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Colorado Water Institute  
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U.S. House of Representatives Committee on Natural Resources  
Subcommittee on Water, Oceans, and Wildlife

The State of Water Supply Reliability in the 21<sup>st</sup> Century

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Longworth House Office Building

Chairman Huffman, Ranking Member McClintock, and other members of the panel, thank you for providing me an opportunity to speak on this important issue.

I am a senior scientist at Colorado State University where I study how climate change will affect Western US water supplies. For over 15 years, I have published and spoken extensively on the impacts of climate change on western rivers, and how we might reduce those impacts. Today I want to use my time to focus on the Colorado River.

## 1 The 21st Century Climate Challenge for the Colorado River Basin

Nineteen years of unprecedented drought in the gaged record have brought the Colorado River basin to the brink of the first ever major water delivery reductions in the Lower Basin. The combined contents of the two largest reservoirs in the United States, Lakes Mead and Powell, are now barely 40% full (Figure 1). Last month the U.S. Bureau of Reclamation said that there is a 69% chance for the first-ever shortage in 2020 and a 21% chance that Lake Mead will be less than 25% full in 2023<sup>2</sup> (Figure 2). At this level, the reservoir's ability to supply water to Nevada, California, Arizona and Mexico is at risk.

Since 2000 flows have been 19% below the 20<sup>th</sup> century average (Figure 3). 2018 was the hottest and driest year in the 4-Corners region since records were first kept in 1895 (Figure 4). Temperatures in the basin are now over 2° F warmer than the 20<sup>th</sup> century average, and those temperatures are certain to continue rising. Because the term drought implies a temporary

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<sup>1</sup> In addition to my position at Colorado State University, I am a co-investigator with the DOI Southwest Climate Adaptation Science Center, and a member of the Colorado River Research Group. ([www.coloradoriverresearchgroup.org](http://www.coloradoriverresearchgroup.org)).

<sup>2</sup> January 2019 Projections from Reclamation's Mid-Term Operations Model (MTOM) model here: <https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html>. Note that these projections use the full 111 years of historical hydrology (1906-2016) which includes the pluvial at the beginning of the 20<sup>th</sup> century. The actual risk using some form of 'stress test' hydrology without the wet period would be substantially higher.

condition, and this 19-year drought has been anything but that, scientists have begun using “aridification” to describe the ongoing hot and dry climate in the basin<sup>3</sup>.

In addition to climate change, overuse has also contributed to the problem. Water users in the Lower Basin states consume roughly 10.2 million acrefeet<sup>4</sup> (maf) annually, while inflows from upstream average 9 maf leaving an imbalance of 1.2 maf/year, or about 7% of the total flow in the system. This imbalance, known as the “Structural Deficit,” along with the low flows, has helped to drive both Lakes Mead and Powell lower (Figures 1 and 5).

## 2 The Salience of Warming Temperatures

In 2017, Dr. Jonathan Overpeck<sup>5</sup> and I published a peer-reviewed paper<sup>6</sup> which said that higher temperatures due to climate change had reduced the flow of the Colorado River by approximately 6%, and that additional warming could reduce flows by approximately 20% in 2050, and up to 35% by 2100, should precipitation remain the same<sup>7</sup>. Higher temperatures increase evaporation from soils and water bodies, increase sublimation from snowpacks, and increase water use by plants due to a longer growing season and more warmth on any given day. A thirstier atmosphere which can now hold more moisture due to higher temperatures also contributes to the problem. Given the large 2° F warming in the basin, we called the current period a “hot drought” and the flow losses “temperature-induced flow reductions” to distinguish them from a more normal “dry drought” that causes precipitation-related flow reductions.

Last year Dr. Dennis Lettenmaier<sup>8</sup>, his doctoral student Mu Xiao, and I published another peer-reviewed paper<sup>9</sup> showing that 50% of the flow reduction from 2000 to 2014 was due to higher temperatures and the remaining 50% was due to shifting precipitation patterns.

Other recent papers have also found significant impacts of temperatures on Colorado River flows<sup>10</sup> and other western rivers. Southwestern US megadroughts--droughts lasting decades--

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<sup>3</sup> It should be noted that it is possible that the Colorado River may see a decade or more of higher flows in the 21<sup>st</sup> century – our enhanced water cycle is now capable of generating very large flows. But on balance, the science tells us that over the course of the 21<sup>st</sup> century the greatest risk is for flow reductions and ongoing aridification.

<sup>4</sup> An acrefoot is 1 foot of water depth over an area of 1 acre or about 325,000 gallons. This is enough water for 2 to 4 families per year.

<sup>5</sup> Dr. Overpeck is Now Dean of the University of Michigan School for Environment and Sustainability. At the time of the paper he was the Director of the Institute of the Environment at the University of Arizona and the Thomas R. Brown Distinguished Professor of Science.

<sup>6</sup> Udall and Overpeck, 2017, The twenty-first century Colorado River hot drought and implications for the future.

<sup>7</sup> In the paper these numbers all have ranges on them. The range of current flow reduction was from 3% to 10%. 6% is roughly the mid-point of this range. The range in 2050 was from 8% to nearly 30%, using 3 different temperature sensitivities and a broad range of future emissions. In 2100 the range was from 12% to 55%. In the text above, I round to the middle of these ranges.

<sup>8</sup> Distinguished Professor of Geography at the University of California at Los Angeles.

<sup>9</sup> Xiao, Udall and Lettenmaier, 2018. On the Causes of Declining Colorado River Streamflows.

<sup>10</sup> See Dettinger, Udall, & Georgakakos, 2015; McCabe, Wolock, Pederson, Woodhouse, & McAfee, 2017; Overpeck & Udall, 2010; Vano, Das, & Lettenmaier, 2012; Vano et al., 2014; Vano & Lettenmaier, 2014; Woodhouse, Pederson, and Morino, McAfee, & McCabe, 2016.

have been shown to be much more likely in the 21<sup>st</sup> century as it warms, even if precipitation increases<sup>11</sup>.

The 2018 4<sup>th</sup> National Climate Assessment<sup>12</sup> found that the hydrologic cycle has already been profoundly modified by climate change. In the West, snowpacks are being reduced, snowmelt runoff is occurring earlier in the year, and flows in the fall are lower. More of our precipitation is occurring as rain rather than snow. Previous National Assessments in 2009 and 2014 reported similar results. Studies also note that past hydrology is no longer a suitable guide to future hydrology, a concept sometimes known as the “Death of Stationarity”.

It is clear the Colorado River, and the entire Southwest, has shifted to a new hotter and drier climate, and, equally important, will continue to shift to a hotter and drier climate for several decades after we stop emitting greenhouse gasses. Last year humans emitted over 37 billion tons of CO<sub>2</sub>, an increase of 2.7% over 2017<sup>13</sup>. Given these unprecedented changes to our climate and water supplies, our 20<sup>th</sup> century water management systems will need fundamental modifications to ensure that humans, our economy, and our environment suffer the least harm from likely future reductions in water supplies.

### 3 The Drought Contingency Plan (DCP)

The 7 Basin States are close to a “Drought Contingency Agreement<sup>14</sup>” that will implement large proactive reductions in deliveries in the basin to protect Lakes Mead and Powell from reaching dangerously low volumes. In the Lower Basin, Central Arizona agriculture will be especially hit hard along with more manageable shortages for Las Vegas and central Arizona municipalities. If flows remain low, California agriculture and municipalities in Southern California will be impacted in future years.

The states, the Central Arizona Project, irrigation districts, NGOs, Indian Tribes and others deserve recognition for the hard work needed to agree on very difficult reductions in water use. And Reclamation has been within its rights to strongly encourage all of the parties to finish these agreements soon.

The agreement is an important first step. To be sure, it significantly reduces the chance of emptying Lake Mead, an event that would prove to be very challenging for the entire Southwest. Most critically, the DCP buys us time to implement more permanent solutions. And on paper the DCP ‘solves’ the Structural Deficit. It is, however, not perfect. It has mechanisms to account for and repay any shortages should flows later partially refill reservoirs. These paybacks have the potential to put the reservoirs back into precarious territory just when they show signs of recovery. Although the agreement has not been finalized, I am very optimistic that it will be completed soon.

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<sup>11</sup> Ault, Mankin, Cook, & Smerdon, 2016; Cook, Ault, & Smerdon, 2015

<sup>12</sup> <https://nca2018.globalchange.gov>

<sup>13</sup> [https://www.washingtonpost.com/energy-environment/2018/12/05/we-are-trouble-global-carbon-emissions-reached-new-record-high/?utm\\_term=.874be32b4d7b](https://www.washingtonpost.com/energy-environment/2018/12/05/we-are-trouble-global-carbon-emissions-reached-new-record-high/?utm_term=.874be32b4d7b)

<sup>14</sup> The DCP is actually a set of agreements. <https://www.usbr.gov/dcp/>

This agreement will only last 7 years. New negotiations will need to begin by the end of 2020 to replace the existing 2007 agreement on shortage sharing and reservoir operations<sup>15</sup> which expires in 2026. Hard issues left unresolved by the DCP will make the coming negotiations even more challenging.

## 4 The 2020-2026 Negotiations leading to the 2026 Agreement

In the long term, the Basin states need not just a Drought Contingency Plan, but a Climate Change Plan that accounts for likely future declines in flows. Should flows continue to drop, as the science suggests is likely, additional reductions in consumption will be needed. Agreeing on reductions that cause the least harm to water users, the overall economy and the environment will be an exceedingly difficult task, much harder to come by than those achieved in the DCP. To ensure water reliability in the 21<sup>st</sup> century, planning for major flow reductions should be the main charge for those leading the negotiations for the new 2026 agreement.

### 4.1 An Open, Inclusive EIS Process Needed

The negotiations will need a full Environmental Impact Statement including the transparency that such a process requires. (With the exception of Arizona, the DCP process lacked transparency and inclusion.) This process should allow for alternatives supplied by the states, tribes, municipalities, academia, NGOs and others. The 2007 process, for example, incorporated an NGO-sponsored ‘Conservation Before Shortage’ alternative that provided some of the ideas implemented in the 2007 agreement and later in the DCP. Reclamation should support making modeling tools available to interested parties; modeling allows for thinking with numbers in much the same fashion that writing allows for thinking with words. Without these open access tools, some stakeholders will be unable to fully participate in the process.

### 4.2 Permanent Structural Deficit Solution Needed and Plans for Extended Low Flows

A permanent solution to the Structural Deficit should be part of the 2026 negotiations. The negotiation also needs to consider how water management will respond to potential future unprecedented low flows that require reductions in addition to those needed to solve the Structural Deficit. The current rules, laws and agreements imply solutions that may lead to litigation, may be undesirable and perhaps even impractical. Rules, laws and agreements around “equalization”, who bears the burden of solving the Structural Deficit, and the agreement around the Upper Basin delivery ‘obligation’ will all need to be considered.

With each passing year, the existing 2007 reservoir rules reduce the possibility of ‘equalization releases’ from Lake Powell to Lake Mead. It has been these large (e.g., 3-5 maf in one year) releases that have allowed the Structural Deficit to persist. The combination of future large temperature-induced flow reductions and the likely continuation of the existing high bar for equalization means that it is very likely that at least 1.2 maf / year of demand will need to be permanently removed from the river in the 2026 agreement with provisions for additional reductions if needed.

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<sup>15</sup> <https://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf>

Contrary to what the 1968 Colorado River Basin Project Act says, the Central Arizona Project (and to a much lesser degree, Nevada) should not have to bear the entire burden of solving the Structural Deficit. This is because 5m people in Phoenix and 1m people in Tucson rely at least to some extent on this surface water. (Tucson has no surface water, although it does sit atop a large but not infinite supply of groundwater.) This fact has been acknowledged implicitly by inclusion of shortages to California in the DCP. It is extremely likely that additional shared sacrifice by all Lower Basin entities will be needed.

Since 1922, the Lower Basin has relied on Section III(d) of the Colorado River Compact which appears to obligate the Upper Basin to deliver 75 maf every ten running years as a backstop to future potential low flow conditions. That wording of that clause says that the Upper Basin shall not cause the flow to decline below 75 maf. However, if climate change causes those flow reductions, and if the Upper Basin is well under their Compact Section III(a) consumptive use limit as they currently are, the Upper Basin has a strong case to make that Section III(d) does not apply. Were this to occur, the Upper Basin would have been in serious drought for a number of years and its reservoirs would likely be empty. In addition, water to meet such a ‘compact call’ would come disproportionately from already suffering Upper Basin municipalities including Colorado’s Front Range, Albuquerque, and Salt Lake City. This could lead to lengthy litigation, an outcome that would do little to provide either water or an immediate solution. In such a situation, the Lower Basin would need to reduce uses well beyond that needed to solve the Structural Deficit.

**4.3 The Tension between Water Conservation to Raise Lake Levels and Later Recovery**  
Well-meaning existing efforts (“Intentionally Created Surplus” and variants) allowed by the 2007 agreement to prop up Lake Mead with unused conserved water may have an implicit flaw, which is that these waters are accounted for and are later allowed to be withdrawn from the system, potentially at times when the system is more exposed. This year Metropolitan Water District announced plans to withdraw its previously stored water rather than have it stranded by the existing rules which prevent withdrawals at low lake elevations. This is the water management equivalent of a bank run, and without a surefire mechanism of deposit insurance, such untimely withdrawals may happen in the future.

To be sure, these efforts were designed to encourage water conservation and this has occurred. But there remains a tension between encouraging conservation and at the same time allowing the recovery of this water later which actually means that no real conservation occurred – the storer merely shifted water use in time. These water storage efforts allow us to push the problem forward in time, hoping that Mother Nature will rescue us. But they can make low flow years worse, with storing entities desiring to recover these saved supplies during such low years exactly when the reservoirs are bottoming out. Unfortunately, there is no clear way to provide the equivalent of deposit insurance, which in this case would be a supply of emergency water to prop up either the reservoir or the depositor.

These rules might make sense in a system where a reasonable expectation is that a better future will soon occur. In a declining system, however, these rules push difficult decisions to the future when those decisions will be even more challenging. It is not clear how to solve this problem, but at least shedding light on it may help identify solutions.

#### 4.4 Developing Future Hydrology that accounts for Warming and Non-Stationarity

One of the most difficult aspects of water resource management in the era of climate change is that the past is no longer a guide to the future<sup>16</sup>. Current floods and droughts are now routinely exceeding the envelope of the historic record. This makes planning, including probabilistic modeling, very difficult.

Current projections for the future of the basin often use the full range of historical hydrology from 1906 onward to generate probabilities of future delivery reductions. Yet we know these probabilities are understated because of a very wet period at the beginning of the 20<sup>th</sup> century that will likely not reoccur. In these modeling efforts, the wet years refill reservoirs and bail out the system. In recent years Reclamation has investigated using shorter periods (“stress test hydrology”) that remove this wet period and use only the more recent dry period. It is possible that even these efforts understate the future risk. Other work is ongoing to understand the increasing influence of temperature on streamflows, including the physical mechanisms for the uncoupling of runoff from precipitation. Much more work needs to be done.

Reclamation has also been experimenting with future hydrology scenarios that step back from probabilities. These scenario-based efforts attempt to provide plausible futures for decision makers without explicit, overly precise and misleading probabilities. Additional work is needed in this area and Reclamation needs to be given the resources to pursue all of this work. This is a national problem as well.

## 5 Other Actions and Considerations

### 5.1 Agricultural Solutions

Agriculture will be at the center of additional water shortages in the basin because of its approximately 70% of total water use. The Drought Contingency Plan provides money and a plan to replace Colorado River water with groundwater to partially mitigate harm to Arizona irrigators. With potential cuts to locations outside of central Arizona and in California, groundwater is unlikely to be available as a replacement source.

In 2017 Greg Peterson and I published a study<sup>17</sup> on how agriculture might adapt to lower flows. We looked at deficit irrigation of alfalfa, rotational fallowing, crop switching, irrigation efficiency<sup>18</sup> and water conservation. All of these water saving techniques offer the promise of at least some water savings, although each also has distinct costs. Perhaps the most promising of these techniques is switching to less water intensive crops, although it is also the least known and least tried. Crop switching requires growers to change labor, equipment, markets, transportation, storage and more. For crop switching to work, growers will need assistance and assurance that these new products will be financially viable.

There is much the federal government can do to assist with such a transformation. The US government should help facilitate all of these techniques through programs at Reclamation such

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<sup>16</sup> Milly et al., “Stationarity Is Dead.”

<sup>17</sup> <http://www.cwi.colostate.edu/media/publications/cr/232.pdf>

<sup>18</sup> Improperly done, irrigation efficiency measures can paradoxically increase water consumption. Properly done, irrigation efficiency can provide needed flexibility and save water. See (Grafton et al., 2018; Ward & Pulido-Velazquez, 2008)

as WaterSMART<sup>19</sup>, and through the Farm Bill. The Department of Interior and the U.S. Department of Agriculture need to ensure that inter-departmental coordination occurs so that programs can be integrated as much as possible. Given that agriculture will bear much of the brunt of coming reductions, it is imperative that USDA be as active as possible in mitigating the impacts to agricultural users. In addition, Reclamation should consider a broad study to see where its large backlog of infrastructure needs might overlap with opportunities to pursue irrigation efficiency and water conservation.

## 5.2 The Salton Sea

The Salton Sea stands out as an area of special concern. 2017 marked the last year of extra flows into the sea to mitigate transfers to San Diego. It has now begun to decline rapidly, falling 1.7 feet in the past two years, threatening both a critical ecological resource and human health in the Imperial and Coachella Valleys. Impacts are already being noted<sup>20</sup>. There are a number of reasonably simple actions that could be taken to resolve problems, and also importantly, to allow future Colorado River problems to be solved. Without a functioning Salton Sea, the Imperial Irrigation District's ability to contribute to a meaningful resolution of the existing Structural Deficit, and additional demand reduction if necessary, will be seriously constrained.

Plans exist to minimize the developing impacts at the sea; what has been missing is resources to implement these ideas. The USGS Salton Sea Science Office needs a fulltime director based near the sea. Reclamation could support hydrologic studies, engineering review and general construction management for Salton Sea habitat projects. The US Fish & Wildlife Service Salton Sea Wildlife Refuge should be fully staffed and funded, including money for the Red Hill Bay project.

Despite its size and apparent last minute nature, the Imperial Irrigation District's recent \$200m request is reasonable. There is a need for long-term funding for Salton Sea monitoring and O&M which is largely unmet by California's bond funding.

## 5.3 New Diversions in the Basin

Despite the ongoing aridification and warning signs that the river is overallocated and overused, additional diversions are still being planned in the Basin. Given all that we know, these plans should be delayed or if built only allowed to divert when the harm to existing users will be very low, such as when Lakes Powell and Mead are full or nearly full. With serious shortages already possible, the last thing this basin should consider is additional diversions.

## 5.4 The Federal Role in Policy

The federal government through Reclamation has long played an important role in the basin. Historically, that role has been primarily to build and run the massive infrastructure. In recent years, Reclamation has provided important scientific support to the Basin States in their negotiation of new water agreements. The agency has played a critical convening and process role, while letting the states lead on policy, as is appropriate given state ownership of most water rights. However, when the states fail to lead, Reclamation has rightly threatened, scared and cajoled the states back to their proper role. This is as it should be and Reclamation should

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<sup>19</sup> <https://www.usbr.gov/watersmart/>

<sup>20</sup> <https://www.desertsun.com/story/news/2019/02/08/salton-sea-california-fish-bird-die-off-winter/2818025002/>

continue to provide scientific support, management and the appropriate leadership on new water agreements including a willingness to impose solutions if the states are unable or unwilling to make the difficult choices required.

## 5.5 Science and Data Collection

Interior through the USGS and its partners needs to continue to fund our national stream gage network, and expand that network where scientists and decision makers agree that additional gaging is necessary. To use a navigation analogy, climate change puts us in uncharted territory. With less than complete “maps” of our climate future, we need to make sure that our instruments are working and providing the very best information on our location.

Congress should continue to support existing programs like the NOAA-funded Regional Integrated Sciences and Assessment (RISA) programs, the Department of Interior Climate Adaptation Science Centers (CASC), Reclamation’s water science efforts and the USDA Climate Hubs<sup>21</sup>, all of which serve to connect scientists with decision-makers so that useful science can be created and understood. These programs have a known track record of knowledge co-production, which includes the breaking down of barriers between scientists and decision makers. The RISA and CASC programs have been especially good at assessing the state of science for stakeholders. The Climate Hubs are much newer, show great promise with helping agriculture adapt to climate change, but need more resources. Reclamation’s scientist-engineers are very talented and deserve recognition and support for moving emerging science into useful engineering.

Note that these actions will have widespread national benefits beyond the Colorado River.

## 5.6 Greenhouse Gas Reduction Efforts

Finally, any solution set must aim at the root cause of the temperature-induced flow reductions. Climate change is as serious a problem as humans have ever faced and thus requires not one, but a vast set of solutions. The ultimate goal must be net zero greenhouse gas emissions as soon as is practical, ideally with net zero reductions by 2050 but no later than by 2070<sup>22</sup>. This is achievable but will take great leadership. To the extent we fail to do this, we will impose great costs on ourselves, our youth, and especially on future generations. Greenhouse gas reductions must be pursued through a suite of actions including carbon pricing, investments in technology, tax credits, and even thru Climate Smart Agriculture<sup>23</sup> which aims to increase farm yields while sequestering carbon in soil.

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<sup>21</sup> I have served as the Director of the Western Water Assessment RISA, am a co-investigator for the Southwest Climate Adaptation Science Center and serve as one of Colorado State University’s liaisons to the Northern Plains Climate Hub.

<sup>22</sup> These are the recommendations from the recent IPCC 1.5 Degree Special Report.

<sup>23</sup> Colorado State University has a new Climate Smart Agriculture initiative and works with the USDA Climate Hubs. Climate Smart Agriculture was initially conceived by the Food and Agriculture Organization in 2013. See Lipper et al, 2014



## 6 Conclusions

Scientists have attributed changes in the global water cycle to human caused climate change including enhanced precipitation in hurricanes like Harvey which dropped 50+ inches of rain in 4 days<sup>24</sup>, record-setting droughts like the one in California from 2012 to 2017<sup>25</sup>, and recent flow declines in the Rio Grande<sup>26</sup>. Climate change is also clearly impacting river flows in the Colorado River, too. Simply put, climate change is water change.

My father was a member of this committee for over 30 years and chaired it for 14 years. This very hearing room is named for him, and his portrait overlooks us all. His generation, the greatest generation, revered science and the knowledge it provided that allowed us to build the amazing water supply infrastructure that now exists on the Colorado River.

That generation did not shy from solving the great problems of its day, including how to provide reliable water supplies for the American Southwest and how to clean up our environment. My best guess is that in this very room the ground breaking 1968 Colorado River Basin Project Act was passed out of committee.

Similarly, this generation should not shy away from solving the great problems of today, which include how do we adapt to climate change and how do we stop it. The science on climate change is now 200 years old, and is very, very clear. When major oil companies accept the science<sup>27</sup> and say we must act, as they have<sup>28</sup>, the debate should be over. It is over in every other major country.

Climate change threatens all we hold dear – our economic well-being, our culture, our way of life, our environment, our kids and future generations. This is especially clear when it reduces our life-giving water supplies as it is now doing in the Colorado River Basin. Climate change is the key threat to 21<sup>st</sup> century water supply reliability.

To minimize this threat, we must act now by adapting to the coming changes with smart water management and policy, with technology, with science and also by reducing greenhouse gas emissions as quickly as we can.

Thank you for your time.

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<sup>24</sup> Risser & Wehner, 2017; Trenberth, Cheng, Jacobs, Zhang, & Fasullo, 2018

<sup>25</sup> Diffenbaugh, Swain, & Touma, 2015

<sup>26</sup> Chavarria & Gutzler, 2018

<sup>27</sup> <https://www.scientificamerican.com/article/oil-giant-accepts-climate-consensus-denies-responsibility-for-warming/>

<sup>28</sup> <https://corporate.exxonmobil.com/en/Energy-and-environment/Environmental-protection/Climate-change/http://reports.shell.com/sustainability-report/2015/energy-transition/addressing-climate-change.html>

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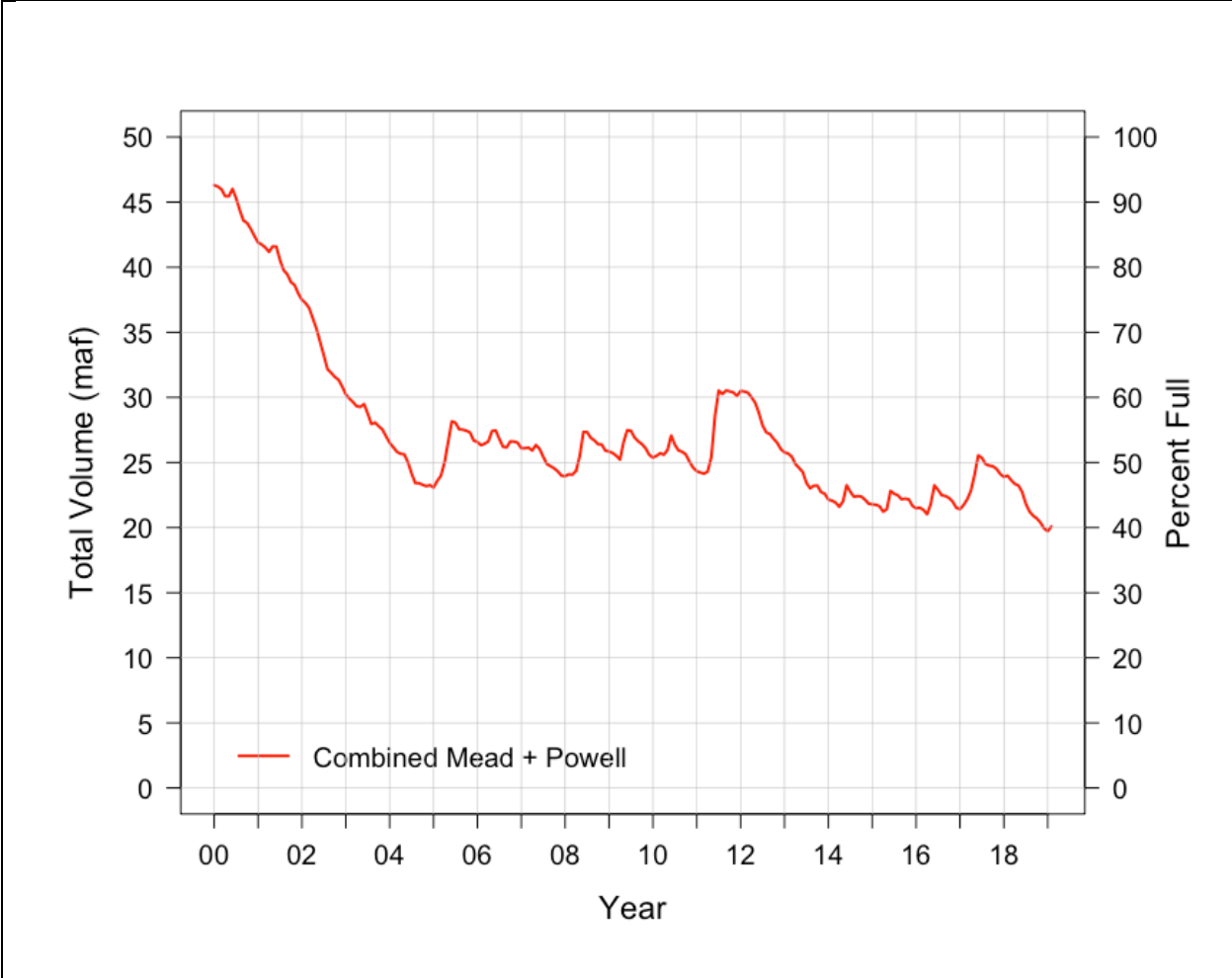


Figure 1: Combined Contents of Lakes Powell and Mead 2000 to January 31, 2019.

**Percent of Traces with Event or System Condition**  
**Results from January 2019 MTOM/CRSS<sup>1,2,3,4</sup> (values in percent)**

	Event or System Condition	2019	2020	2021	2022	2023
<b>Upper Basin – Lake Powell</b>	<b>Equalization Tier</b>	<b>0</b>	<b>1</b>	<b>10</b>	<b>13</b>	<b>17</b>
	<i>Equalization – annual release &gt; 8.23 maf</i>	0	1	10	13	17
	<i>Equalization – annual release = 8.23 maf</i>	0	0	0	0	0
	<b>Upper Elevation Balancing Tier</b>	<b>100</b>	<b>31</b>	<b>42</b>	<b>48</b>	<b>46</b>
	<i>Upper Elevation Balancing – annual release &gt; 8.23 maf</i>	43	19	39	44	40
	<i>Upper Elevation Balancing – annual release = 8.23 maf</i>	57	11	3	4	6
	<i>Upper Elevation Balancing – annual release &lt; 8.23 maf</i>	0	1	0	1	0
	<b>Mid-Elevation Release Tier</b>	<b>0</b>	<b>66</b>	<b>42</b>	<b>24</b>	<b>22</b>
	<i>Mid-Elevation Release – annual release = 8.23 maf</i>	0	0	0	3	4
	<i>Mid-Elevation Release – annual release = 7.48 maf</i>	0	66	42	21	18
	<b>Lower Elevation Balancing Tier</b>	<b>0</b>	<b>3</b>	<b>6</b>	<b>15</b>	<b>16</b>
<b>Lower Basin – Lake Mead</b>	<b>Shortage Condition – any amount (Mead ≤ 1,075 ft)</b>	<b>0</b>	<b>69</b>	<b>82</b>	<b>81</b>	<b>79</b>
	<i>Shortage – 1<sup>st</sup> level (Mead ≤ 1,075 and ≥ 1,050)</i>	0	69	50	33	26
	<i>Shortage – 2<sup>nd</sup> level (Mead &lt; 1,050 and ≥ 1,025)</i>	0	0	31	39	31
	<i>Shortage – 3<sup>rd</sup> level (Mead &lt; 1,025)</i>	0	0	0	9	21
	<b>Surplus Condition – any amount (Mead ≥ 1,145 ft)</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>4</b>
	<i>Surplus – Flood Control</i>	0	0	0	0	0
	<b>Normal or ICS Surplus Condition</b>	<b>100</b>	<b>31</b>	<b>18</b>	<b>17</b>	<b>17</b>

<sup>1</sup> Reservoir initial conditions based on December 31, 2019 conditions using the Mid-term Probabilistic Operations Model. MTOM uses the January 4, 2019 unregulated inflow forecast from the CBRFC.

<sup>2</sup> Each of the 35 initial conditions were coupled with 111 hydrologic inflow sequences based on resampling of the observed natural flow record from 1906-2016 for a total of 3,885 traces analyzed.

<sup>3</sup> Percentages shown may not sum to 100% due to rounding to the nearest percent.

<sup>4</sup> Percentages shown may not be representative of the full range of future possibilities that could occur with different modeling assumptions.

**RECLAMATION**  
*Managing Water in the West*

Figure 2: Shortage Probabilities for 2019 to 2023 from Reclamation’s January 2019 study.

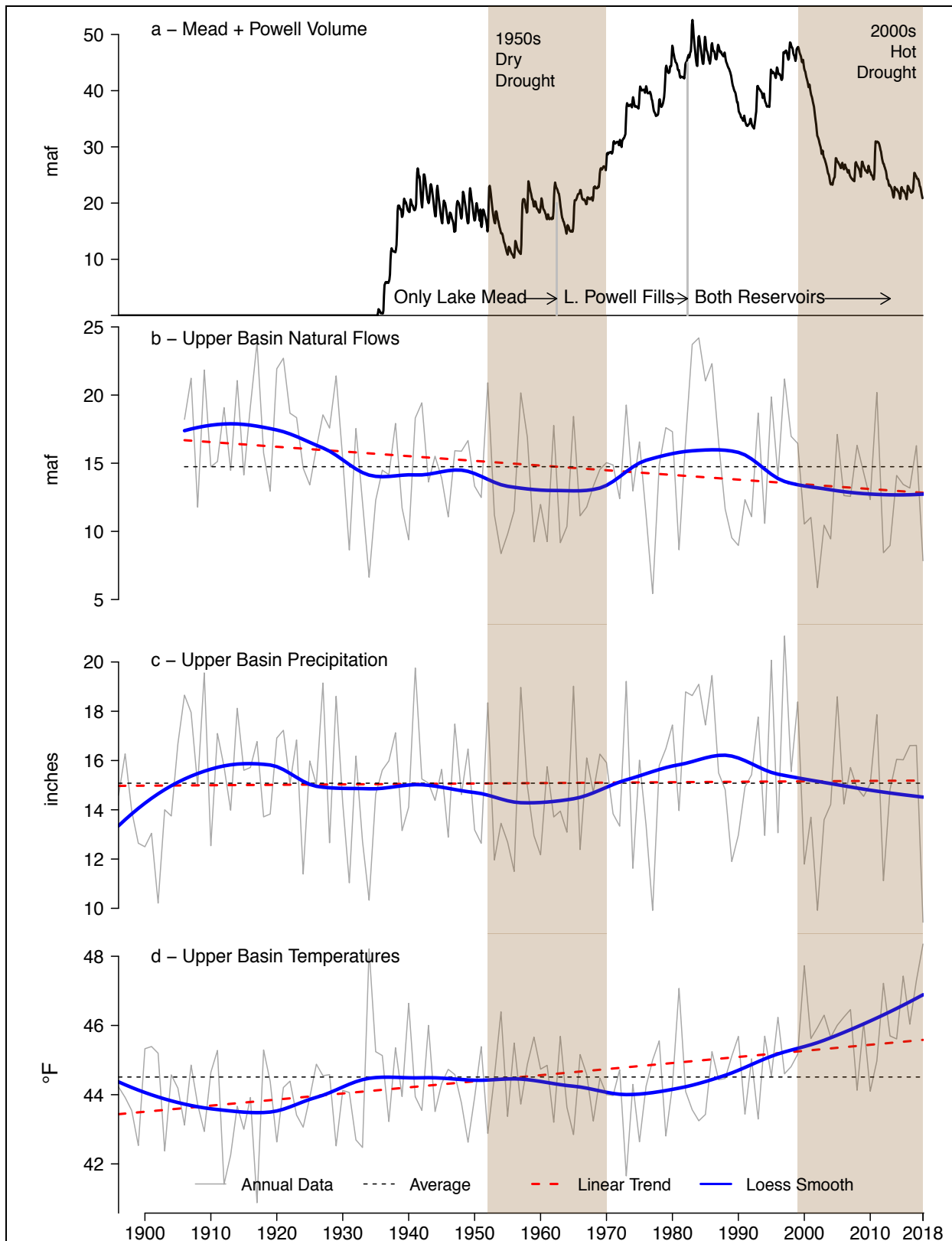


Figure 3: Reservoir Contents, Upper Basin Natural (undepleted) Flows, Precipitation, and Temperature for various periods to end of September 2018.

## 2018 was a brutal year for Colorado Agriculture

Lowest Precipitation on Record 4 Corners Area

Warmest Temps on Record in Many Parts of the State

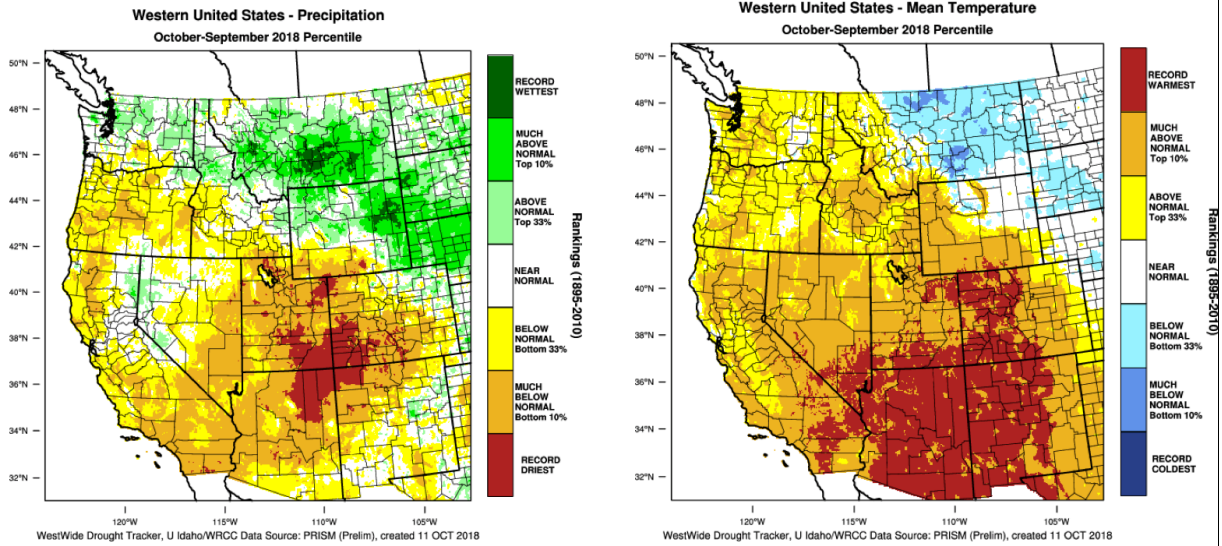


Figure 4. 2018 was a record setting hot and dry year in large parts of the American Southwest.

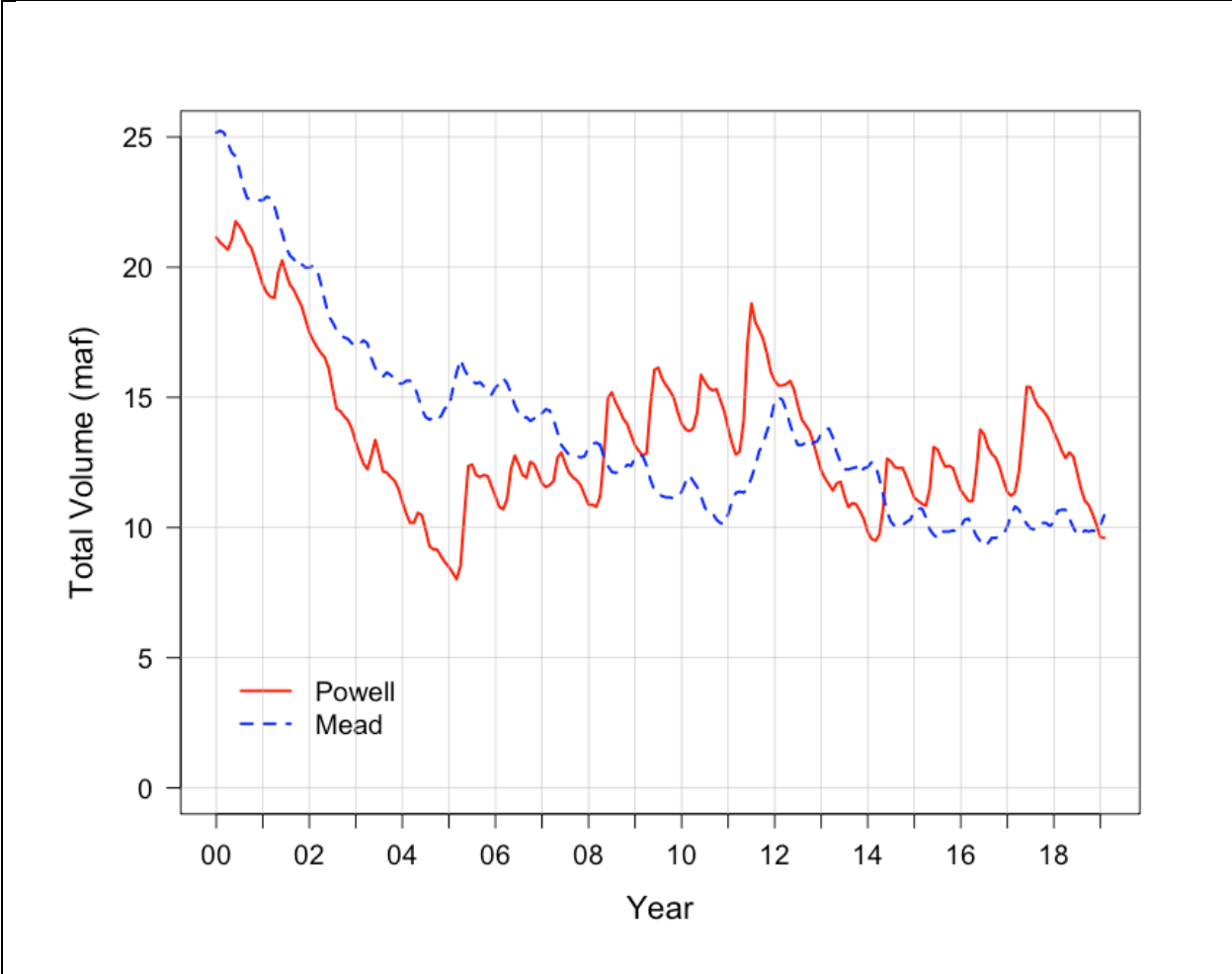


Figure 5. Contents in millions of acrefeet of Lakes Powell and Mead, January 1, 2000 to January 31, 2019.