Meeting the Need for Water in the Lower Colorado River by Diverting Water from the Mississippi River - A Practical Assessment of a Popular Proposal

Keywords: Drought, Colorado River Basin, Mississippi River, water diversion, climate change, water scarcity

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Introduction

The decades-long drought that has impacted the southwestern US has renewed interest in plans to divert a portion of the Mississippi River to help meet the need for water in the Colorado River Basin. After seeing this suggestion in editorials and news articles in local, regional, and national venues, we noticed a lack of information that can be used by the public to weigh the practical aspects of these proposals. This has created a void that's being filled by proposals that lack realistic goals, violate a number of physical laws, and convey a poor understanding of scale, among other issues. To help people understand these proposals, we've conducted an assessment based on credible data that are available to the public. We've also clearly defined our assumptions - including basic engineering constraints - and we've "shown our work" so everyone can see where our numbers come from.

While there are many things that can be done, most large-scale projects are limited by economic, social, and/or political realities. It can be easy for some to decry these limitations as artificial boundaries set by people who lack the will to make things happen. However, there are a number of legitimate challenges that are set by the scale of the proposed work. By considering a few of these issues, the magnitude of this proposal becomes more evident. For example, regardless of the dire need for water in the west, it is unlikely that a pipeline ranging in length from 1,200 to 1,600 miles with a diameter of 88 ft will be built across multiple states in the near future. Likewise, even at a penny per gallon, the ~$135 BILLION water bill to fill Lake Mead and Lake Powell is enough to keep this proposal on the back burner.

As you might suspect, there is no single approach that will meet all of the water needs of people in the Colorado River Basin. Hopefully, after considering this assessment, people will consider pursuing more practical measures to meet the immediate requirements of the region while also working to develop a combination of efforts to meet longer-term water needs.

Respectfully,

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Overview

The monumental scale of the water resource projects built in the 1930s provided water to support unprecedented growth in the population and productivity in the Colorado River Basin through the balance of the 20th century. Simultaneously, global climate change has brought rapid declines in the availability of water to people from across the globe. For example, waterborne commerce on the Rhine River in Germany is being adversely affected by record-low water levels.[1] Likewise, the low water level on the Yangtze River has caused the Chinese to limit irrigation and power generation.[2] In the United States, these same trends are reflected in a record twenty-plus year-long drought that's led to an unprecedented water shortage in the Lower Colorado River Basin.

It is abundantly clear that a critical source of water for around 40 million people and farms across the western United States is in serious peril. This has doubtlessly led to tangible losses to agricultural producers as well as to the recreation and tourism industries. Efforts by federal and state governments to manage this challenge have largely failed. Recently, people have revisited the idea of diverting a portion of water from the Mississippi River to replenish major western water reservoirs. While the issue was rekindled by a proposal in the Arizona State legislature in 2021,[3] this idea gained new traction after a recent editorial in the Palm Springs Desert Sun that went viral. In his June 26, 2022, editorial, Mr. Don Siefkes of San Leandro, California, proposed the diversion of water from the Mississippi River westward to refill Lake Powell and Lake Mead.[4] This proposal has sparked

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[1] Wittels, Jack, Kwaku Gyasi, and Laura Malsch. 2022. "Europe's Rhine River Is on the Brink of Effectively Closing." Bloomberg.com. https://www.bloomberg.com/news/articles/2022-08-02/europe-s-vital-rhine-river-is-on-brink-of-effectively-closing?leadSource=uverify%20wall.

[2] Davidson, Helen. 2022. "China drought causes Yangtze to dry up, sparking shortage of hydropower." The Guardian, August 22, 2022. https://www.theguardian.com/world/2022/aug/22/china-drought-causes-yangtze-river-to-dry-up-sparking-shortage-of-hydropower.

[3] Arizona House Concurrent Memorial 2004, May 11, 2021, https://trackbill.com/bill/arizona-house-concurrent-memorial-2004-floodwater-harvesting-study-urging-congress/1991520/

[4] Siefkes, Don. 2022. "We could fill Lake Powell in less than a year with an aqueduct from Mississippi River." The Desert Sun, June 30, 2022. https://www.desertsun.com/story/opinion/readers/2022/06/30/we-can-lake-powell-less-than-year-via-mississippi-aqueduct/7751467001/.

widespread discussions of the issue in venues including USA Today, the Los Angeles Times, and the Waterways Journal.[5] [6] [7]

To help people better understand these issues, an assessment of popular proposals and ideas was performed using publicly available information.

Background

The huge water resource projects of the 1930s provided water to support unprecedented growth in the population and productivity in the Colorado River Basin through the balance of the 20th century. Due to a combination of climate change, population growth, and intensive agricultural production, the seven states in the Colorado River Basin are facing an unprecedented water shortage. This issue is exacerbated by a lack of coherent water resource planning, mistrust among Colorado River Basin states, and a rising sense of desperation over the current and future impacts on people and commerce.

The Colorado River Compact

The Colorado River extends ~1,450 miles through seven US and two Mexican states. To avoid federal intervention in the allocation of water rights on the Colorado River, Wyoming, Colorado, Nevada, New Mexico, Utah, and California signed the Colorado River Compact to help divide water from the Colorado River equitably among the seven states it passes through.[8] The Compact was ratified in November 1922. In 1944, Arizona signed the Compact. Through this agreement, the Colorado Basin was divided into an upper (Colorado, New Mexico, Utah, and Wyoming) and lower basin (Arizona, California, and Nevada) at Lees Ferry, AZ.[9] Using this division, water allocations were made by basin - not by state. This issue remains at the heart of modern disagreements over the allocation of water resources and is a large factor that limits the likelihood of any new agreements on water allocation in the region.

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[5] Wilson, Janet. 2022. “Climate change has dried the West. Could a pipeline be the answer?” USA Today, August 15, 2022. https://www.usatoday.com/story/news/nation/2022/08/15/climate-change-west-mississippi-river-pipeline/10332092002/.

[6] Los Angeles Times. 2021. “A water pipeline from the Mississippi River to the west?” July 13, 2021. https://www.latimes.com/opinion/story/2021-07-13/drought-water-pipleline.

[7] Waterways Journal Editorial Board, “Drought Revives Mississippi River Pipe Dreams,” Waterways Journal, JULY 22, 2022, https://www.waterwaysjournal.net/2022/07/22/drought-revives-mississippi-river-pipe-dreams/.

[8] "Colorado River Compact," Article 1 (1922).

[9] "Colorado River Compact," Article 2 (1922).

In June 1922, the US Supreme Court established the law of prior appropriation as the legal means by which water rights were allocated in the American West. Under the Law of Prior Appropriation,[10] whoever used a water source first had the first right of use. This applied regardless of state boundaries. This serves as the basis for the Law of the River that establishes the relationship between the Upper and Lower Colorado River Basin states.

The states ultimately agreed to allocate 7.5 million acre-feet (MAF) per year of water from the Colorado River system in perpetuity for "beneficial use" to both the upper and lower basins.[11] This was believed to be enough water to meet current needs while also allowing for future development. In fact, this initial premise was a gross overestimation of the actual amount of water available in the Basin. Further, the Compact stipulated that upper basin states could not cut the flow of water to lower basin states. The allocation of 1.5 MAF of water from the Colorado River to Mexico was negotiated through a treaty that was ratified in 1944.[12] Since its inception, the allocation of water to specific states has been affected by the passage of legislation and federal regulations including the Boulder Canyon Project Act (1928),[13] the Colorado River Storage Project Act (1956),[14] the Colorado River Basin Project Act (1968),[15] and the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007),[16] among others.

Mandatory Water Reductions

In 2021, the federal government declared a Tier 1 water shortage on the Colorado River system which required water use reductions of 18, 7, and 5% in AZ, NV, and NM, respectively. This step was taken under the assumption that diminishing water levels would be replenished by winter rains and snow

[10] Wyoming v. Colorado, 259 U.S. 419 (1922), https://supreme.justia.com/cases/federal/us/259/419/

[11] "Colorado River Compact," Article 3 (1922).

[12] "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico"(1944).

[13] https://uscode.house.gov/view.xhtml?path=/prelim@title43/chapter12A&edition=prelim

[14] https://uscode.house.gov/view.xhtml?path=/prelim@title43/chapter12B&edition=prelim

[15] http://uscode.house.gov/view.xhtml?path=/prelim@title43/chapter32&edition=prelim

[16] 72 FR 62272 - Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, https://www.govinfo.gov/app/details/FR-2007-11-02/E7-21417.

melt. Unfortunately, the actual water recharge was much less than anticipated and water levels continued to fall across the basin. In June 2022, a Tier 2 water shortage was declared. As a result, the federal government will further reduce water allocations to Arizona by 21%, Nevada by 8%, and Mexico by 7% beginning in January 2023.[17]

Previous Studies of Water Diversion

Many proposals have been made to supplement water in the Colorado River. The Columbia River, the Mississippi River, and Lake Superior are among the most common proposed sources of supplemental water. The most recent credible study was published by the US Bureau of Reclamation (USBR) in 2012.[18] In this document, the USBR summarized a number of possible approaches to increasing the supply of water to/in the Colorado River Basin; this included desalination of ocean water, water reuse, and rainwater harvesting. Importing water from the Mississippi, Green, Snake, and Yellowstone Rivers was also considered. Diverting water from the Mississippi River was noted to be a 30-year-long project while importing water from the other rivers was thought to take around 15 years. The USBR also recommended a number of options to reduce the demand for water. In this study, it was predicted that the conservation of agricultural water would yield 1.0 MAF per year by 2035. Over the same time period, the diversion of water from each of the rivers noted above would only add ~0.76 MAF per year. This lends strength to the belief that some combination of efforts will be needed to address the water shortage.

Despite these studies, in 2021, the Arizona legislature petitioned the US Congress to conduct a study on the diversion of Mississippi River water to the Lower Colorado River Basin.[19] According to Representative Tim Dunn, a member of the Arizona Legislature and cosponsor of the bill, "... A new water source could help augment Colorado River supplies. One promising possibility involves piping water that is harvested from Mississippi River flood waters. Diverting this water, which is otherwise lost into the Gulf of Mexico, would also help prevent the loss of human life and billions in economic damages when such flooding occurs. ..."[20]

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[17] Briscoe, Tony. 2022. "As Talks On Colorado River Water Falter, U.S. Government Imposes New Restrictions". Los Angeles Times,

https://www.latimes.com/environment/story/2022-08-16/colorado-river-basin-states-fail-to-reach-drought-agreement.

[18] "Colorado River Basin Water Supply and Demand Study, US Bureau of Reclamation, US Department of the Interior (2012), https://www.usbr.gov/watersmart/bsp/docs/finalreport/ColoradoRiver/CRBS_Executive_Summary_FINAL.pdf.

[19] Arizona House Concurrent Memorial 2004, 2021,
https://trackbill.com/bill/arizona-house-concurrent-memorial-2004-floodwater-harvesting-study-urging-congress/1991520.

[20] News Release: Arizona Legislature Urges Congress to Study Feasibility of Harvesting Mississippi River Floodwaters to Replenish Colorado River Supply, May 11, 2021, https://www.azleg.gov/press/house/55LEG/1R/210511DUNNHCM2004.pdf.

An Assessment of the Diversion of Mississippi River Water to Refill Lake Powell and Lake Mead

Our Approach

Since Mr. Siefkes' editorial appeared to be the driving force behind this most recent round of debate and discussion of moving water from the Mississippi River to the west, the assertions and assumptions from his article were used as a starting point in this assessment. This approach is based on three main premises. (1) "Citizens of Louisiana and Mississippi south of the Old River Control Structure do not need all that water. All it does is cause flooding and massive tax expenditures to repair and strengthen dikes." (2) "The best solution would be for the U.S. Army Corps of Engineers to build an aqueduct from the Old River Control Structure on the Mississippi to Lake Powell, fill it, and then send more water from there down the Colorado to fill lake Mead." and (3) "Within a year and eight months of the aqueduct's finish, both reservoirs would be filled and most of the Southwest's water problems would be gone." The underlying assumptions that support these claims include the following:

- About 4.5 million gallons of Mississippi River water flow past the Old River Control Structure (ORCS) every second.
- 250,000 gallons of water per second will be diverted westward.
- The water shortage in Lake Powell and Lake Mead is 13.5 trillion gallons (5.5 trillion gallons in Lake Powell and 8 trillion gallons in Lake Mead).

These statements and the underlying assumptions beg a number of important questions that remain unanswered. For example, how much Mississippi River water is actually available for potential diversion? Many proponents of water diversion fail to recognize how drought conditions affect the entire US - including in the Mississippi River Basin. It's equally unclear how the diversion of water to the west would reduce flooding downstream of the ORCS or save taxpayers money from future flood response. Likewise, the actual scale of a proposed diversion structure is not addressed. In this case, the saying "the devil's in the details" is not a cliche.

Problems from the Start

USBR Discharge Data, 1906 - 1920

Before considering any particular aspect of recent proposals, it is necessary to understand the provenance of the data that are used to make water allocation decisions in the west. For example, the initial water allocation of 7.5 million acre-feet of water per basin was reportedly determined based on data provided by the USBR. At the time, the USBR estimated the annual Colorado River flow rate at Lees Ferry, AZ, to be 16.4 million acre-feet.[21] However, the average natural flow rate of the Colorado River at Lees Ferry, AZ, from 1906 to 1920, is 17.7 MAF based on data published by the USBR (Figure 1).[22] This corresponds to an 8% disagreement between data from the USBR. Regardless of the disparity in these data, it's important to recognize that the annual average natural flow rate of the Colorado River failed to exceed 15 MAF thirty percent of the time. ***At the very least, it's fair to say that decision-makers of the time had an optimistic view of the future availability of water in the west.***

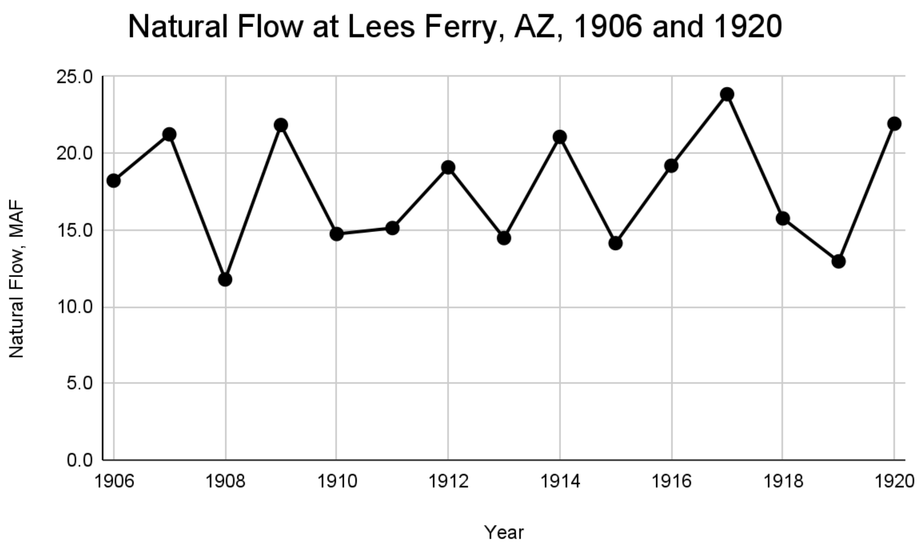

Figure 1. Natural Flow Rate at Lees Ferry, AZ, between 1906 and 1920.

USGS and USBR River Discharge Data from 1920 through 2022

The US Geological Survey (USGS) maintains a network of streamgages that provide continuous water level and discharge (flow rate) data on over 8,500 streams. Before the advent of modern

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[21] National Research Council, Committee on the Scientific Bases of Colorado River Basin Water Management, Water Science and Technology Board, Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability, 2007, at https://www.nap.edu/read/11857/chapter/1.
[22] https://www.usbr.gov/lc/region/g4000/NaturalFlow/LFnatFlow1906-2022.2022.5.2.xlsx

instrumentation, hydrologists would manually make these measurements. Discharge data have been measured at a USGS gage station at Lees Ferry, AZ, since 1921. From 1921 to August 2022, the average measured discharge at Lees Ferry was 14,457 cfs (10.5 MAF/yr).[23] In contrast, the average annual natural flow rate reported by the USBR over the same time period was 14.2 MAF, which is 35% higher than the discharge measured by USGS. The differences between data from these two sources is largely the result of differences in terminology and data reduction methods, which are addressed in a 50-page-long Scientific Investigation Report issued by the USGS in 2018.[24] However, even the appearance of a difference in these data is a needless complication to the already contentious issues surrounding water abundance and availability in the Colorado River Basin. ***Regardless, the annual allocation of 15 MAF between the Upper and Lower Colorado River Basins could never be satisfied using either set of average annual flow data from 1921 through August 2022.***

The difference between the amount of water promised and the amount of water that's actually available remains at the heart of almost all water issues across the Colorado River Basin. When combined with the impacts of climate change, this disparity will only become greater over time.

How Much Mississippi River Water is Available for Diversion?

Mississippi River Discharge from 2002 - 2022

According to Mr. Siefkes, "About 4.5 million gallons a second flow past that structure on the Mississippi." The source of his data was not provided. To assess this premise, low, average, and high water discharge data for the Mississippi River from 2002 to 2022 at the USGS streamgage located immediately above the ORCS were obtained and are summarized in Table 1.[25] From these data, ***the discharge of 4.5 M gal/s overstates the 20-year average by 38%***.

In reality, 4.5 M gal/s corresponds to the highest flow rate based on the most recent 20 years of water which occurred in 2019 during the most significant Mississippi River flooding event in recent times. On a related note, the flow of water past the ORCS serves a number of additional purposes that might not be immediately apparent. For example, the flow of sediment-laden Mississippi River water below

[23] https://waterdata.usgs.gov/monitoring-location/09380000/#parameterCode=00065&period=P7D

[24] Bruce, B.W., Prairie, J.R., Maupin, M.A., Dodds, J.R., Eckhardt, D.W., Ivahnenko, T.I., Matuska, P.J., Evenson, E.J., and Harrison, A.D., 2018, Comparison of U.S. Geological Survey and Bureau of Reclamation water-use reporting in the Colorado River Basin (ver. 1.1, September 2019): U.S. Geological Survey Scientific Investigations Report 2018–5021, 41 p., https://doi.org/10.3133/sir20185021.

[25] USGS National Water Information System, https://waterdata.usgs.gov/nwis/uv?site_no=07289000, accessed August 31, 2022.

the ORCS is vital to efforts to reduce the further disappearance of the Louisiana coastline and barrier islands.[26]

Table 1. Mississippi River Discharge at Vicksburg, MS, Station 07289000 (from 8/24/02 to 8/31/22).

Discharge (8/24/02 to 8/31/22)	ft^3/s	gal/s	250,000 gal/s diversion as a % of discharge
low (2012)	200,000	1,496,000	16.7%
average	435,000	3,253,800	7.7%
high (2019)	600,000	4,488,000	5.6%

The Proposed Diversion Rate in Relation to Mississippi River Discharge

At the average Mississippi River discharge rate, the diversion of 250,000 gal/s is less than 8% of the total average flow (Table 1). However, ***when the lowest discharge conditions are considered, the proposed diversion is nearly 17% of the river flow***. This difference is not negligible. In fact, this is similar to the 21% reduction in Colorado River water that will be imposed in January 2023 as a result of a Tier 2 water shortage. As people in the west know all too well, careful consideration should be given before suggesting that the allocation of water to any population should be reduced by 17%. In light of this analysis, the argument that "Citizens of Louisiana and Mississippi south of the Old River Control Structure don't need all that water" becomes much more tenuous.

The Impacts of Drought are Widespread

The western US is experiencing a significant drought that is having long-term hydrologic and ecological effects. Based on data from the National Drought Mitigation Center (NDMC), the states that make up the Colorado River Basin have been under drought conditions since at least 2000. However, over the same period, other parts of the nation - including the Mississippi River Basin have also experienced drought conditions. To place this into context, the extent of drought conditions across the continental US in 2002, 2012, and 2022 are presented in Figure 2.[27]

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[26] Cornwall, Warren. "Unleashing the Big Muddy: By Sending Mississippi Waters on a New Course, Engineers Hope to Build New Land—and Test Ways to Save a Retreating Coast," Science, 22 April 2021.
doi: 10.1126/science.abj1040

[27] U.S. Drought Monitor. National Drought Mitigation Center, U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration, https://droughtmonitor.unl.edu.

In 2012, the severity of the drought was greater in the Upper and Lower Mississippi River Basins than in the Upper and Lower Colorado River Basins (Figure 2, middle). Fortunately, the severe drought along the Mississippi River Basin was relatively short-lived. However, drought conditions still exist in Minnesota, Wisconsin, Iowa, Illinois, Missouri, Arkansas, Kentucky, Tennessee, and Mississippi. While the duration and severity of the drought in the Mississippi River Basin are substantially less than in the Colorado River Basin, the presence of drought conditions in the east cannot be neglected - particularly if plans involve moving water from the Mississippi River to the west. The widespread impacts of drought continue to affect the entire nation and beyond. For instance, in late September 2022, a drought along the Mississippi River Basin caused low water conditions that had adverse impacts on waterborne commerce.[28] [29] Further, the severity of dry conditions has become worse over time. Given the length and geographic extent of these dry conditions, it is unlikely that this will abate under natural circumstances.

Could Diverting Water Help Reduce Flooding?

Could the diversion of 250,000 gal/s of Mississippi River water reduce the cost of flooding? Earlier, we saw that diverting 250,000 gal/s from the Mississippi River would reduce the average downstream flow by 7.7% (~8%). Under flooding conditions, the average downstream flow would be reduced by only 5.6%. This diversion would reduce the flow to Baton Rouge, New Orleans, and other locations that are downstream from the ORCS. During the height of a flooding event, it's reasonable to assume that local people would welcome the diversion of even the smallest fraction of water. However, Mississippi River flooding isn't limited to the final reach of the River. Consequently, the proposed benefit of diverting Mississippi River water from the ORCS to the west would be of little significance to basin-wide flooding.

For a water diversion project to have a meaningful impact on flooding downstream from the ORCS, any system would have to be able to accommodate a large surge in water volume over a relatively short period of time. Accommodating a surge flow of water has its own challenges that include the need for a large pumping capacity and a place to send the water.

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[28] Press, Jim, "Low Water On The Mississippi River Impacting Barge Traffic". www.STLtoday.Com, September 30, 2022, https://www.stltoday.com/news/national/low-water-on-the-mississippi-river-impacting-barge-traffic/article_0702562c-45c3-5b18-9c6d-47733168de95.html.

[29] Chris Isidore, Amanda Watts, Judson Jones and Brandon Miller "Another supply chain crisis: Barge traffic halted on Mississippi River by lowest water levels in a decade," CNN Business, October 8, 2022, https://www.cnn.com/2022/10/07/business/mississippi-river-closures-grounded-barges-drought-climate

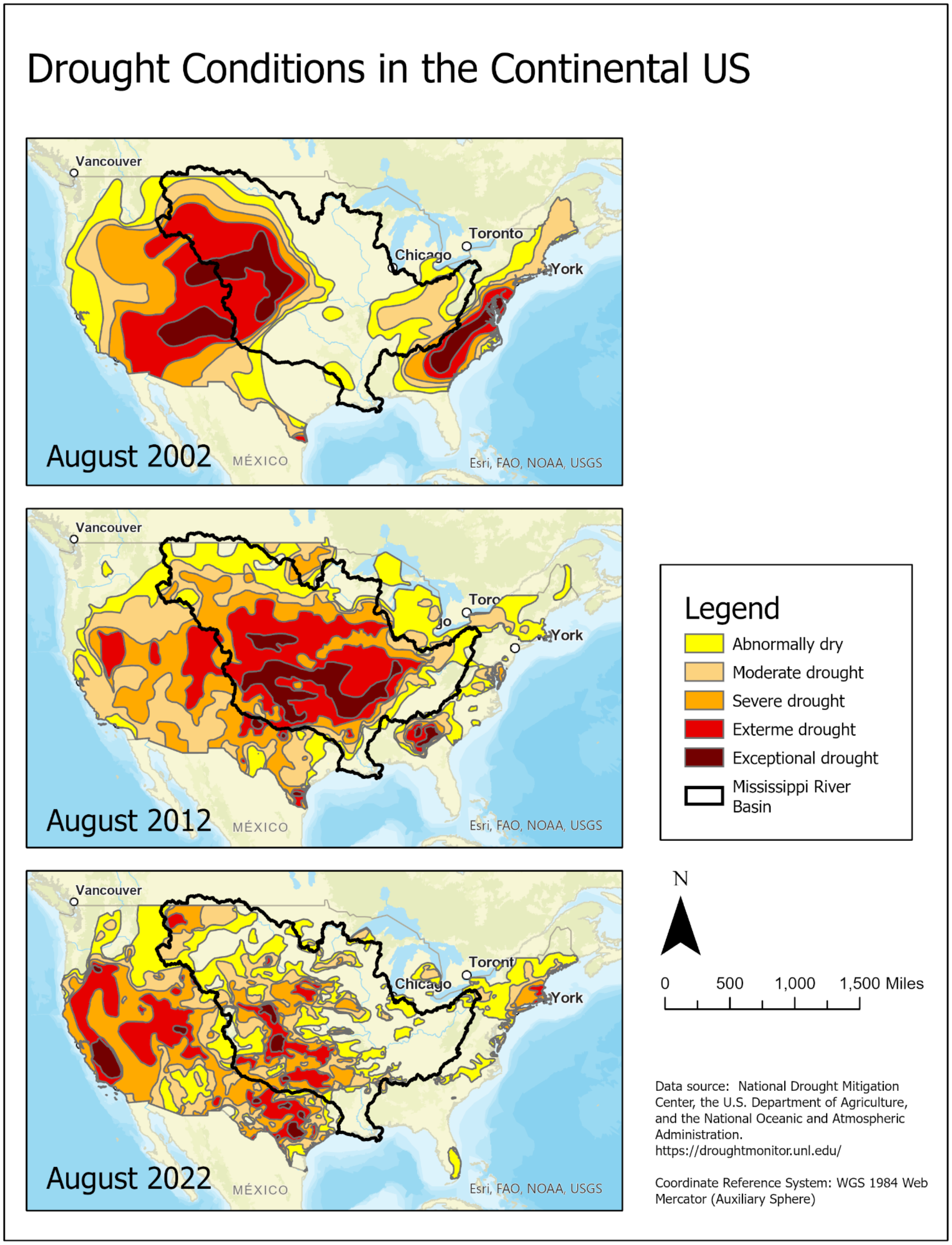

Figure 2. Drought conditions in the Continental United States, 2002, 2012, and 2022.

Assessing the Alleged Benefits of Water Diversion

Could Diverting Water Save Taxpayers Money on Flood Response and Recovery?

Any natural disaster - including flooding - has expensive consequences. In the United States, the federal government provides support (skilled workers, supplies, rescue capabilities, and money) to help communities respond to and recover from these events. In this regard, many people suggest that the water shortage in the western US should be treated like any other natural disaster. However, others cast the issue in different terms. It has been suggested that diverting water from the Mississippi River to refill Lake Powell and Lake Mead would save taxpayers money by reducing the need to build and maintain levees and other infrastructure along the Mississippi River and its major tributaries.

A number of approaches can be used to weigh this assertion, though none are ideal. To use contemporary data, we considered the cost associated with flooding across the Mississippi River Basin in 2019 as the worst case in terms of economic impact. While there have been numerous floods along the Mississippi River in the intervening years, the next most recent rival to the flooding in 2019 occurred in 1993. According to the National Oceanic and Atmospheric Administration (NOAA), the total cost of the 2019 flood in the midwest was approximately \$20 billion (\$20,000,000,000).[30] [31] This estimate included costs associated with flood response and recovery, reconstruction and/or relocation, and other direct economic losses. At the rate suggested by Mr. Siefkes, 21.6 billion gallons of water would be diverted from the Mississippi River each day.

How many gallons of Mississippi River water would be diverted each day?

$$\left(\frac{250{,}000\,gal}{\cancel{sec}}\right)\left(\frac{86{,}400\,\cancel{sec}}{day}\right)=\frac{21{,}600{,}000{,}000\,gal}{day}$$

This is enough water to fill the Washington Monument (~8,200,000 gallons) more than 2,600 times each day. Laid end-to-end, this would be a distance of 1,430,000 ft. or a little less than 271 miles.

A cost must be assigned to a gallon of water to carry the assessment further. For the sake of argument, ***assume that water is worth \$0.01 per gallon***. Mr. Siefkes estimated that 624 days would be needed to fill both Lake Powell and Lake Mead and that the rate of water drawdown remains constant. Under these conditions, the cost of water to fill both lakes would be \$134.8 billion or ~6.7 times the cost of the response to the basin-wide Mississippi River flooding in 2019. This is the cost of water and ***doesn't***

[30] https://www.enr.com/articles/48586-noaa-says-2019-floods-caused-62b-in-damage-expects-more
[31] https://www.noaa.gov/news/2019-was-2nd-wettest-year-on-record-for-us

include the cost to acquire land, design and construct a conveyance system, treat the water, and provide for annual operation and maintenance.

What's the cost of water to fill Lake Powell and Lake Mead?

$$\left(\frac{21{,}600{,}000{,}000\ \cancel{gal}}{\cancel{day}}\right)(624\ \cancel{days})\left(\frac{\$0.01}{\cancel{gal}}\right)=\$134{,}784{,}000{,}000$$

How does the cost of water needed to fill Lake Powell and Lake Mead relate to the cost of Mississipi River flooding in 2019?

$$\frac{\$134{,}784{,}000{,}000}{\$20{,}000{,}000{,}000}=6.7$$

Moving Water to the West is a Matter of Scale

Any assessment of the diversion of water to the west should include an estimate of the actual scale of any new infrastructure. For example, a water diversion rate of 250,000 gal/s was suggested, though no rationale was provided. However, that figure plays a large role in determining the overall feasibility of any proposal. The water discharge rate is directly related to the water velocity and cross-sectional area of the channel or pipe that's used to move the water. To operate pumps at reasonable efficiencies while also minimizing mechanical wear to the pump, valves, and other fixtures, a maximum fluid velocity range is used. For water conveyance systems, a maximum average[32] water velocity of 3 to 8 ft/s is common (5.5 ft/s average).[33] In this case, a cross-sectional area of ~6,100 ft^2 would be needed to meet the proposed flow requirement.

[32] This isn't a typographical error. "Maximum average" is correct.

[33] Engineering ToolBox (2003). Water Systems - Maximum Flow Velocities. https://www.engineeringtoolbox.com/flow-velocity-water-pipes-d_385.html (accessed 18 August 2022).

Flowrate, Q, is related to the water velocity, v, and the cross sectional area of the pipe or channel, A.

$$Q = vA$$

$$A = \frac{Q}{v}$$

At a rate of 250,000 gal/s with a velocity of 5.5 ft/s, the cross sectional area of a pipe or channel is 6,100 ft^2.

$$A = \frac{Q}{v} = \frac{\left(250{,}000\frac{\cancel{gal}}{\cancel{s}}\right)\left(0.134\frac{ft^3}{\cancel{gal}}\right)}{5.5\frac{ft}{\cancel{s}}} = 6{,}091\,ft^2 \simeq 6{,}100\ ft^2$$

An Open Channel

In theory, this cross-sectional area would correspond to a channel that's 100 ft wide and 61 ft deep, or 1,000 ft wide and 6.1 ft deep. Alternatively, 10 channels that are 100 ft wide and 6.1 ft deep could also be used. For perspective, the lanes of an interstate highway are 12 ft wide with a 4 ft wide left shoulder and a 10 ft wide right shoulder. If the median is 50 ft wide, an interstate that's two lanes in each direction would be around 126 ft wide from shoulder to shoulder. When considering the need for a foundation and a right-of-way, a 100 ft wide water aqueduct would occupy a footprint that's similar to an interstate highway in a nonurban area. However, the "highway" would be at least 61 ft deep and extend at least 1,200 miles (see Figure 3).

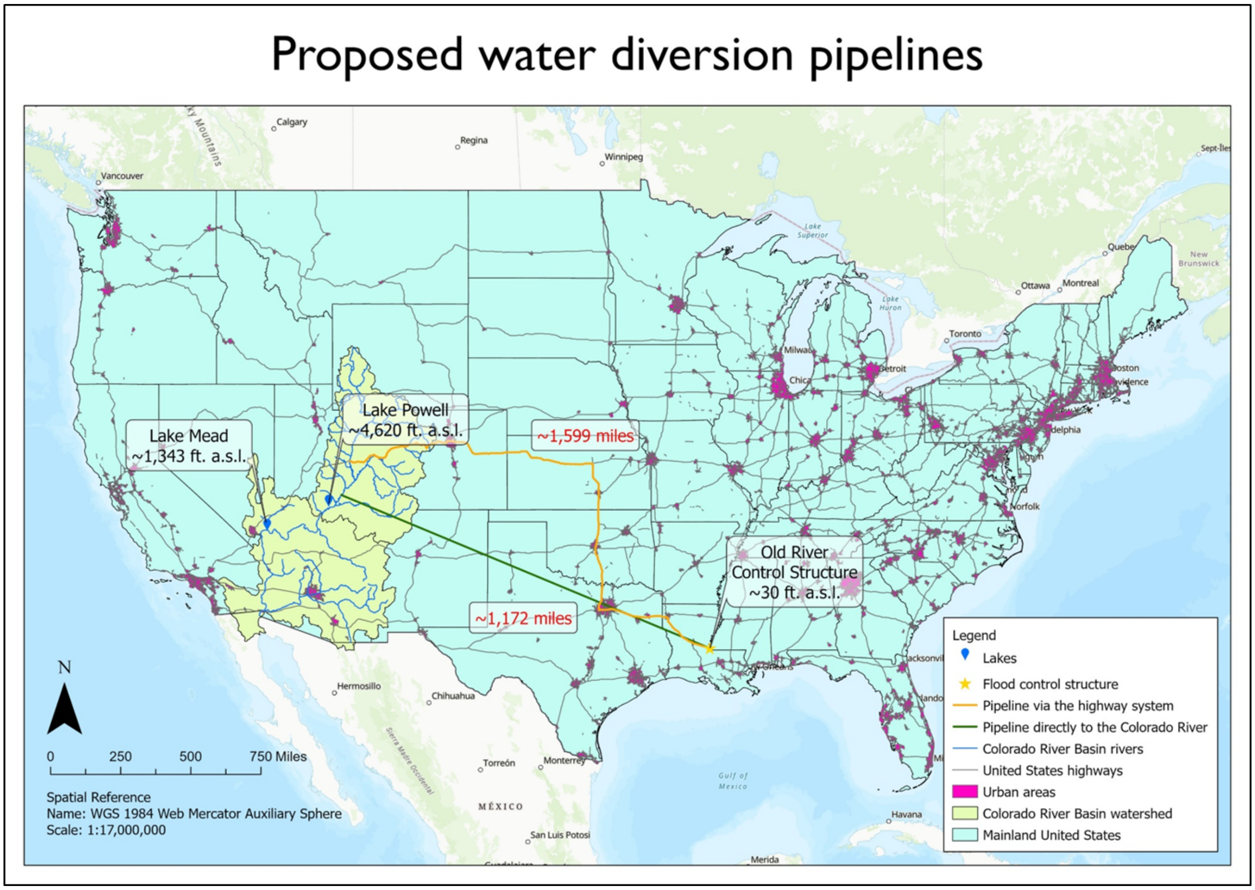

Figure 3. Possible routes for a water diversion project from the Old River Control Structure on the Mississippi River in LA, to Lake Powell, AZ.

A Water Super Highway?!

The comparison of a water channel to an interstate has been made by some who have proposed building the water conveyance structure next to existing interstate highways. Unfortunately, the shortest route between the ORCS and Lake Powell when following existing interstate highways is around 1,600 miles long (see Figure 3). That's approximately 1.4 times the distance of a straight-line path. This corresponds to around ***1.9 billion yd³ of excavated material for the channel, alone***. This channel would have to be lined and would require additional excavation to build a suitable foundation. Construction along existing interstates is further complicated by the presence of ten metropolitan areas with populations ranging from ~82k to 5.1 million people (2010) along the route.

Piping Water to the West

Some have suggested using a closed pipe to minimize the loss of water to evaporation in an open channel. Under the constraints established earlier, such a pipe would require a diameter of around 88 ft. This is more than 1.5 times the length of a standard semi-trailer (53 ft long)!

The diameter of a single circular pipe can be found from the flowrate, Q, and the avearege maximum water velocity, v.

$$Q=vA$$

$$A=\pi r^2=\frac{\pi}{4}d^2$$

$$Q=v\left(\frac{\pi}{4}d^2\right)$$

$$d=\sqrt{\frac{4Q}{\pi v}}$$

The diameter of a pipe needed to move 250,000 gal/s of water at a velocity of 5.5 ft/s, is 88 ft.

$$Q=250{,}000\tfrac{gal}{s}$$

$$v=5.5\tfrac{ft}{s}$$

$$d=\sqrt{\frac{4\left(250{,}000\frac{\cancel{gal}}{\cancel{s}}\right)\left(\frac{0.134\,ft^3}{1\,\cancel{gal}}\right)}{\pi\left(5.5\frac{\cancel{ft}}{\cancel{s}}\right)}}=88\ ft$$

Other Factors

The "Elephant in the Room" - Elevation

Beyond any of the previous issues, the single most significant limiting factor in this proposal is the difference in elevation between the Mississippi River at the ORCS and the highest point the water would need to be lifted before flowing into the Colorado River or a tributary. Any overland route would have to go over the Western Continental Divide. For example, if a direct overland route were taken from the ORCS to Lake Powell, a pipeline or aqueduct would have to traverse a path with a maximum elevation of just under 11,000 ft (around 12 miles east of Santa Fe, NM). Regardless of the height of any particular mountain peak, the elevation difference between the Mississippi River at the ORCS and Lake Powell is ~4,600 ft. This is substantially different from other aqueduct systems that rely on gravity to move water; the most well-known of these systems is the water supply for New York City which begins in the Catskill Mountains.

Some have noted that the US Army Corps of Engineers (USACE) has pumps that can move huge volumes of water. This is true. They believe these pumps could be used to move water westward to the Colorado River Basin. This is not true. When selecting a water pump, engineers consider several factors including the discharge flow rate and the height that water needs to be lifted. The pumps used to respond to flooding are capable of very high discharge rates, while their lift capabilities are relatively low. When compared to the difference in elevation between the ORCS and Lake Powell, the lift capacity of these pumps is irrelevant. Rather, new pumps and infrastructure would be required.

Invasive Species

In addition to the factors above, other, less obvious issues must be considered. For example, Mississippi River water is home to a wide range of aquatic organisms that aren't native to the Colorado River Basin. It would be beneficial for those who consider this to be a trivial concern to learn more about the proliferation of silver and bighead carp (*Hypophthalmichthys molitrix* and *Hypophthalmichthys nobilis*, respectively) along the Mississippi River and its tributaries.[34] Likewise, similar lessons can be learned by considering the impacts of zebra mussels (*Dreissena polymorphaon*) that were introduced into freshwater habitats in the Upper Mississippi River Basin through ballast water.[35]

Water Quality

It is also worthwhile to consider the quality and characteristics of the Mississippi River water before exporting it westward. Lake Mead is known to contain elevated concentrations of nitrogen and phosphorus. According to the USBR, nitrate concentrations in Lake Mead range from 0.28 to 0.50

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[34] "Asian Carp Overview - Mississippi National River and Recreation Area (U.S. National Park Service)". 2022. Nps.Gov. https://www.nps.gov/miss/learn/nature/ascarpover.htm#.

[35] Chou, P. 1999. "What Is The Current Status Of The 'Invasion' Of Non-Native Zebramussels In The Great Lakes? Has The Invasion Been Stopped Or Controlled? And Whatecological Damage Has This Creature Caused Other Than The Clogging Of Drainagepipes?". Scientific American. https://www.scientificamerican.com/article/what-is-the-current-statu/.

mg/L (0.39 mg/L average). This corresponds to a nitrogen concentration of 0.09 mg/L NO_3 as N. According to data from the USGS, in 2021, the average concentration of nitrate and nitrite in the Mississippi River at Vicksburg was 0.61 mg/L NO_3 and NO_2 as N. Consequently, on average, the concentration of nitrogen in the water from the Mississippi River is 6.8 times greater than the concentration in Lake Mead. At a rate of 250,000 gal/s with an average nitrate concentration of 0.61 mg/L NO_3 as N, a total of 68,605,828 lb of nitrogen would be sent westward during the 624 days proposed to fill Lake Powell and Lake Mead. That's almost 69 million pounds of nitrogen! For the sake of argument, assume that Lake Powell and Lake Mead are at about 27% of their full volume. After refilling the lakes with water from the Mississippi River, the concentration of nitrogen will be around 0.47 mg/L NO_3 as N or 2.1 mg/L NO_3. To avoid the known adverse impacts of increased nitrogen loading, treatment would be needed at a considerable additional expense.

Final Thoughts

It is abundantly clear that a critical source of water for the southwest US is in serious peril. In response to the failed efforts of federal and state governments to manage this challenge, people have renewed their interest in ideas that include diverting water from the Mississippi River to replenish major western water reservoirs. Unfortunately, time, space, ecology, finances, and politics aren't on the side of this proposal. While the proposal is interesting, the diversion of Mississippi River water is not likely to help anyone meet the increasingly dire need for water in the west. As water levels continue to decrease in major reservoirs that are used for hydropower production, the current water deficit is increasingly becoming a water and power crisis. Hopefully, this work will allow people to gain a better understanding of a few popular proposals and will be able to give a more practical combination of approaches that lead to a sustainable supply of water in the west.

Conversion Factors

1 mi = 5,280 ft

1 Ac = 43,560 ft^2

1 day = 86,400 sec

1 Ac-ft = 32,5851 gal = 43,560 ft^3

1 ft^3 = 7.48 gal (US)

1 gal (US) = 3.785 L

1 yd^3 = 27 ft^3

1 lb = 453.6 g

1 mg/L NO_3 = 0.226 mg/L NO_3 as N