A LOOK BACK AT CO-PRODUCTION

The Joint Front Range CC Vulnerability Study

Laurna Kaatz, Climate Adaptation Program Director, Denver Water

DENVER WATER

Participants

Water Interests	Support Agencies	Additional Interest
Aurora Water	Water Research Foundation	Cheyenne Board of Public Utilities, WY
City of Boulder	Western Water Assessment	City of Longmont
Colorado Springs Utilities	Riverside Technology, inc.	City of Westminster
Denver Water	NCAR	Others Welcome
City of Fort Collins		
Northern Water		
Colorado Water Conservation Board		

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JFRCCVS

- Classic top down
- CMIP3, BCSD, “delta” approach
- 2040 and 2070 versus 1950-1999
- 4 Static T and P offsets and 10 GCM based T/P deltas
- 2 hydrology models: WEAP, Sac/SMA
- Lots of data, lots of meetings, lots of education

Educational Sessions

- ***2007***
  - WEAP 101, Sac/SMA 101 – David Yates, Riverside
- ***2008***
  - WWA Workshop: Climate, Water, and Modeling – Brad Udall, Balaji Rajagopalan, Levi Brekke, Chris Anderson, Joe Barsugli, Jess Lowrey
  - Methodology Overview and Kick-off meeting – Laurna Kaatz
  - Global Climate Modeling 101 – Joe Barsugli
  - Long Term Precipitation Trends – Nolan Doesken
  - Temperature Trends and Water Management – Klaus Wolter
  - Riverside's C2D2S2 climate interface with NOAA - Riverside
- ***2009***
  - The complexity of the Climate System and Human Roles – Roger Pielke Sr.
  - The impacts of climate change on snowpack in the Colorado headwaters – David Yates
  - The Colorado River Water Availability Study – Ben Harding
  - Statistical Downscaling 101 – Levi Brekke
  - Adapting to Climate Change – Jess Lowrey
  - Incorporating Climate Uncertainty into Planning – Jennifer Daw

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Benefits of a Regional Approach

- ***Scale:*** Projections are coarse and cover watersheds
- ***Communication:*** Cohesively communicate with customers and the media
- ***Safety:*** Provided political coverage
- ***Coordination:*** Coordinate with other investigations and participants
- ***Collaboration:*** Continue collaboration on education and other investigations
- ***Resources:*** Pool finances, staff, and expert resources
- ***Attention:*** Everyone wanted to work with us

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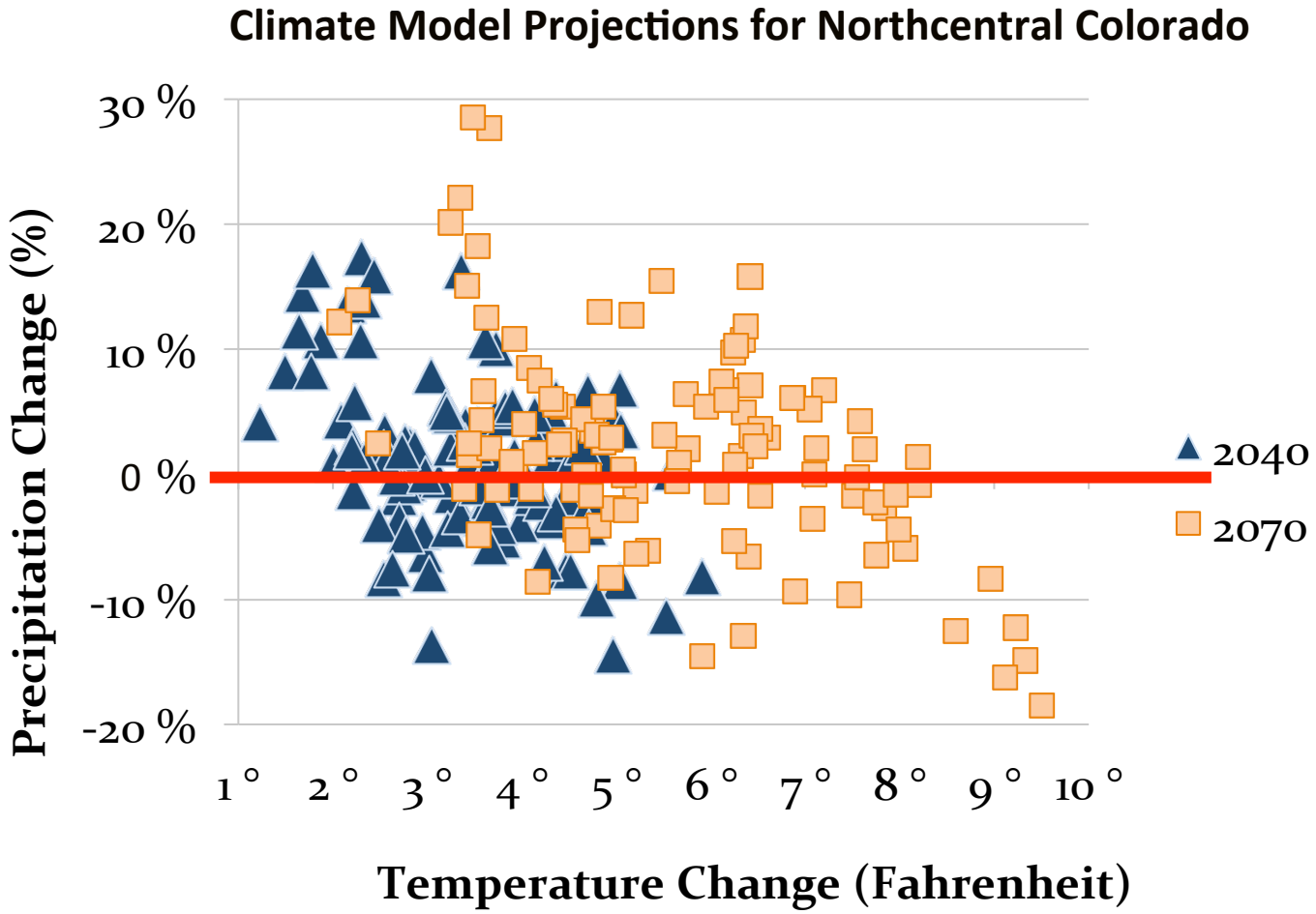
Science will *solve* this problem



Science can only take us so far.

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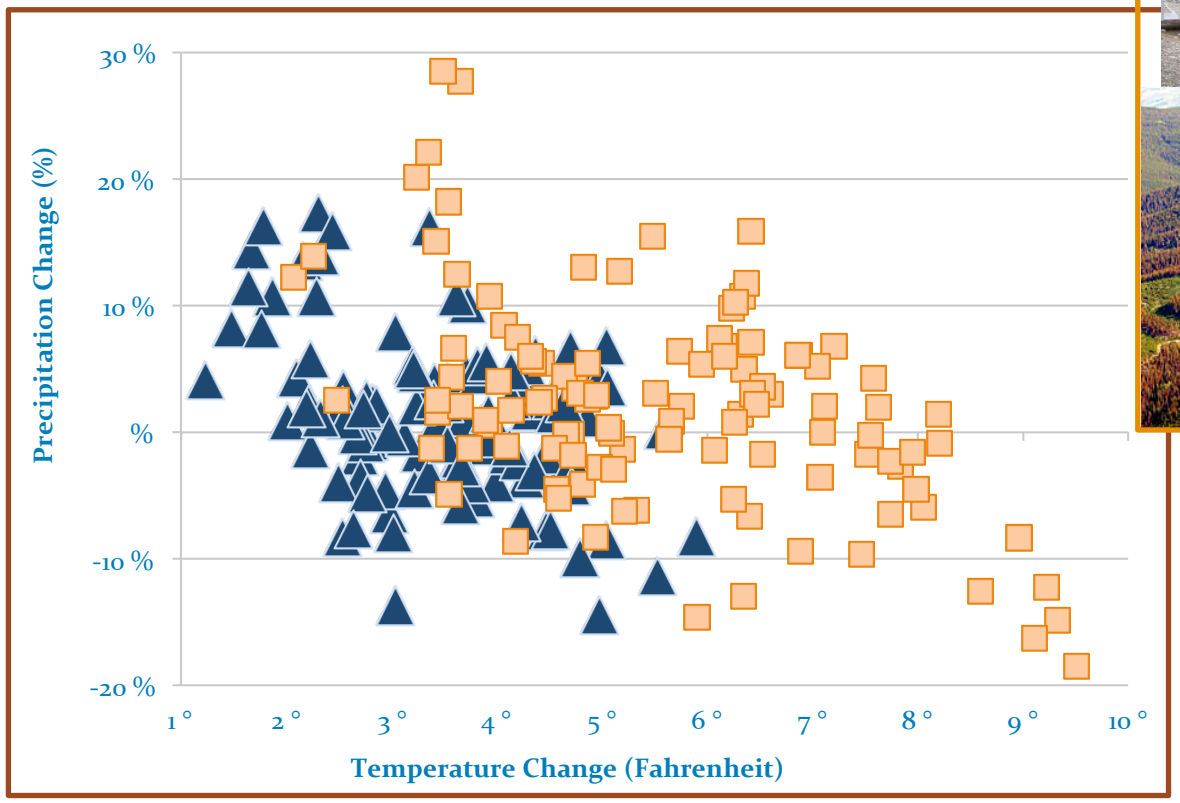
Traditional Predict then Plan

Present Future



2002: Unprecedented Simultaneous Natural Disasters

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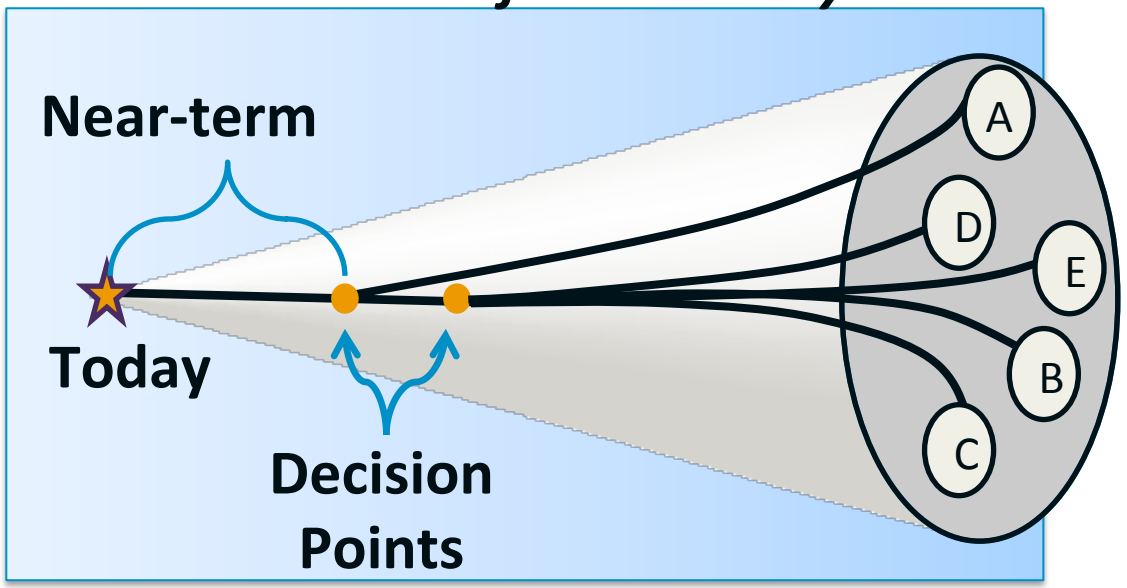
5° F Warming Means	
Reduced Supply	22%
Increased Demand	7%
Additional precipitation needed to offset warming	**10%**

The Cone of Uncertainty



- New planning techniques - multiple futures
- Understanding - uncertainty and science for applications
- Adaptive planning - identifying and preserving options
- Mainstreaming new culture into organization-wide decisions

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Important outcomes

- Informed DWs philosophy on climate adaptation and planning
- Informed DWs work with WUCA
- Climate change in CO report
- CRWAS I, II – State climate modeling of CO river
- State bringing climate change and scenario planning into supply and demand analysis – SWSI
- FRCCG – quarterly meetings still!
- Endless collaborations with NCAR, WWA, RTi

CO-PRODUCTION TO INFORM DROUGHT ADAPTATION

The Shoshone Relaxation Agreement

David Yates – NCAR, RAL Hydrometeorology Applications Program
yates@ucar.edu

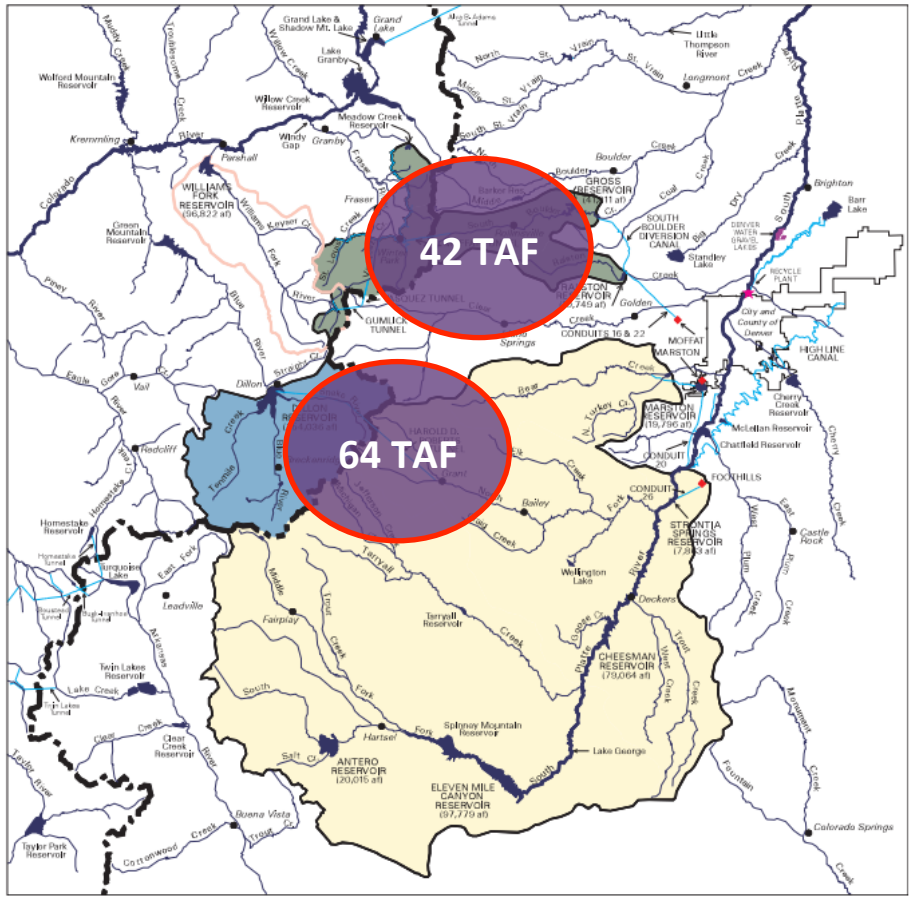
Laurna Kaatz – Denver Water, Climate Scientist
Laurna.Kaatz@denverwater.org

Rob Wilby, Loughborough University
r.l.wilby@lboro.ac.uk

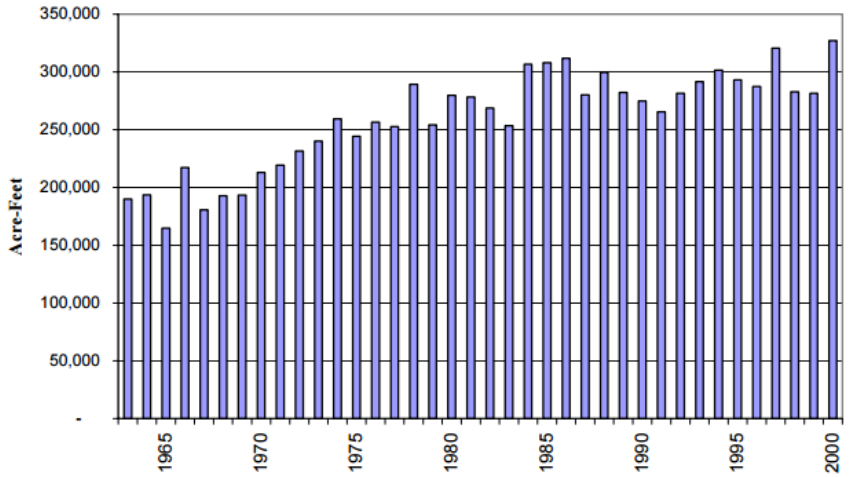
ER WATER

Denver Water's Supply & Use

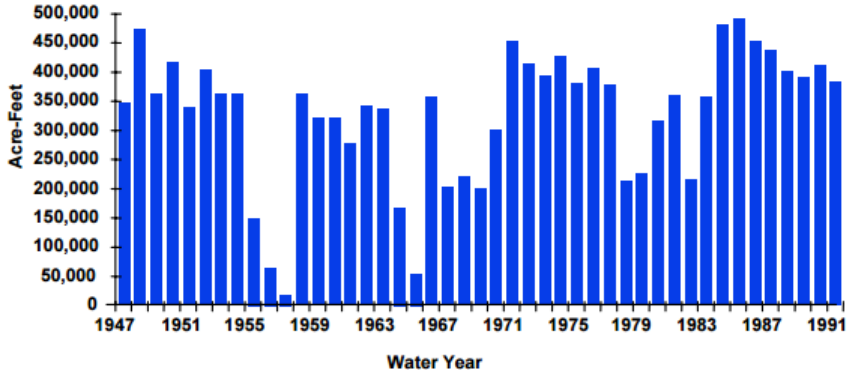
Water Collection System



Annual Water Use



Simulated Reservoir Contents



So Roughly 30%-40% of Denver's supply from West Slope

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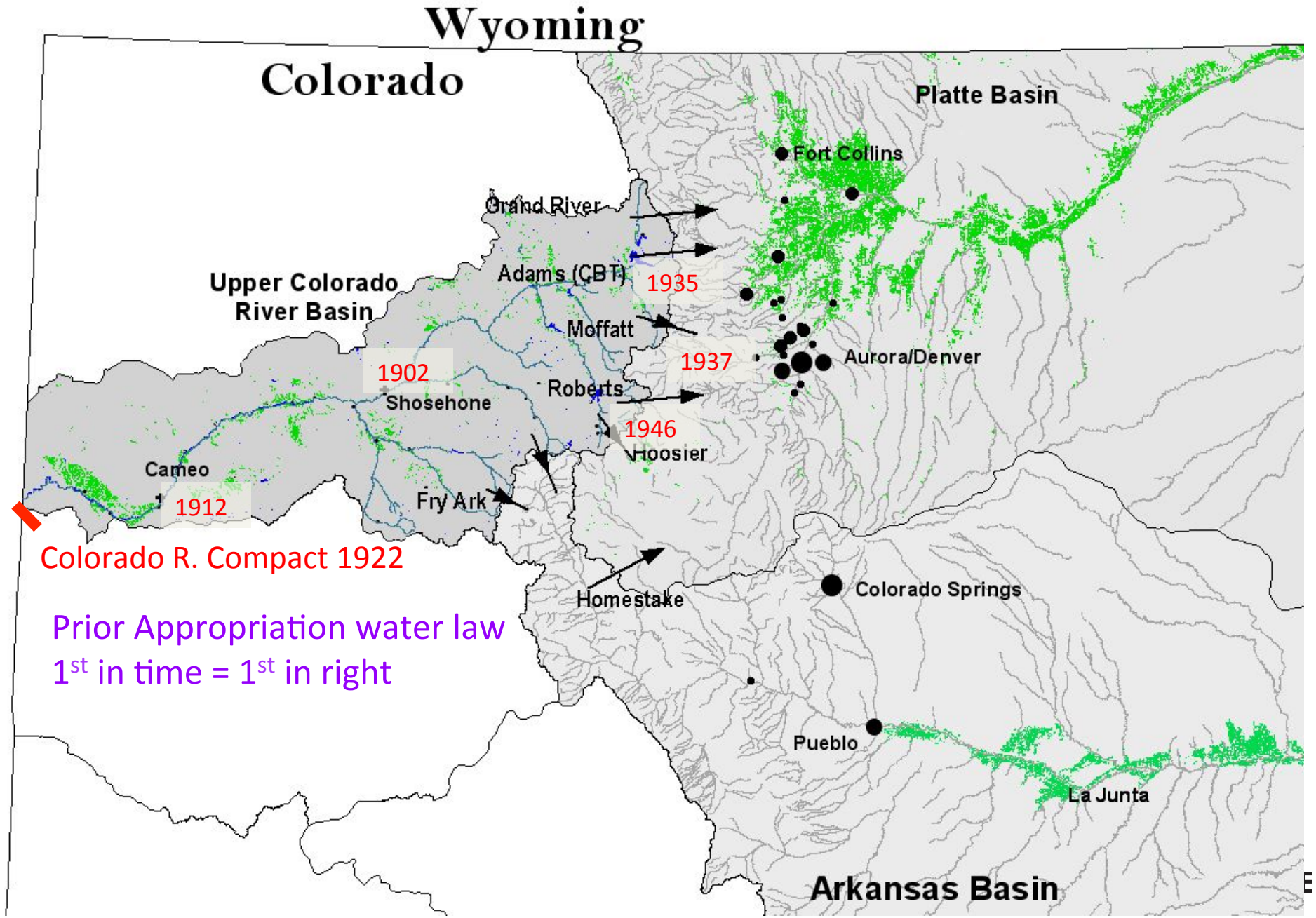

Wyoming
Colorado
Platte Basin
Fort Collins
Grand River
Adams (CBT)
1935
Upper Colorado
River Basin
Moffatt
1937
Aurora/Denver
1902
Roberts
Shosehone
1946
Hoosier
Cameo
1912
Fry Ark
Colorado R. Compact 1922
Homestake
Colorado Springs
Prior Appropriation water law
1st in time = 1st in right
Pueblo
La Junta
Arkansas Basin

ENVER WATER

Shoshone Hydroelectric Plant – Senior Water Rights:

1250 CFS (1902);
158 CFS (1929)

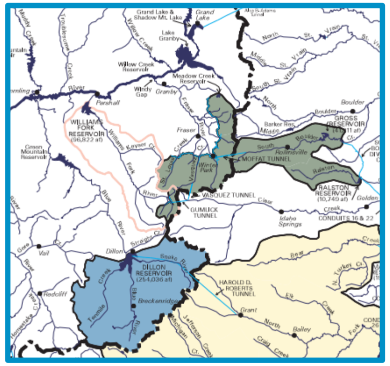
Shoshone Call

(Xcel Energy)

Commands the entire flow of the Colorado River at that point for much of the year

Supplies about 0.25% of Xcel's energy

Not Quite so Simple.. The Green Mountain Administrative Protocol (28 pgs. of legalize)



GREEN MOUNTAIN RESERVOIR ADMINSTRATIVE PROTOCOL
DRAFT 7-13-12

GREEN MOUNTAIN RESERVOIR ADMINSTRATIVE PROTOC

I. BLUE RIVER DECREE BACKGROUND

I.A. Definitions. The following definitions apply for purposes of this / Protocol ("Protocol"). In addition, terms defined elsewhere in this Protocol s meanings there provided.

I.A.1. "Blue River Decree": means the Findings of Fact and C Law, the Final Judgment entered on October 12, 1955 in Consolidated Cases No. 5 and the Final Decree entered on October 12, 1955 in Consolidated Cases Nos. 27 5017 ("Consolidated Cases") by the United States District Court, District of Co Decree"), and all supplemental or amendatory orders, judgments, and decrees including, without limitation, the Decree entered on April 16, 1964 therein ("1964 the Supplemental Judgment and Decree dated February 9, 1978 ("1978 Judgment")

I.A.2. "Blue River Decree Stipulations" or "Stipulations": m Stipulation and 1964 Stipulation entered into among the parties to the Consolid connection with the Blue River Decree, which are further defined as follows:

I.A.2.a. "1955 Stipulation": means the Stipulation among the Consolidated Cases entered into on October 5, 1955, and amended on October 10, set forth in full in paragraph 17 of the Finding of Fact and Conclusions of Lav Decree.

I.A.2.b. "1964 Stipulation": means the Stipulation among t Parties dated April 16, 1964, in the Consolidated Cases.

I.A.3. "Bypassed Storage Water": means bypasses of inflo Mountain Reservoir between the Start of Fill Date and May 1 that have been acc the 1935 First Fill Storage Right pursuant to direction from the Division Enginee were neither used to generate electrical energy at the Green Mountain Reservoir P bypassed to satisfy senior water rights. Bypasses made at any time to satisfy a d of a senior downstream water right and bypasses of 60 c.f.s. made from May 1 th of the irrigation season shall not be considered Bypassed Storage Water, nor shall be accounted toward any of the Green Mountain Reservoir Storage Rights.

I.A.4. "CA 1710 Water Rights": means those water rights decreed 26, 1937, by the Summit County District Court in Civil Action No. 1710, including adjudicated by Climax Molybdenum Company, a Delaware Corporation ("Climax" and mining purposes at the Climax mine near Leadville, Colorado ("Climax CA 17 Rights"). The Climax CA 1710 Water Rights are as follows:

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Water Right	Appropriation Date	Adjudication Date	Amount
Supply Canal No. 1			
Humbug Creek	08-15-1935	10-26-1937	20.0 cfs
Mayflower Creek	08-15-1935	10-26-1937	30.0 cfs
Clinton Creek	08-15-1935	10-26-1937	50.0 cfs
Other Drainages into Canal	08-15-1935	10-26-1937	20.0 cfs
Supply Canal No. 2			
Searle Gulch	08-15-1935	10-26-1937	35.0 cfs
Kokomo Gulch	08-15-1935	10-26-1937	25.0 cfs
Other Drainages into Canal	08-15-1935	10-26-1937	10.0 cfs
Tenmile Diversion Ditch No. 1			
McNulty Ditch	06-04-1		
Transferred to West Gravity Line	06-04-1		
Tenmile Diversion Ditch No. 2			
Transferred to West Gravity Line	06-04-1		
Storage of the amounts above in:			
Robinson Reservoir			
Chalk Mountain Reservoir			

The water rights listed above are subject to the CasesNo. 92CW233 and 92CW336.

I.A.5. "Cities": means the City a Board of Water Commissioners ("Denver Wate through its Utilities Department ("CS-U").

I.A.6. "Cities' Depletions": mea exercise of their decreed water rights pursuant to Stipulations. The Cities must pay power interfere the Cities' Depletions in accordance with the P water in storage to the extent of the Cities' Depl the satisfaction of the 1935 First Fill Storage Rig Protocol, all or part of the Cities' Depletions ma First Fill Storage Right." The Cities' Depletions

I.A.7. "Cities' Replacement Ob this Protocol.

I.A.8. "Contract Depletions": storage upstream from Green Mountain Reserv Contract Beneficiaries") pursuant to contractual replaces such depletions ("City Replacement interference charges to the United States on acc with the Power Interference Agreements, and m Contract Depletions and provide replacement wa

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Green Mountain Reservoir Administrative Protocol

Fill Storage Right. Responsibility for payment of power interference charg Cities and the City Contract Beneficiaries, shall be in accordance with the Contracts, and nothing in this Protocol is intended to alter the terms of the Contracts. In certain circumstances as provided in this Protocol, all or pa Depletions may be considered to "Deplete Against the 1935 First Fill Stor Contract Depletions are separate from the Cities' Depletions.

I.A.9. "Deplete Against the 1935 First Fill Storage Rig method, pursuant to the 1955 Stipulation, 1955 Decree, paragraph 4 of the 19 Power Interference Agreements, by which the Cities may, with the approval notwithstanding a river call instituted by the United States pursuant to this water upstream from Green Mountain Reservoir through exercise of the C pursuant to the Blue River Decree and Stipulations in an amount up to the States would otherwise have stored in Green Mountain Reservoir pursuant to Storage Right, without simultaneously releasing water from replacement stor Depleted Against the 1935 First Fill Storage Right is not accounted toward the 1935 First Fill Storage Right, but is included in the determination of the E pursuant to the provisions of Paragraph II.A.3.b.v below. The provisions below apply in the administration of the 1935 First Fill Storage Right Depletions and Contract Depletions are considered to Deplete Against the 193 Right.

I.A.10. "Denver Water's 1946 Blue River Water Rights": m water rights[1]:

I.A.10.a. "1946 Dillon Reservoir storage right": means storage water right adjudicated in Civil Action Nos. 1805 and 1806 by th District Court on March 10, 1952 and confirmed by the Blue River Decree.

I.A.10.b. "1946 Blue River Diversion Project direct f means the June 24, 1946 direct flow water right through the Harold D. R Montezuma Tunnel adjudicated in Civil Action Nos. 1805 and 1806 by th District Court on March 10, 1952 and confirmed by the Blue River Decree.

I.A.11. "Discretionary Power Diversions": is defined in Pa this Protocol.

I.A.12. "End of Fill Season": means the date on which the 1935 First Fill Storage Right is deemed ended, pursuant to Paragraph II.A.3 of

[1] Nothing in this protocol should be construed or applied to preclude Denver Water's exercise Refill water right adjudicated in Case No. 87CW376, WD #5.

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Green Mountain Reservoir Administrative Protocol

I.A.13. "Exchange and Deplete Upstream": means the method by which the Cities, in accordance with Paragraph II.C below, and subject to the approval of the Secretary, may, in the exercise of the Cities' water rights, release water from replacement storage (e.g., Williams Fork Reservoir) to satisfy the requirements of a calling water right downstream on the Colorado River and, to the extent that such replacement water is made available to meet the requirement of such calling right, deplete an equivalent volume of water, at an equivalent rate of flow, at their facilities. In certain circumstances, the Cities may Exchange and Deplete Upstream to effectuate their obligations to the City Contract Beneficiaries under the City Replacement Contracts.

I.A.14. "Fill Level": means the water level elevation in Green Mountain Reservoir determined by the Secretary, in the exercise of the Secretary's reasonable discretion pursuant to applicable law, to be the fill of Green Mountain Reservoir for that water year. The Fill Level is determined by the Secretary, and is not necessarily determined by a Maximum Water Elevation Limitation imposed on Green Mountain Reservoir. The Fill Level is not a storage volume.

I.A.15. "Fill Schedule": is defined in Paragraph II.A.1.a of this Protocol.

I.A.16. "Fill Season": means the period between the Start of Fill Date and the End of Fill Season.

I.A.17. "Green Mountain Reservoir Storage Rights": means the 1935 First Fill Storage Right, the 1935 Senior Refill Storage Right, and the Junior Refill Storage Right.

I.A.18. "Green Mountain Reservoir Water Rights": means the following water rights:

I.A.18.a. "1935 First Fill Storage Right": means the Green Mountain Reservoir storage right with a priority date of August 1, 1935 from the Blue River and its tributaries in the amount of 154,645 acre-feet.

I.A.18.b. "1935 Senior Refill Storage Right": means the Green Mountain Reservoir storage refill right with a priority date of August 1, 1935 from the Blue River and its tributaries in the amount of 6,316 acre-feet.

I.A.18.c. "1935 Direct Flow Power Right": means the Green Mountain Powerplant direct flow right with a priority date of August 1, 1935 from the Blue River and its tributaries in the amount of 1726 cubic feet per second ("c.f.s.") for the generation of electrical power at the Green Mountain Powerplant.

I.A.18.d. "Junior Refill Storage Right": means the Green Mountain Reservoir storage refill right with an appropriation date of January 1, 1985 from the Blue River and its tributaries in the amount of 154,645 acre-feet.

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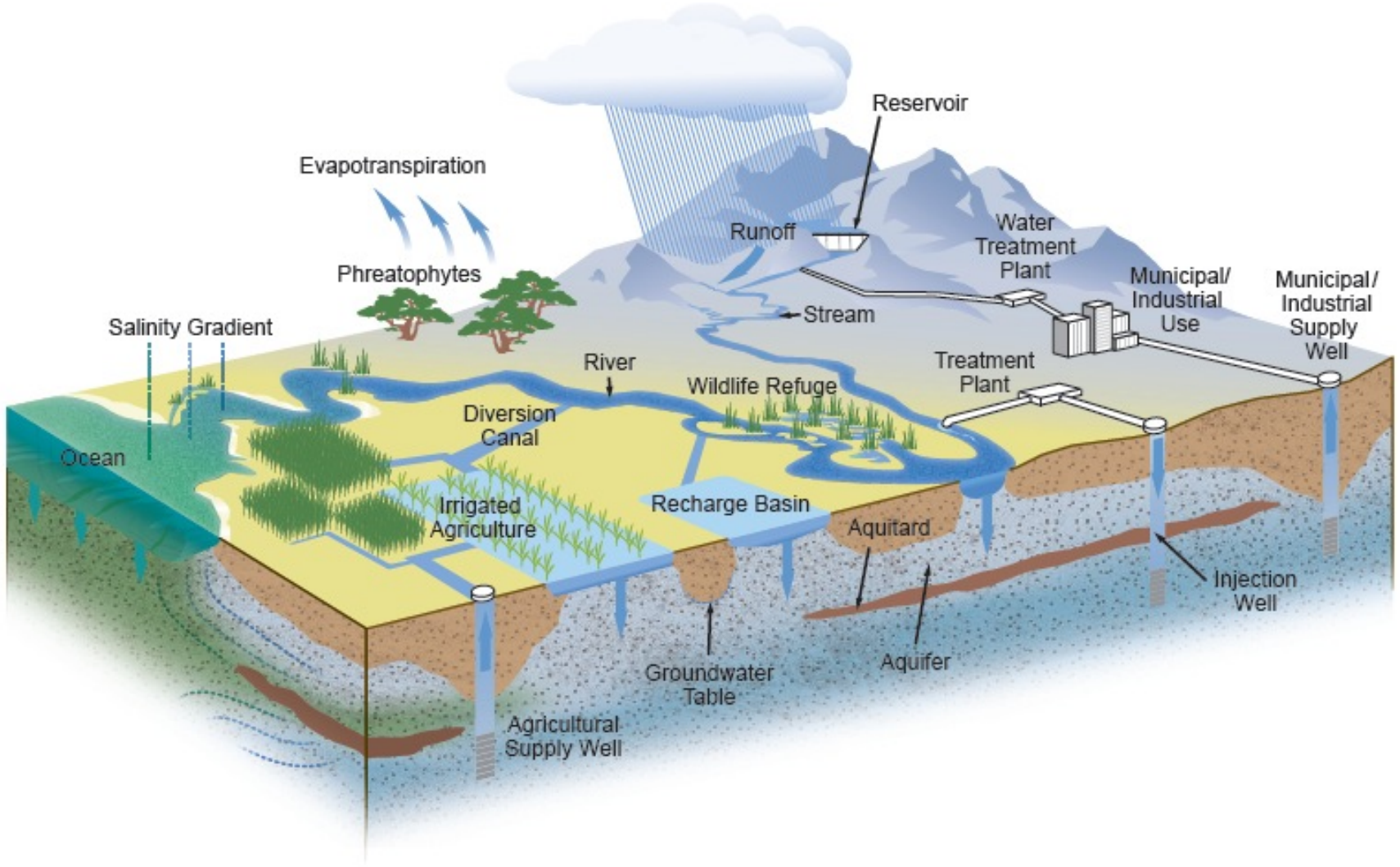
Water Planning Need: Ability to model interactions across physical and management systems



Co-Production of Climate Narratives- (NCAR, DW, U of L)

Scenario	Description	Climate
Vegetative change (PM20T2VC)	Fewer cold winters reduce mortality amongst infecting beetle populations. Warmer, prolonged dry conditions stress forests increasing their susceptibility to insect attack. 5% of forest dies above reservoirs GranbyGrand, and Green Mountain permanently replaced by low scrub.	P-20% T+2°C
Dust on snow (PM10T1DS)	Modest warming and drying increases the annual likelihood of dust on snow events by 10%. No other effects.	P-10% T+1°C
Mild Warming (PM0T2WM)	Seasonal precipitation totals are unchanged but temperatures are warmer across all seasons.	P-0% T+2°C

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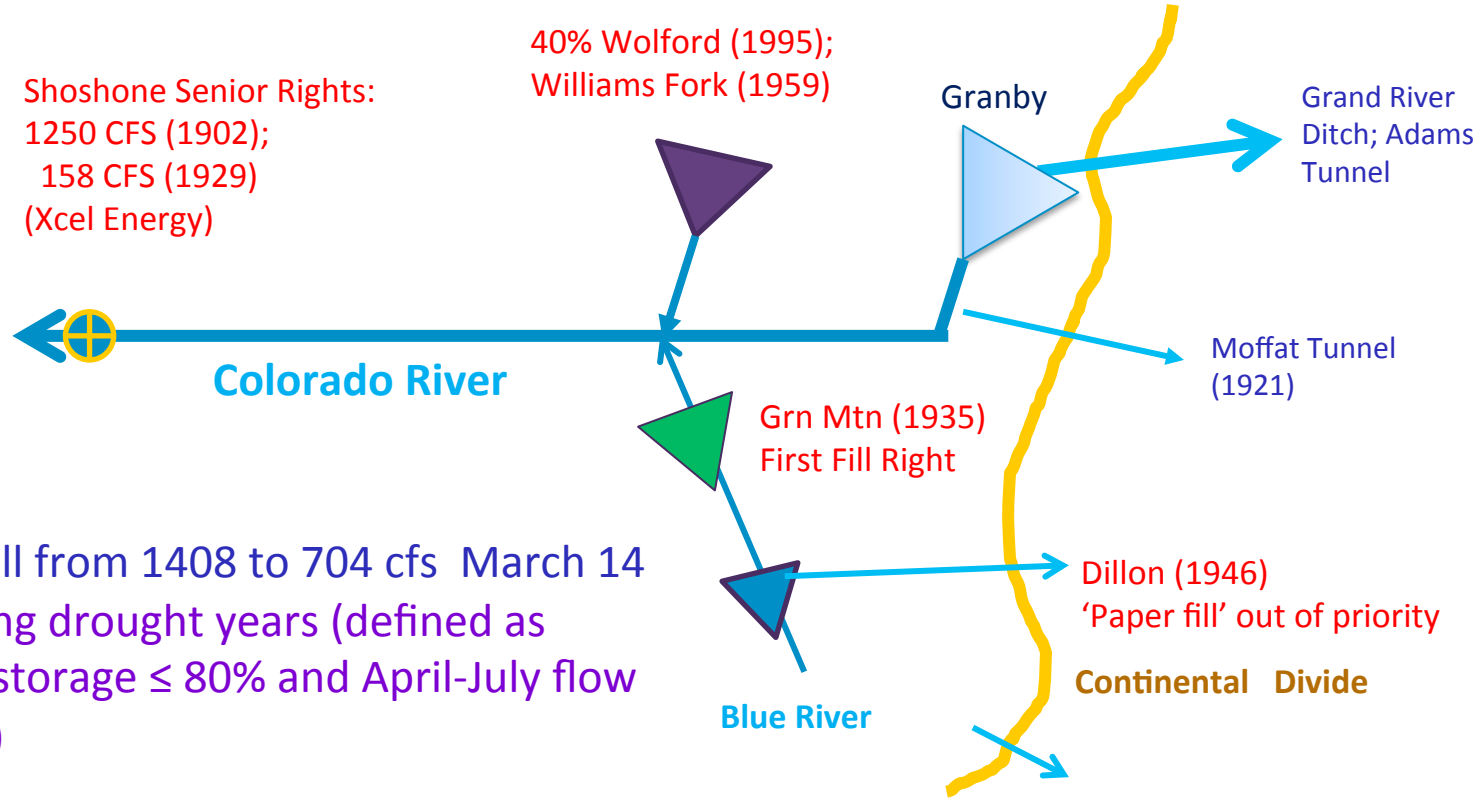
Drought mitigation measure - Shoshone Call Relaxation Agreement (SCRA)



Key features

- Reduces the Call from 1408 to 704 cfs March 14 to May 20 during drought years (defined as forecast July 1 storage ≤ 80% and April-July flow forecast ≤ 85%)
- Colorado River Cooperative Agreement allows call relaxation to begin Nov 11 (severe drought & lawn water ban)
- Purpose is to increase Upper Basin Storage

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Modeled flows:

Blue River above Dillon Reservoir (top)

Colorado River at Shoshone (bottom)

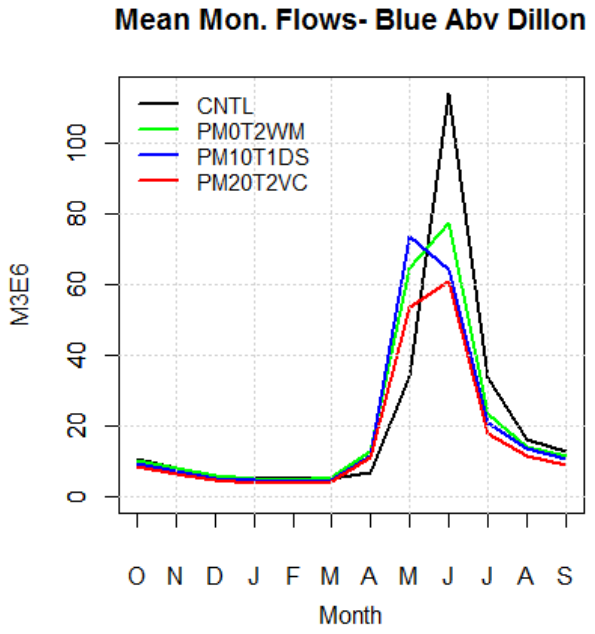
Scenarios:

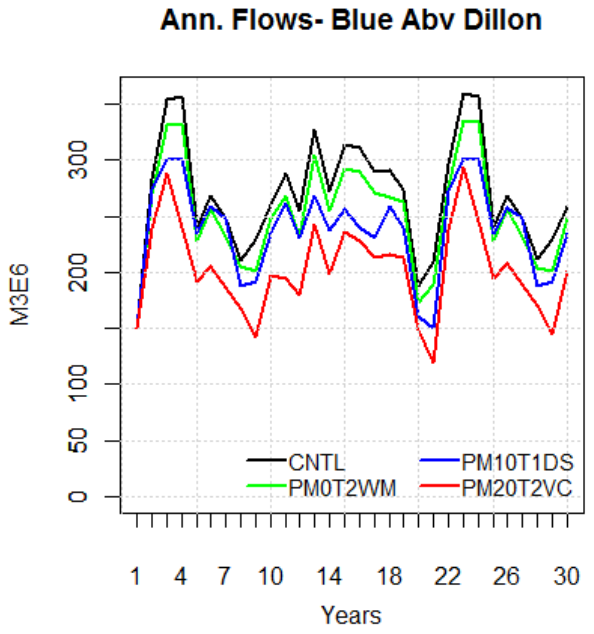
CNTL = current climate

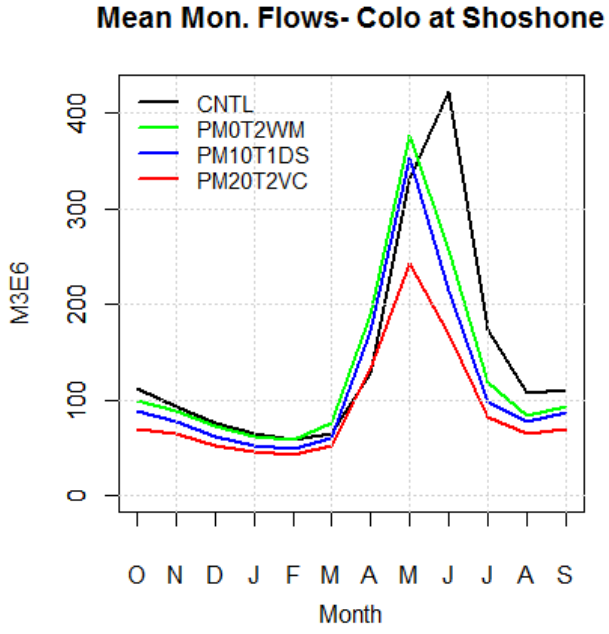
PM0T2WM (Mild Warming) = No precipitation change & 2°C warming.

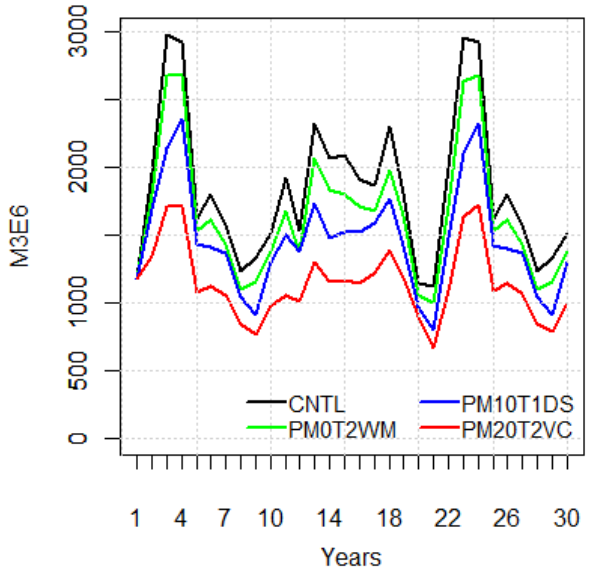
PM10T1DS (Dust on snow) = decline in snow albedo caused by more frequent dust on snow events, coupled with 10% less precip. with 1°C warming.

PM20T2VC (Vegetative change) = Altered vegetation and runoff rates, coupled with 20% less precipitation & 2°C warming.

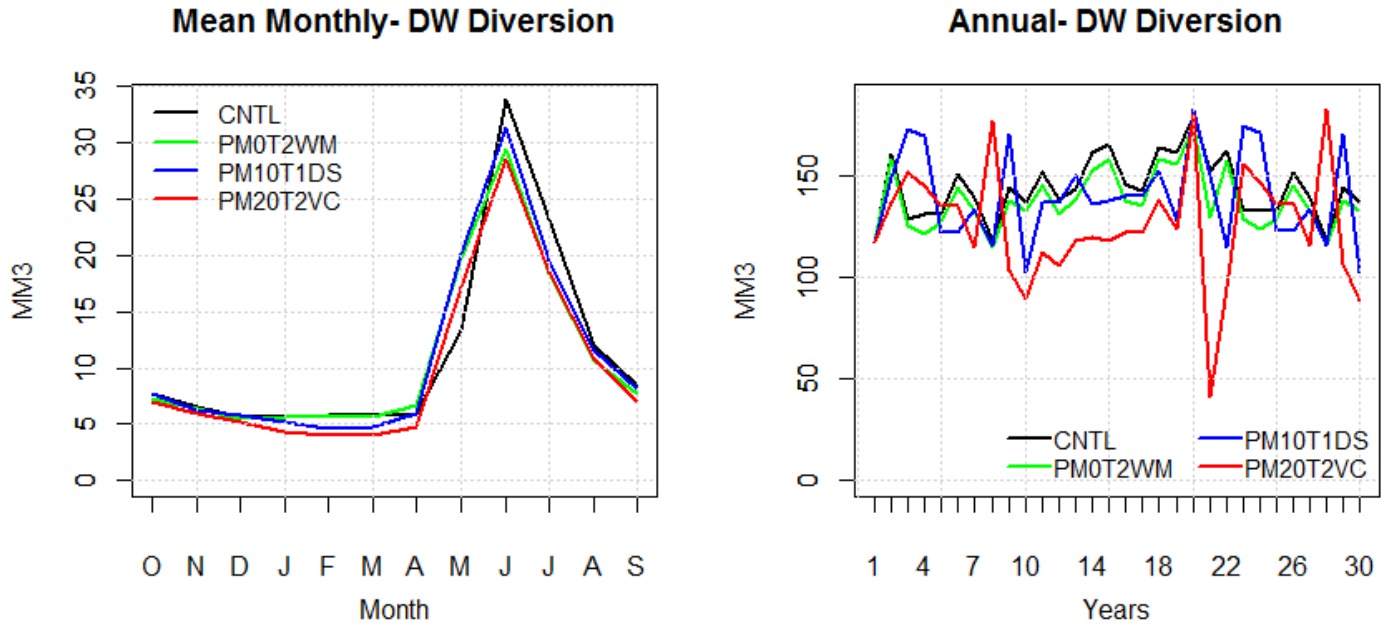








Impacts Without Relaxation



Under the warmer and drier scenarios Denver begins storing water earlier, but average annual diversions are reduced by 3%, 4%, and 13% for the *PM0T2WM*, *PM10T1DS*, and *PM20T2VC* scenarios, respectively.

Denver's storage softens the impact of declining stream flow except in the second severe drought year in the warmest and driest scenario.

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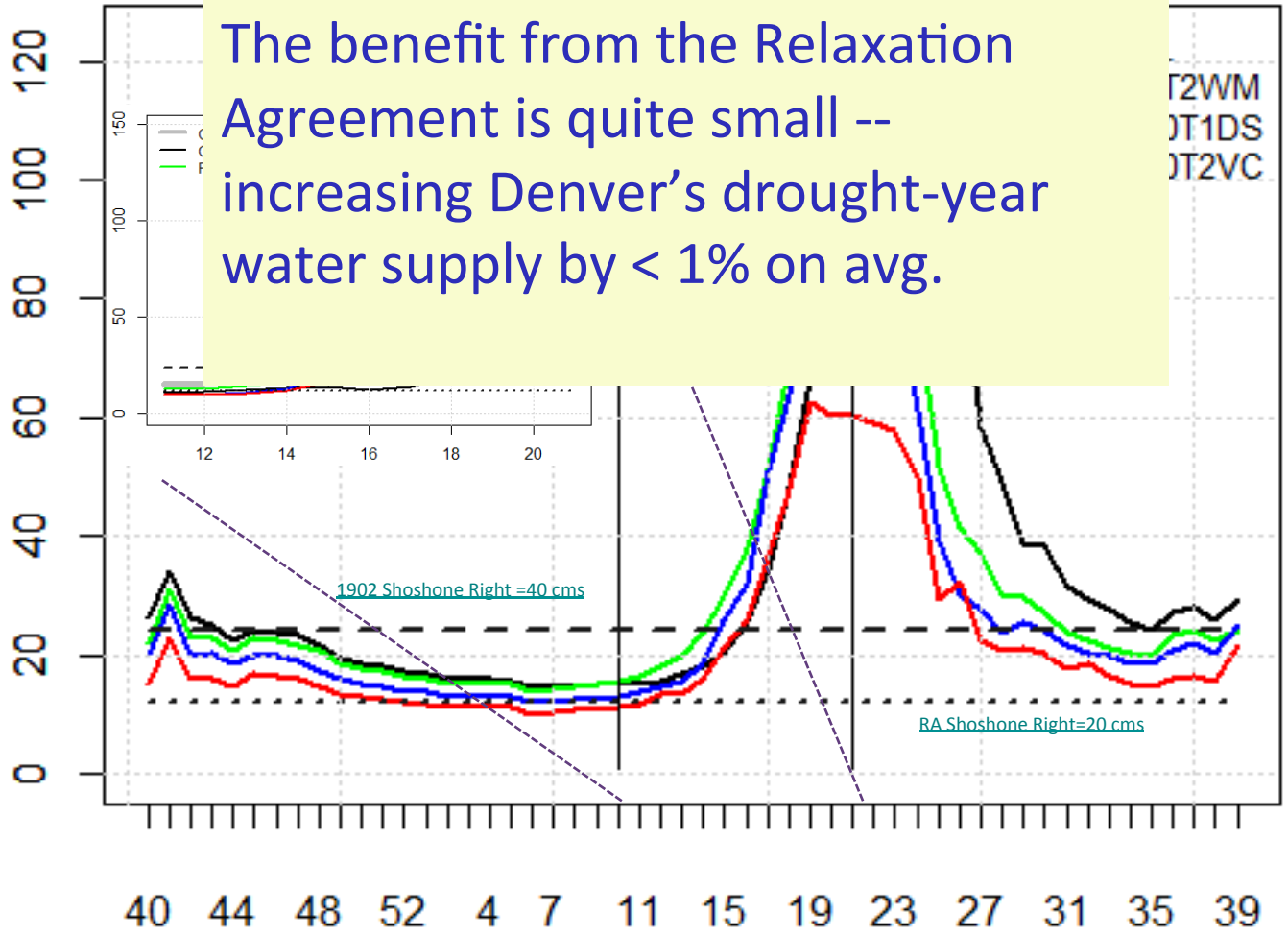
Bottom line:

The benefit from the Relaxation Agreement is quite small -- increasing Denver's drought-year water supply by < 1% on avg.



Inset: thick gray-line = weekly mean flows for all years of **CNTL** scenario; thin black line = flows during the 3 **CNTL** scenario relaxation years; warming scenarios have greater frequency of relaxation years but shorter periods before benefit of relaxation disappears.

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END -- THANKS

Source: Fire Mountain Canal and Reservoir Company

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