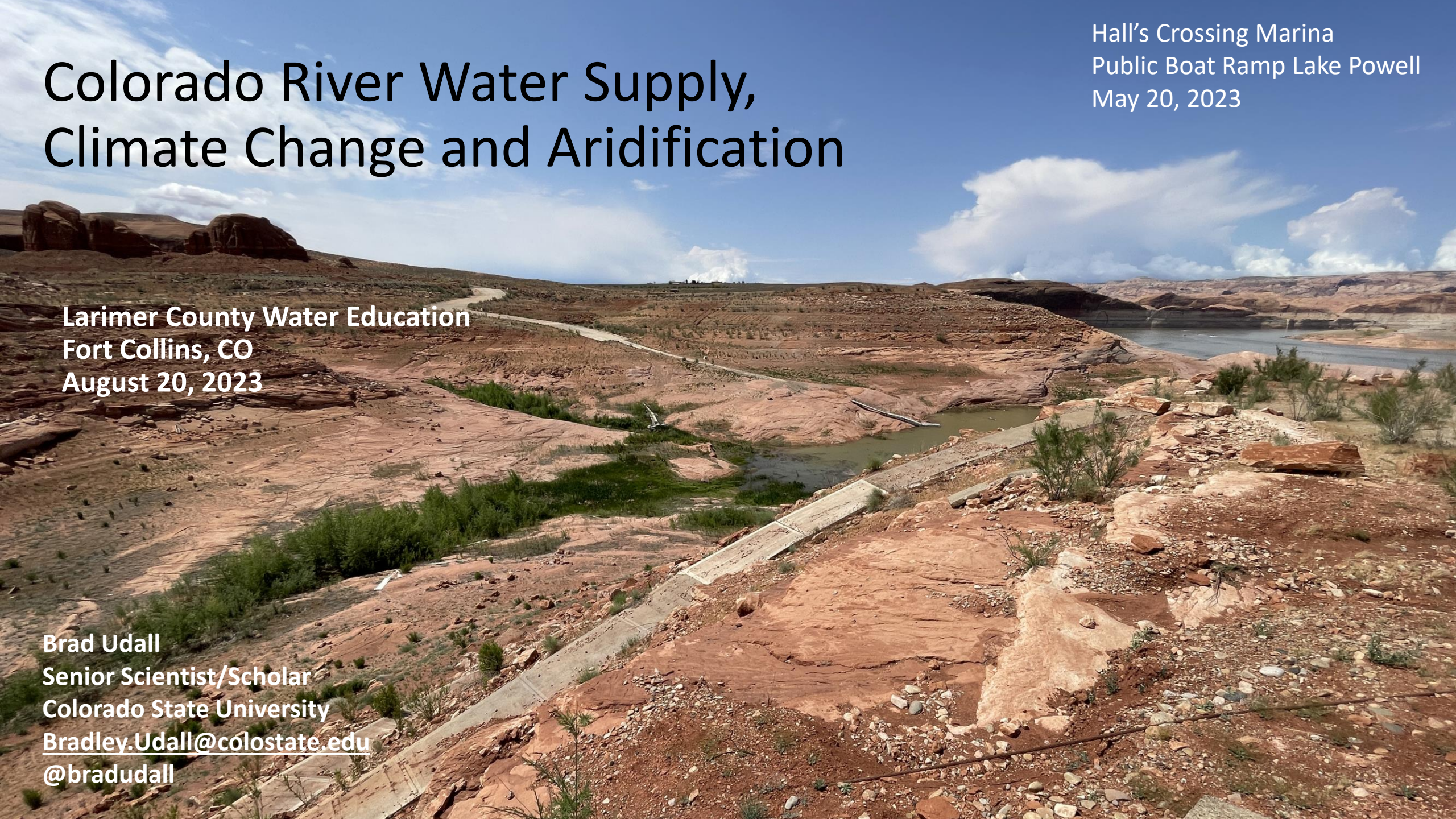
Colorado River Water Supply, Climate Change and Aridification



Larimer County Water Education
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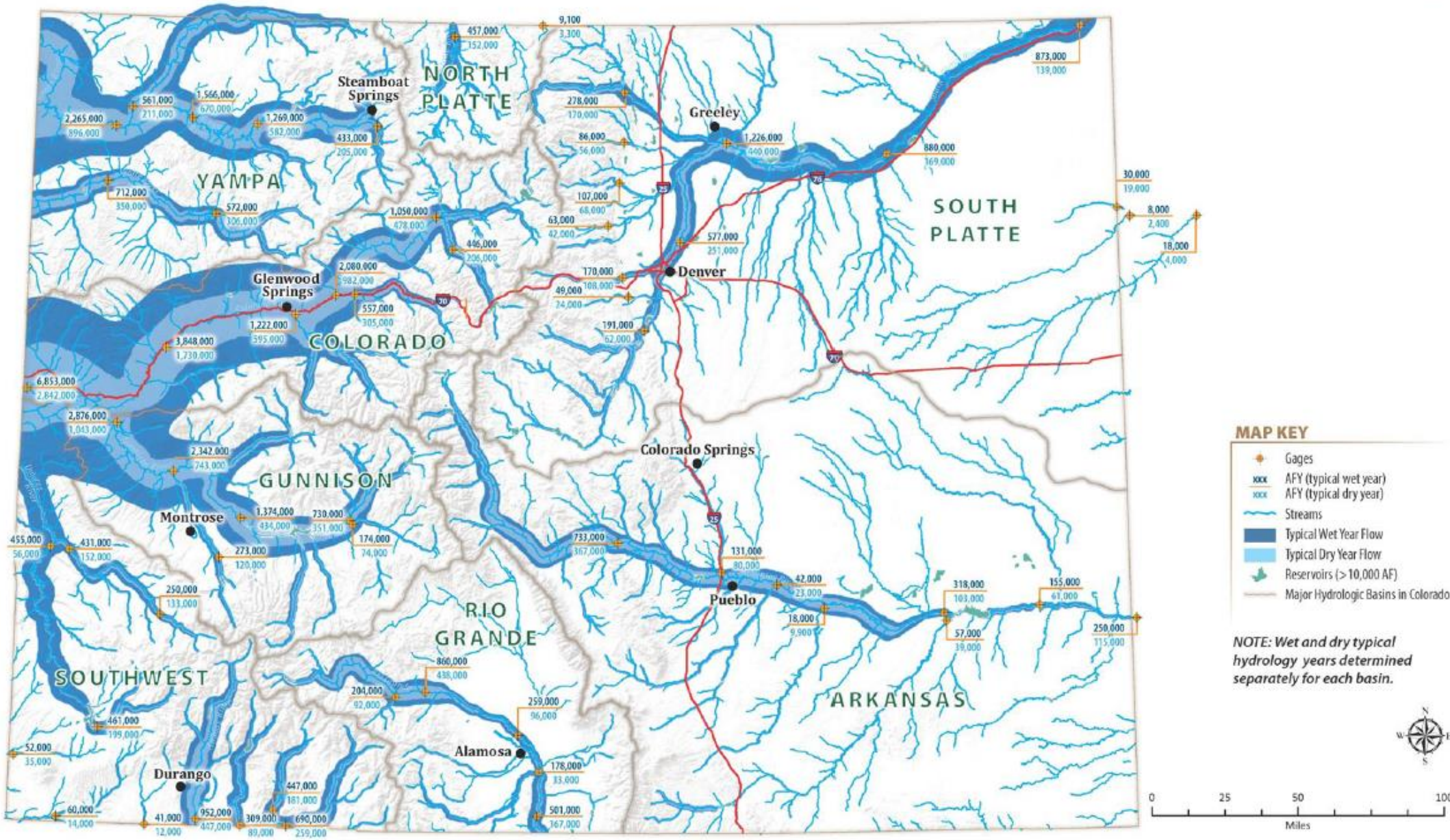
Colorado Rivers Scaled to Size

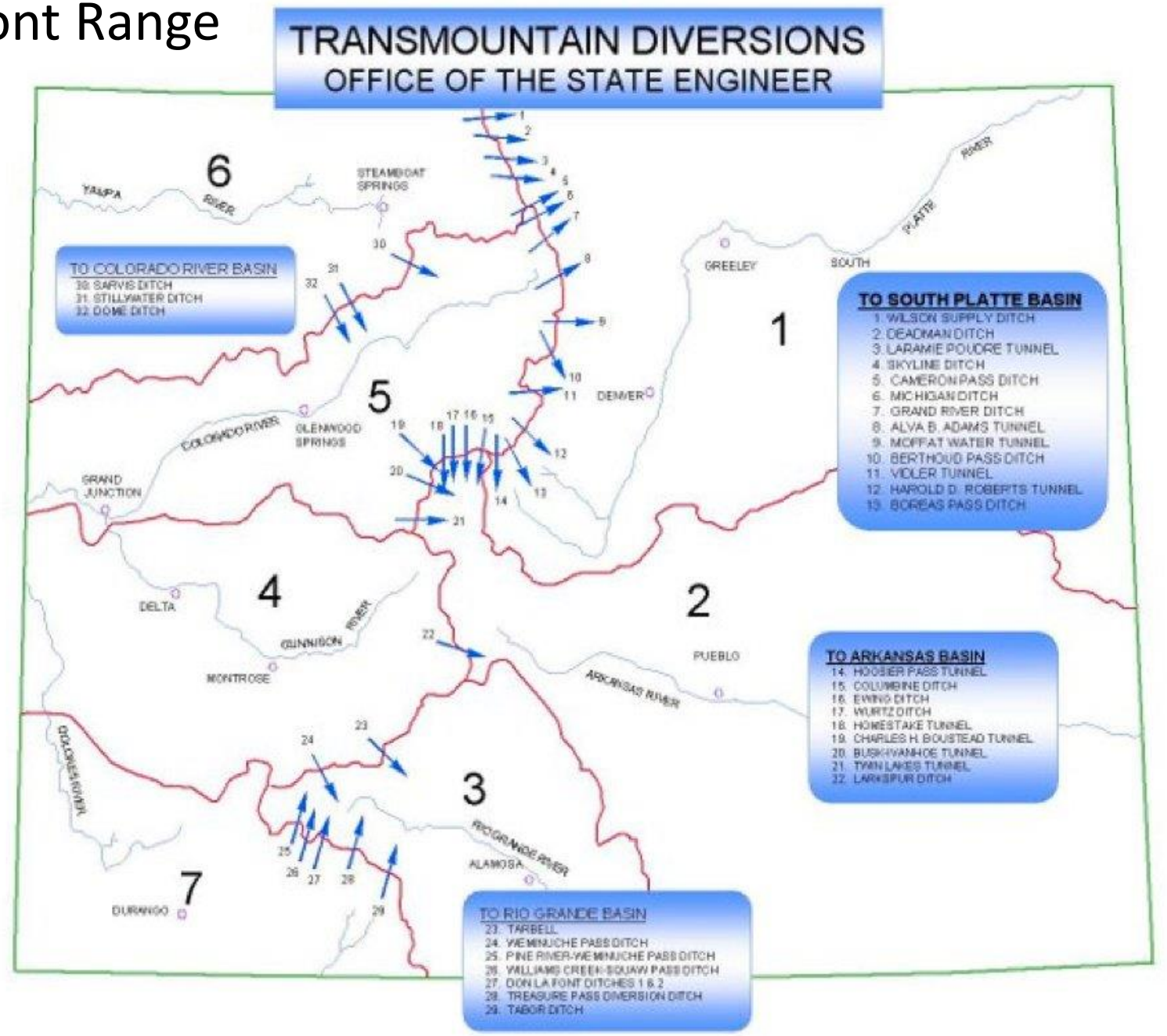
Colorado River and Tributaries:

- 80% of the Surface Water in Colorado
- Far Bigger than all other rivers



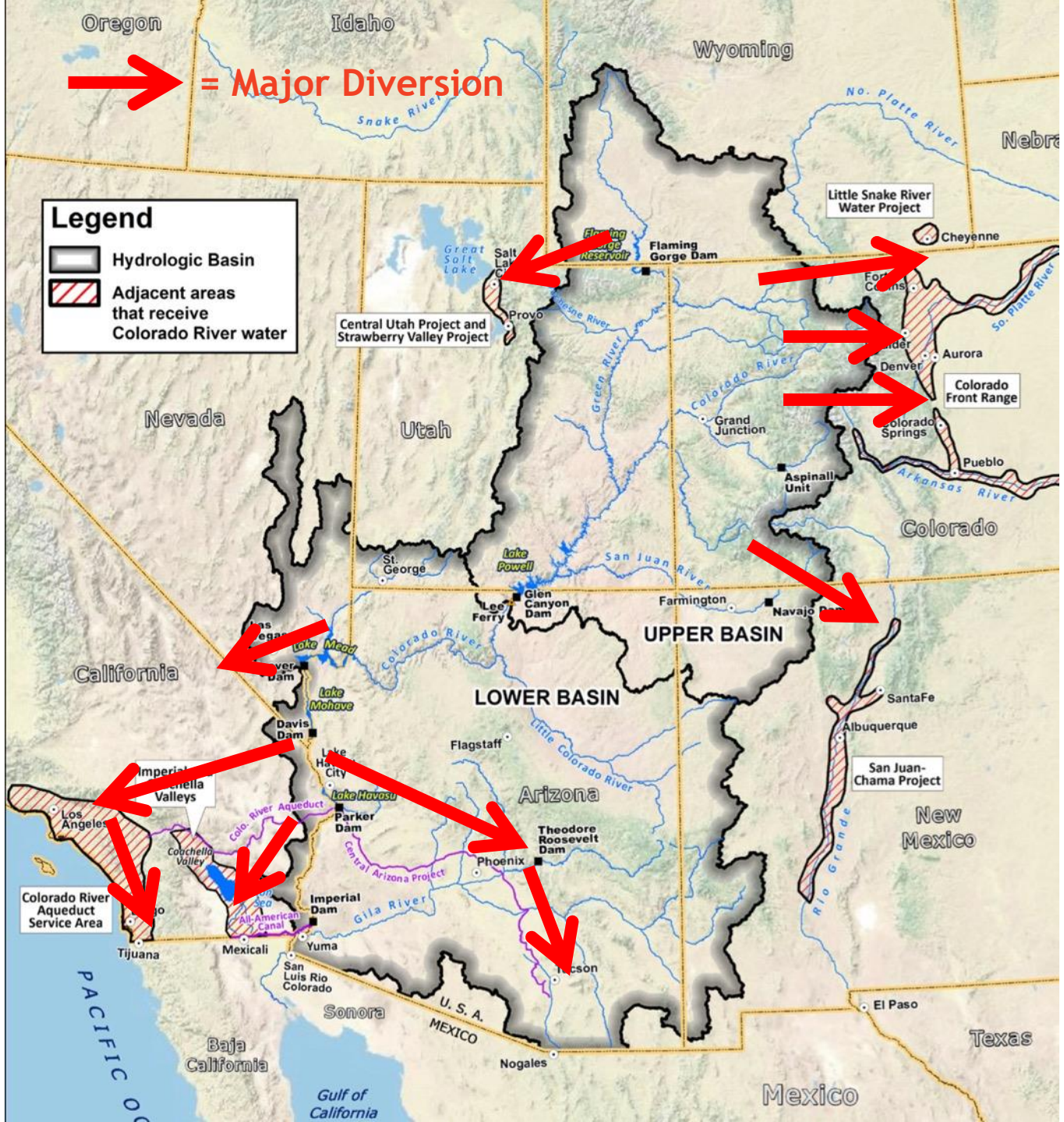
Colorado River Critical to Front Range

- About ½ of the Water used in the Front Range is Colorado River Water
- South Platte and Arkansas Rivers can not support the Front Range Population alone
- Major Front Range Colorado River Diversions
  - Colorado Big Thompson (“CBT”)
  - Denver Water
  - Aurora
  - Colorado Springs

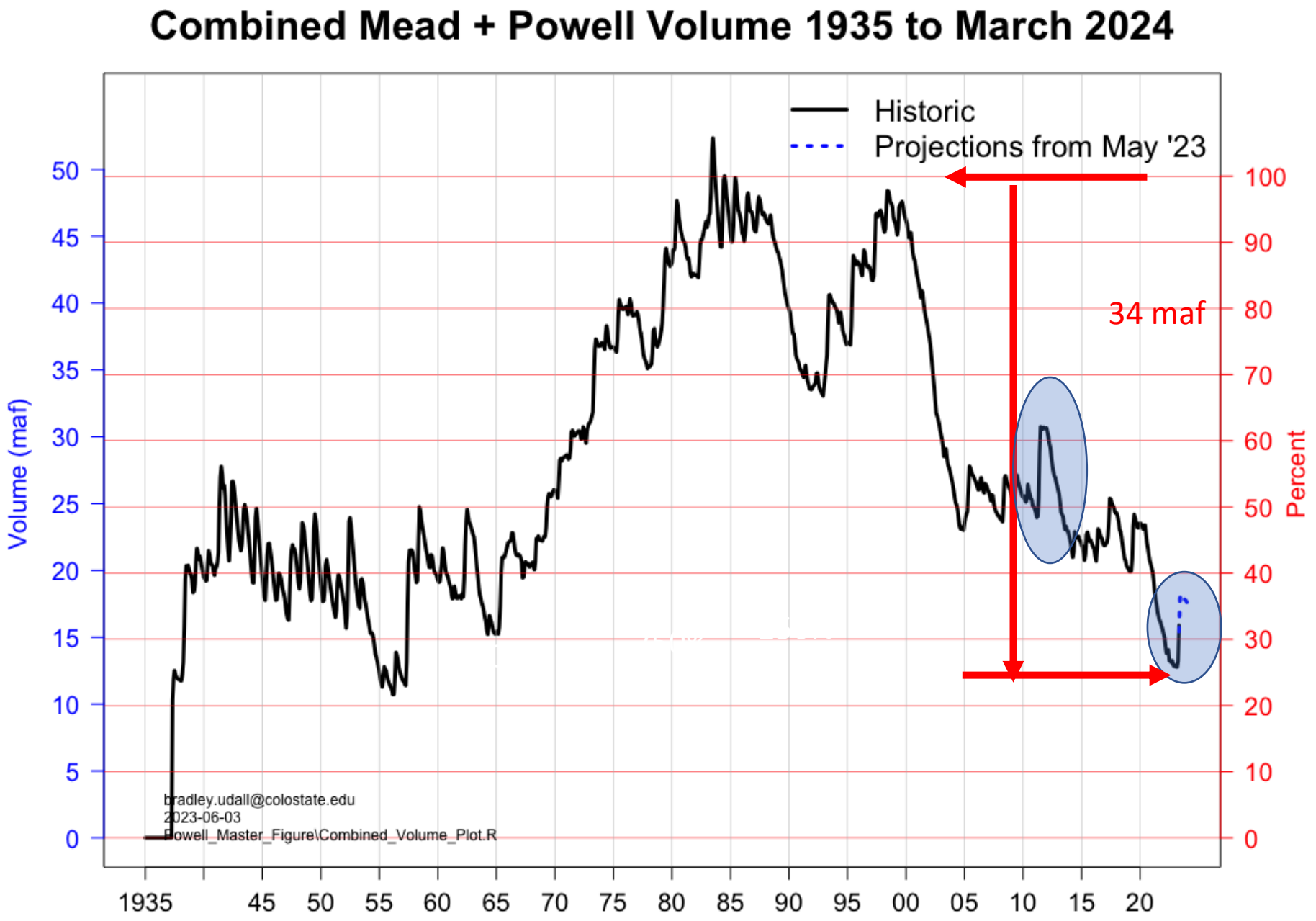


Colorado River

- 7 States, 2 Nations, 30 Tribes
- Annual Flow ~14.75 MAF
  = Hudson River
- Worst drought in gaged record started 2000 ~12.5 MAF/yr (= ~20% decline)
- 40 M People
- All of the Major Cities in SW US
- 4.5m Irrigated Acres – ag uses 80% of water
- Fully Allocated in 1922 – “Law of the River”
- Withdrawals equaled Supplies ~2000
- Feds Announce 2-4 maf reductions in June 2022 for 2023 and beyond
- SEIS Process Announced Late 2022
- 7-State Tentative Agreement May 2023
- New EIS for Post 2026 Rules Underway



- January 2000:
  Powell + Mead 95% Full, 47 MAF
- By April 2023:
  Powell + Mead about 25 % Full, 13 MAF
- Loss of 34 MAF or 1.5 MAF/Year
- Flows down ~ 20% compared to 20th Century
- Wet 2023 does little to status

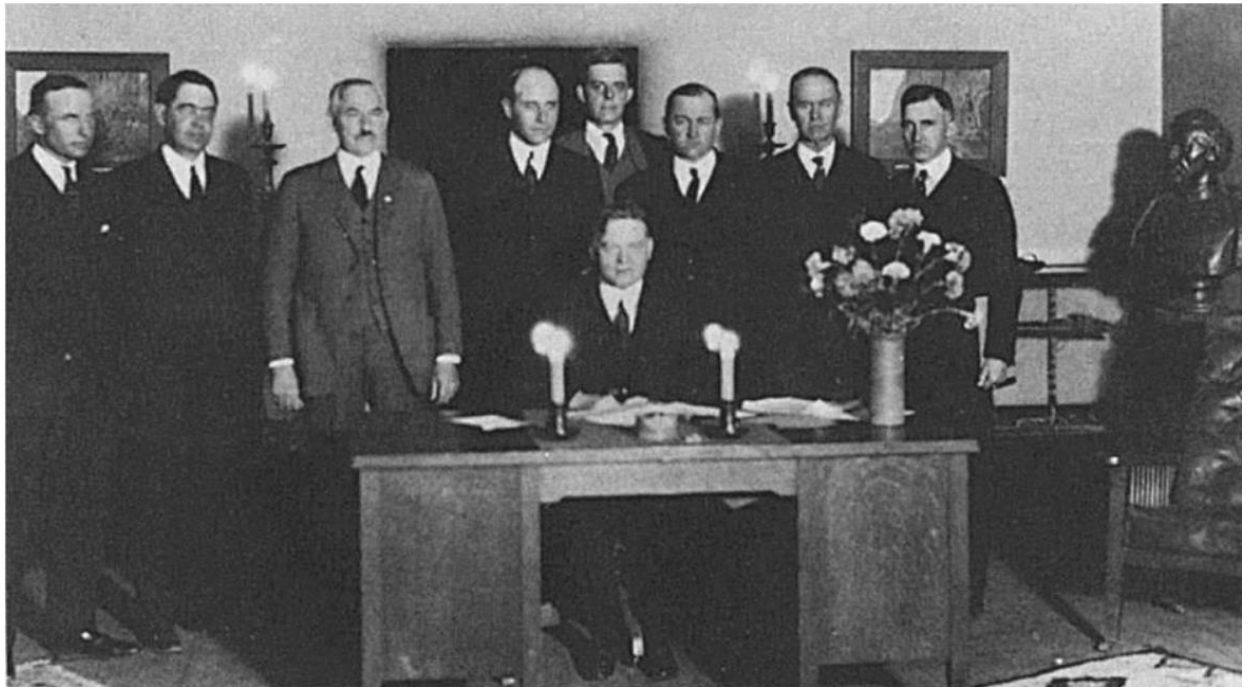


Climate Change is Water Change

- Heat Drives the Water Cycle –
  1000 km3 evaporates daily from the oceans
- The Water Cycle mixes heat from areas of too much to too little
- As the Atmosphere Warms it Holds More Moisture:
  ~5F warming is 20% increase
- Heating Up the Earth (and uneven heating) results in Water Cycle changes
  - More Evaporation, More Precipitation, More Moisture
  - Changes in weather patterns
  - Wet Wetter, Dry Drier Standard Rule
  - More Intense Floods and Droughts
- All Kinds of Water Changes Already Noted
  - More rain/less snow, Earlier Runoff, Higher Water Temps, More Intense Rain

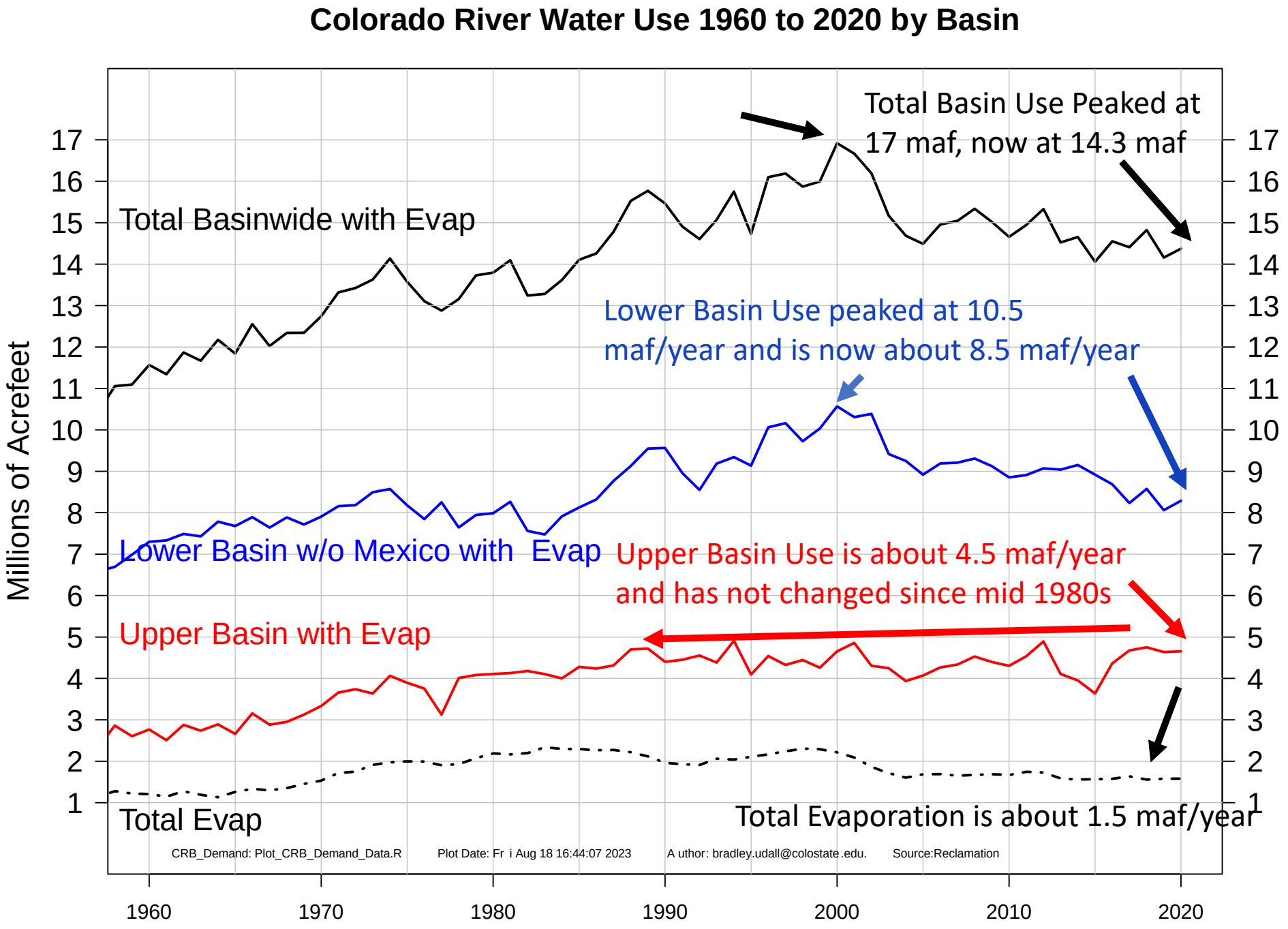
1922 Colorado River Compact Basics

- River Divided into Upper Basin (UB) and Lower Basin (LB)
- Each Basin gets 7.5 maf/year 'Beneficial Consumptive Use' (BCU)
- Lower Basin gets extra 1 maf/year BCU
- Mexico Treaty supplied first from surplus, then equally from LB and UB
- Upper Basin "will not cause the flow to be depleted" below 75 maf/ 10 year ("Compact Call" Provision, Article III D)
- Tribes completely excluded from Compact
- Every one of above provisions has an ongoing dispute about its interpretation
- "Law of the River" encompasses far more than the Compact



Signing of the 1922 Colorado River Compact

Key Point:
About 80% of the Water Demand in both basins is for Agriculture.
About half used on forage crops.



“Compact Call” – Conventional (Old) Take

- A River “Call” is in-state mechanism by which Senior Diverters can ask the State Engineer to curtail Junior Diverters if limited water
- A ‘Compact Call’ is an imperfect analogy for the C. River Compact Article IIID
  - No enforcement mechanism
- Upper Basin must deliver 75 maf/ 10 years (plus its part of the Mexico Treaty Obligation, so 82.3 maf / 10 years)
  - Upper Basin would have to curtail uses to meet this obligation – very messy, unknown
  - Transbasin Diverters Impacted (e.g. Front Range Cities are Jr to West Slope Ag)
- Critically, Compact does not have affirmative delivery obligation despite many claims to the contrary
- Much Study by State Engineer, AG, on how a “Compact Call” would affect Colorado, even recently

“Compact Call” – New Interpretation

- III D Phrased as a ‘negative’ obligation, not a ‘positive’ obligation
  - ”will not cause the flow to be depleted below…” vs “will deliver”
- It was an anti-hoarding drought obligation, not appropriate for climate change world
  - Drought: a temporary flow reduction around a non-varying mean flow
  - Climate Change: a permanent flow reduction due to declining mean flow
- UB would never have agreed to a fixed delivery obligation under permanently declining flows
- Equal Sharing of total flow is embedded in the Compact (7.5 maf to each)
- Problem: Lower Basin used to, and dependent upon, fixed delivery amount
  - But Dawning LB Awareness that must share risk of climate change flow reductions
- New Basin-Wide Interpretation Needed, but not clear exactly what that is…
  - Simple Possibility – UB has no obligation until supplies decline to twice UB use (i.e. 9 maf)
- How to Reconcile Old vs New Interpretation?

‘Aridification’, Not Drought

- Not a Drought and Not a ‘New Normal’
- Declining Snowpacks
- Earlier runoff
- Shorter Winter
- More rain, less snow
- Higher Temperatures: > 3°F
- Drying Soils
- Severe Fires
- Forest Mortality
- Warm Thirsty Atmosphere (holds more moisture)
- Northward moving storm tracks (less certain, but a worry)
- Megadrought

COMMENTARY

Climate change and the aridification of North America

Jonathan T. Overpeck[a,b,1] and Bradley Udall[b,c]

Discussions of droughts and their impacts often center on the lack of precipitation, just as assessments of hydrologic impacts under a changing climate most often focus on how average precipitation in a given locale is likely to change in the future. Within climate science, however, focus has begun to include the growing role warming temperatures are playing as a potent driver of greater aridity: hotter climate extremes; drier soil conditions; more severe drought; and the impacts of hydrologic stress on rivers, forests, agriculture, and other systems. This shift in the hydrologic paradigm is most clear in the American Southwest, where declining flows in the region’s two most important rivers, the Colorado (Fig. 1) and Rio Grande, have been attributed in part to increasing temperatures caused by human activities, most notably the burning of fossil fuels (1–5). Warmer summers are also likely to reduce flows in the Columbia River, as well as in rivers along the Sierra Nevada in California (6). Now, an important study (7) documents how warming is also causing flow declines in the northern Rocky Mountains and in the largest river basin in the United States, the Missouri. This work further highlights the mechanisms behind the temperature-driven river flow declines and places more focus on how anthropogenic climate warming is progressively increasing the risk of hot drought and more arid conditions across an expanding swath of the United States.

The work by Martin et al. (7) on the temperature-driven flow reductions in the Upper Missouri River has broader implications. As they note, many aspects of river management could be increasingly impacted by a more arid river basin, including agricultural water deliveries, river management and navigation, and ecosystem services associated with the river; economies of a large region will likely suffer if the aridification continues. This mirrors the change occurring in the Southwest, where rivers provide the only large sustainable water supply to the region and more than 40 million water users, yet flows have already declined significantly since just the late 20th century (3, 4).

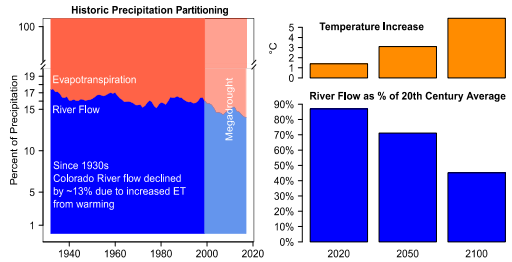


Fig. 1. Climate change is causing the Southwest to aridify. (*Left*) Since the 1930s, increasing temperatures have caused the percentage of precipitation going to evapotranspiration (ET) to increase at the expense of precipitation going to Colorado River flow, resulting in an unprecedented and still ongoing megadrought (shading) starting in 1999 (8). (*Right*) Higher temperatures have already reduced Colorado River flow by 13%, and projected additional warming, assuming continued high emissions of greenhouse gases, will increase ET while reducing river flow even more through the 21st century. Data on *Left* are 20-y running means from ref. 5, and data on *Right* are calculated from Representative Concentration Pathways (RCP) 8.5 multimodel Coupled Model Intercomparison Project–Phase 5 (CMIP5) ensemble temperature increases projected for the Upper Colorado River Basin combined with temperature sensitivity of –9.3%/°C estimated by ref. 5, assuming no change in precipitation.

Across the US West, warming is also contributing to drier soils (8), widespread tree death (9), and more severe wildfires (10). The recent unprecedented drought conditions in California also have been tied to human-caused warming (11). Greater aridity is redefining the West in many ways, and the costs to human and natural systems will only increase as we let the warming continue.

Martin et al. (7) also highlight how increasing temperature-driven aridity is more often framed in the West in terms of episodic drought. Just as in the Southwest, where an unprecedented drought began in 1999 and has continued through 2020 with drier-than-normal soils, reduced river flows, and low levels in major reservoirs, the worst drought of the instrumental era gripped the Upper Missouri River Basin

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The authors declare no competing interest.

See companion article, “Increased drought severity tracks warming in the United States’ largest river basin,” 10.1073/pnas.1916208117.
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Summary

- Colorado River Demands out of Balance with Supplies
  - Unsustainable Reservoirs Levels, Flows down ~20% since 2000
  - Reservoirs can no longer release water to fix the imbalance
- Much of the Problem is in the Lower Basin but UB not exempt
  - Everyone needs to help solve this problem
- Upper Basin Demand Growth Problematic
  - New UB Demands add risk to Existing UB Demand
  - Also, UB Demand Growth would come at expense of existing LB Demands (i.e., even more difficult LB reductions needed if new UB Demands)
- Potential for Additional Large Climate Change Flow Reductions
  - Up to 20% more flow loss (60% of 20C Average, 9 maf) by Mid-century
- UB Obligation to deliver flows to LB unclear, new understanding needed
- Large Process underway for new LB rules post 2026
  - UB Delivery Obligation an important part of these rules
- Winner-Take-All Water Allocation Schemes very Problematic in 21st Century