts in LB - Reservoirs are unprepared for drought - LB increases storage during wet period - Mead in surplus during wet, Powell equalization releases
Social - Wet long enough for people to get complacent - People aren't as water aware, particularly in urban areas - Boom in recreation during wet time	Economic - Markets work easily during wet periods - Everyone monetizes water during dry periods - Fast drought hurts rural people the most

Arid and Unfair

Legal/Political - Re-invent legal structure - New and revised rules for infrastructure	Governance - Completely reinvent how we manage water systems - Fractured relationships get worse
Ecological - Rivers collapse	Physical - Movement to direct potable re-use
Social - Poor communities lose - Wealthy communities invest in water trading and water tracking - Refugees and population migration - Boundaries of rich areas increase	Economic - Water pricing goes up - Economy crashes - Hedge funds take over

Rural Revival

Legal/Political - Focus on local politics and legal structures - Shift away from national and global policies	Governance - Gradual drying has allowed for more policies that support and foster resilience
Ecological - Monetizing water for some species - Endangered Species disappear - Less water leads to lower quality habitat values - Shift in fire regimes - Forest ecosystems shift - Sediment build up in Grand Canyon promotes some fish species	Physical - Quality and use of hydropower infrastructure declines
Social - Bridge between rural and urban communities - Social cohesion increases in agricultural communities - Shift in demographics	Economic - Shift in values for local economies - Marginal ag lands are pulled out of production - Recreational economy shifts towards summer activities

Sad Skiers

Legal/Political - Decrease in environmental protections	Governance - Water buffalo mentality - Relationship with Mexico degrades
Ecological - Channelized rivers - Grand Canyon flows not optimized - Sediment issues - Loss of biodiversity and wildlife - Fires more abundant - Decrease in water quality - Warming temperatures	Physical - Use of infrastructure to maximize water for existing users
Social - Fewer people move to recreational hubs - People more north and to higher elevations to escape hot temperatures - Collective memory loss of environmental values - Shift in new recreational activities - Loss of rural populations	Economic - Boom in the extractive industries - Hit on recreational economies - Lowered values for ranches and ranching economy

Disaster Strikes

Legal/Political - Limited interest in regulations - Focus on fixing the economy and immediate problems - Water demands go way down due to survival conditions (no room for luxuries)	Governance - More federal participation and governing - Resources directed towards California - More litigation and pressure on transfers
Ecological - Environmental values, Delta, Salton Sea, ESA and other environmental values gone - Funding for those issues lost as well	Physical - Assumption that California suffers the feared earthquake --> Disruption to Bay/California water project - Climate and environmental changes impact - - Powell and Mead - Pressure to keep CA aqueducts full
Social - Stress in agricultural communities and cities - Agriculture could drive a return to food crops - Demographic shifts in the basin are different than in 2008 and 2009, because of differences in economic conditions and geographic scale of recession.	Economic - Economic depression on global scale - Tribes in a position to capitalize on the water markets, and if they can't, then might get run over by panicked efforts to fix problems

Dig it Deeper

Legal/Political - Exceptions to water use limits enacted as drought measures - Pressure to move water from Yuma to Central AZ	Governance - Break down in governance - AZ ramps up self-importance
Ecological - Rivers completely dry-up - No riparian habitat	Physical - Temperatures continue to increase - More pressure on Lake Powell - Importance of inflows to Lake Mead - More pressure on other water supplies in the LB, like the Salt River Project - Greater reliance on CAP, but without much resilience
Social - Urban and rural divide - Agriculture pumping increases until groundwater is gone	Economic - Investment in infrastructure for tribal water and investment in augmentation - Reduction in ag subsidies

Flood Gates

Legal/Political - Finalizing Tribal water rights - Increased allocations in the LB - Increased legalization of demand in LB	Governance - Development of agreements to send more water to Mexico - Agreements to send water to Salton Sea - Status quo rules
Ecological - Reconnecting water for the sea - Ramping up investments in the river - Pulse flows everywhere	Physical - Increased connectivity in the basin - Build more dams - Increase groundwater banking - Pipeline from IID to San Diego and bypass MET - No arguments against any of the UB users - New infrastructure to take water to Mexican cities - Atmospheric rivers creates localized flooding
Social - Reducing demand --> now it will be about allocating surplus - Low demands and surplus water - Migration to AZ due to lower water pricing - Improved technology --> decreased in-person collaboration	Economic - Recreational economy expands - Boom in the Delta - Increase customer base - Growth in the southwest - More development - Hedge funders play a role in water pricing - Increased investments in water and infrastructure

Appendix L – Summary of Concluding Discussion: Workshop #2

- Storylines: What are potential next steps to deepen and refine the storylines?
    - Collapse into four storylines
    - Include a focus on science gaps and physical and social/economic tipping points
    - Focus on the audience, timeframe, scale of the storyline and impacts.
    - For all the storylines, distill common themes, opportunities and challenges. Once this is synthesized, develop strategies and solutions.

- Process: What are the next steps for expanding the discussion?
    - How can the process include Tribes in a more meaningful way?
    - At what point do we transition to responses, and who is involved in the discussion?
    - When/how do we bring more people into these conversations?
    - How do we bring these ideas for thinking about risk to legislators/decision-makers?

- Next Steps: What are next steps for exploring responses and solutions?
    - Identify solutions that are common to all, eg strong governance, good connections, investments in infrastructure, empowering Native nations, creative urban/rural partnerships.
    - Identify no regrets strategies.
    - Reference Decision Making under Deep Uncertainty (DMDU) for helping people set expectations and approach, eg robust decision-making, and scenario planning in the military to direct resources towards managing risk.
    - Reframing: We need to plan for a 10 maf future, then think about 11maf as a surplus -rather than expecting 16.5 maf.
    - Shift focus from drought (supply focus) to demand focus.
    - Need legislation to require insurance companies to cover fire, floods, drought, etc.
    - Power mapping: a few people can make a big difference in this arena.
    - Develop scenarios that are more meaningful for agriculture.

- Products: What materials will be most useful moving forward?
    - Set of storylines with more context and a set of impacts.
    - Feedback for Reclamation as an input to planning for the renegotiations.

Appendix M – Agenda: Workshop #3

Purpose

The Colorado River Conversations (CRC) Project is intended to help build broad, interdisciplinary support and a science foundation for the upcoming renegotiations of the 2007 Colorado River Interim Guidelines. The overall objective of this project is to expand the parameters of the conversation about future conditions in the Colorado River Basin. The Scenario Planning component of the CRC is focused on helping to identify and consider the implications of extreme events.

The first Scenario Planning workshop was held in June 2019 and focused on identifying plausible low probability/high consequence disruptive socio-economic and water management events within the context of extreme drought and catastrophic floods. The second workshop was held in October 2019 and was designed to a) present detailed scenarios that combined selected extreme conditions, b) discuss the implications of each storyline, and c) explore options for participants to apply the scenarios within their work and moving forward towards the start of the renegotiation of the basin guidelines.

At the end of the second workshop, the group outlined a third and final workshop that would focus on a path forward, with a particular focus on solutions.

Important Note about Zoom
To increase chances of a smooth and uninterrupted zoom call during our workshop, **please join the workshop by calling into the audio portion with your phone and then linking to the video**. Hopefully this will lower the chance of audio issues due to an unstable internet connection. **At the end of this agenda, we provide detailed step-by-step instructions for joining a zoom meeting by phone**. We also illustrate several user options during the meeting and other details that may be useful during the workshop.

Workshop Goals

1. Develop common themes of the storylines (tipping points, concerns, who wins/loses).
2. Identify directions for low-regret strategies, e.g. what will put us on a path that will allow us to adapt (or at least be somewhat better prepared) in the context of black swan events.
3. Describe useful ideas, research or paths forward specific to the common themes.

Agenda
Tuesday, April 7, 2020

1:00 – 1:15	Welcome, Introductions, Overview of Workshop Goals
1:15 – 1:40	Reflections on Scenario Process in Light of Current Conditions
1:40 – 2:00	Overview of Storylines and Impacts
2:00 – 4:00	Break-out Groups – Solutions for Managing Risk for Each Storyline
2:00 – 2:45	*Brainstorm All Responses/Solutions for First Storyline*
	Break
2:45 – 3:30	*Brainstorm All Reponses/Solutions for Second Storyline*
3:30 – 3:50	*Identify Common Low-Regret Responses for Both Storylines*
3:50 – 4:00	Wrap up in the Full Group

Wednesday, April 8, 2020

9:00 – 9:20	Presentation of Synthesis of Ideas from Breakout Groups
9:20 – 10:00	Preferred Low-Regret Solutions
10:00 – 10:30	Helpful Paths Forward for Identified Solutions
10:30 – 10:45	Ways to Work Together for a Better Future
10:45 – 11:00	Wrap-Up and Next Steps

Appendix N – Participants: Workshop #3

Participants

Bidtah Becker, Navajo Nation
Peter Culp, Culp & Kelly
Tom Davis, Yuma County Water Users Association
Carolyn Enquist, University of Arizona
Jennifer Gimbel, Colorado State University
Nadia Hardjadinata, Metropolitan Water District
Chris Harris, Colorado River Board of California
Mark Harris, Grand Valley Water Users Association
Taylor Hawes, The Nature Conservancy
Laurna Kaatz, Denver Water
Vineetha Kartha, Arizona Department of Water Resources
Jamie Kelley, Mohave County
Eric Kuhn, Author
Jeff Lukas, Western Water Assessment
Mohammed Mahmoud, Central Arizona Project
Jennifer Pitt, National Audubon
Seth Shanahan, Southern Arizona Water Association
Rebecca Smith, Bureau of Reclamation
Tim Thomure, Tucson Water
Crystal Tulley-Cordova, Navajo Nation
Brad Udall, Colorado State University
John Weisheit, Living Rivers
Steve Wolff, Wyoming State Engineer's Office

Project Team

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Kathy Jacobs, University of Arizona
Season Martin, Martin & McCoy
Amy McCoy, Martin & McCoy
Amanda Leinberger, University of Arizona
Mariana Rivera-Torres, University of Arizona

Appendix O – Four Storylines Discussed in Workshop #3

Orange Group	**1 - Caught Off Guard** Wet to Dry Swing Infrastructure Failure Governance Failure	**2 - Social Shifts** Long Duration Dry Increased Wealth Gap Increased Tribal Engagement in the Upper Basin
Blue Group	**3 - Disaster Strikes** Less Snow Collapse of California Water Systems Bad Economy	**4 - Dig It Deeper** No Monsoon Aquifer Crash Increased Tribal Engagement in the Lower Basin

Appendix P – Summary of Solutions and Concluding Discussion from Workshop #3

The range of solutions were grouped into four categories: Social, Economic, Science, and Governance (summarized in the table below). Interestingly, the group focused on the importance of building and maintaining relationships and trust across governance institutions (from local to federal), water-use and management sectors, and geographies. There was a significant emphasis on identifying opportunities for collaboration, assisting one another in finding and fostering ways to support each other, and coalition building. The participants noted that they wanted to extend conversations beyond the tenure of this scenario planning series and find new and innovative ways to work together to collectively manage risk. Additional solutions discussed focused on increasing flexibility and agility, pursuing strategic financial and water supply reserves that could be deployed during times of crisis and shortage, and integrating scientific research and data into decision-making processes.

Social	Economic	Science	Governance
Collaboration and alliance-building across sectors	Developing creative financing for implementation of all solutions	Access to best available science for decision-making	Solutions with co-benefits across regions and sectors
Expanding and building water leadership across the basin	Investments in Tribal infrastructure, capacity, and water supplies	Connecting benefits of water management, environmental systems, and public health	Greater flexibility for water transfers
Diversifying options for communicating hydrologic risk		Research into multiple water supply benefits of watershed management	Redundant water supplies and strategic water reserves
Develop contingency plans and continuity of operations planning across multiple scales		Best practices for implementing technology solutions (e.g. green infrastructure)	Water conservation and demand management