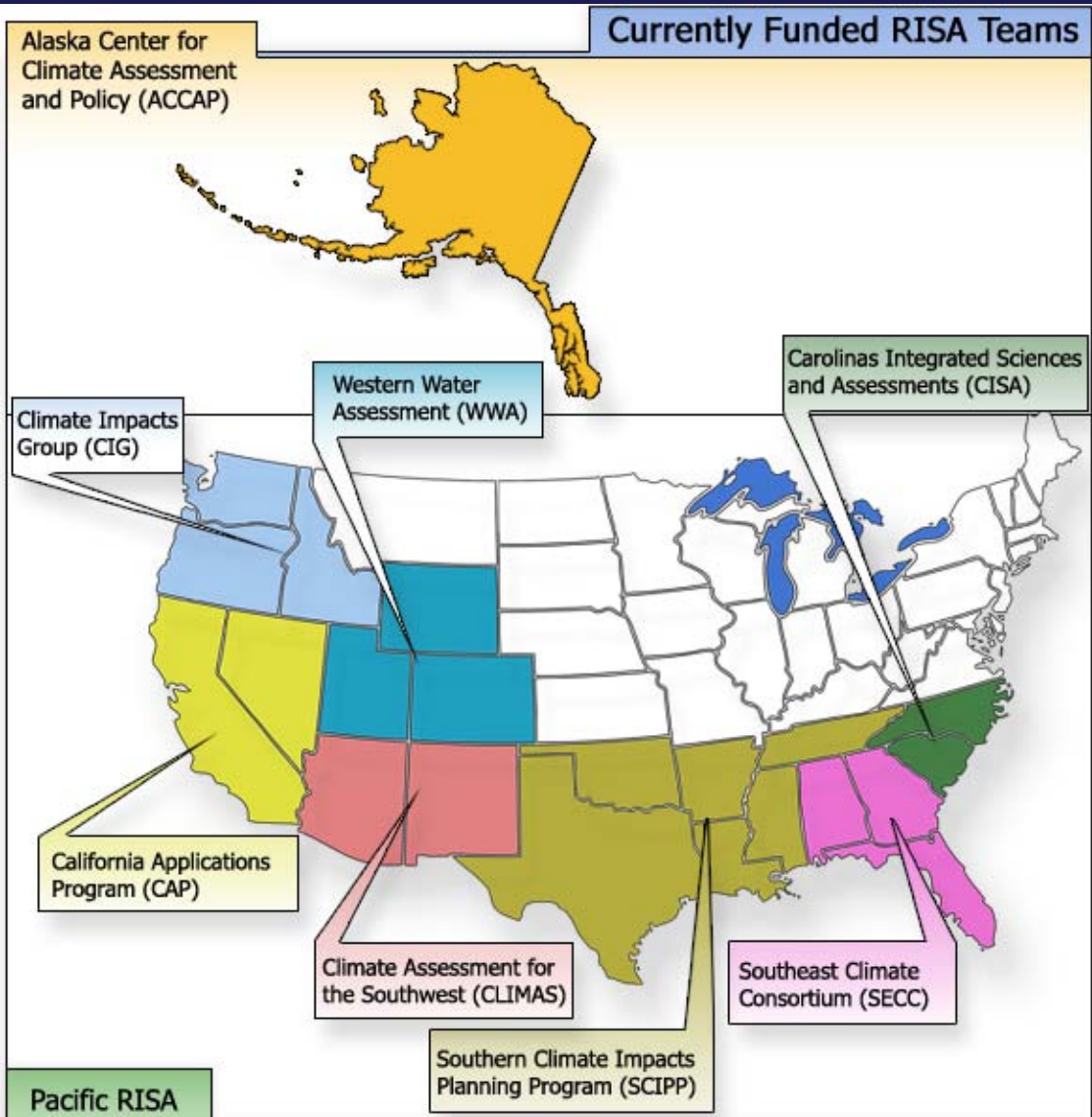


# Western Water Assessment one of 9 Similar NOAA Regional Integrated Sciences and Assessments (“RISA”) Programs.

[http://www.climate.noaa.gov/cpo\\_pa/risa/](http://www.climate.noaa.gov/cpo_pa/risa/)



Regional Integrated Sciences and Assessments

**Building  
Bridges Between  
Climate Sciences  
and Society**

**Colorado**  
University of Colorado at Boulder



# RISA = Regional Integrated Sciences and Assessments

- Funded by NOAA Climate Program Office
- Created mid 1990s to connect regional decision makers with newly available climate information (ENSO, especially)
- Enable NOAA to learn about how to create a National Climate Service
- Operate at all time scales: past, present, future
- Generally 'climate', not 'weather', centric
- At universities with strong climate programs
- Interact with NOAA Climate Offices
- Interdisciplinary Teams
- WWA Unique: at NOAA ESRL



# Sampling of Recent Activities

- Paleoclimate Flow Reconstructions – Woodhouse, Lukas
- Intermountain Climate Summary – Lowrey, Ray, Averyt
- Experimental Climate Predictions - Wolter
- Climate Prediction Postdoc (Galina Guentchev) w/ Reclamation and Las Vegas – Barsugli, Webb, Udall
- Climate Change Appendix for C. River Recent Environmental Impact Statement - Udall
- Reconciling Colorado River Flows – Cross RISA
- Policy Analysis w/ Reclamation re C. River Future Management – Rajagopalan, Hoerling, Udall, Barsugli
- Colorado Climate Report for State Colorado Water Conservation Board – Ray, Barsugli, Averyt
- Water – Energy Nexus – Averyt, Pulwarty, Udall
- Workshops – climate modeling, paleo climate, NWS / Colorado Basin RFC Water Supply Forecast Verification
- Regular communications with many, many water users in the Colorado River Basin – WGA, WSWC, CADWR, AMWA, AWWARF, WUCA

# Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation

## Lead Authors

Andrea J. Ray<sup>1,2</sup>, Joseph J. Barsugli<sup>3</sup>, Kristen B. Averyt<sup>2</sup>

## Authors

Klaus Wolter<sup>3</sup>, Martin Hoerling<sup>1</sup>, Nolan Doesken<sup>4</sup>,  
Bradley Udall<sup>2</sup>, Robert S. Webb<sup>1</sup>



<sup>1</sup>NOAA, Earth Systems Research Laboratory

<sup>2</sup>University of Colorado at Boulder, Western Water Assessment

<sup>3</sup>University of Colorado at Boulder, Climate Diagnostics Center

<sup>4</sup>Colorado State University



State of the science regarding the physical aspects of climate change that are important for evaluating impacts on Colorado's water resources, and developing adaptation strategies out to the mid-21<sup>st</sup> century



## Climate Change in Colorado

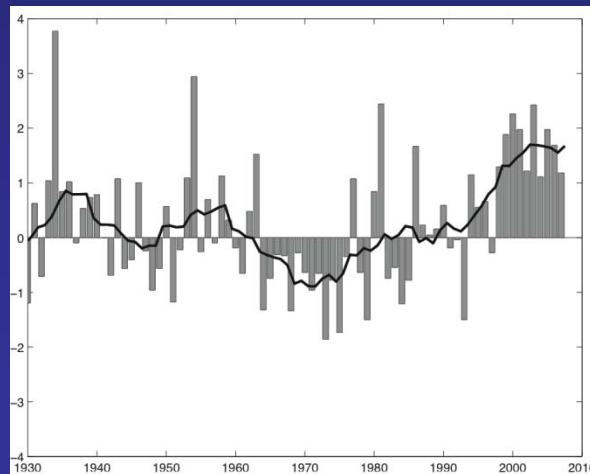
A Synthesis to Support Water Resources  
Management and Adaptation

A REPORT FOR THE COLORADO WATER CONSERVATION BOARD



Colorado  
University of Colorado at Boulder

Multiple independent measurements confirm widespread warming in the Western U.S.; in Colorado, temperatures have increased by approximately 2°F from 1977–2006. No consistent long-term trends in annual precipitation have been detected.



Western Water Assessment

# The Fundamental Problem with Climate Change For Water Management

- All water resource planning based on the idea of “climate stationarity” – climate of the future will look like the climate of the past.
  - Reservoir sizing
  - Flood Control Curves
  - System Yields
  - Water Demands
  - Urban Runoff Amounts
- This will be less and less true as we move forward.
- Existing Yields now not as certain given both supply and demand changes
- New water projects have an additional and new element of uncertainty.

Science, February 1, 2008

POLICYFORUM

CLIMATE CHANGE

## Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,<sup>1\*</sup> Julio Betancourt,<sup>2</sup> Malin Falkenmark,<sup>3</sup> Robert M. Hirsch,<sup>4</sup> Zbigniew W. Kundzewicz,<sup>5</sup> Dennis P. Lettenmaier,<sup>6</sup> Ronald J. Stouffer<sup>7</sup>



Western Water Assessment

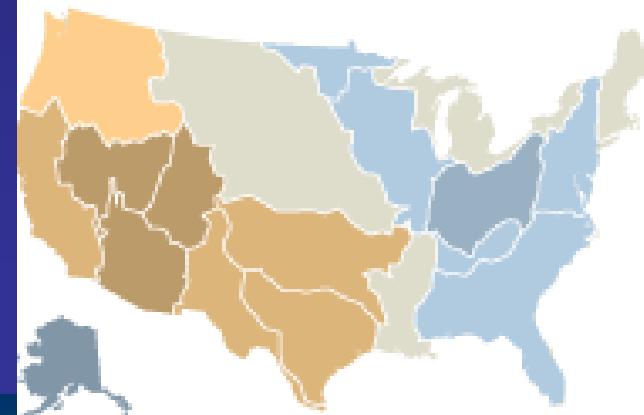
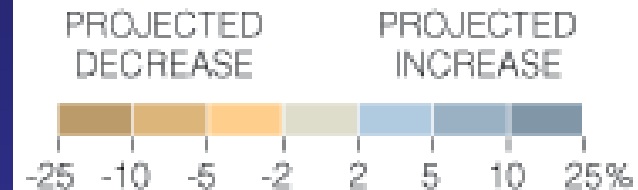
# A Large Number of Studies Point to a Drying American Southwest

- Milly et al., 2005
- Seager et al., 2007
- IPCC WG1, IPCC WG2, 2007
- National Academy Study, 2007
- IPCC Water Report, 2008
- CCSP SAP 4.3, 2008

“From 2040 to 2060, anticipated water flows from rainfall in much of the West are likely to approach a 20 percent decrease in the average from 1901 to 1970, and are likely to be much lower in places like the fast-growing Southwest.” ~ May 28, 2008, New York Times

## Water Flows in 2040-60

A new federal report compares water flows expected later this century with average water flows from 1901-70. The Southwest is likely to have less water from precipitation, while the Midwest and East are likely to have more.



Source: U.S. Climate Change  
Science Program

THE NEW YORK TIMES



# Colorado River Basin Overview



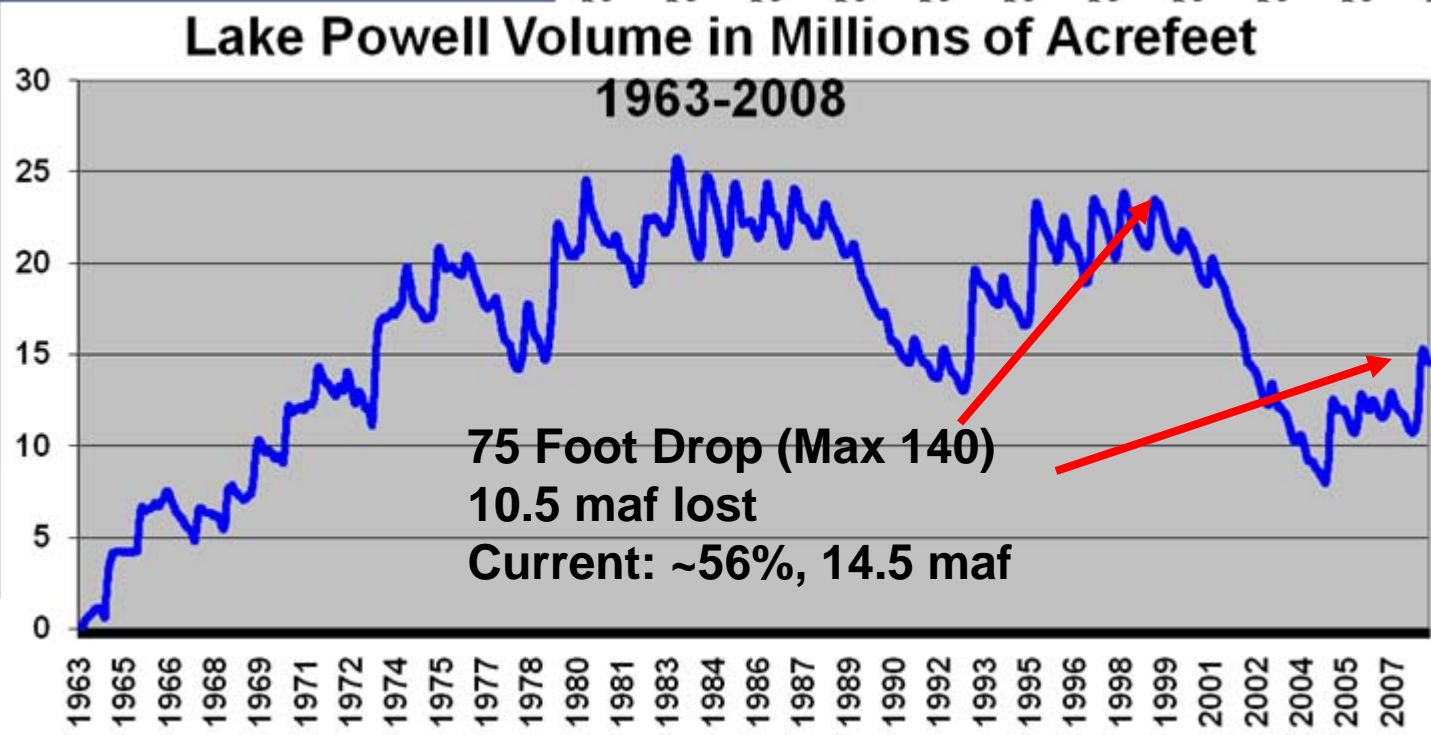
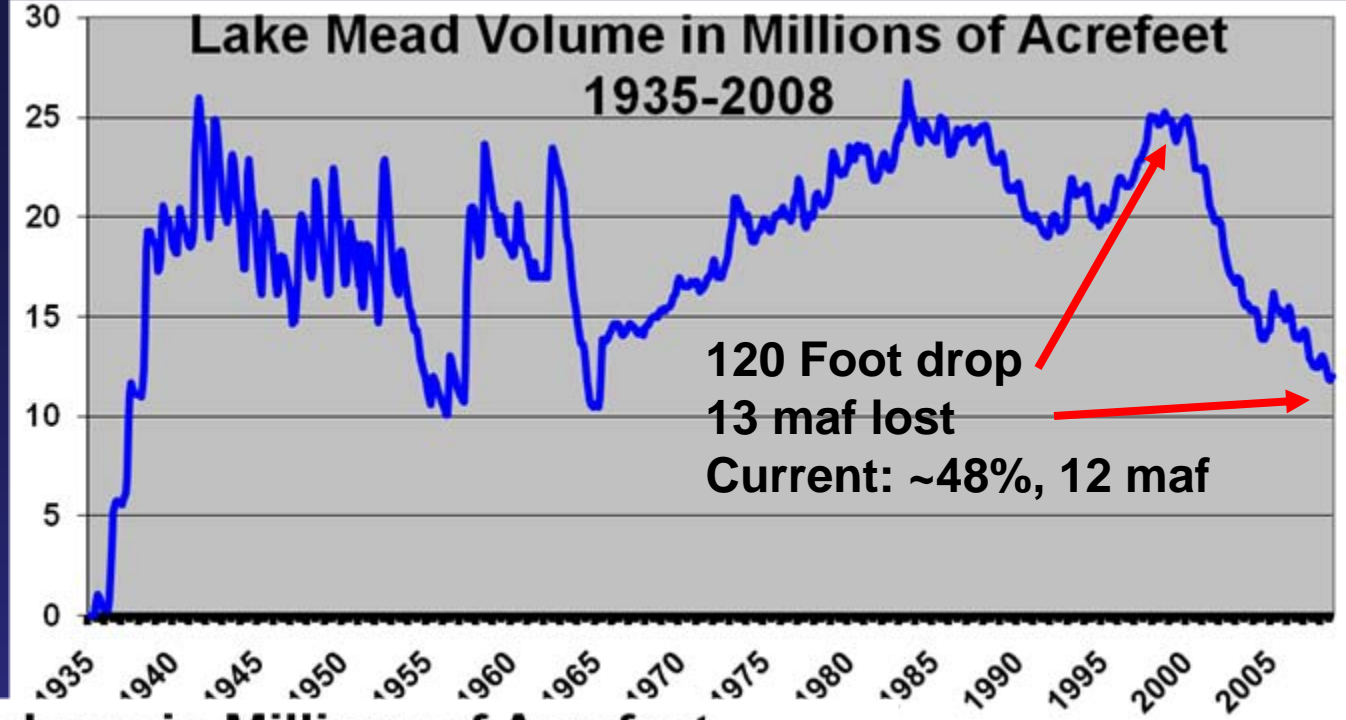
- 7 States, 2 Nations
  - Upper Basin: CO, UT, WY, NM
  - Lower Basin: AZ, CA, NV
- Fastest Growing Part of the U.S.
- Over 1,450 miles in length
- Basin makes up about 8% of total U.S. lands
- Highly variable Natural Flow which averages 15 MAF
- 60 MAF of total storage
  - 4x Annual Flow
  - 50 MAF in Powell + Mead
- Irrigates 3.5 million acres
- Serves 30 million people
- Very Complicated Legal Environment
- Denver, Albuquerque, Phoenix, Tucson, Las Vegas, Los Angeles, San Diego all use CRB water
- DOI Reclamation Operates Mead/Powell

1 acre-foot = 325,000 gals, 1 maf = 325 \* 10<sup>9</sup> gals

1 maf = 1.23 km<sup>3</sup> = 1.23\*10<sup>9</sup> m<sup>3</sup>



# Declining Lakes Mead and Powell



5 Years of 10 maf/yr  
66% of average flows  
Worst drought in  
historic record



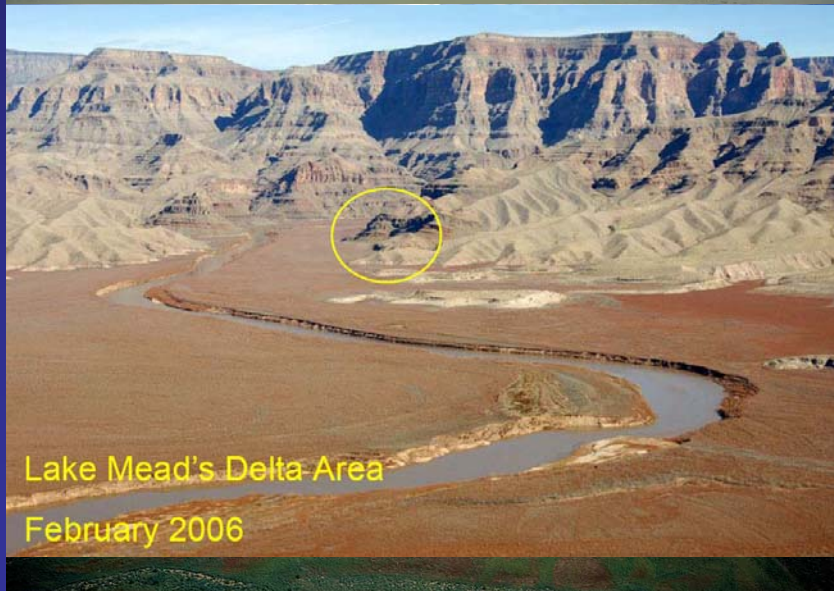
The New York Times Magazine



# The Perfect Drought



New York Times Sunday  
Magazine, October 21, 2007



# A Current Problem in the Lower Basin: AZ, CA, NV

- Avg Lake Mead Inflows = 9.0 maf
  - 8.23 maf from Powell (Current Operating Rules)
  - 0.77 maf tributaries below Powell
  - This is Lower Basin's full legal entitlement
  - Historically they have received more from unused Upper Basin Flows
- Avg Lake Mead Outflows = 10.4 maf
  - 7.5 maf LB States (4.4 CA, 2.8 AZ, 0.3 NV maf)
  - 1.5 maf Mexico
  - 1.4 maf Evap (8 Feet Every Year) + Delivery Losses
- Net Balance = **-1.4 maf/year**
  - (Mead at 12 maf now)
- **Note: Las Vegas (2m people) uses Mead for 90% of their supply; they are spending \$1B on a new intake at the bottom of the Mead.**

# A Lurking Problem in the Upper Basin CO, UT, WY, NM

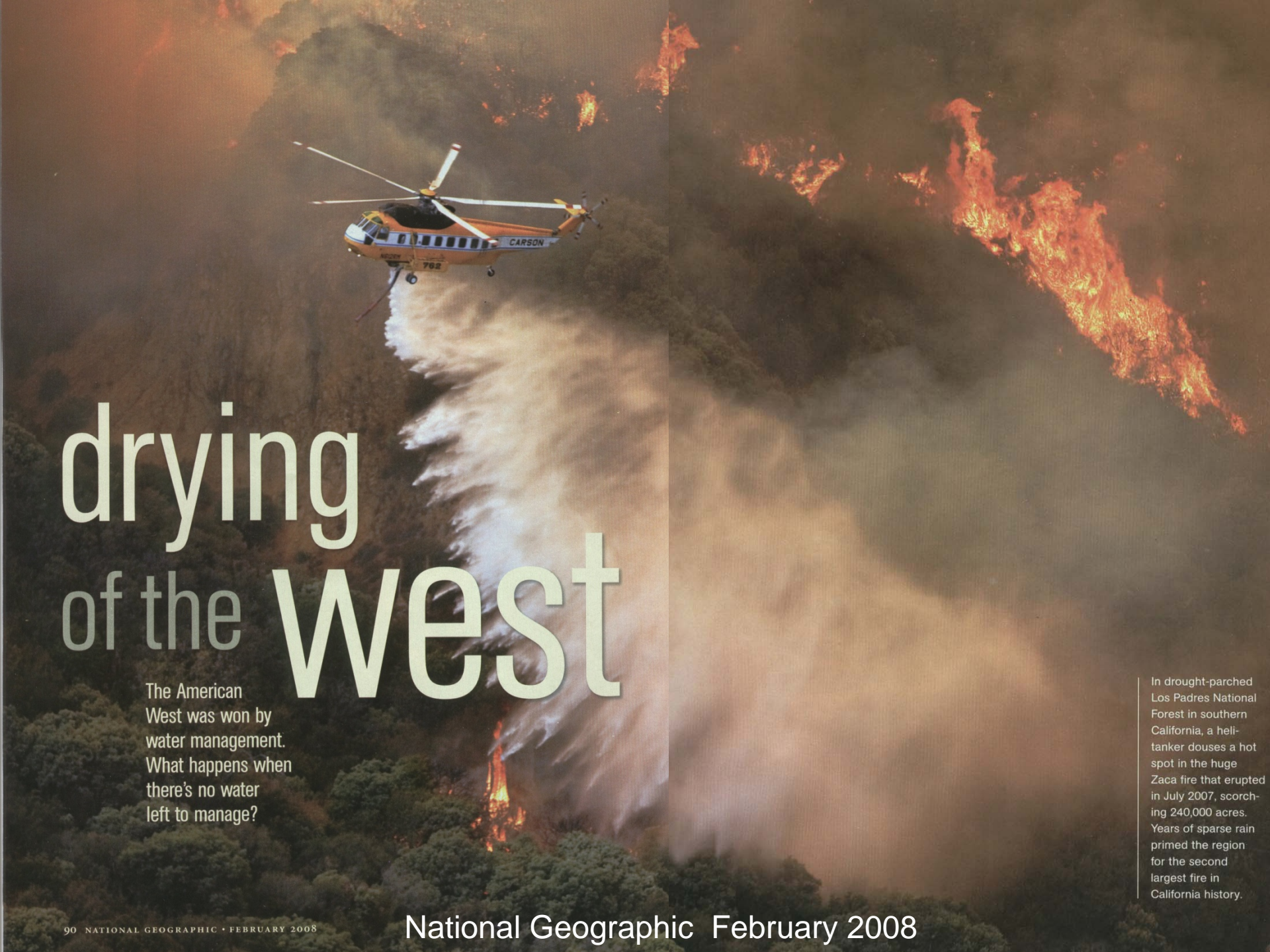
- How Much Water Left to Develop?
  - Current uses: ~4.7 maf per year
  - At 13.5 maf avg , ~0.5 maf left to develop
  - At 15.0 maf avg, ~1.5 maf left to develop
- ‘Hydrologic Leftovers’ Creates Uncertainty
- Upper Basin Compact severely penalizes for overuse, but only determined after the fact
- Concern over Compact ‘Call’ Ramifications
  - Might involve cutting off 50% of Front Range Water

# 2007 Reclamation Environmental Impact Statement

- 2 Purposes
  - Coordinated Mead/Powell Operations
  - Shortage Criteria for Lower Basin (AZ junior issues)
- Signed December 2007 by DOI Sec. Kempthorne
- Rules to be in place through 2026
- Modeling used historical hydrology, BUT a paleo hydrology appendix
  - Very Small Chance ~1-2% of not making full deliveries by 2026
- Basis is Feb '06 Innovative Basin States' Proposal
  - Water Banking in Mead – First Time Ever
  - Shortages at certain reservoir levels agreed upon
    - AZ, Mexico take full brunt of shortages for legal reasons
    - Max Shortage 0.6 maf (vs. 1.4 maf overuse)
  - New Rules for Operating Mead and Powell
    - Upper Basin considers Powell their bank account for making compact mandated deliveries to Lower Basin
- Appendix U considered Climate Change

# One Water Manager Speaks Out

- ‘Mulroy hopes the next president will create a team of all federal agencies attached to water resources to develop a survival plan for the driest and fastest-growing region of the United States. The rapid decline of Lake Mead "begs the question for a comprehensive look at climate change," she said. "Our world is going to change dramatically.”’

A dramatic aerial photograph of a firefighting helicopter, named 'CARSON' with the number '762', dropping a large volume of water onto a forest fire. The fire is intense, with bright orange and yellow flames and thick black smoke rising from the trees. The helicopter is positioned in the upper left quadrant, and the water is falling in a wide, white stream towards the center of the frame. The background is a dark, smoky forest.

# drying of the west

The American West was won by water management. What happens when there's no water left to manage?

In drought-parched Los Padres National Forest in southern California, a heli-tanker douses a hot spot in the huge Zaca fire that erupted in July 2007, scorching 240,000 acres. Years of sparse rain primed the region for the second largest fire in California history.