Arkansas Basin RiverWare Model – Putting RiverWare's Flexibility to the Test & Pueblo Water's Water Rights Change Case

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&

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2019 RiverWare User Group Meeting

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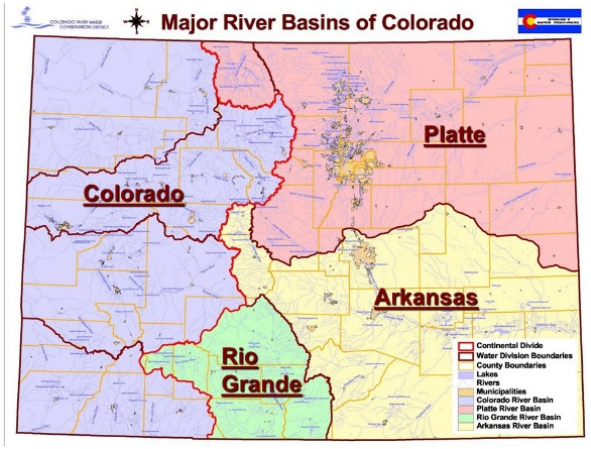
Pueblo Dam and Reservoir

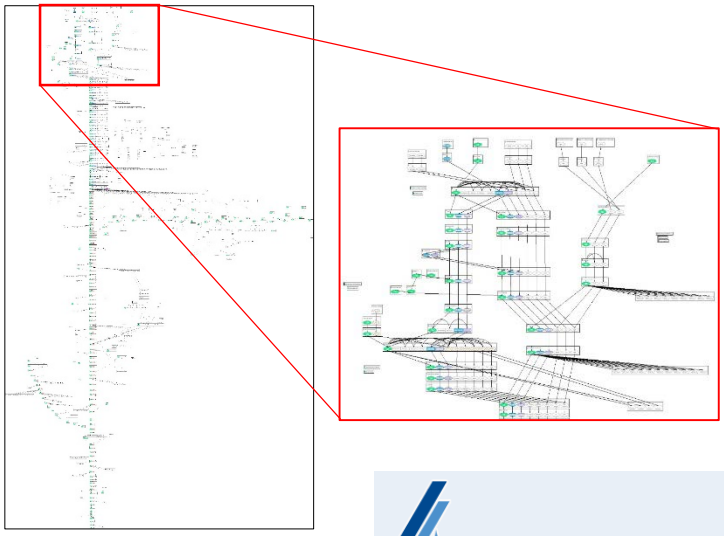
PRECISION WATER RESOURCES ENGINEERING

Board of Water Works of Pueblo, Colorado

Quick Model Overview

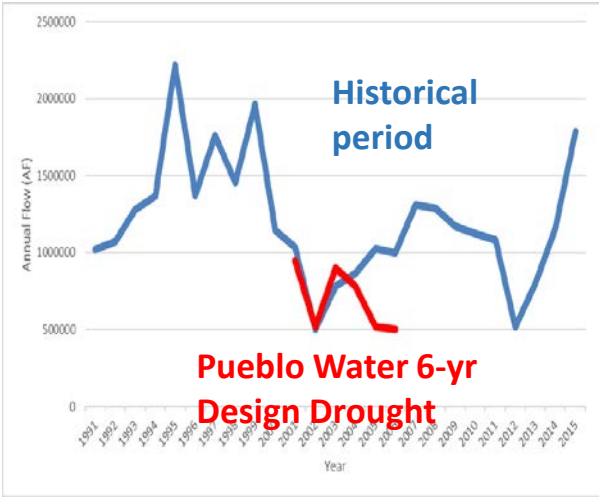
- Extent: Arkansas River headwaters near Leadville to CO-KS border, ~330 mainstem river miles
- Daily-timestep
- Flexible model period
- Heavy Accounting and Water Rights simulation
- 11+ reservoirs (incl. Turquoise Lake and Twin Lakes, Pueblo Res, John Martin Res)
- 90+ water user objects, 200+ flow nodes

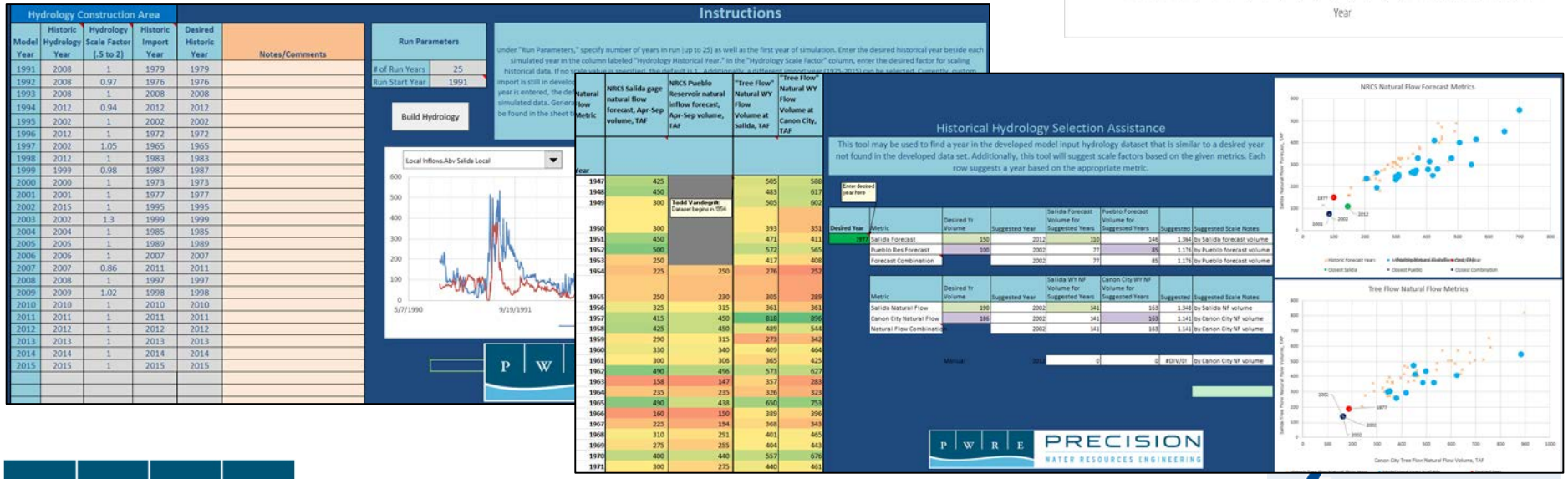




Hydrology Construction Workbook

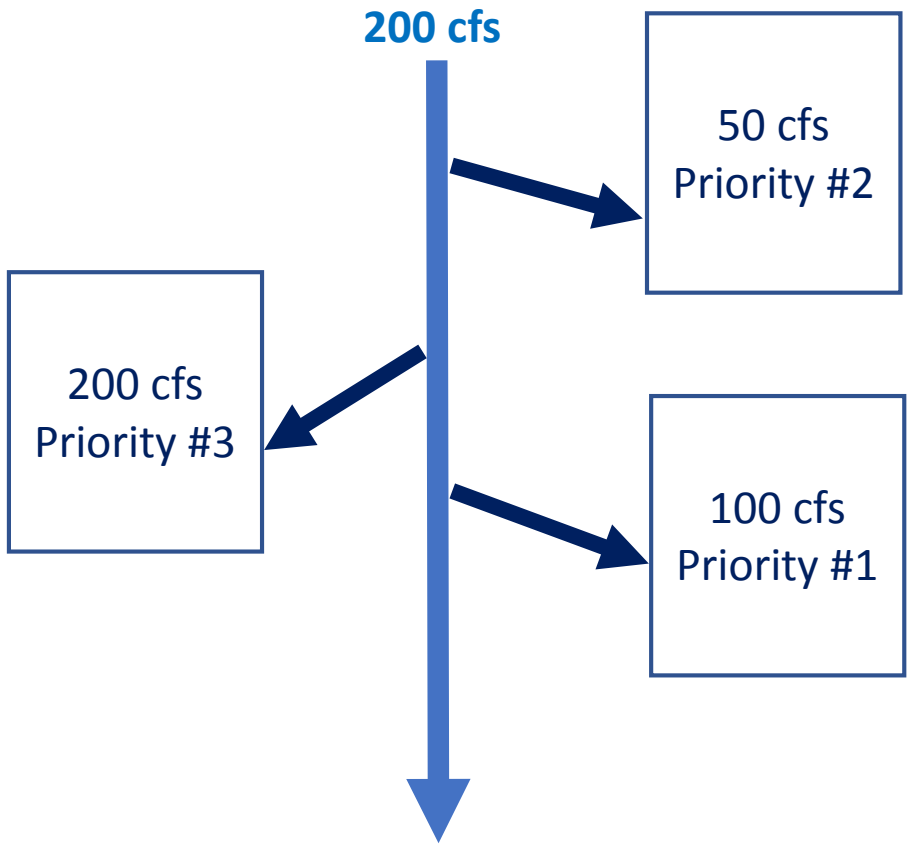
- Base, "naturalized" model input hydrology (25 years, 1991-2015) for 51 inflow nodes
- Workbook facilitates sampling, re-sequencing, adjusting to create novel hydrology sequences
- Automates generation of hydrology data for all input nodes and sets up for DMI





Complex Water Rights System

- Over 300 unique water rights
  - Direct flow and storage
- Multi-part, "piecemeal" water rights



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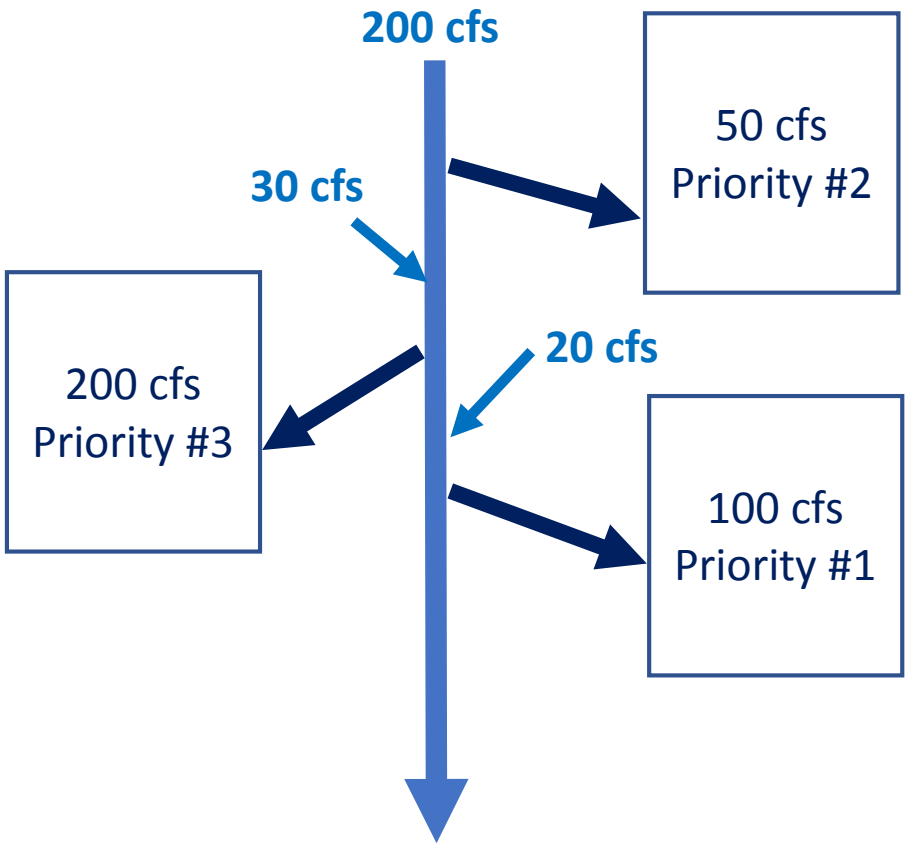

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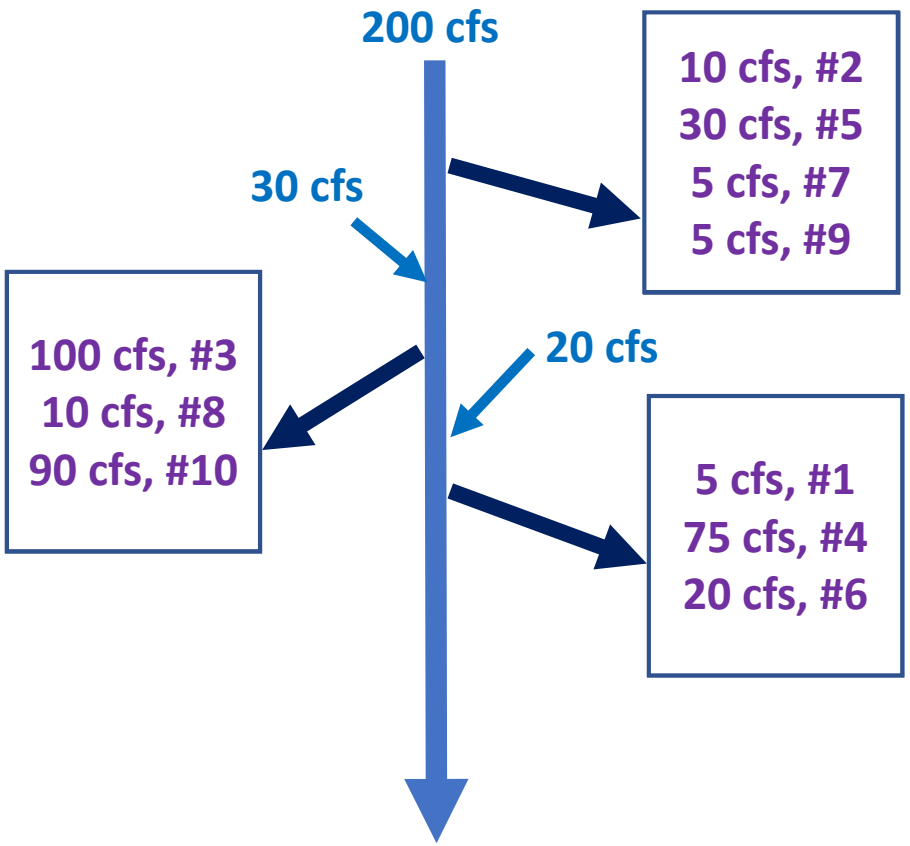

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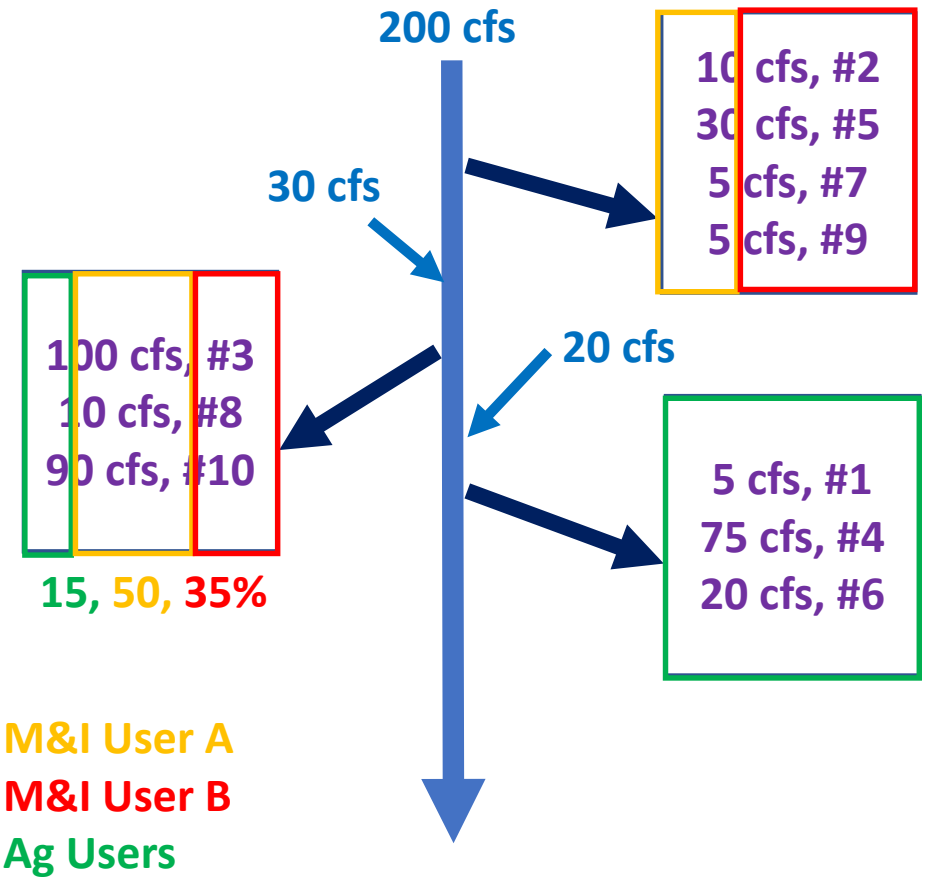
- Ditch ownership often divided by shares
- WR allocations prorated by ownership %'s



Complex Water Rights System

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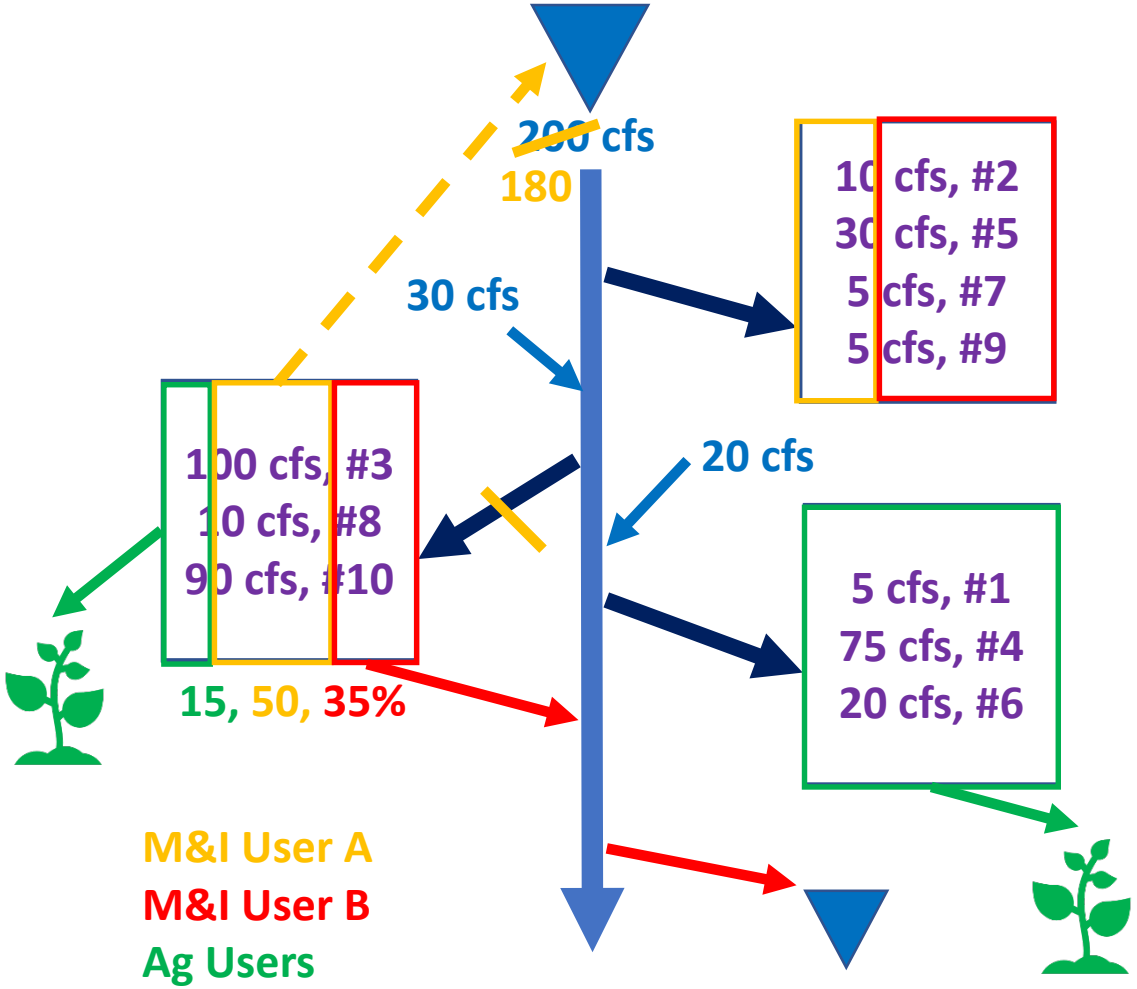
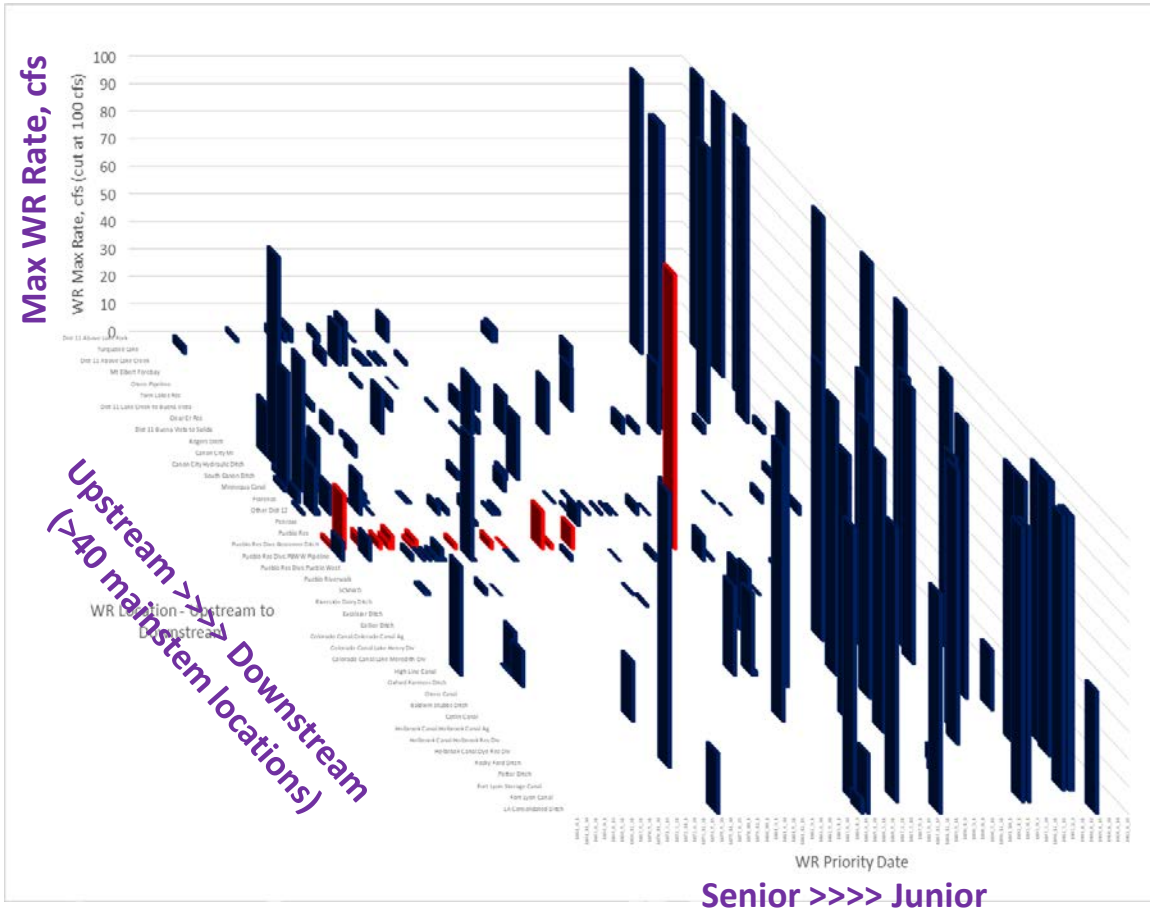
- Multi-part, "piecemeal" water rights
- Ditch ownership often divided by shares
- WR allocations prorated by ownership %'s
- Different owners can do different things with their portion of allocation



Max WR Rate, cfs (cut at 100 cfs)

Senior >>>> Junior (>180 priority dates)

Bessemer Ditch Water Rights (14 different priority dates, ranging from <1 to 322 cfs)



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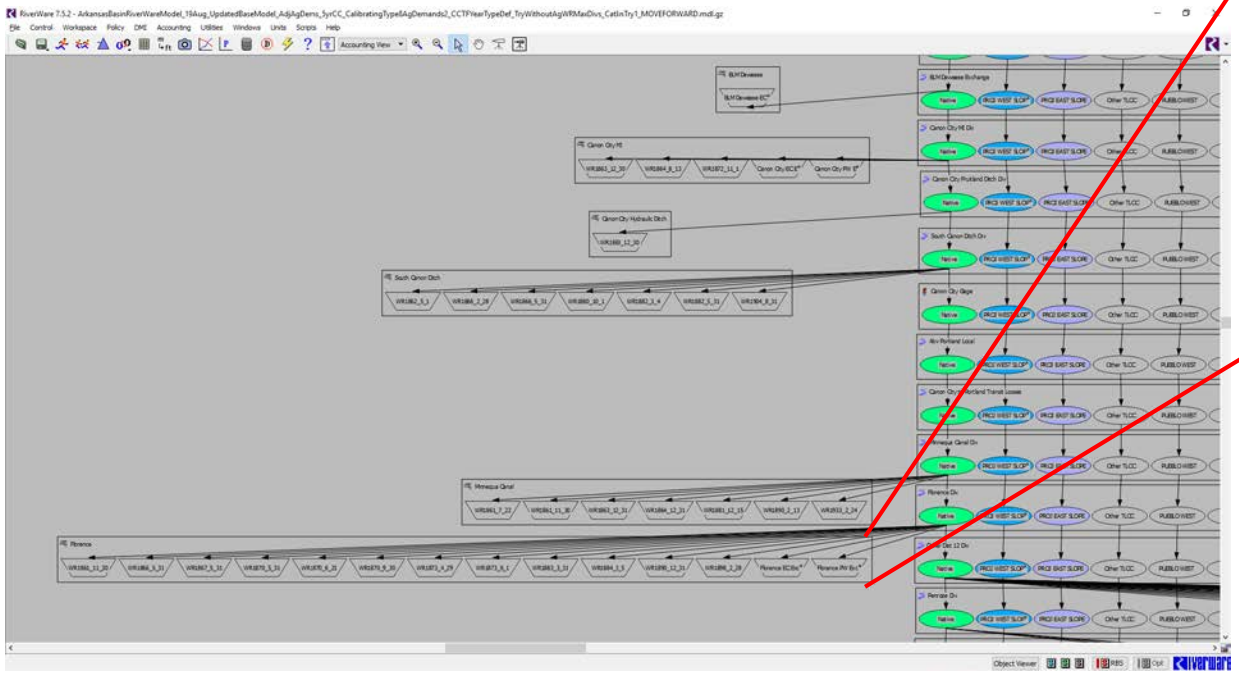
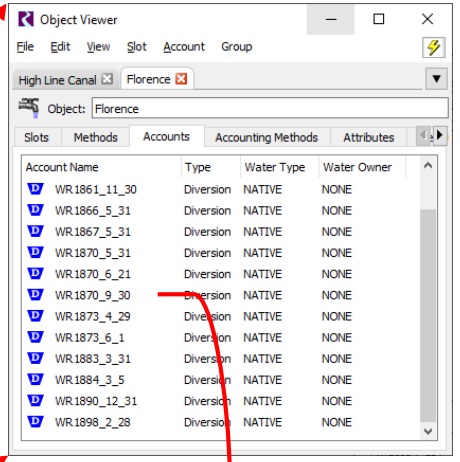
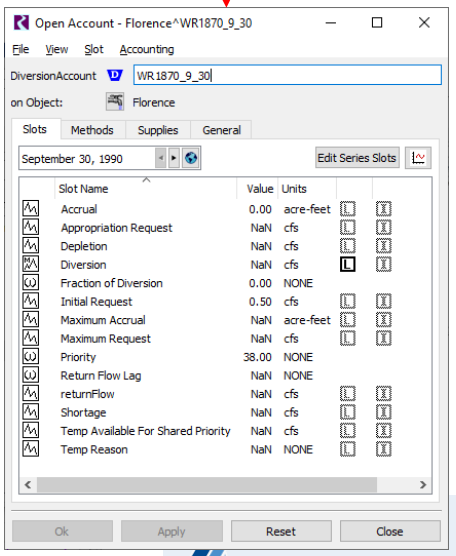
Implementation in RiverWare







Complex Water Rights, cont.

- Detailed WR limits (w/ more exceptions than rules)
  - Max flow rates, often annual volumes
  - Monthly/other period rates & volumes limits
  - Variable limits based on type of use, demands, etc.
- Other complexities, e.g. alternative points of diversion, "fixed call" dates, storage availability constraints
- **RiverWare's flexibility has been crucial for implementation of complex WRs**
- **Water Rights Solver has handled everything thrown at it**
- Currently doing a Water Right Simulation Comparison Study between RiverWare and StateMod with the Colorado Water Conservation Board using White basin

PBWW Data.Booth Orchard Max WR Rates by Comanche D...

File Edit Row Column View Adjust

Booth Orchard Max WR Rates by Comanche Demands

Value:

	Comanche Annual Demand acre-feet	June July Aug Max Rate cfs	Other Months Max Rate cfs
0	0.00	18.00	16.00
1	2,500.00	17.50	14.80
2	5,100.00	17.00	13.50
3	6,600.00	16.40	13.10
4	7,300.00	16.10	12.90
5	7,600.00	16.00	12.80
6	7,900.00	15.80	12.70
7	8,600.00	15.60	12.50
8	9,600.00	15.20	12.20
9	10,200.00	15.00	12.00
10	99,999.00	15.00	12.00

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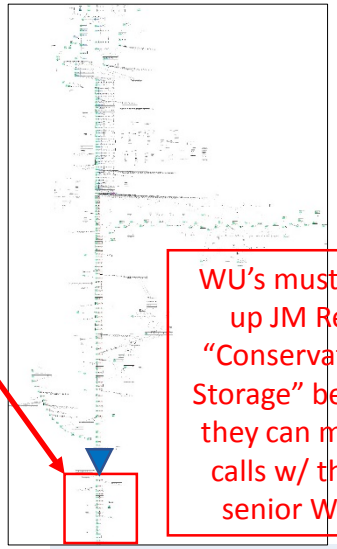


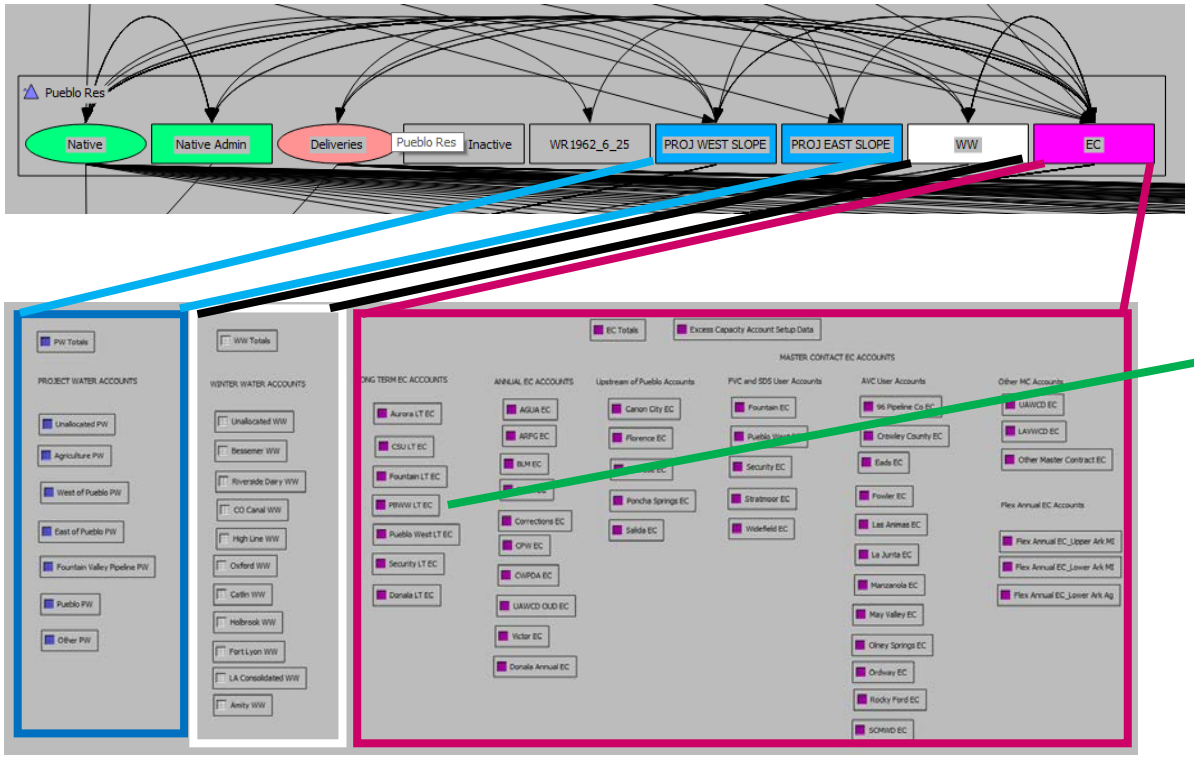
WU's must use up JM Res "Conservation Storage" before they can make calls w/ their senior WRs

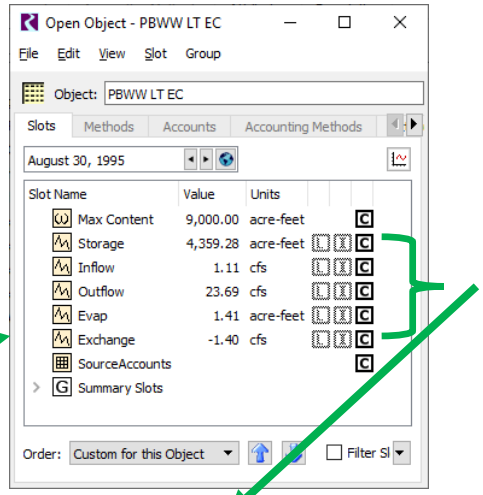
Flexible Storage Accounting Framework

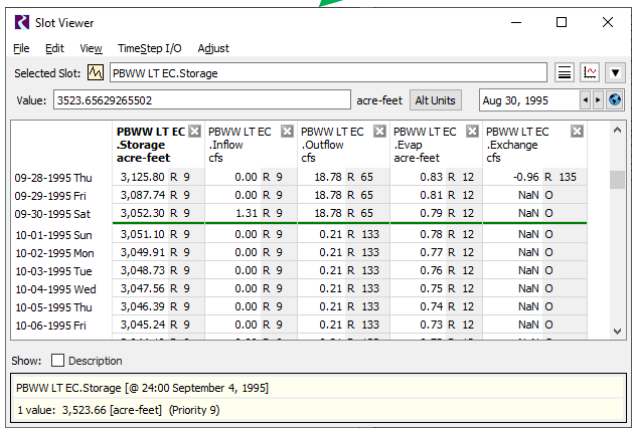
- Real-world administration necessitates very detailed accounting
- In Pueblo Reservoir, Reclamation tracks over 150 individual accounts
  - After lumping… ONLY ~70 accounts are modeled in Pueblo

- Flexible framework was developed to allow variable levels of detail
- "Traditional" RW storage accounts can be divided into subaccounts,
  - Subaccounts can be further subdivided, and so on
- Allows model development & enhancements to be tailored to specific needs, without the need for highest level of detail everywhere

“Proxy” Accounts





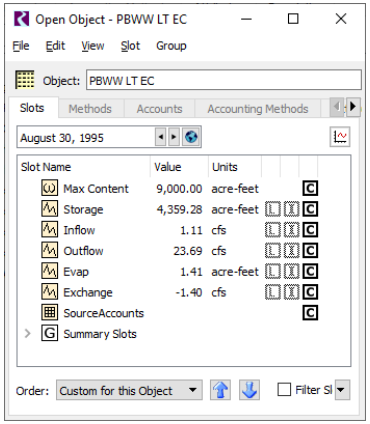


- Semi-standardized data objects represent subaccounts
- Mapped to main accounts by object attributes
- Rules set up to manage aggregation, reconcile, etc.

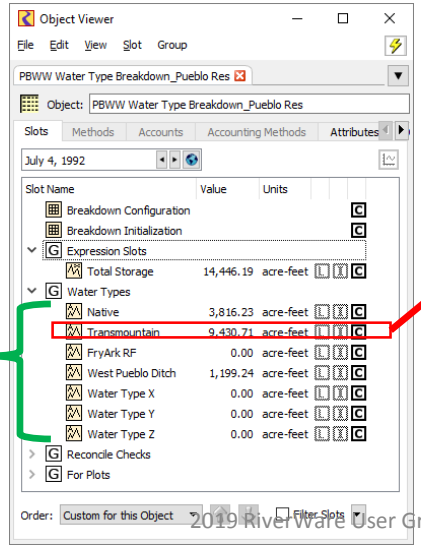
Further Subaccounting

- Some accounts must be further sub-accounted by different "water types"
- Each with unique rules/limits/criteria (which are often limiting factors)
  - E.g., PBWW's "West Pueblo Ditch" water can't be used at Comanche Power Plant
- Similar to how main accounts are subdivided into Proxy Accounts, Proxy Accounts can be further subdivided by water types
- AggSeries slots have really helped keep this manageable!

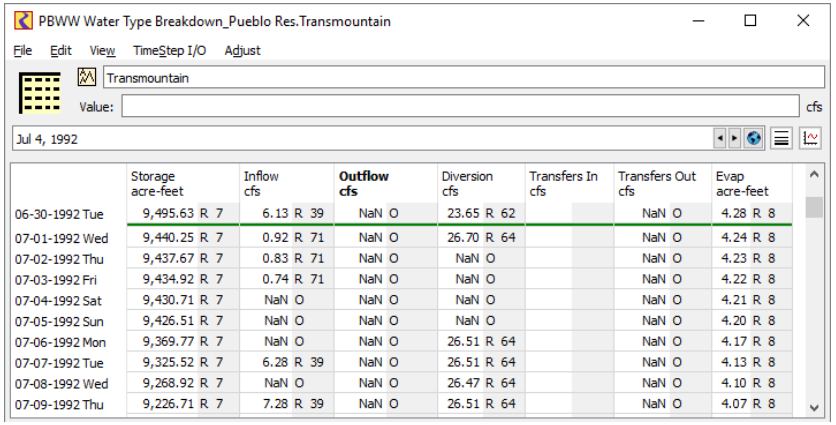
Single Proxy Account



Breakdown into Water Type Accounts (held on single data object)

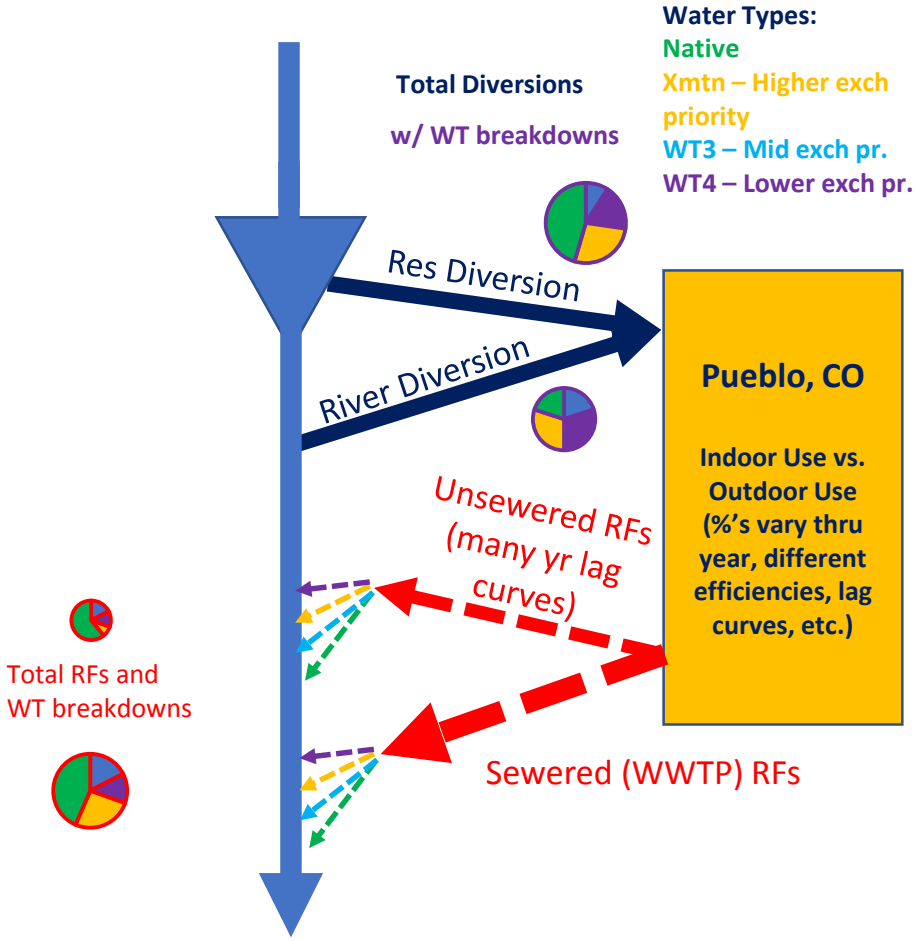


Each Water Type Account



Detailed Return Flow Accounting

- Many water types are "reusable" or "fully consumable" (e.g., xmtn, ΔWRs)
- These can be significant supply sources and important to operations
- Thus, need to simulate detailed RF processes and accounting



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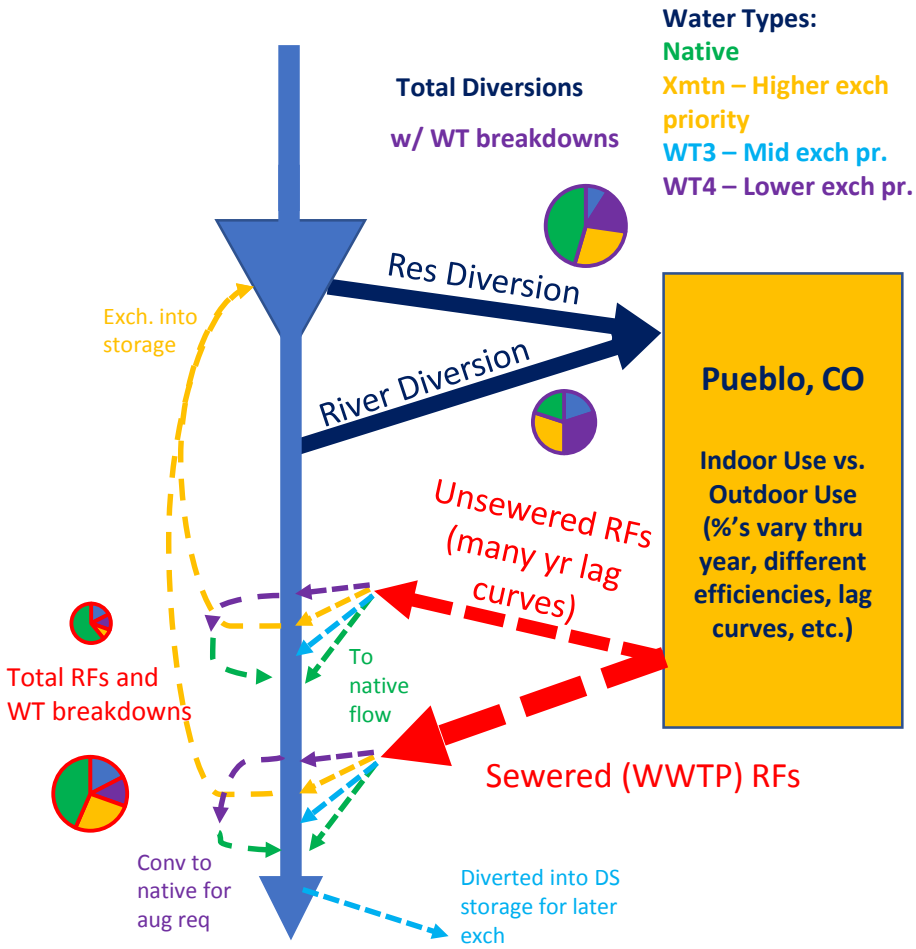

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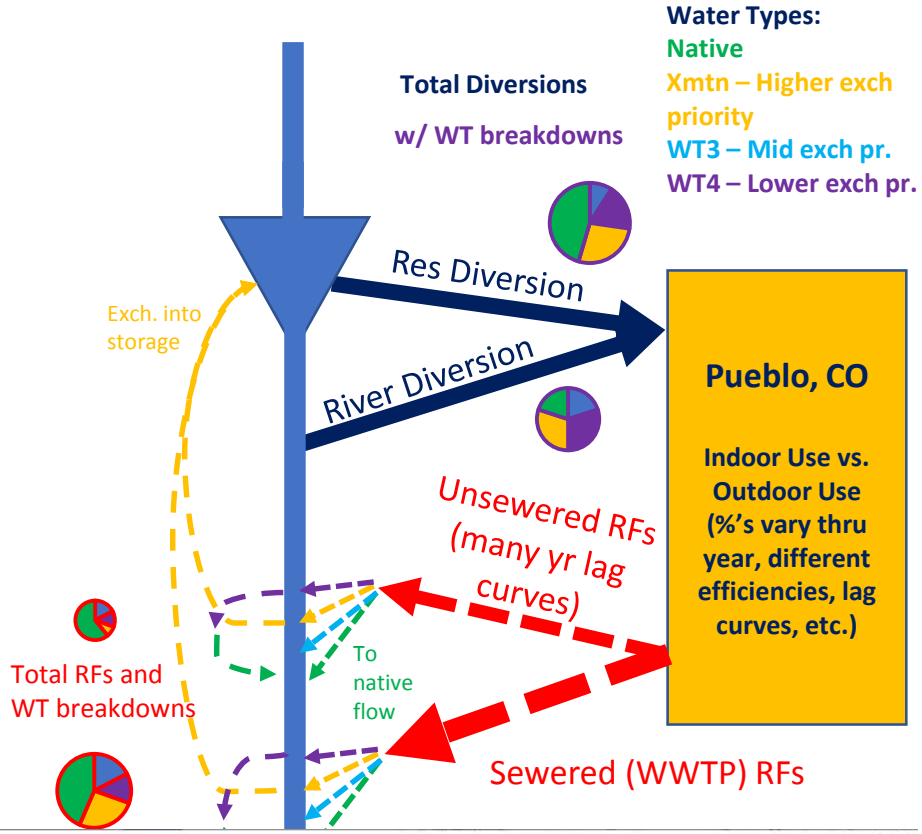
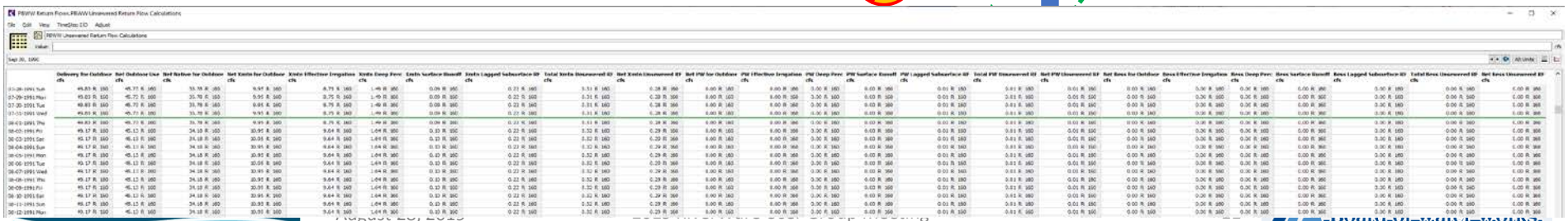
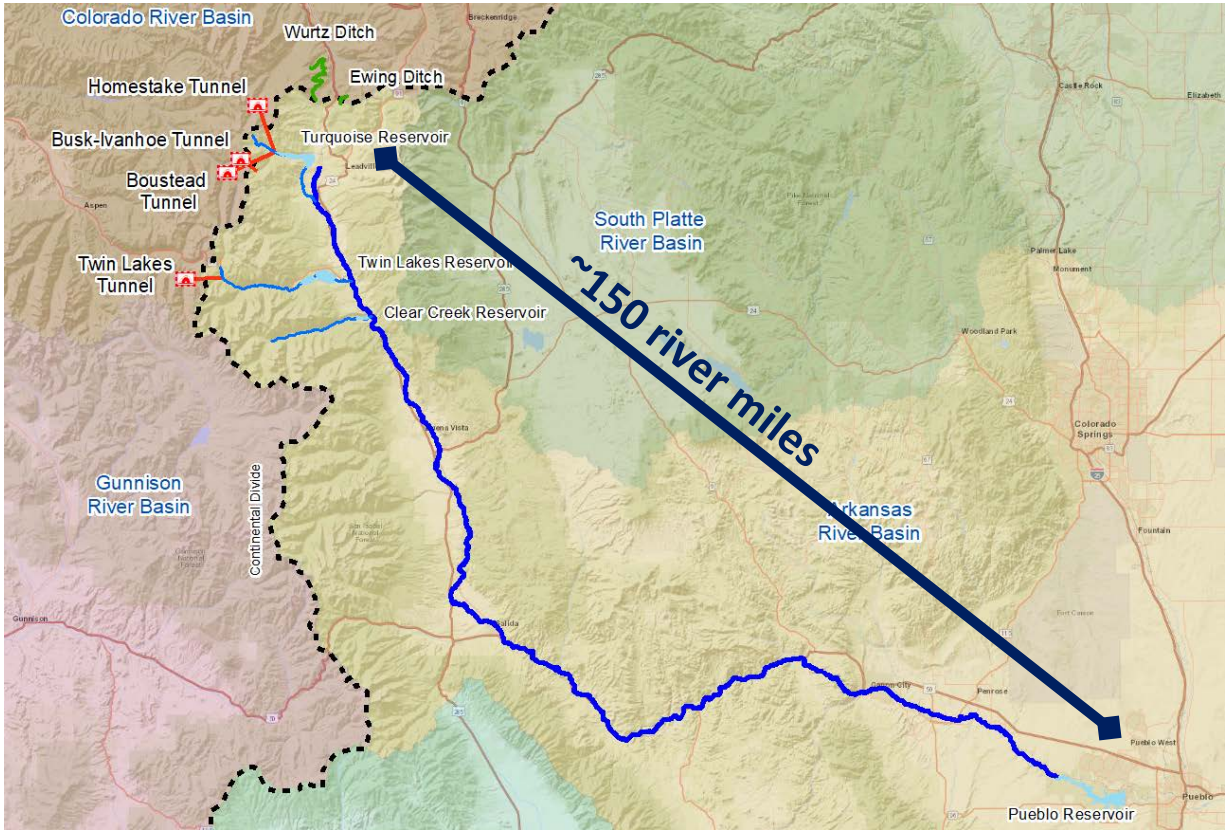
- Thank goodness for AggSeries slots!
  - Help to view and track detailed calcs in familiar, transparent forms





Overview of Pueblo Water's System



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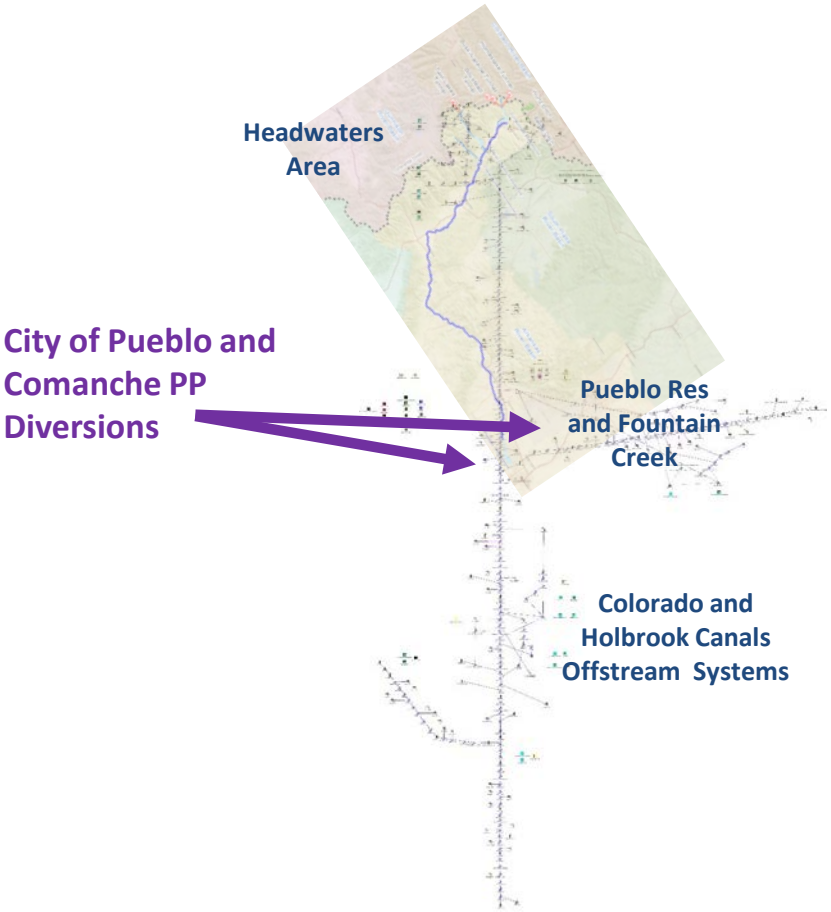

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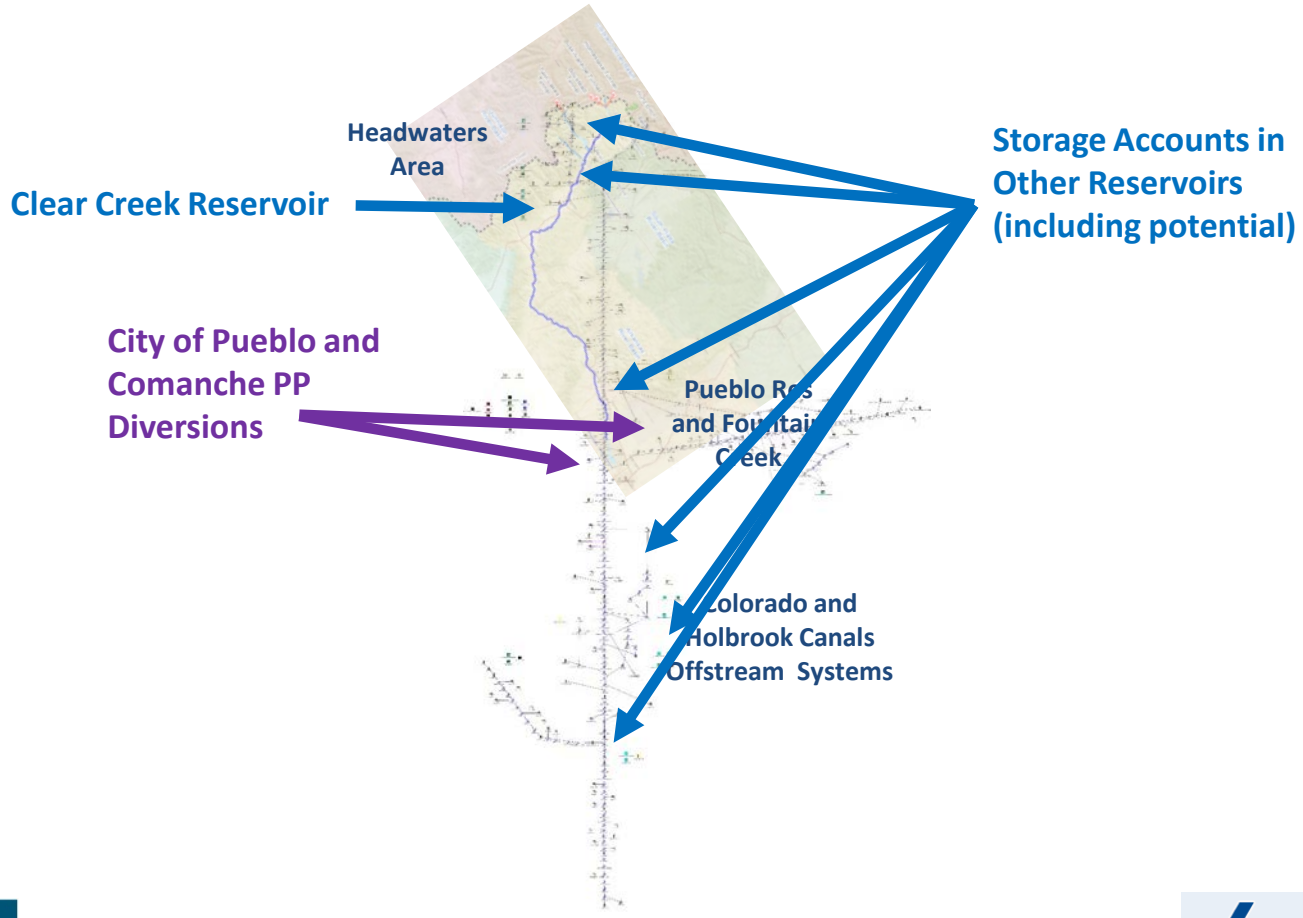

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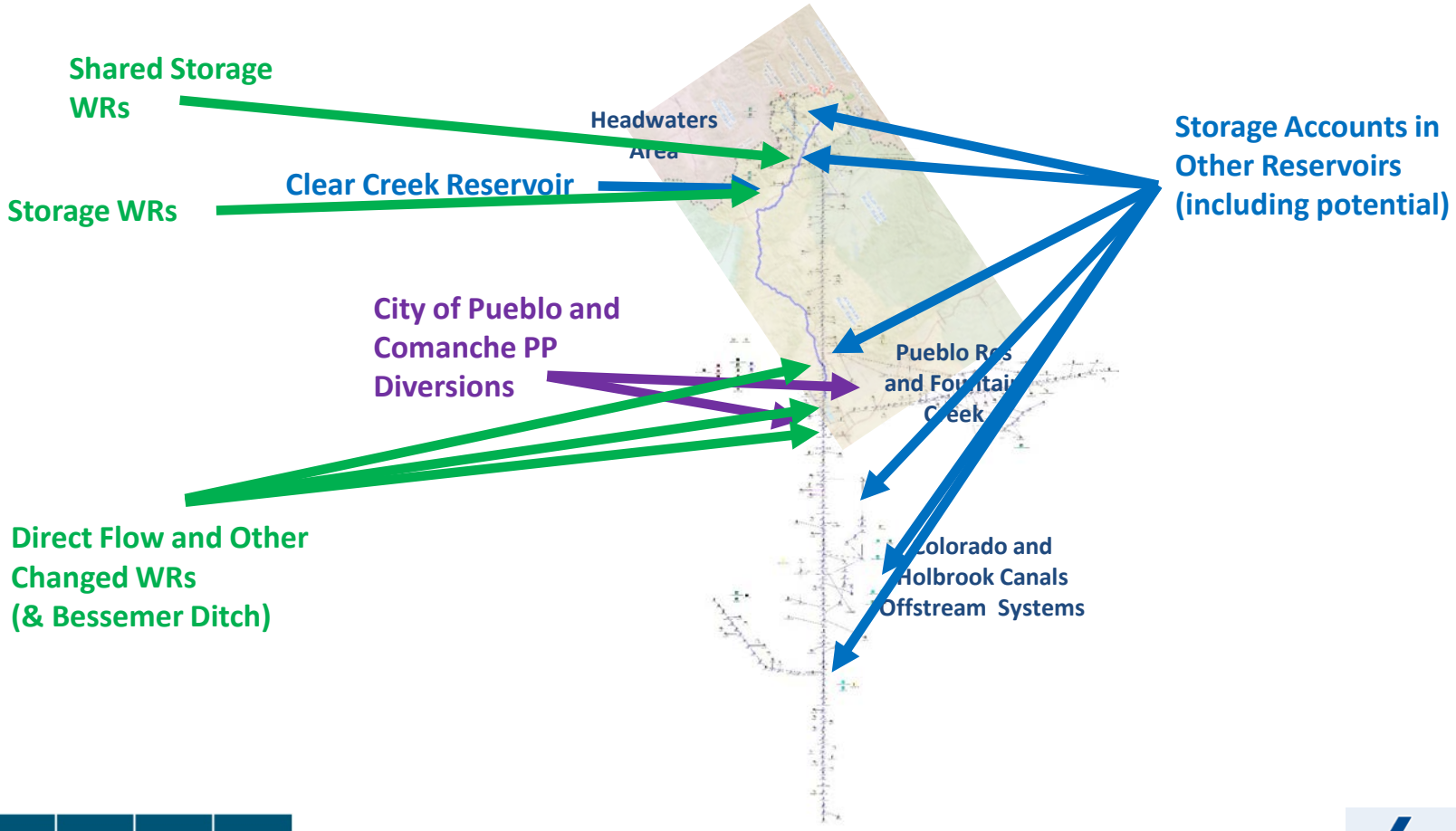

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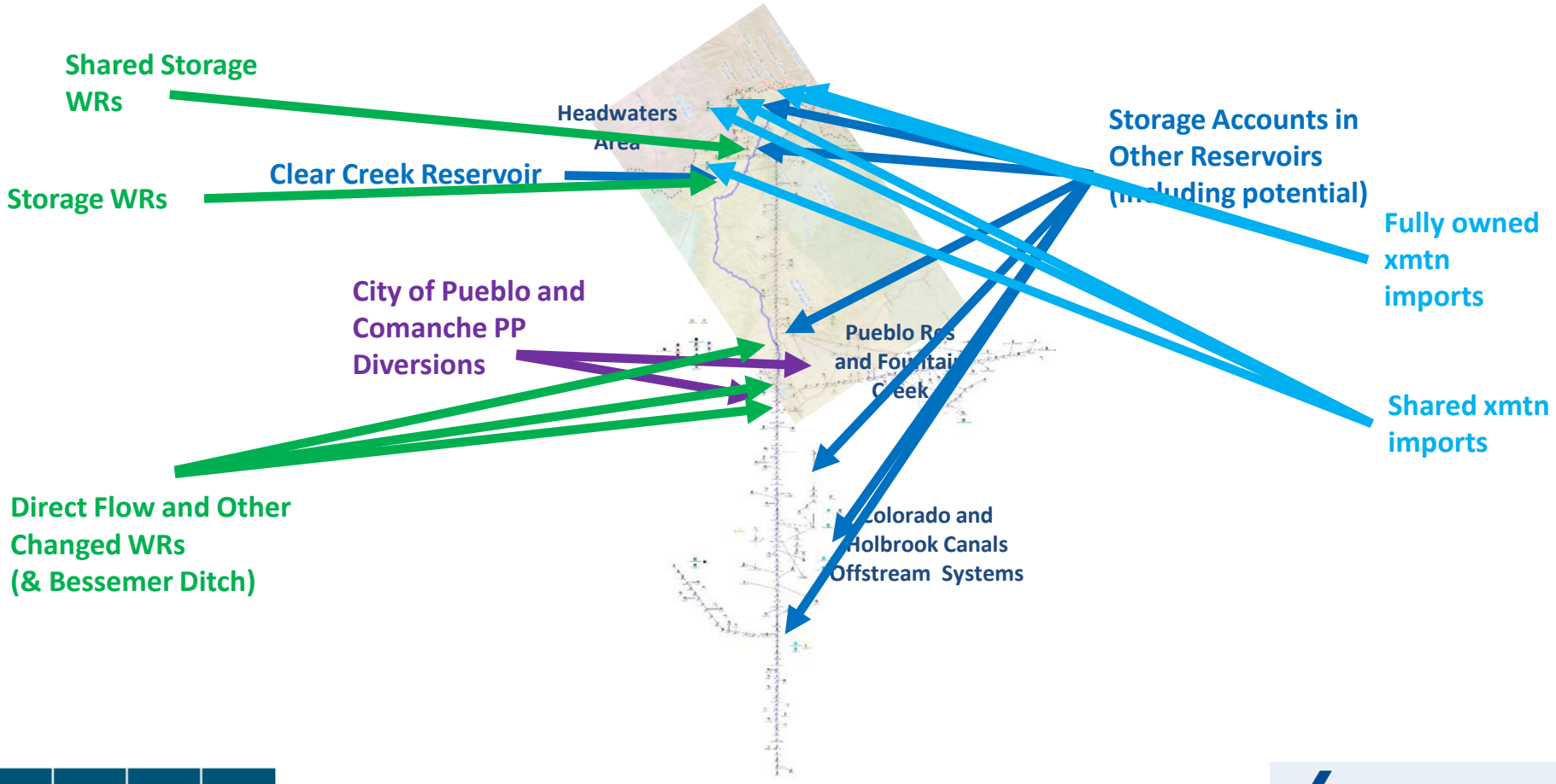

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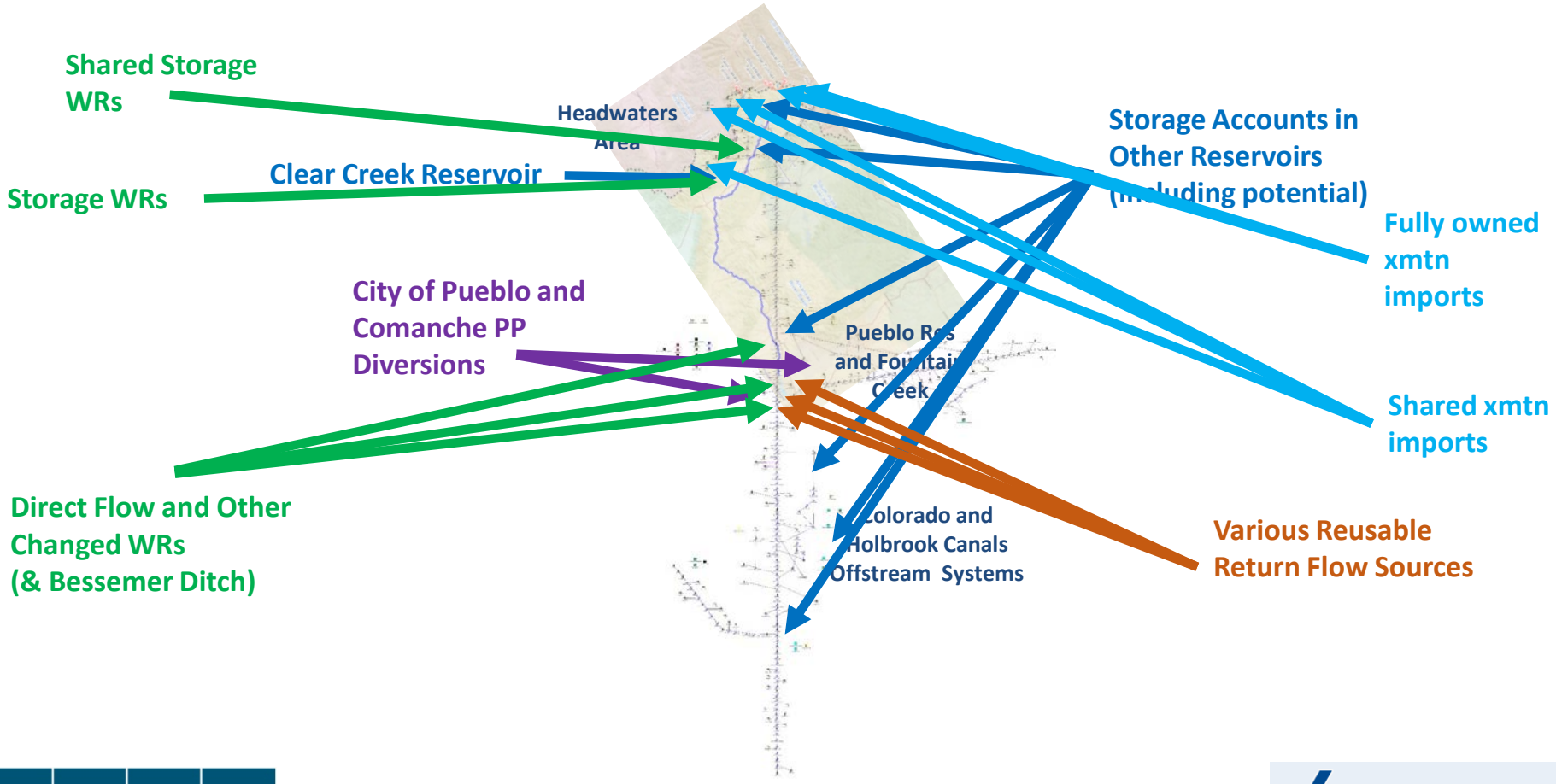

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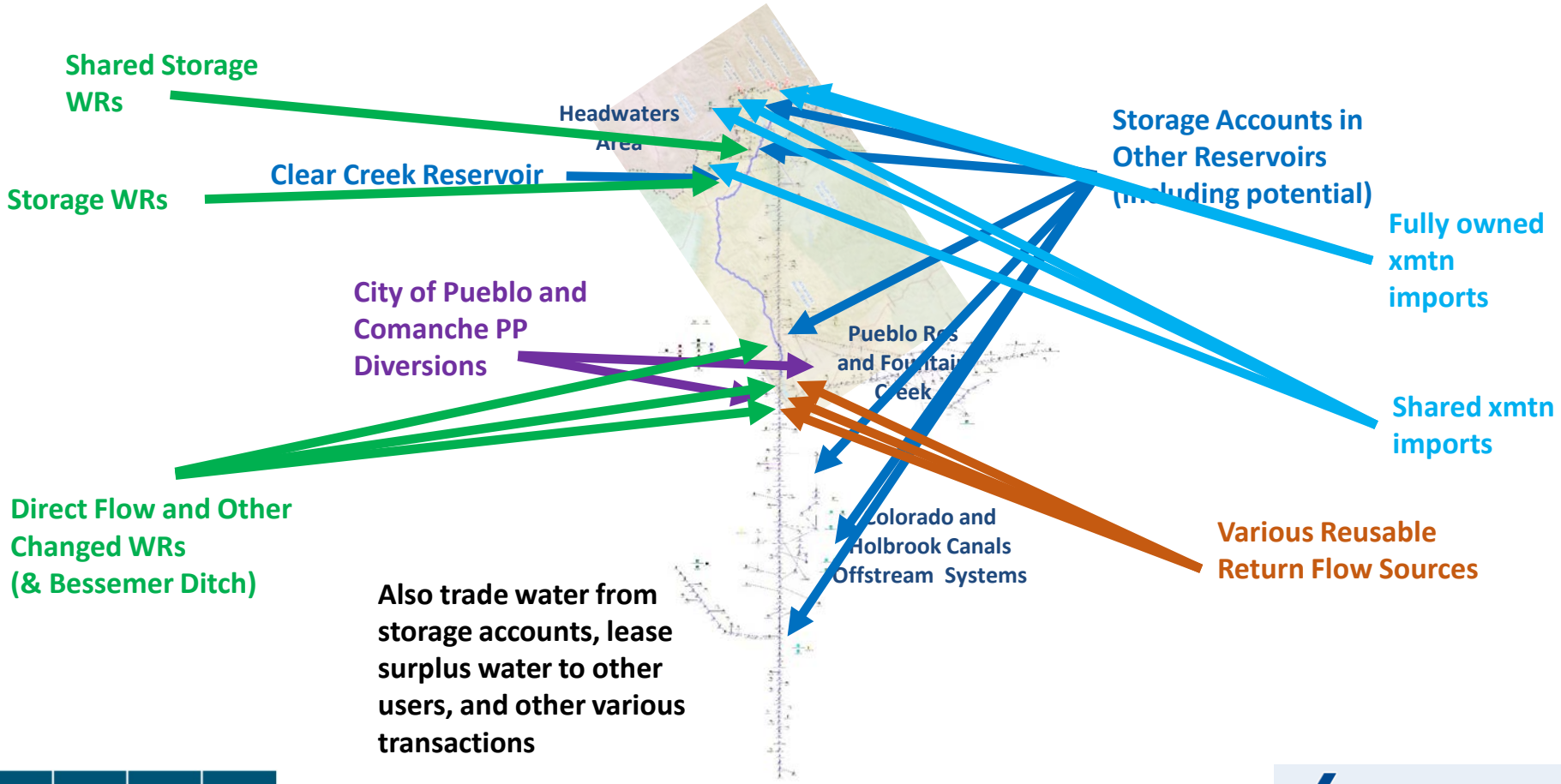
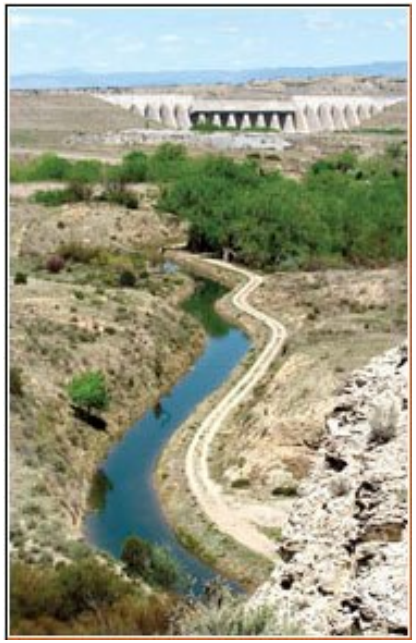


Pueblo Water's Water Rights Change Case

Emily Logan, Pueblo Water

Background

- Pueblo Water purchased ~28% of Bessemer Ditch in 2009
  - ~5488.36 shares at >$10,000/share = >$55,000,000
  - Annual yield ~ 7,500 AF/year
- Bessemer Ditch Water Rights:
  - 322 cfs with May 1887 priority date
  - 70.65 cfs of 1882 and earlier priority date
  - Winter Water – annual average diversion of about 63,000 AF
- Water Rights currently only allow for agricultural uses
  - Yields are leased back to farmers
  - Plan is to gradually convert shares to municipal use as need grows
- Need to go through Colorado Water Courts to change them to allow for municipal, storage, and other uses



Pueblo Water's Team of Experts

- Water Rights & Engineering - Deere and Ault Consultants
- System Modeling - Precision Water Resources Engineering
- Population Growth – Summit Economics, State Demography Office
- Demand Projections – Pueblo Water
- Climate Change – Abt Associates, Corona Environmental Consulting
- Colorado Compact/Transbasin Imports – Anne Castle
- Water Quality - Timothy Gates, CSU

Main Study Objectives

- Colorado's Anti-Speculation Water Doctrine
  - Essentially, to get water rights changed to allow for municipal uses and storage, need to show an actual need for the water
  - Pagosa Springs v. Trout Unlimited Supreme Court case
- Pueblo Water's Planning Objective:
  - 50-year Planning Horizon – Year 2070
  - Have sufficient water supplies to meet projected future demands
- Develop a range of potential scenarios and alternatives
- Two Failure Conditions:
  - "Minimum Storage Reserve" and/or "Delivery Shortage" failures

Model Scenarios and Alternatives

- 20 total scenarios developed to envelope potential future conditions

Hydrology Alternatives (3 total)	6-Year "Base" Design Drought
	6-Year Design Drought Adjusted -4% for Climate Change and Curtailed Imports in last 3 years
	6-Year Design Drought Adjusted -10% for Climate Change and Curtailed Imports in last 3 years
Demand Alternatives (6 total)	Future-Mid Growth
	Future-High Growth
	Future-Mid + 6%
	Future-High + 6%
	Future-Mid + 6% with Reduced Comanche PP
	Future-High + 6% with Reduced Comanche PP
Bessemer Ditch Yield Usage Alternatives (2 total)	No Bessemer Usage
	With Bessemer Usage

Hydrology Alternatives

- Base Design Drought, existing from previous studies
  - 6-year long, ~100 year return period
  - Model inputs not available for all years, analog years used

Climate Change and Import Curtailment Scenarios

- -4% Naturalized Hydrology Inputs
- -10% Naturalized Hydrology Inputs
- In both, last 3 years of drought have curtailed imports (those junior to Colorado Compact)

- ABRW Model "Hydrology Construction Workbook" used to very efficiently develop alternative inputs

Pueblo Water 6-yr Design Drought Sequence Historical Year	Analog Model Input Hydrology Year Used	Historical Import Year Used
1976	2001	1976
1977	2012	1977
1988	1992	1988
1990	1991	1990
1981	2012	1981
2002	2002	2002

Summary of Modeling Results

- Clear need for Bessemer water under all but the least severe scenario
- Many scenarios show additional need even with Bessemer yields

Shorthand Model Scenario Name	Water Supply Performance	Minimum Storage Reserve (AF)	Simulated Minimum Total Pueblo Water System Storage, AF	Simulated Total Delivery Shortages, AF
DD_FM_NoBess	No failures	45,270	34,388 (in 6th yr)	0
DD_FH_NoBess	Minimum Storage Reserve failure	48,440	25,850 (in 6th yr)	0
DD-4%+ImpX_FM+6%_NoBess	Minimum Storage Reserve and Delivery Shortage failures	47,990	Empty (in 6th yr)	8,686 (in 6th yr)
DD-4%+ImpX_FH+6%_NoBess	Minimum Storage Reserve and Delivery Shortage failures	51,350	Empty (in 6th yr)	19,206 (in 6th yr)
DD-10%+ImpX_FM+6%_NoBess	Minimum Storage Reserve and Delivery Shortage failures	47,990	Empty (in 6th yr)	15,500 (in 6th yr)
DD-10%+ImpX_FH+6%_NoBess	Minimum Storage Reserve and Delivery Shortage failures	51,350	Empty (in 5th and 6th yrs)	25,869 (in 5th and 6th yrs)

Shorthand Model Scenario Name	Water Supply Performance	Minimum Storage Reserve (AF)	Simulated Minimum Total Pueblo Water System Storage, AF	Simulated Total Delivery Shortages, AF
DD_FM_WithBess	No failures	45,270	51,706 (in 6th yr)	0
DD_FH_WithBess	No failures	48,440	47,959 (in 6th yr)	0
DD-4%+ImpX_FM+6%_WithBess	Minimum Storage Reserve failure	47,990	17,546 (in 6th yr)	0
DD-4%+ImpX_FH+6%_WithBess	Minimum Storage Reserve failure	51,350	10,054 (in 6th yr)	0
DD-10%+ImpX_FM+6%_WithBess	Minimum Storage Reserve failure	47,990	10,623 (in 6th yr)	0
DD-10%+ImpX_FH+6%_WithBess	Minimum Storage Reserve failure	51,350	631 (in 6th yr)	0 (narrowly)

Proposed Bessemer Ditch Ops

- Implement procedures following mutual ditch operations
  - Prorated amount of water delivered based on share quantity
- Portion of our shares will be delivered to Pueblo Reservoir
  - This will result in an incremental reduction of canal loss by volume; therefore, 4.25% of its lateral headgate deliveries will be returned to the river to mitigate the possible increased consumptive use
- 10% of our shares will be delivered down the ditch to replicate surface return flows
- Lagged return flows will be delivered based on timing function at appropriate band

PBWW portion based on 27.8% shares

Theoretical amount going to "head gate"

PBWW agreed to deliver 10% through the ditch and keep 90% in storage

Ditch Loss Percent	0.124
Total WR Allocation	150
PBWW Shares	0.278
PBWW Portion	41.7
PBWW Ditch Loss	5.17
PBWW Total Equiv Lat HG Div	36.52
PBWW Transfer to Storage	32.87
PBWW Deliver through Ditch	3.65

Ditch operators guess based on flows (historical records indicate an average ditch loss from 11.5% - 16% based on diversion)

Direct Flow Rights in priority

Outcome

- RiverWare modeling and results were well accepted and not challenged by opposing parties
- While we don't have a final decree yet because we are waiting on settlement in our exchange case, we were successful in reaching agreements with opposers and proving our need

Future Uses:

- Expansion of reservoir storage
- Operational decision model for short term planning
- More accurate determination for leases
- Primary tool for Integrated Water Resources Plan

Thank You!

Acknowledgements

- Pueblo Water
  - Alan Ward, Steven Anselmo, Seth Clayton
- USBR Pueblo Field Office
  - Terry Dawson
- USBR Eastern Colorado Area Office
  - Claudia Leon, Terry Stroh
- Aurora Water
  - Tom Simpson, Rick Kienitz
- Colorado Springs Utilities
  - Abigail Ortega, Kalsoum Abbasi, Kevin Lusk
- Pueblo West Metro District
- Southeastern Colorado Water Conservancy District
- Colorado DWR Division 2
  - John Van Oort, Bill Tyner
- Colorado Water Conservation Board
  - Brian Macpherson
- Deere and Ault Consultants
  - Mark McLean
- Abt Associates
  - Joel Smith
- Corona Consultants
- Anne Castle
- Stantec
- And many more!