Evaluating the consistency of inferred multi-actor vulnerabilities to agricultural water shortages through the use of rival framings

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EWRI 2021

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RJ Sangosti, The Denver Post

Bottom-up vulnerability assessment of hundreds of multisectoral stakeholders

Exploratory modeling for changes in:

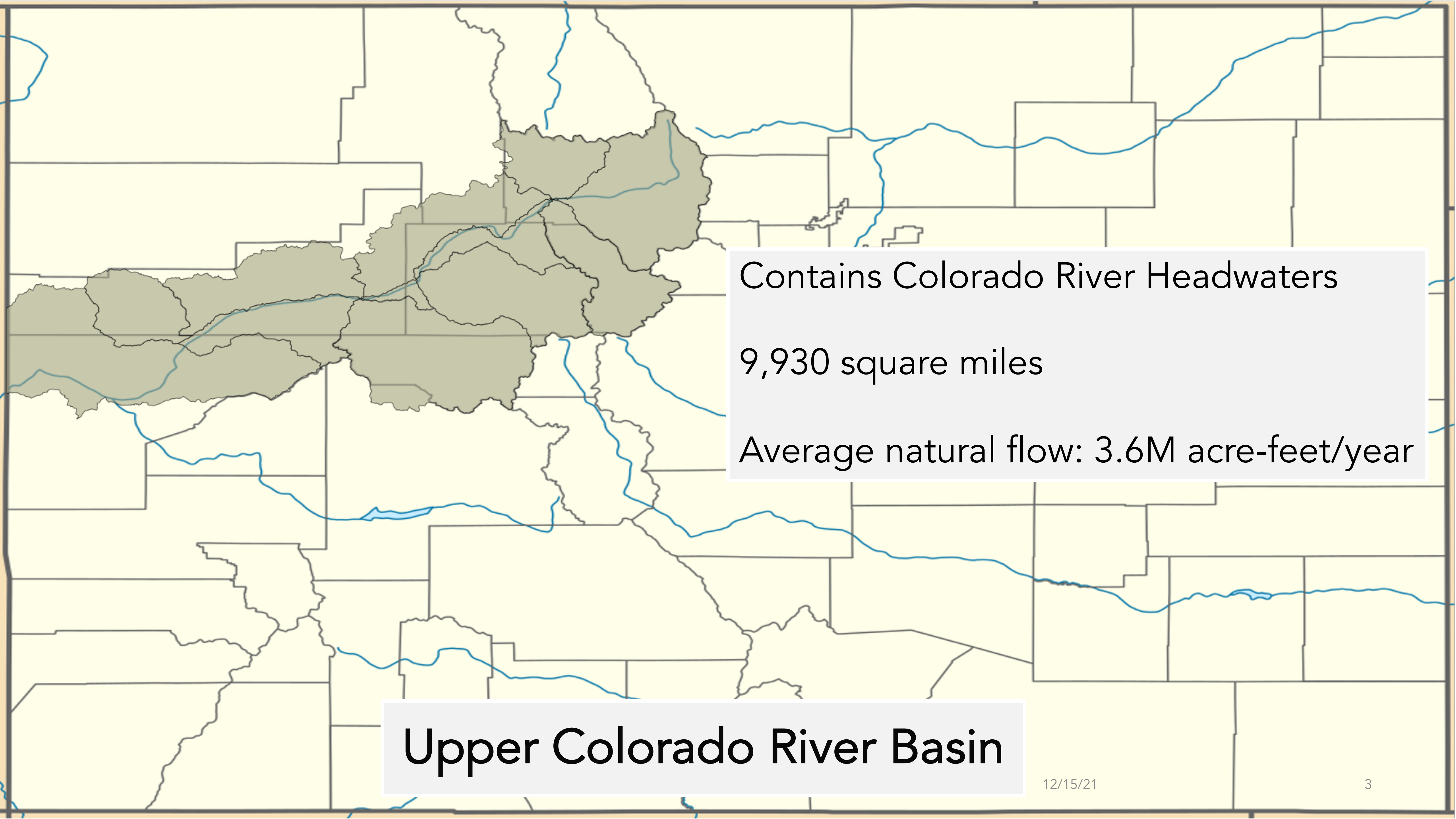
Hydrologic conditions
Physical infrastructure
Institutional structure
Societal needs

+

Sensitivity analysis

Rival framings of informal water right agreements

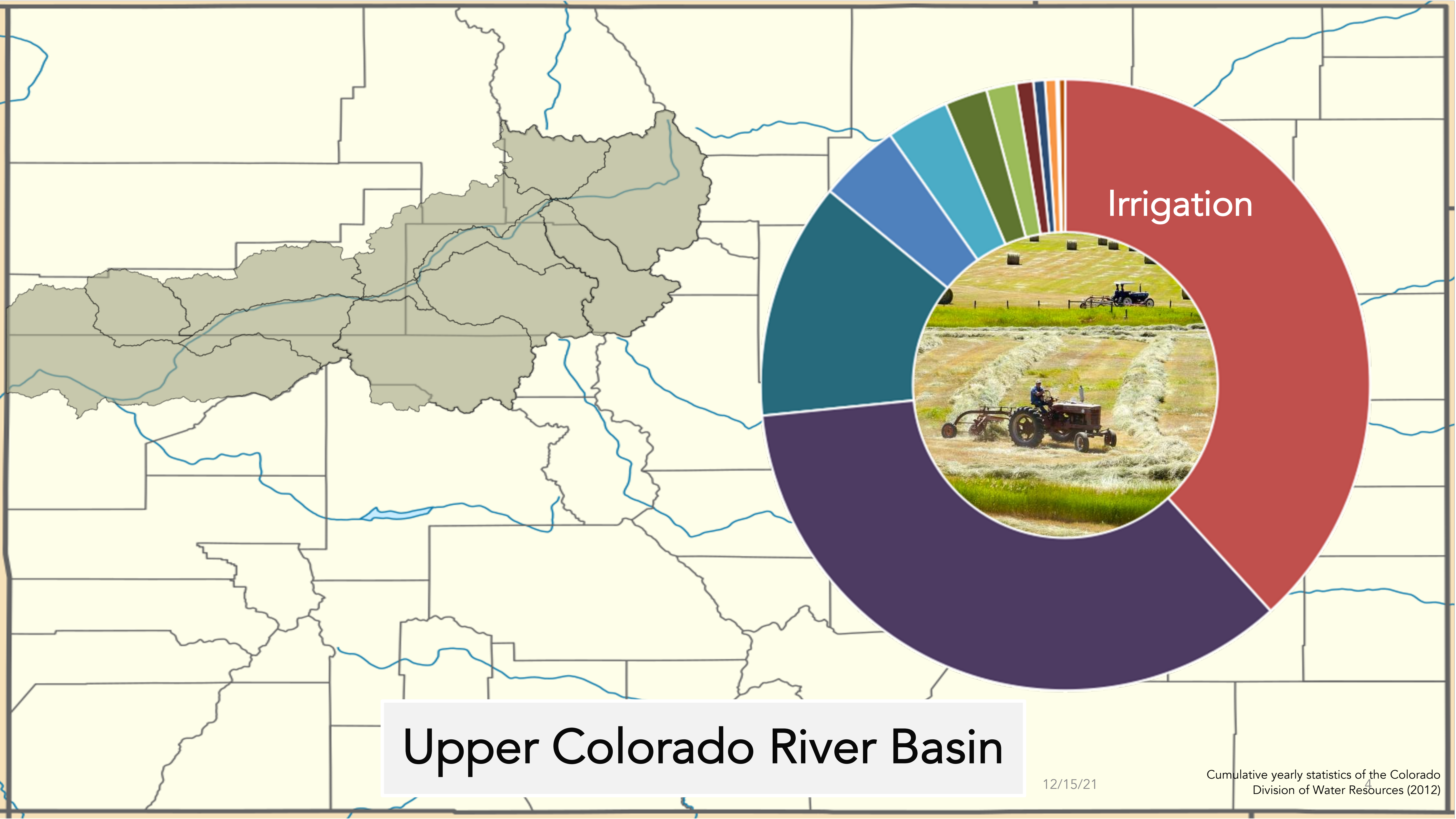
Upper Colorado River Basin



Contains Colorado River Headwaters

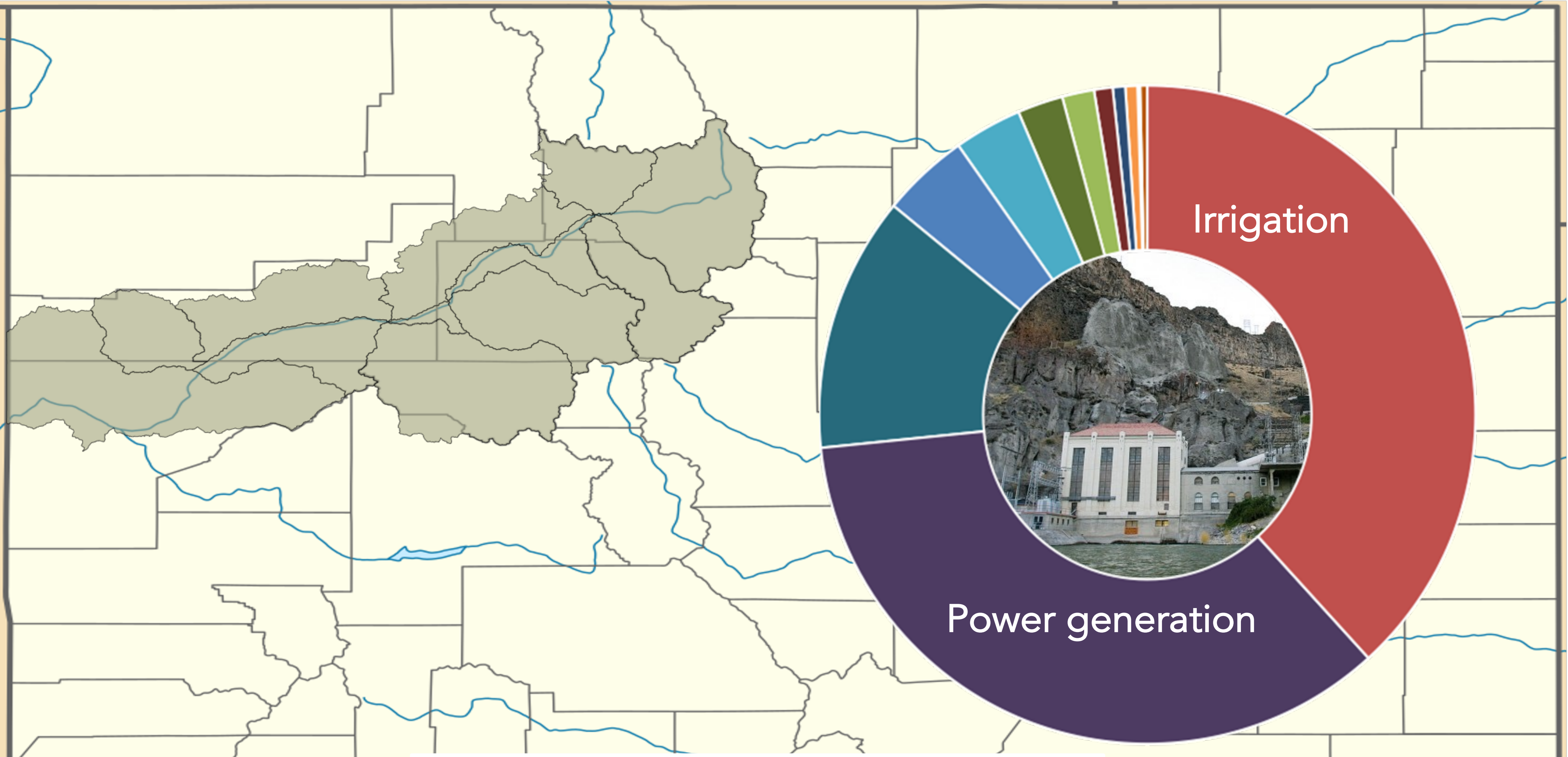
9,930 square miles

Average natural flow: 3.6M acre-feet/year



Upper Colorado River Basin

Cumulative yearly statistics of the Colorado Division of Water Resources (2012)



Upper Colorado River Basin

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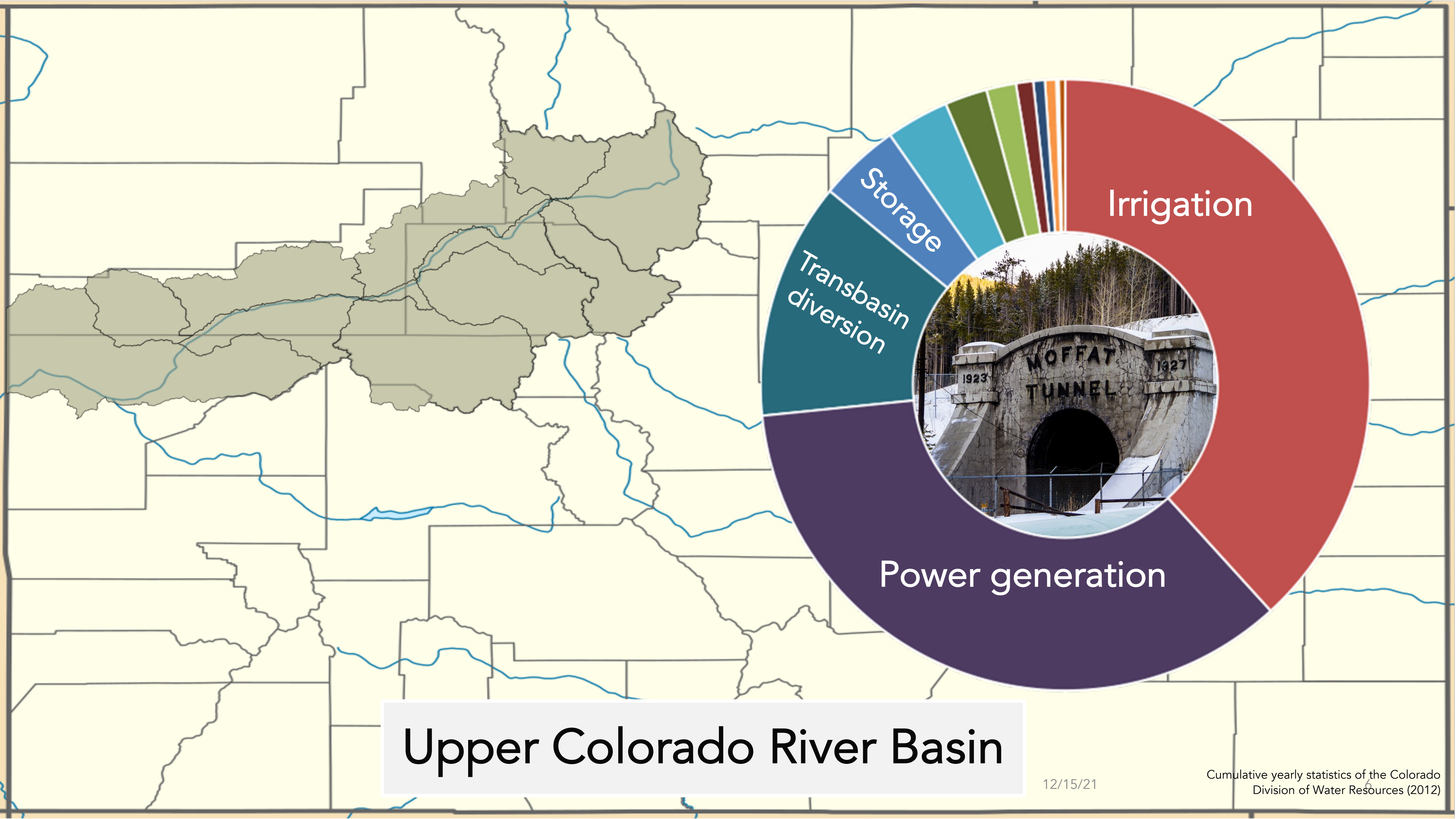
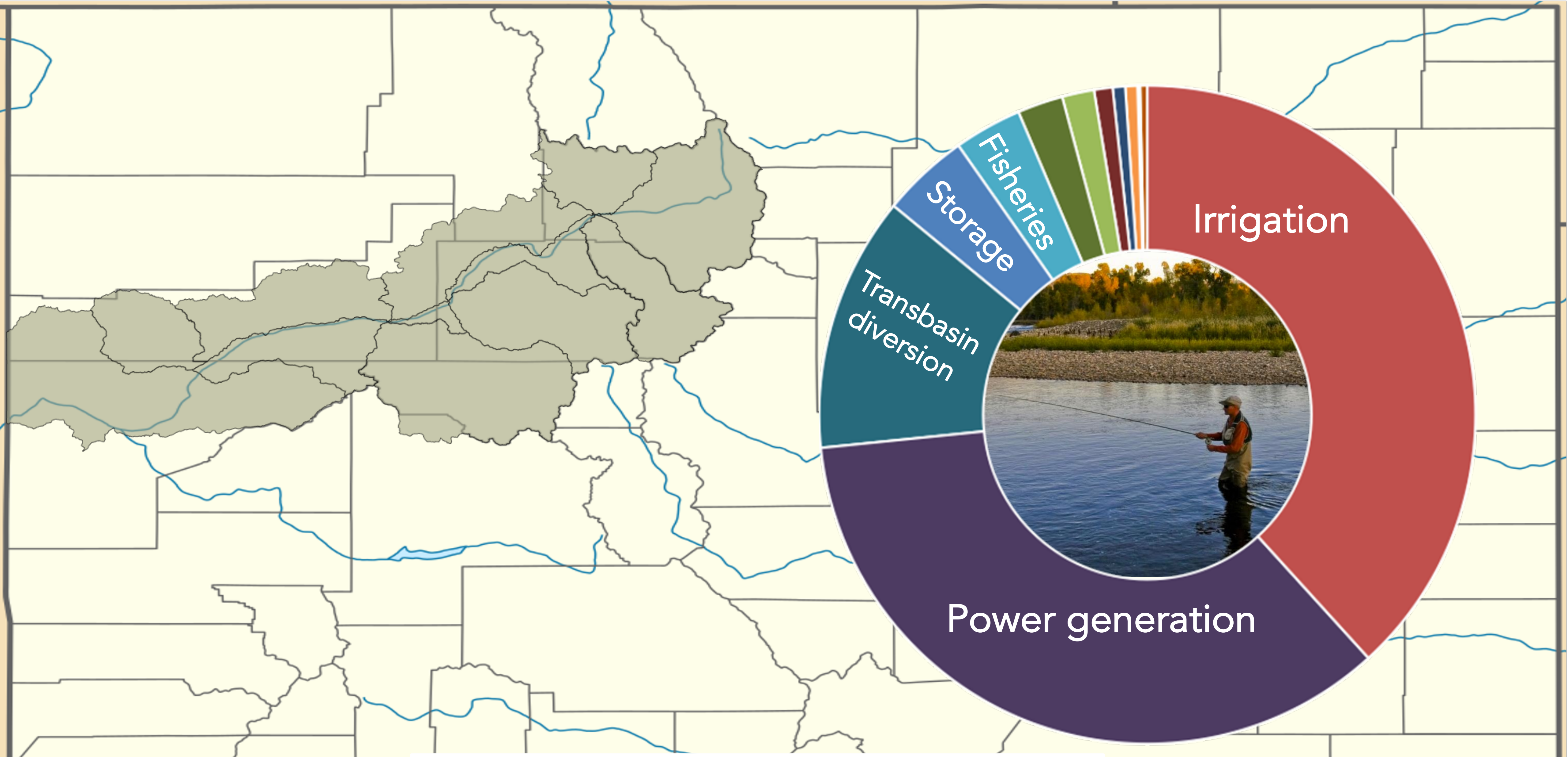

Storage
Transbasin diversion
Irrigation
Power generation
MOFFAT TUNNEL
1923
1927
Upper Colorado River Basin
12/15/21
Cumulative yearly statistics of the Colorado Division of Water Resources (2012)



Upper Colorado River Basin

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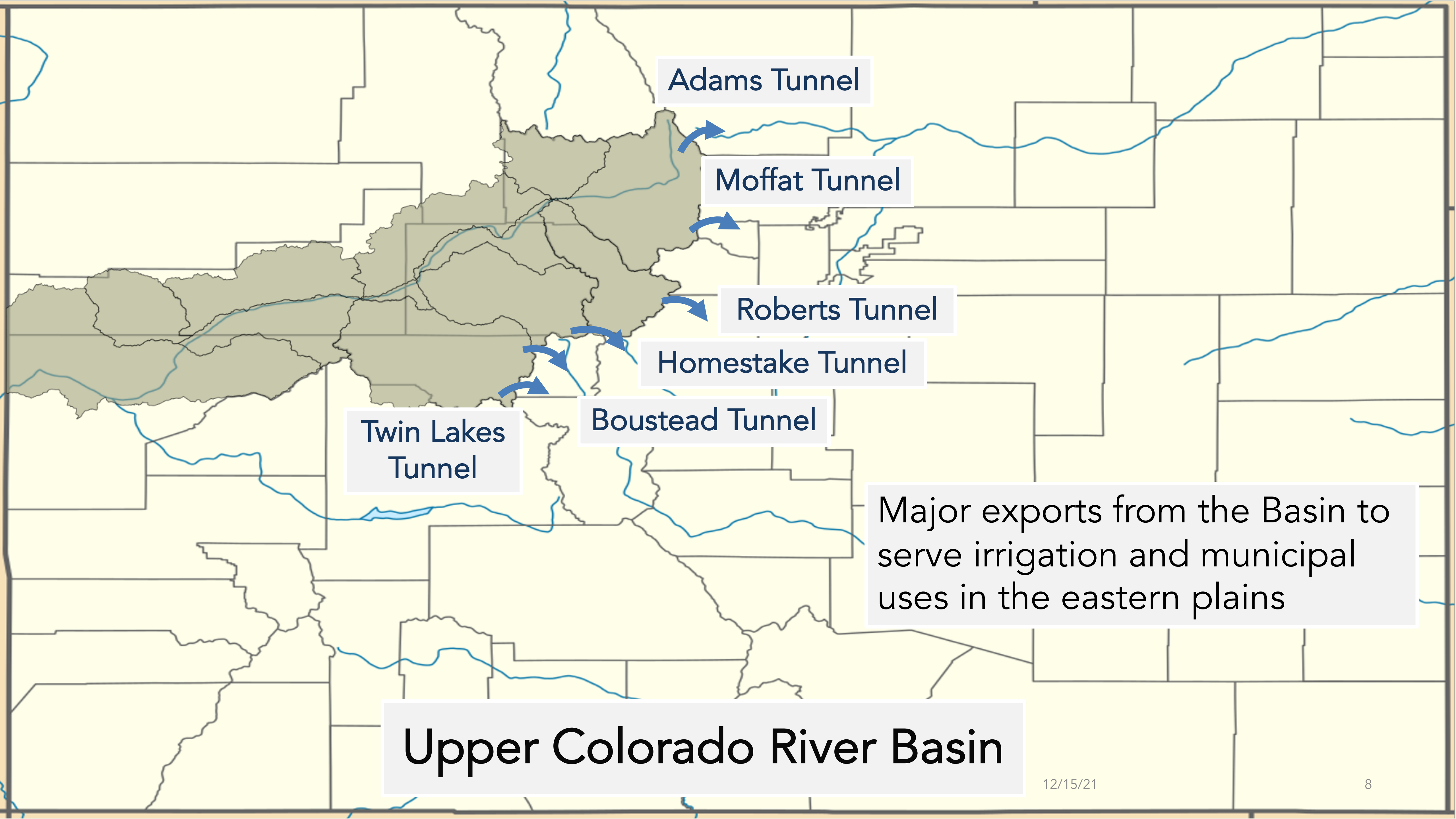
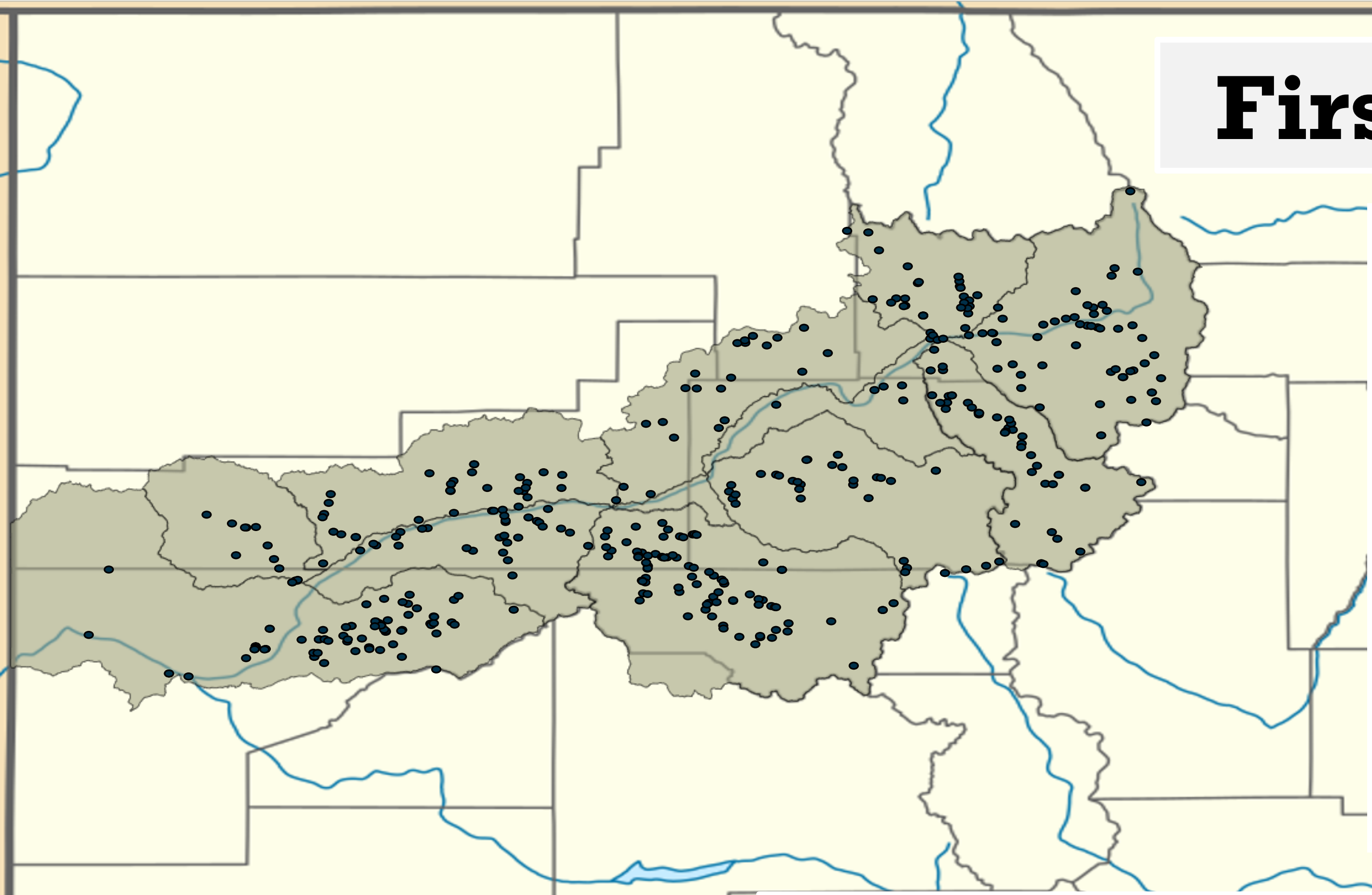
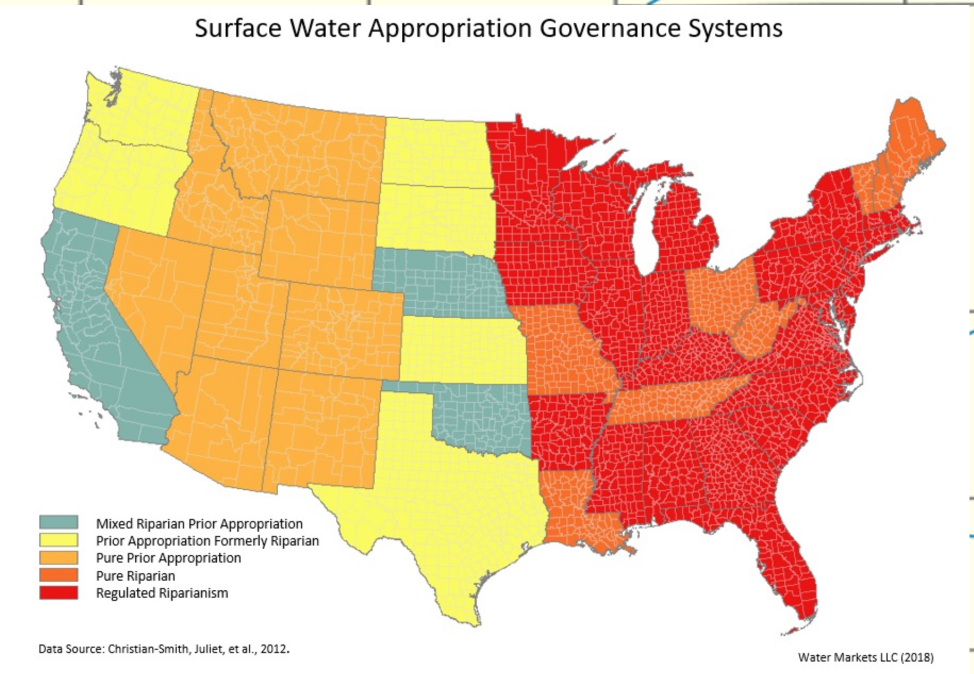
Upper Colorado River Basin



Major exports from the Basin to serve irrigation and municipal uses in the eastern plains

First in time, first in right





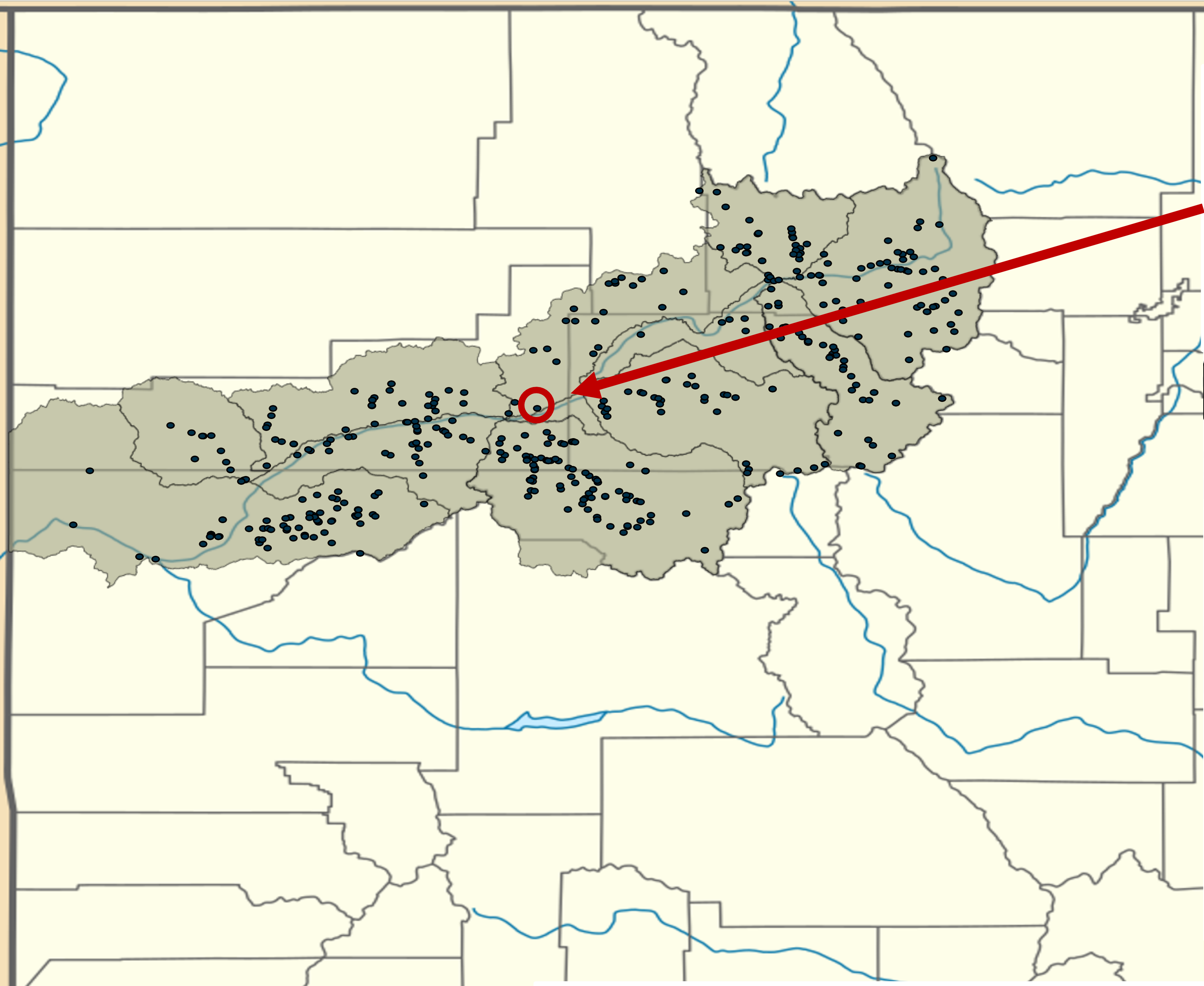
*Gets **all** water demands met before others*

Prior-appropriation doctrine:
Each diversion with level of seniority and decreed flow

Upper Colorado River Basin

Shoshone power plant

Biggest, oldest water right on the river



MENU | High Country News

COLORADO RIVER

The tiny power plant that shapes the Colorado River — merely by existing

The Shoshone power plant is the cornerstone for water rights in the upper river.

Emily Benson | NEWS | Jan. 2, 2018 |

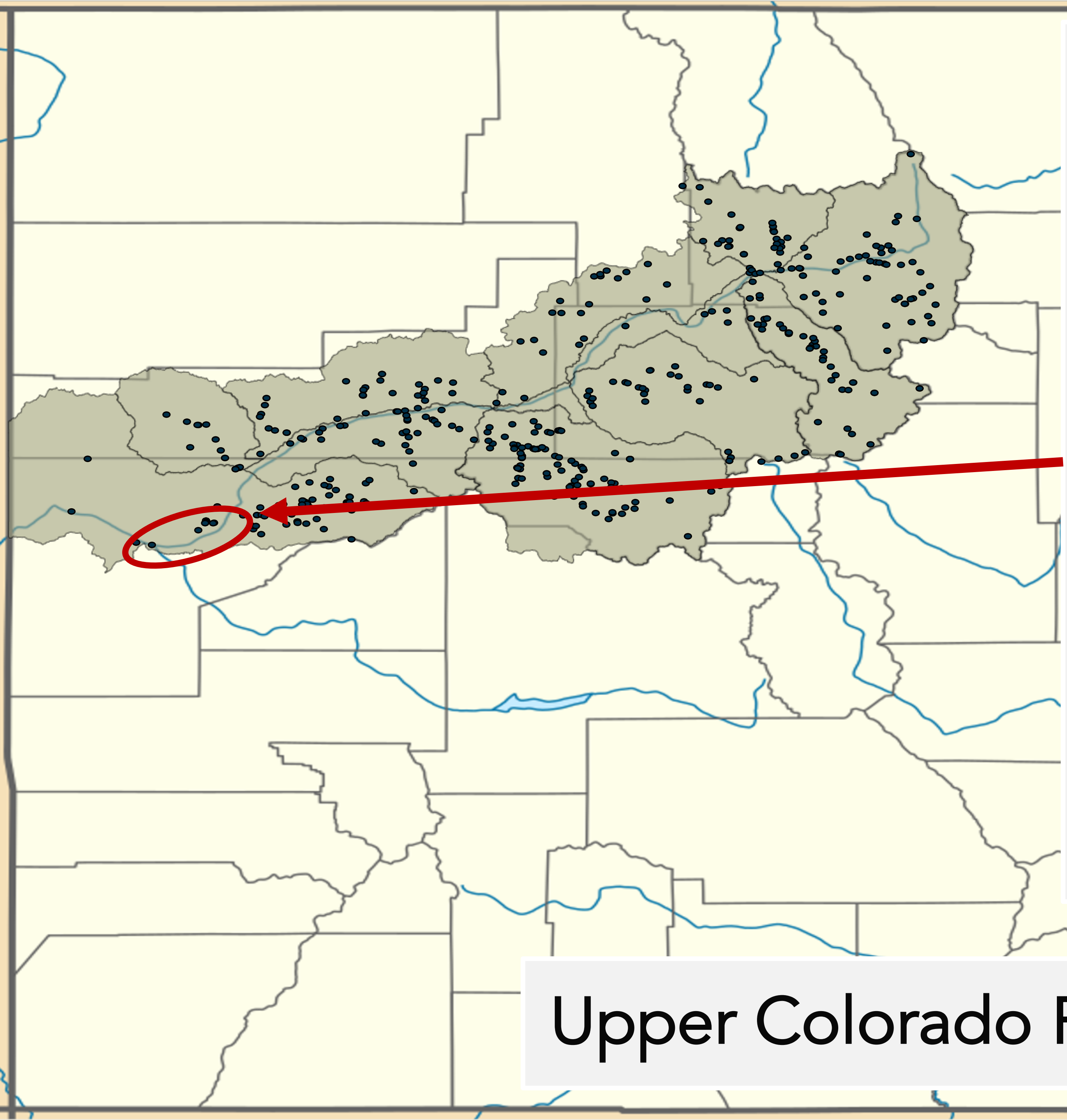
PRINT

Upper Colorado River Basin

15-mile reach

Critical flow for the protection of endangered species

Illustrations by Joseph R. Tomelleri



Upper Colorado River Basin

How **vulnerable** are these water users to increasing climatic stress, competing water demands and other uncertain factors?

Can we identify which stressors are most **consequential** for these users and under what conditions?

How do **asymmetries** in water right shape the users' drought experience?

University of Virginia

wilsonwater group

NCAR

DNR CO

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

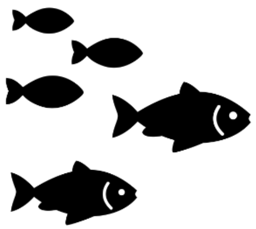
Evaluate **operation** in many **potential futures**

Quantify **user vulnerabilities** and determine most important **uncertainties**

Bottom-up assessment of stakeholder vulnerabilities

Investigate vulnerabilities across users in the basin using exploratory modeling

Look at how future changes and uncertainties may affect water shortages for:

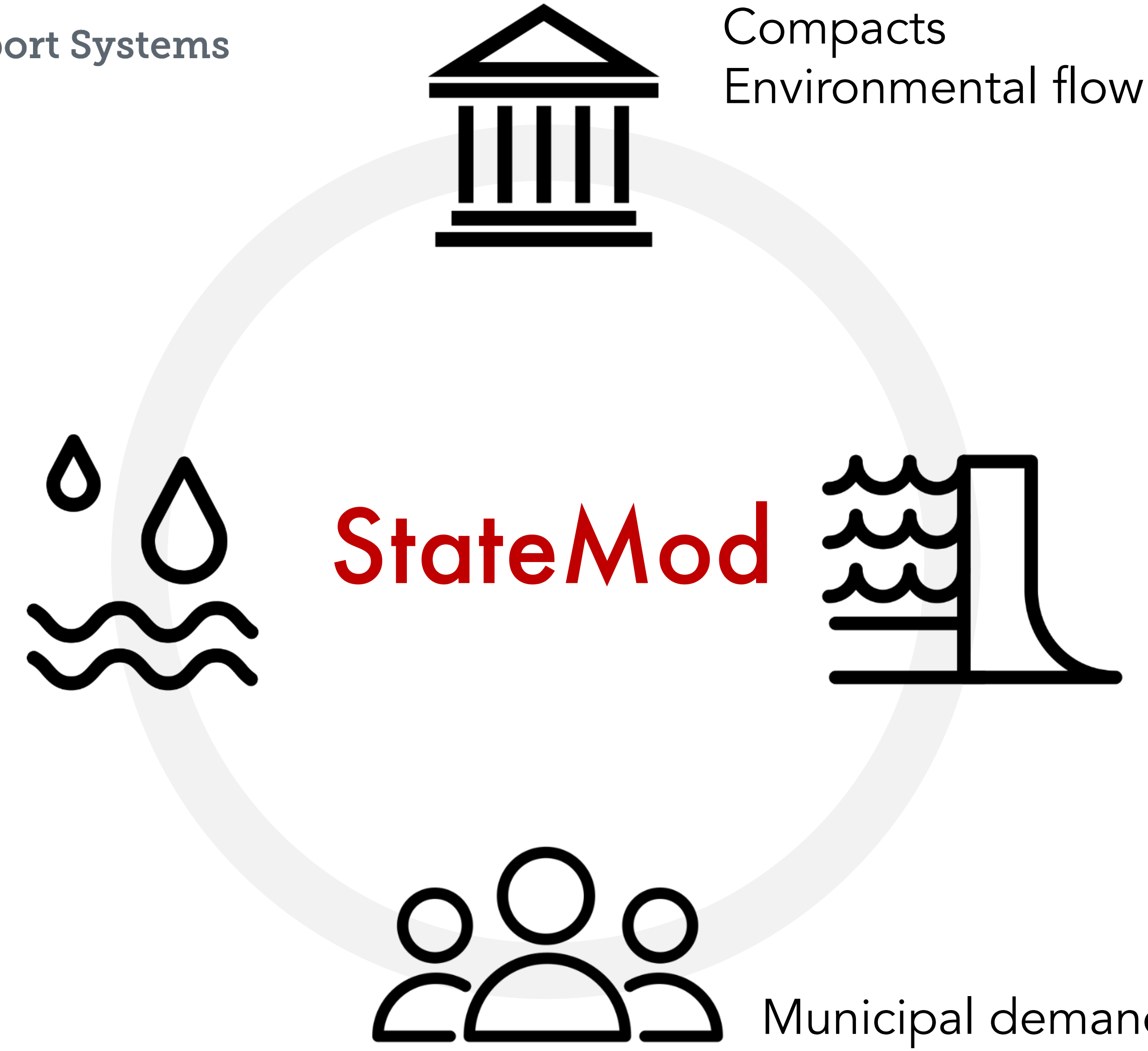


15-mile reach

Transbasin diversions

Irrigation diversions

COLORADO'S
Decision Support Systems
CWCB / DWR



1 Use StateMod to perform **explorative analysis** on sensitivities and vulnerabilities in the Basin

Address the following questions for 338 water users :

2a *How are their shortages are affected?*

2b *Which uncertain factors are driving their shortages?*

2c *How can informal water right agreements modulate these effects?*

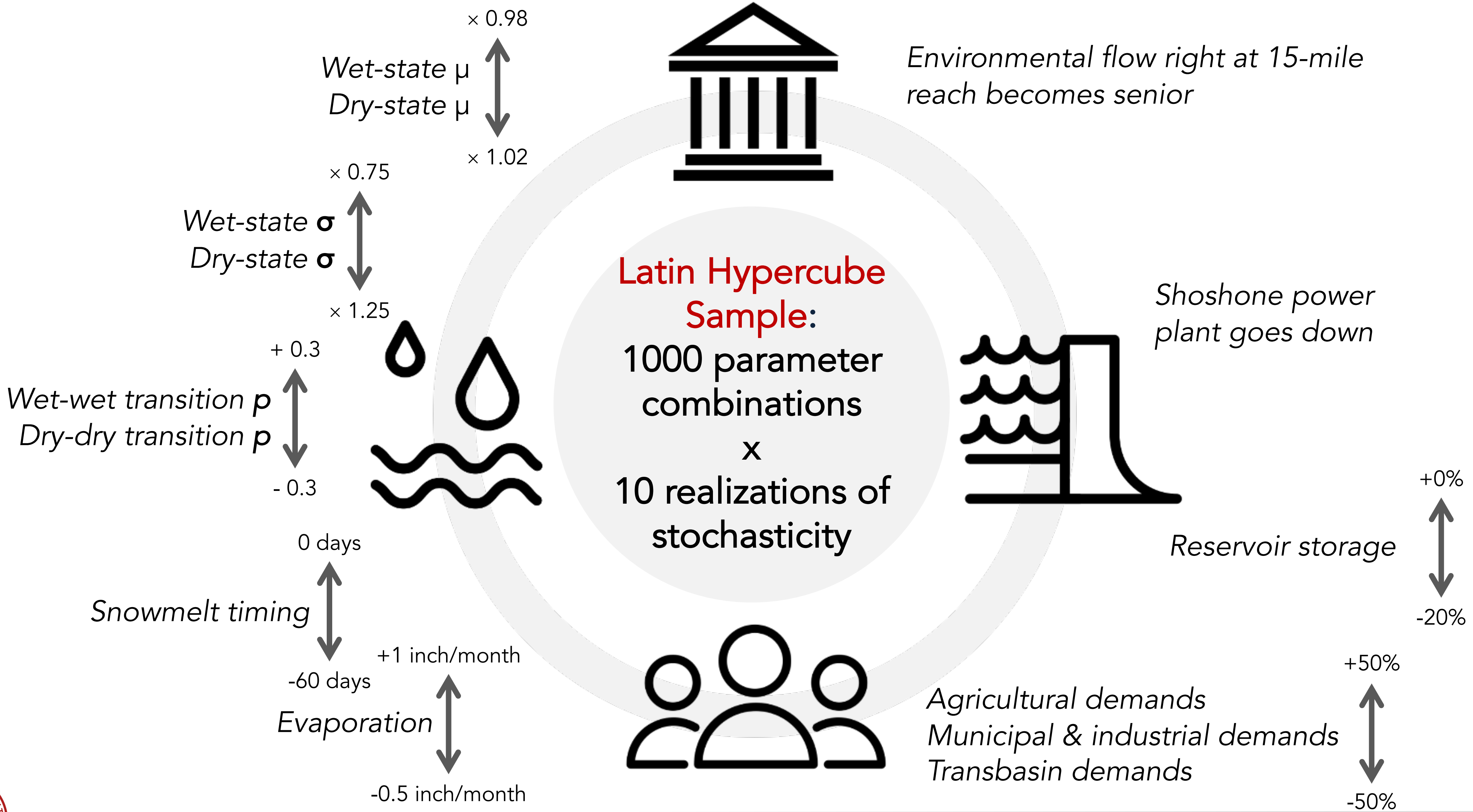
Hydrologic Model - Synthetic Generator

Change **distributions** of wet and dry flows

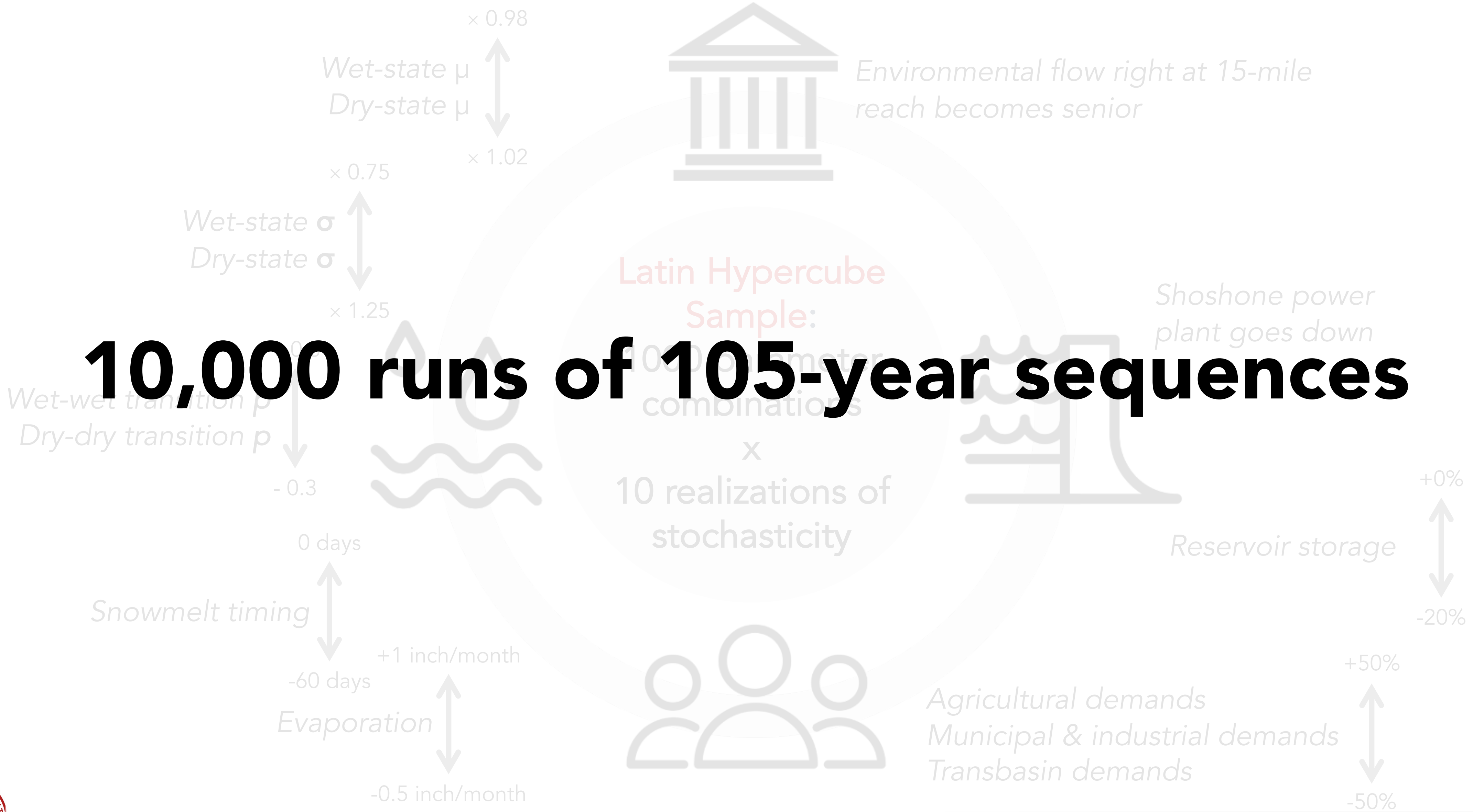
Change **persistence** of wet and dry flows

Shift annual flow **peak**

Exploratory experiment



Exploratory experiment



10,000 runs of 105-year sequences

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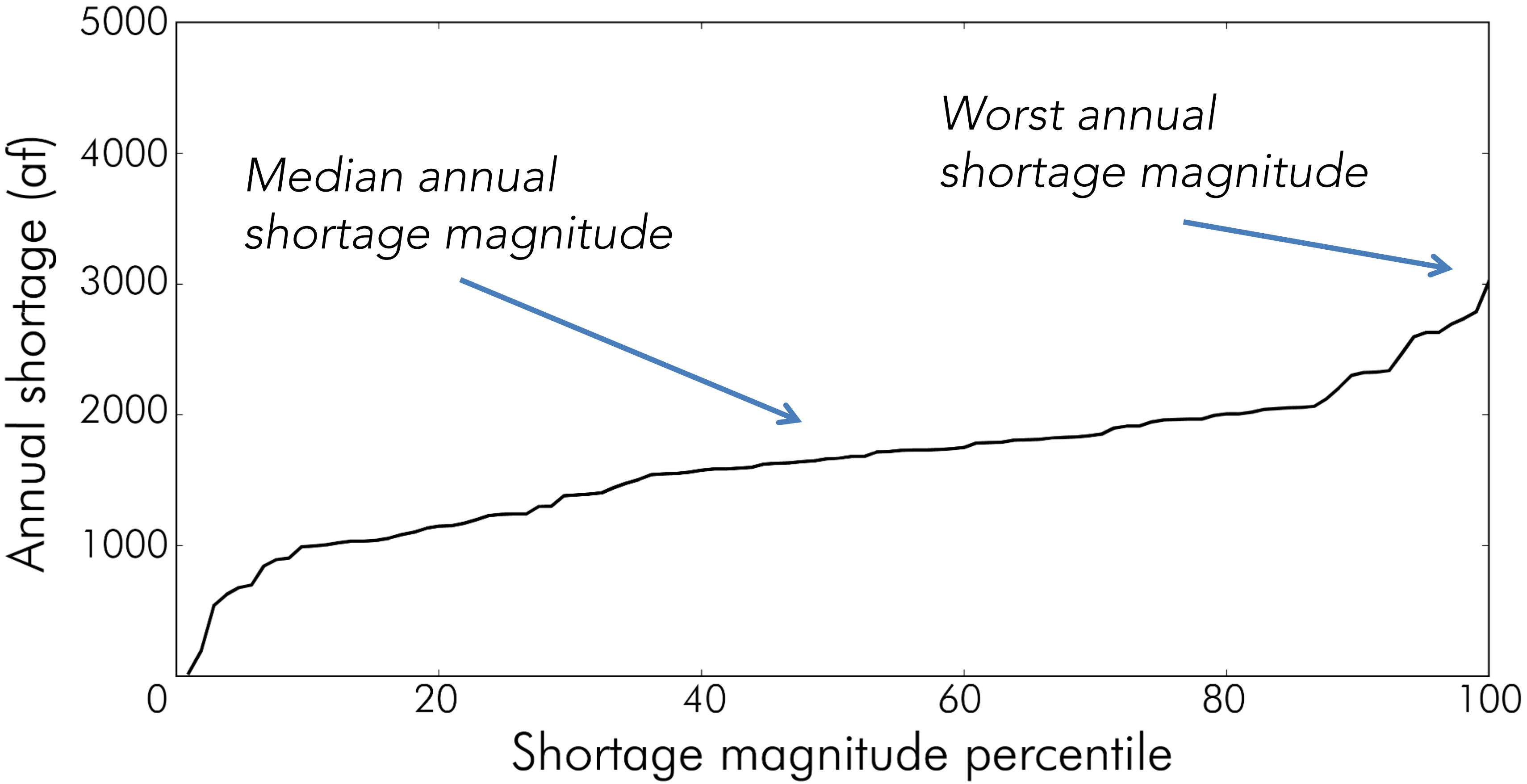
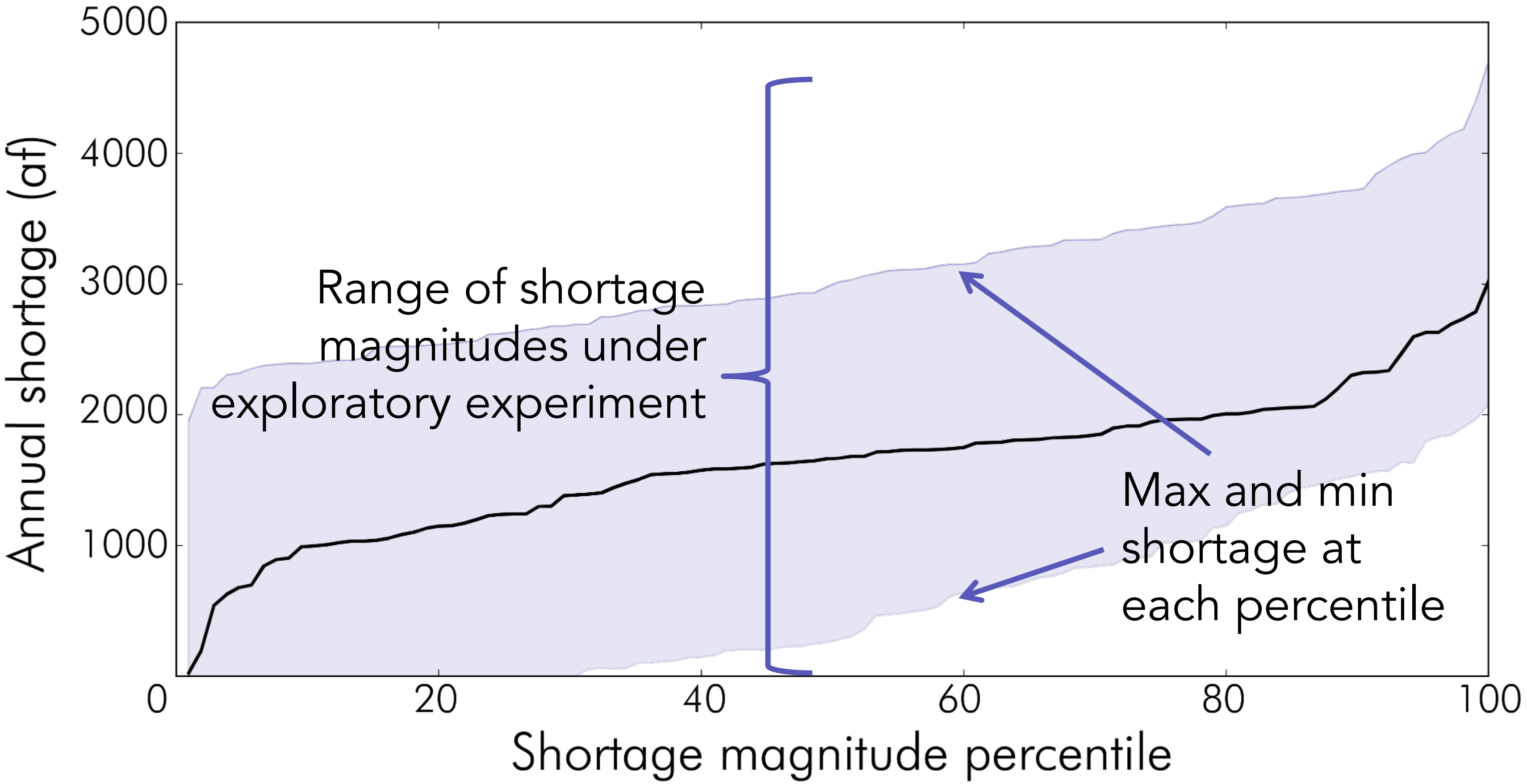
Shortage magnitudes for an irrigation site

Rank all annual shortages experienced in the 105-year record

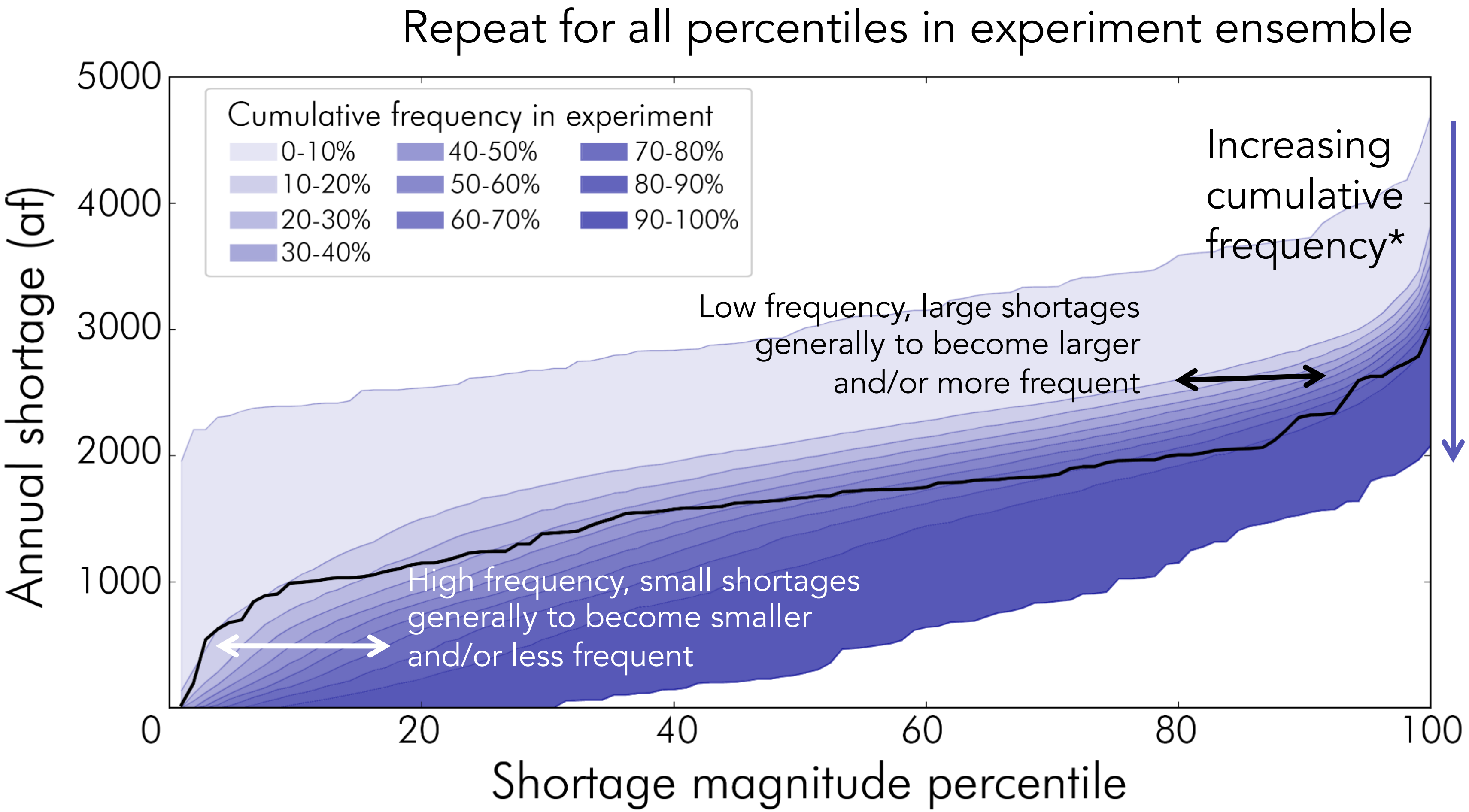


Shortage magnitudes for an irrigation site

Perform experiment
Extract all 105-year sequences and rank as before



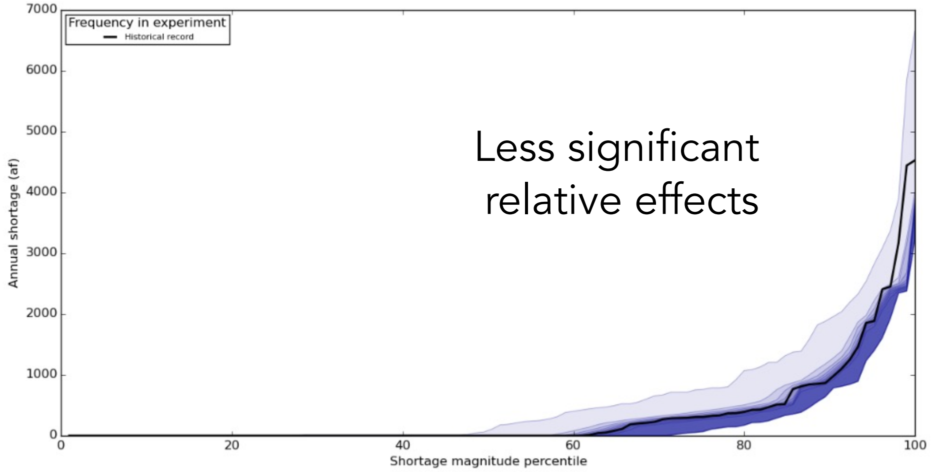
Shortage magnitudes for an irrigation site

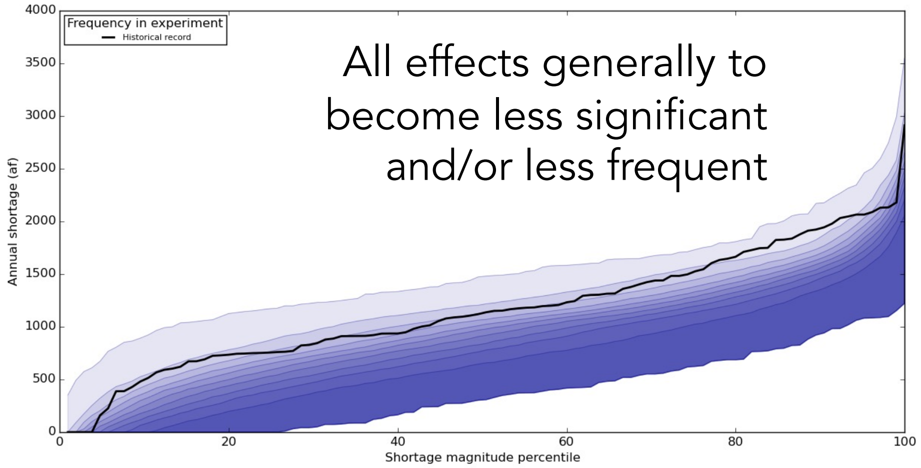


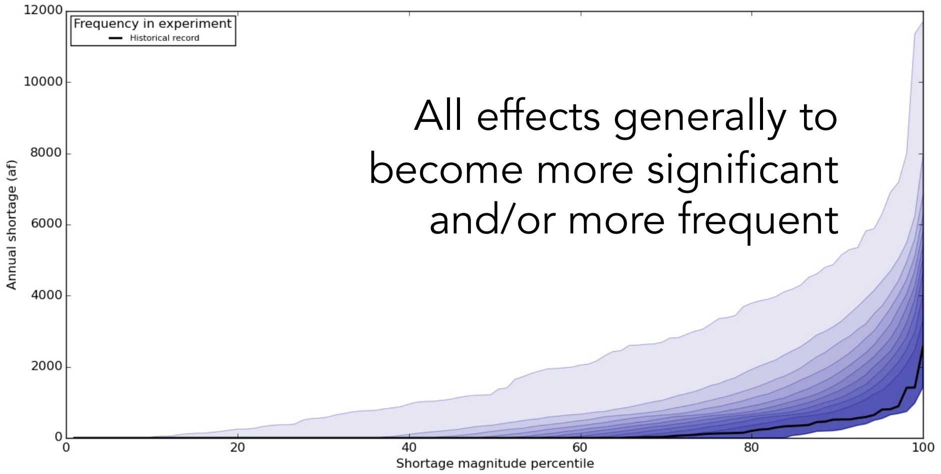
*Conditional on the sample (ranges and distributions)

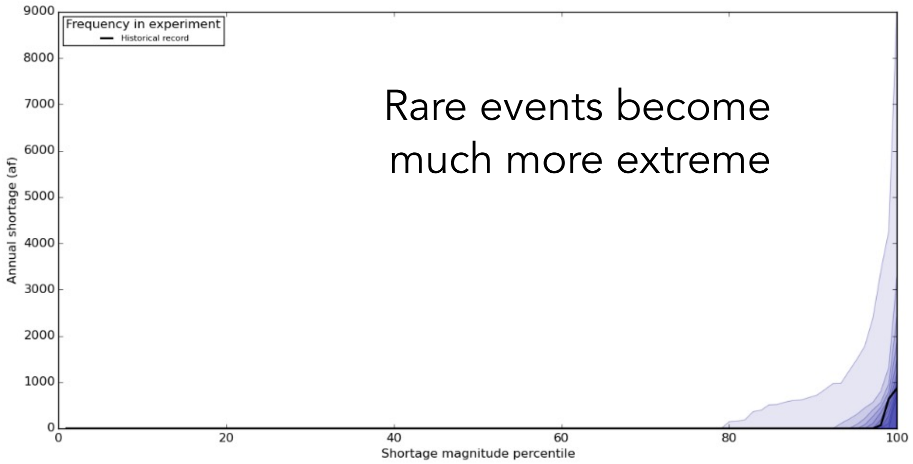
Are these effects common among other sites?

Shortage magnitudes across irrigation sites









Users of different sectors, right seniority, and demand levels experience vastly different impacts

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Address the following questions for 338 water users :

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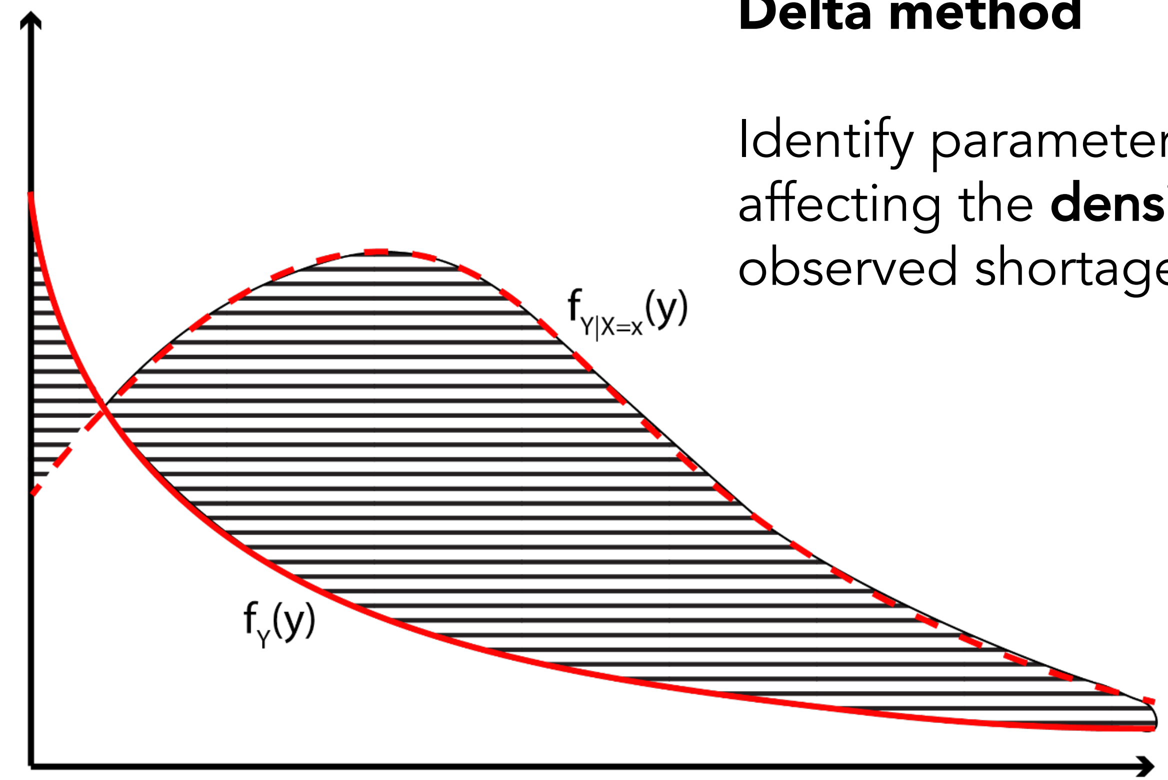
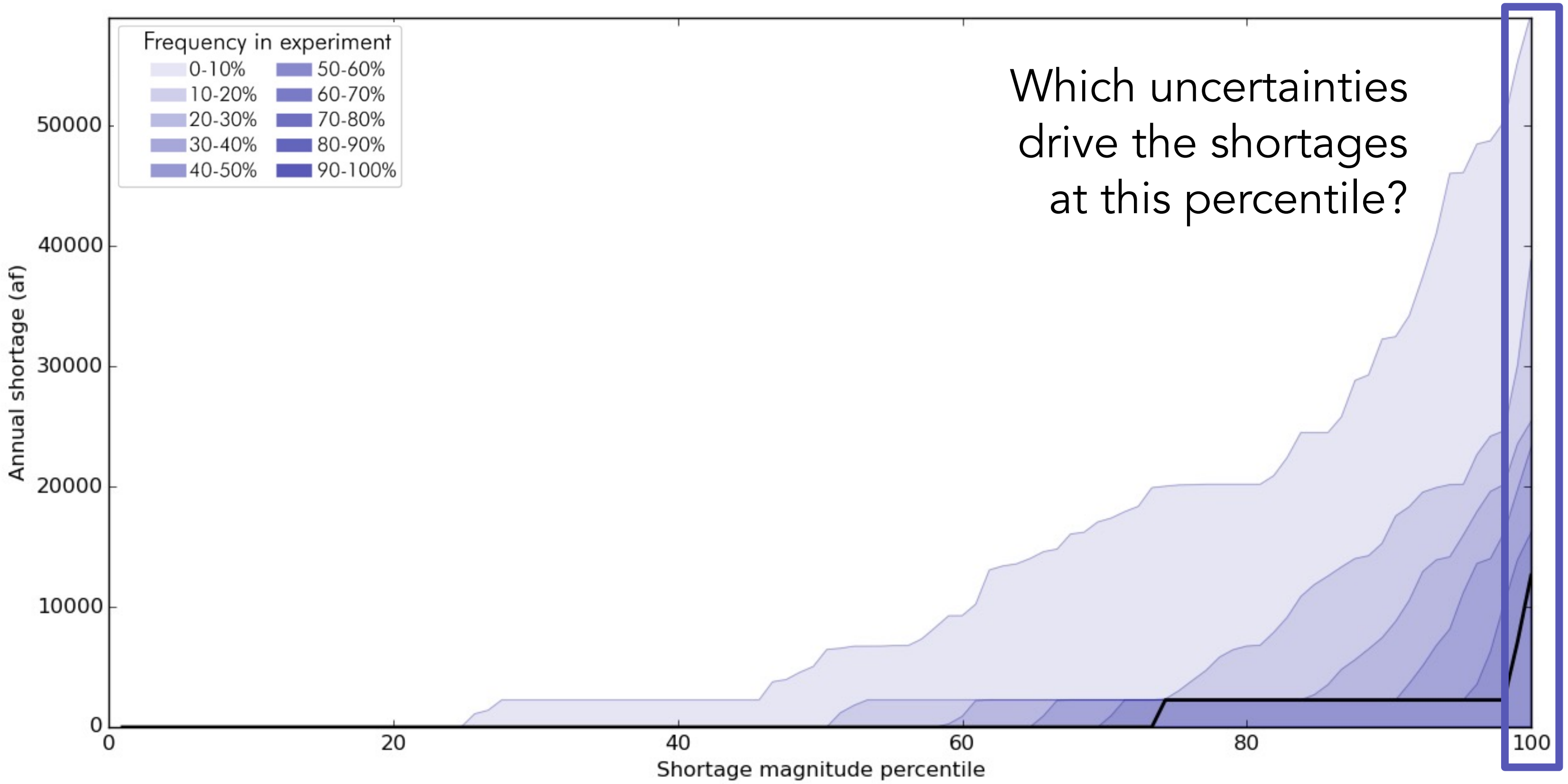
Which uncertain factors are driving their shortages?



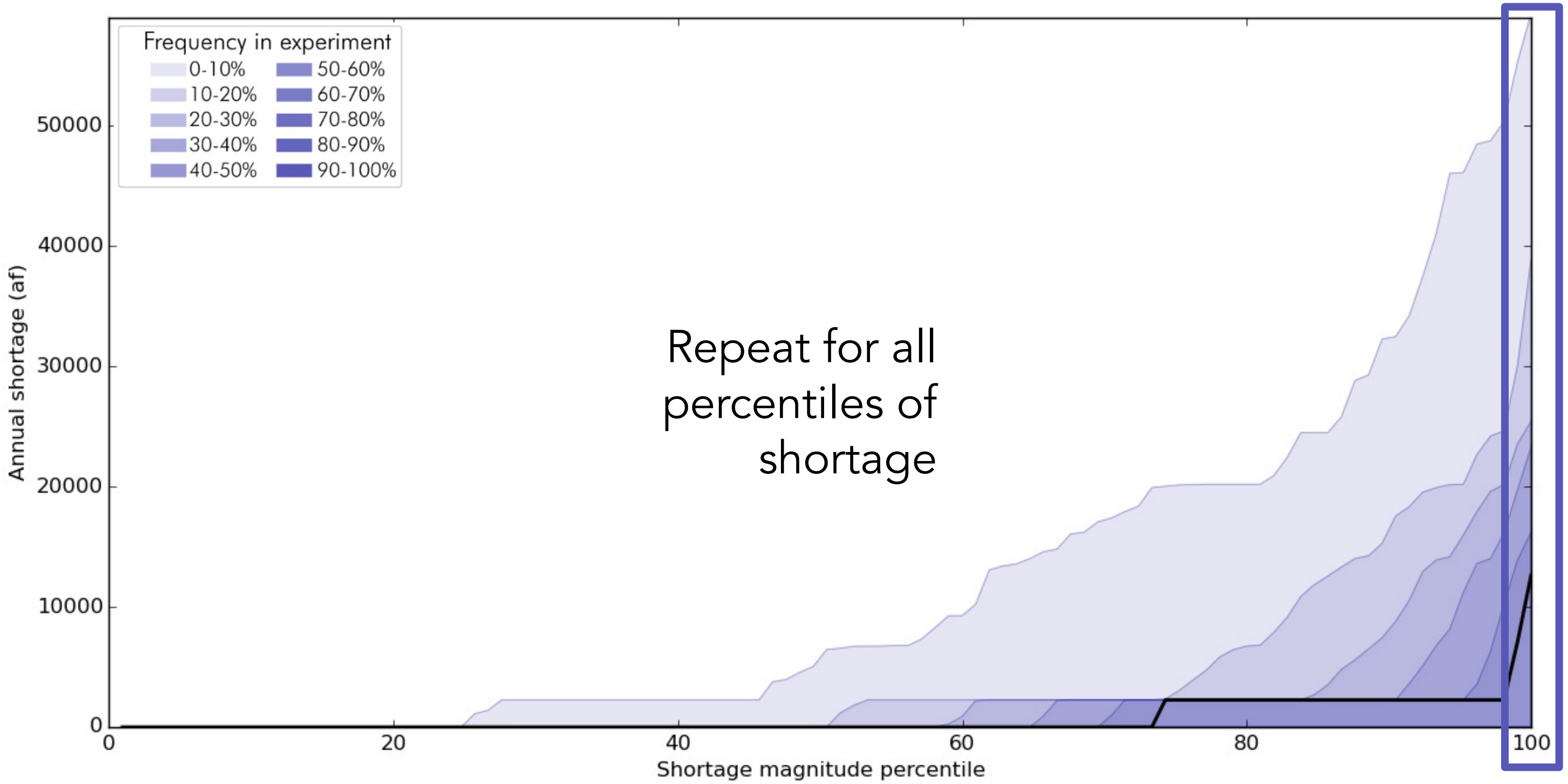
Delta method

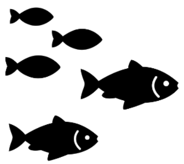
Identify parameters most significantly affecting the **density function** of observed shortages

Magnitude impacts on the 15-mile reach

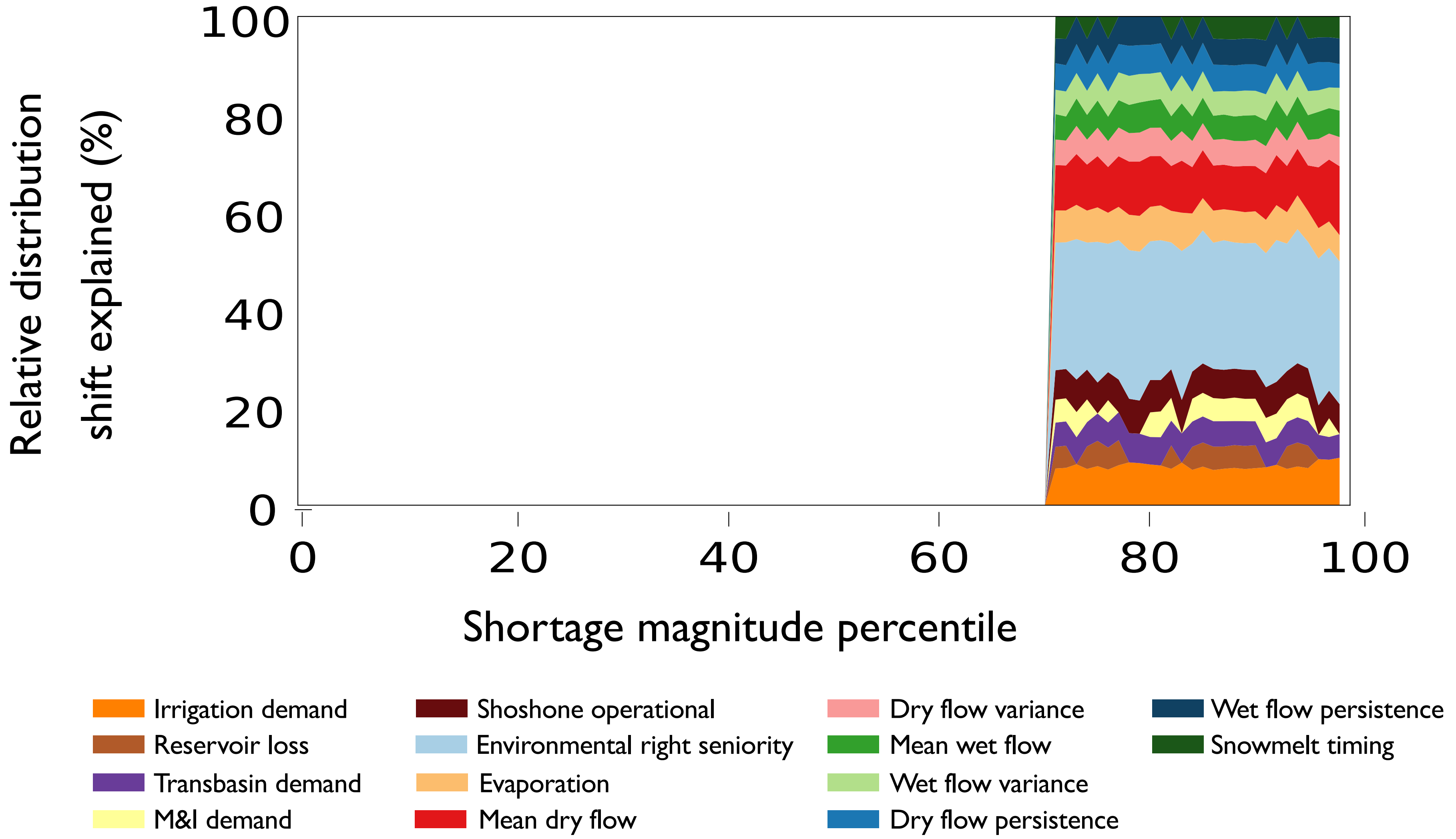


Magnitude impacts on the 15-mile reach

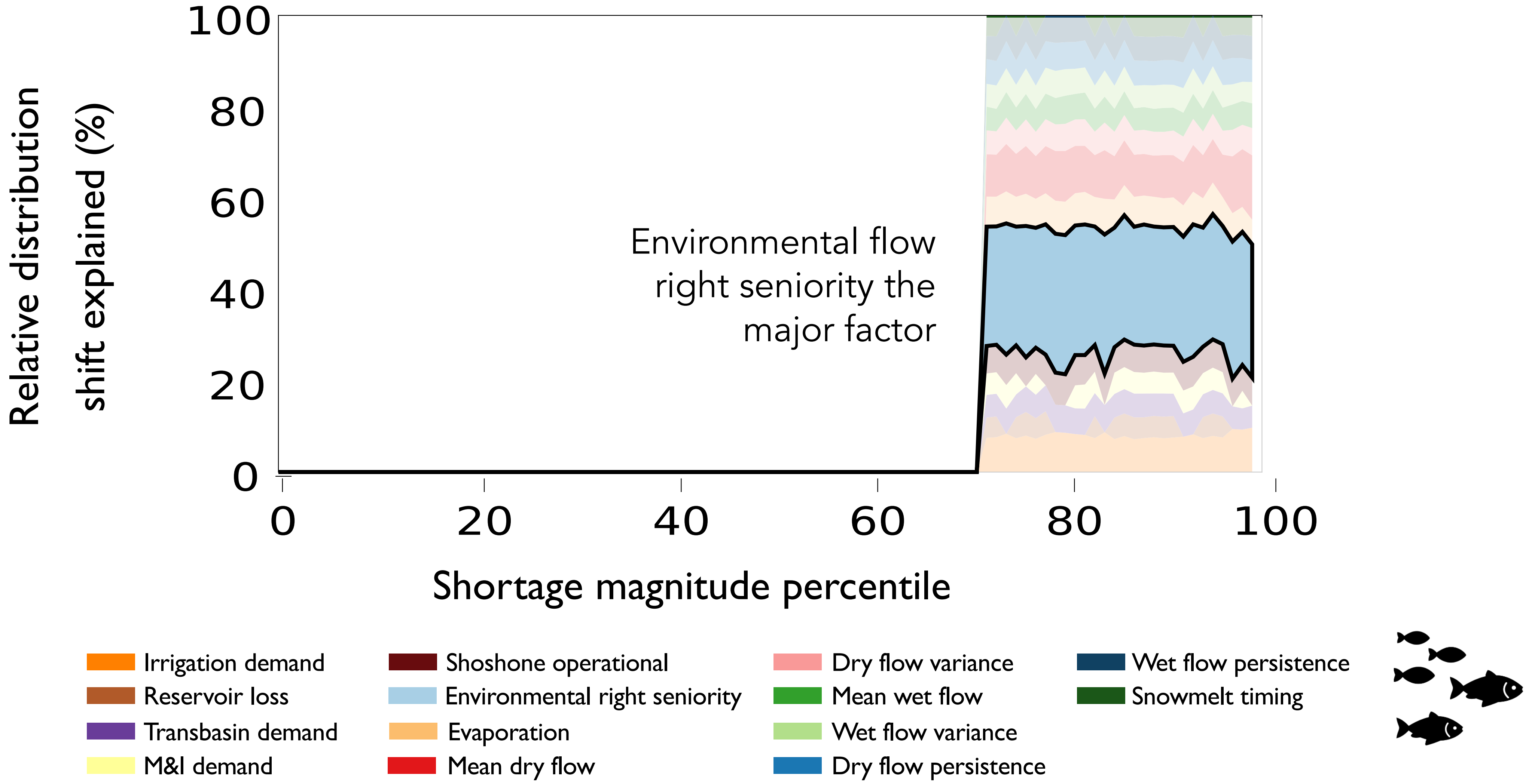




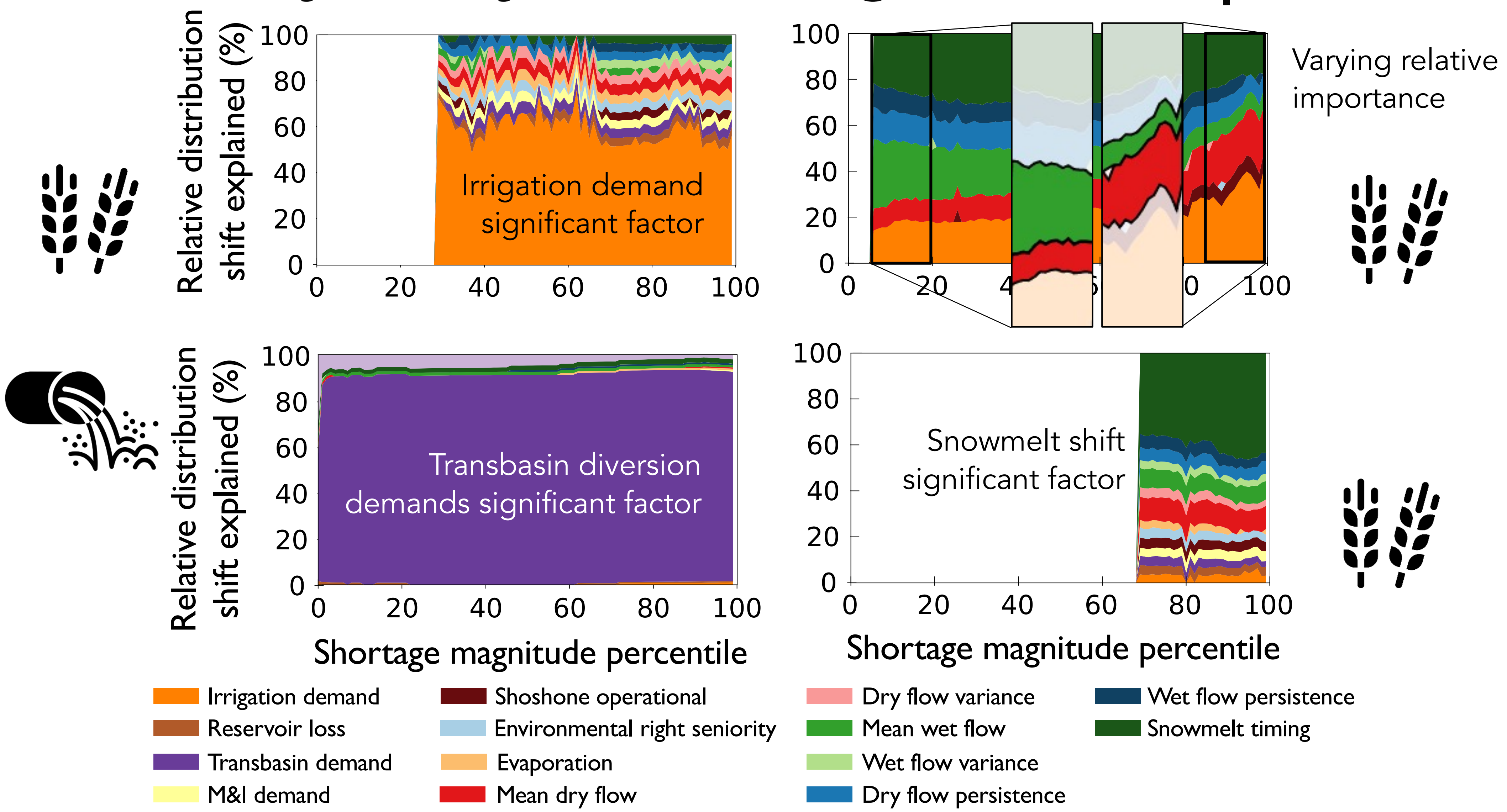
Sensitivity analysis on magnitude impacts



Sensitivity analysis on magnitude impacts



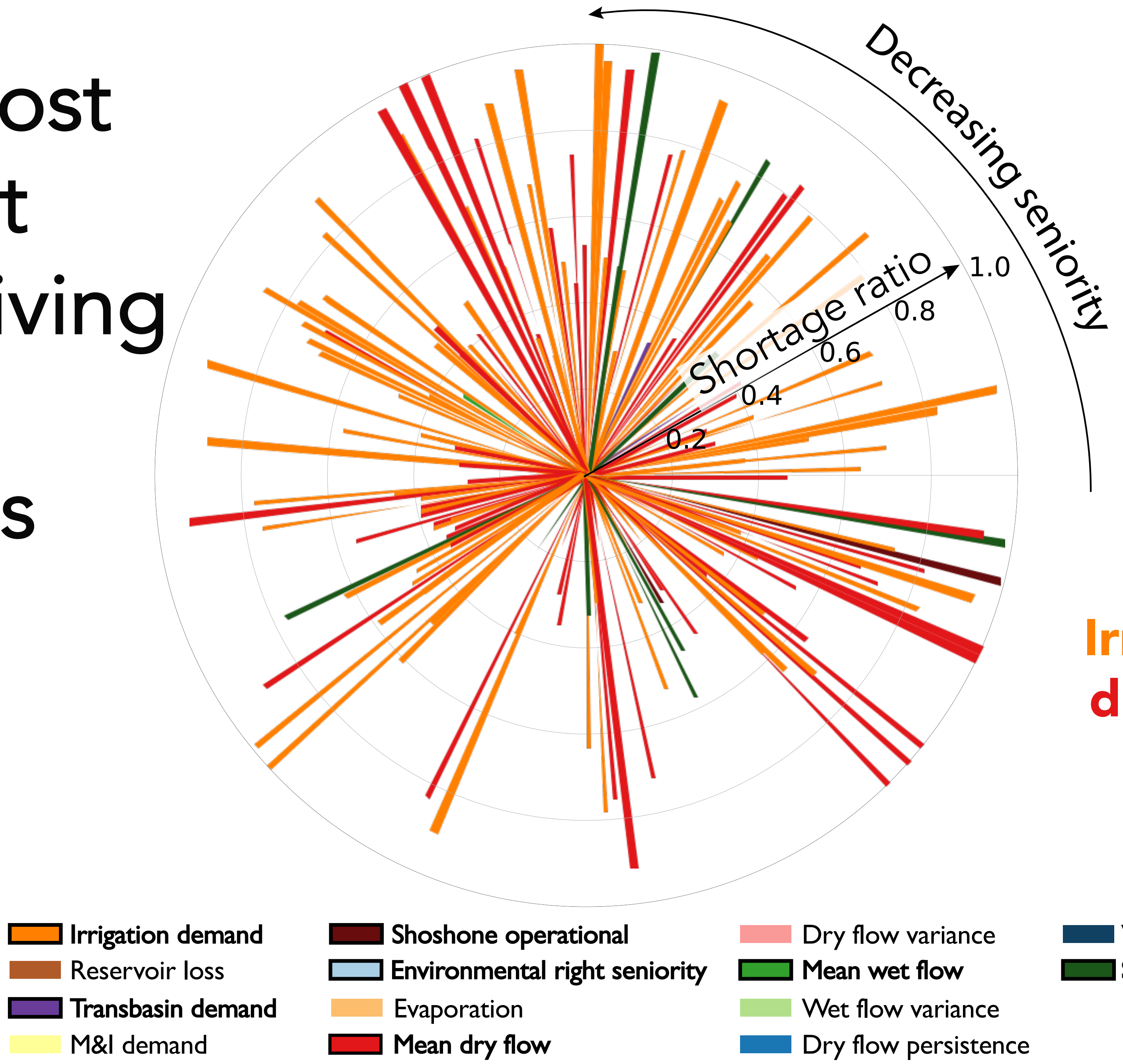
Sensitivity analysis on magnitude impacts



Impacts are driven by different sets of changes and uncertainties

What dominant factors affect all other users?

Single most dominant factor driving worst shortages

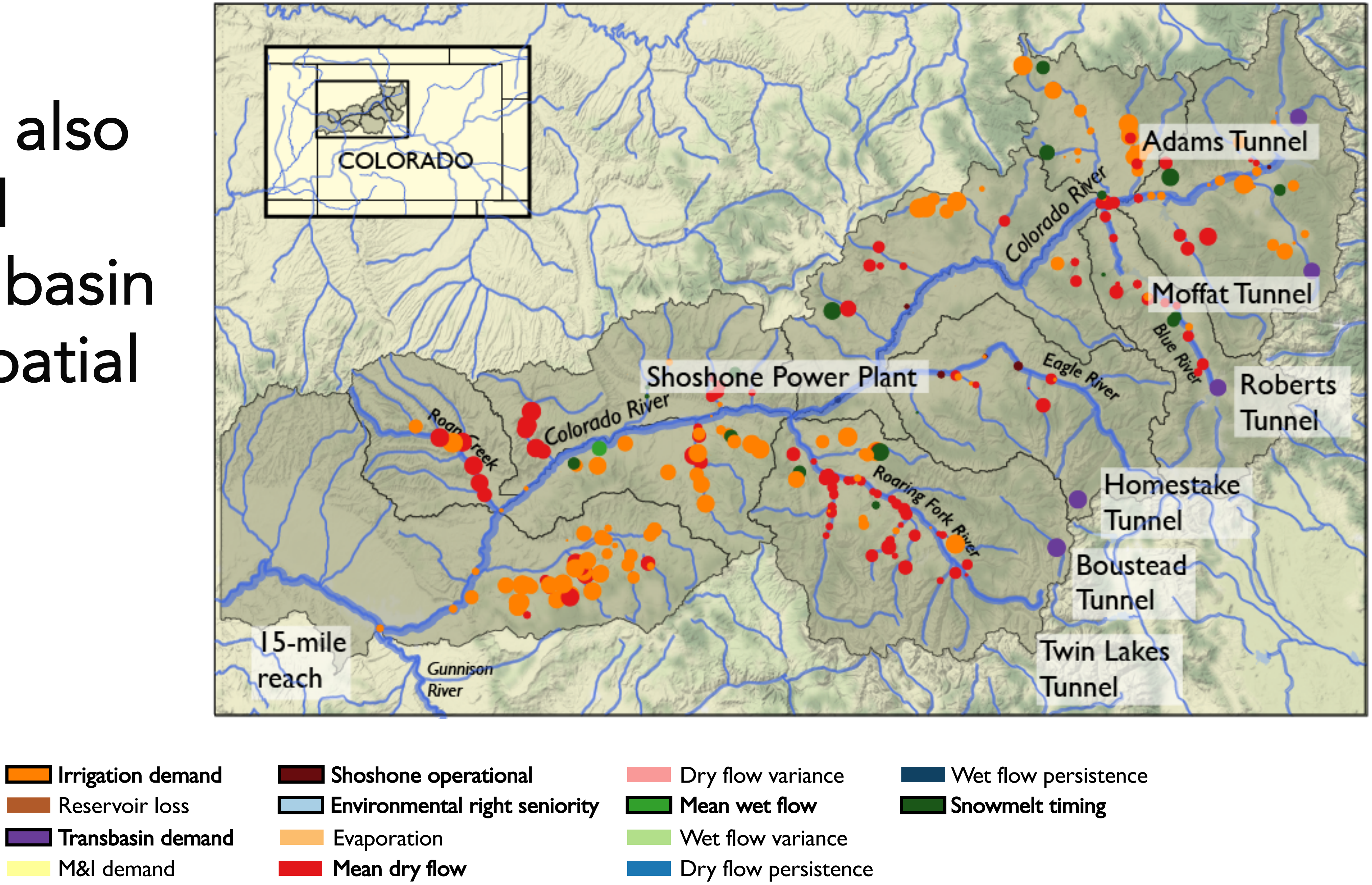


No clear pattern as we move down the priority of users

Irrigation demand and **dry flows** appear most commonly, among several other factors

Are there any spatial patterns?

Dominant factors are also distributed across the basin with few spatial clusters



Several dominant factors affect the basin, some are human-driven, some are not

1 Use StateMod to perform **explorative analysis** on sensitivities and vulnerabilities in the Basin

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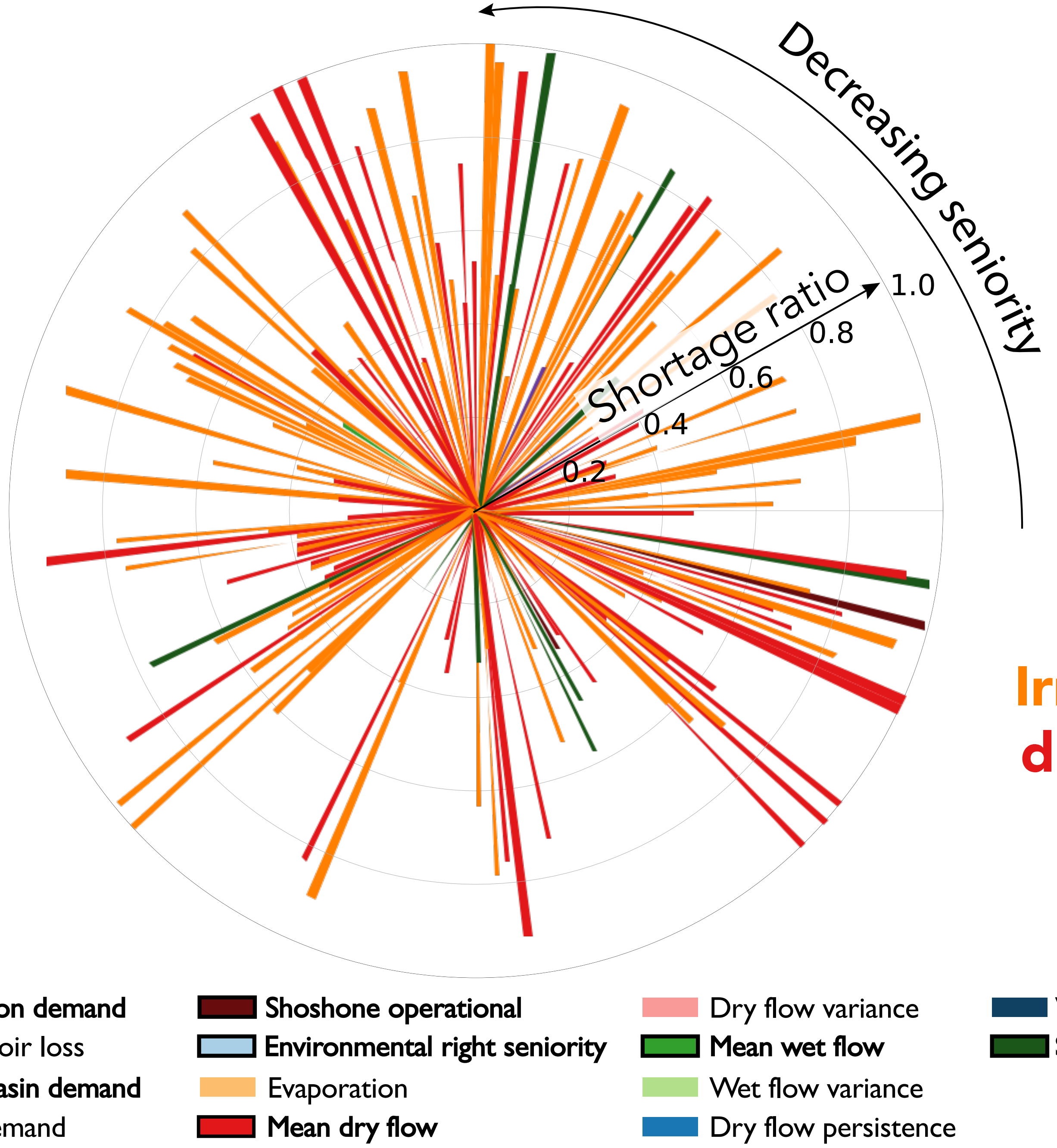
How can informal demand agreements modulate shortages?



Irrigation demand and **dry flows** appear most commonly, among several other factors

An alternative to “buy and dry”

Stressed municipal water providers safeguard their supply through permanent acquisition of irrigation water rights

The practice is controversial as it permanently damages agricultural communities


MENU HighCountryNews

WATER

Can leasing irrigation water keep Colorado farms alive?

Farmers try to stop “buy and dry” by pooling water rights to supply growing cities.

Joshua Zaffos | June 8, 2015 | From the print edition | PRINT

Luke Runyon/Harvest Public Media

The Colorado Water Plan suggests several alternatives such as lease/fallowing agreements, pooling of water rights or interruptible supply

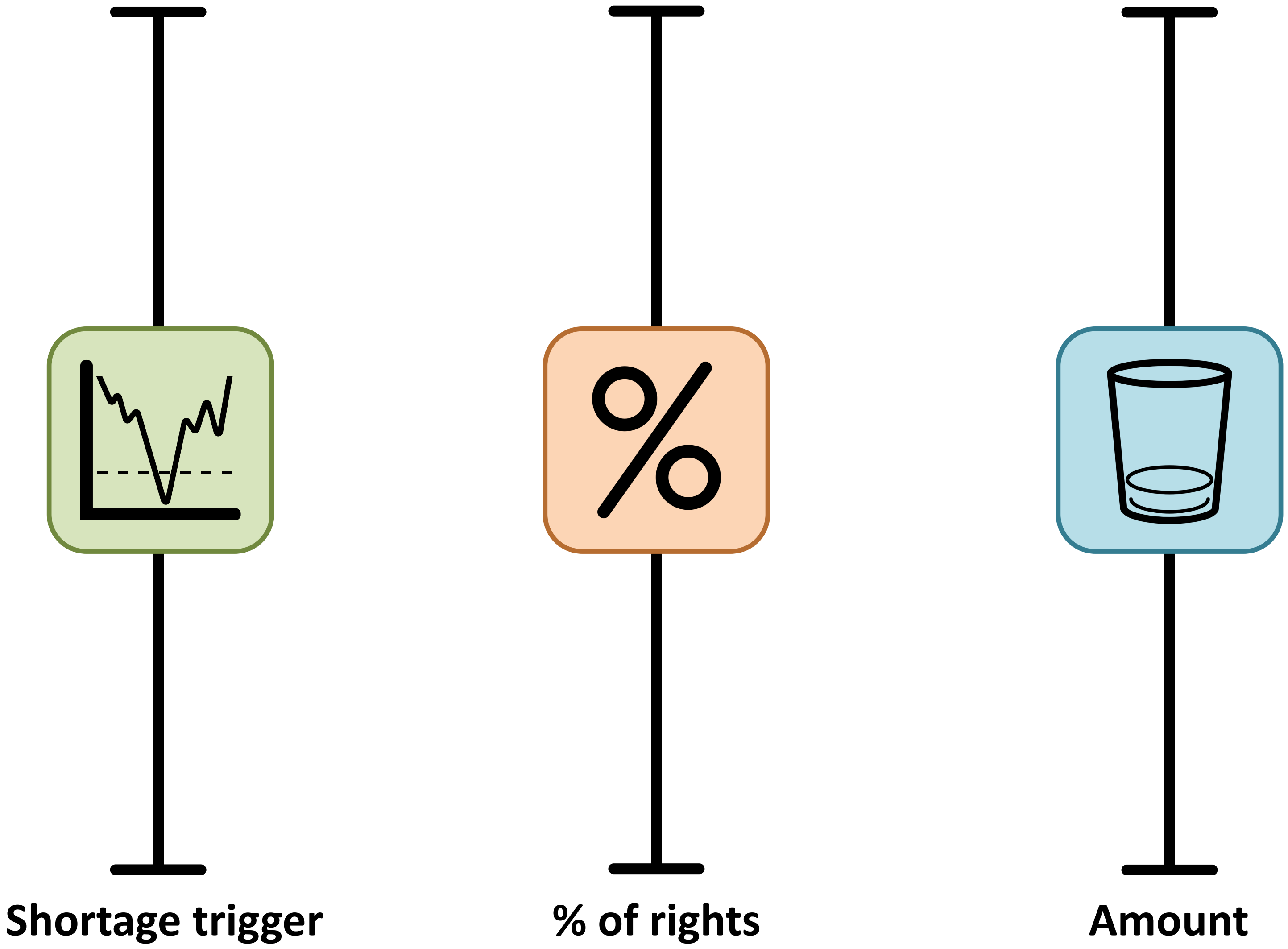
Adaptive trigger of demand reduction

Basin-wide shortage that triggers demand reduction

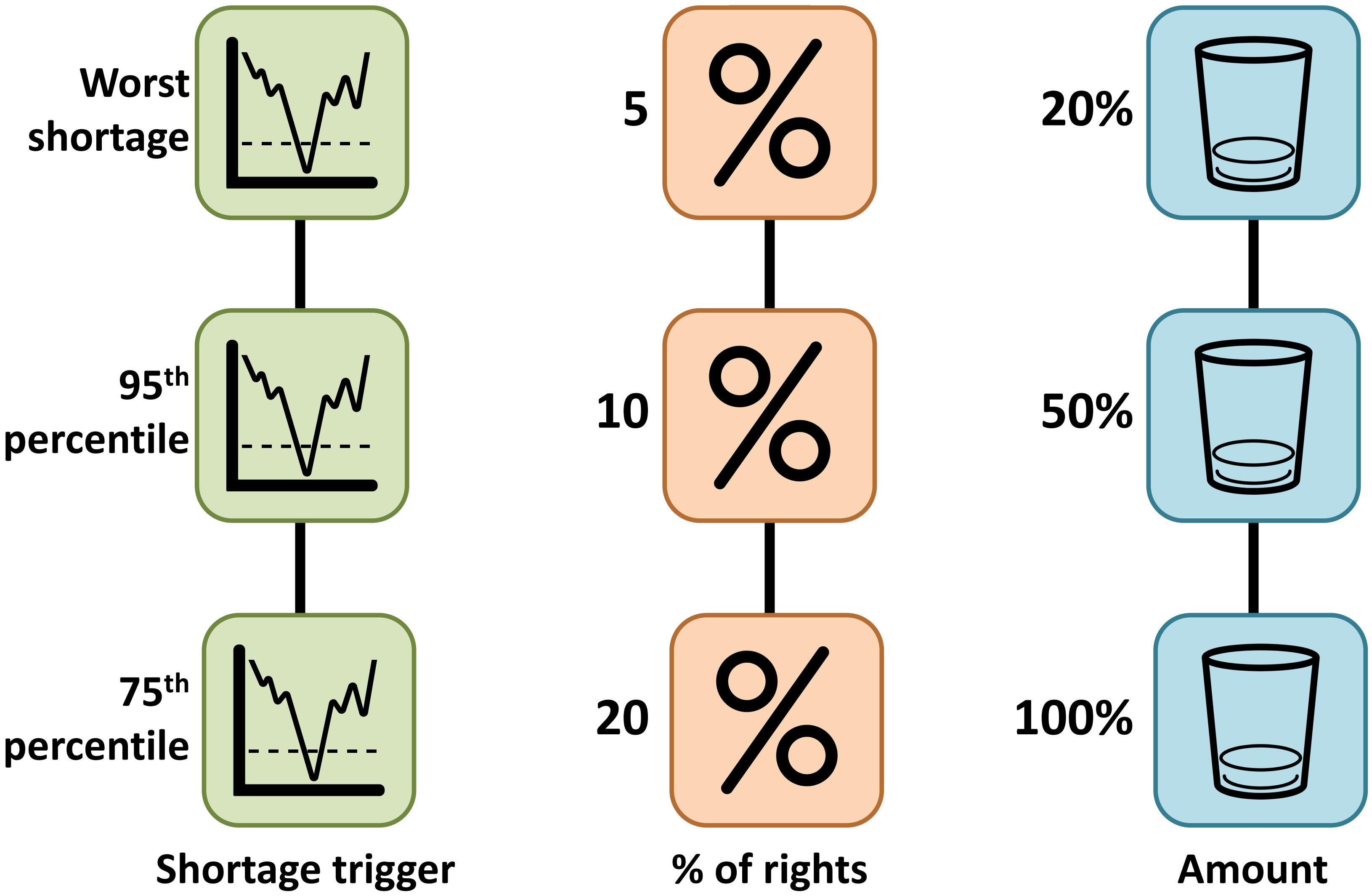
% of junior rights with demand reduction

Amount of reduction

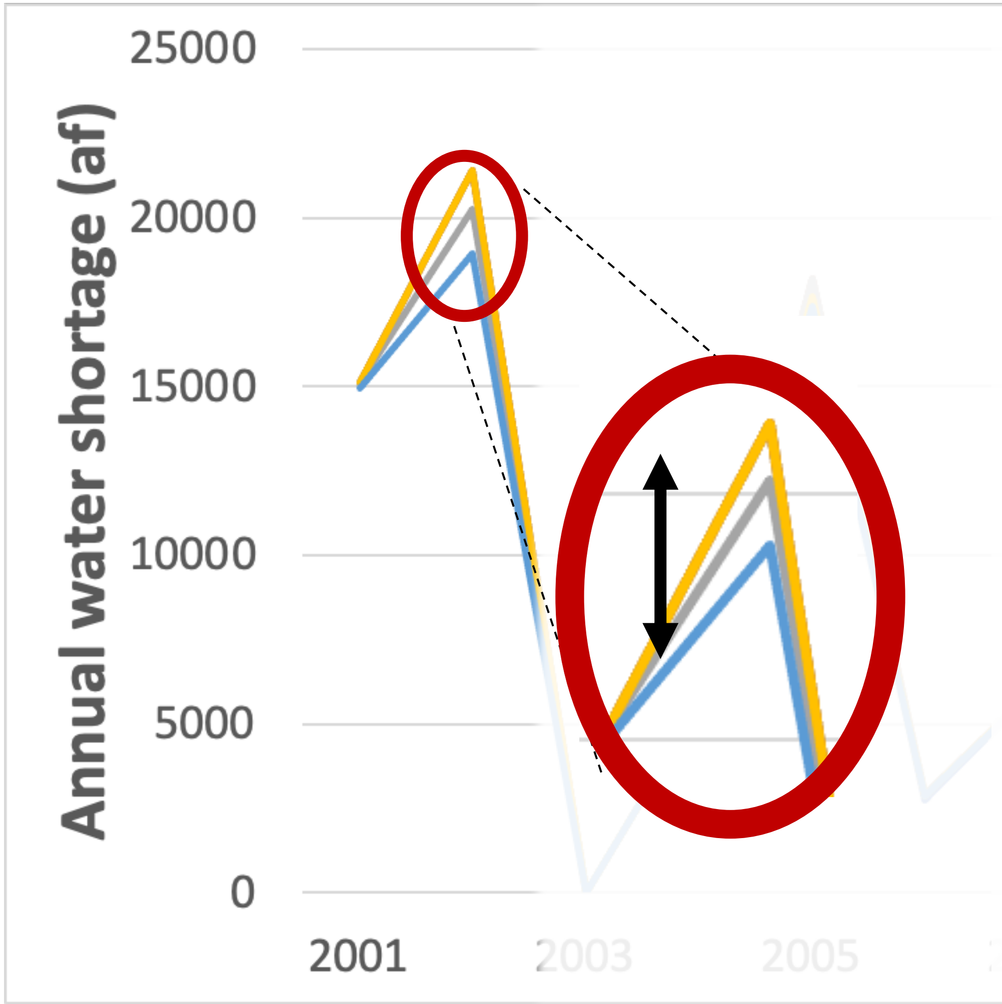
Adaptive trigger of demand reduction



Adaptive trigger of demand reduction



Proof of concept for a senior municipal supply



~10% reduction during their worst experienced drought

Equivalent to the needs of 5,000 households

Take-away messages and next steps

In complex multi-sector river basins:

1. A single impact metric across multiple users, a sector, or geographic location cannot fully capture the diversity of experienced impacts

2. Water conservation policies will not be equally effective for everyone, as the effects of changing demands vary across users

3. Exploratory sensitivity analyses and iterative metric formulations are necessary when diverse sets of stakeholders are involved

Next steps:

Fully explore the capacity of adaptive demands and informal water right agreements to modulate the effects of drought under a wide range of hydroclimatic conditions

Thank you!

Water Resources Research

Research Article | Full Access

Advancing Diagnostic Model Evaluation to Better Understand Water Shortage Mechanisms in Institutionally Complex River Basins

Antonia Hadjimichael, Julianne Quinn, Patrick Reed

First published: 05 October 2020 | https://doi-org.proxy.library.cornell.edu/10.1029/2020WR028079

Hadjimichael, A., Quinn, J., Reed, P., 2020. Advancing Diagnostic Model Evaluation to Better Understand Water Shortage Mechanisms in Institutionally Complex River Basins. Water Resources Research 56, e2020WR028079. https://doi.org/10.1029/2020WR028079