Integration of RiverWare into a Collaborative Modeling Framework to Support Climate Change Impacts Analysis

RiverWare User Group Meeting
February 1st , 2018

Shane Coors, PE and Linnet Jose, EIT
Precision Water Resources Engineering
www.precisionwre.com

PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Water for the Seasons

"A Program for Sustaining Water Resources in a Changing Climate"

- In 2014 a grant was offered jointly by the NSF and USDA to explore impacts of climate change in snow-fed arid lands
- An interdisciplinary team from Northern Nevada won the grant
  - University of Nevada at Reno
  - Desert Research Institute
  - United States Geological Survey
  - Precision Water Resources Engineering
- Project included
  - Development of an integrated system of models (climate models, hydrology models, system operation models, and groundwater models
  - Robust stakeholder interaction process whereby study team engaged water managers to develop climate scenarios and adaptation strategies
  - Characterization of impacts to the basin due to changing climate
  - Identification of potential adaptation strategies to address impacts
- Truckee RiverWare TROA Planning Model was the operations model for the Truckee river basin

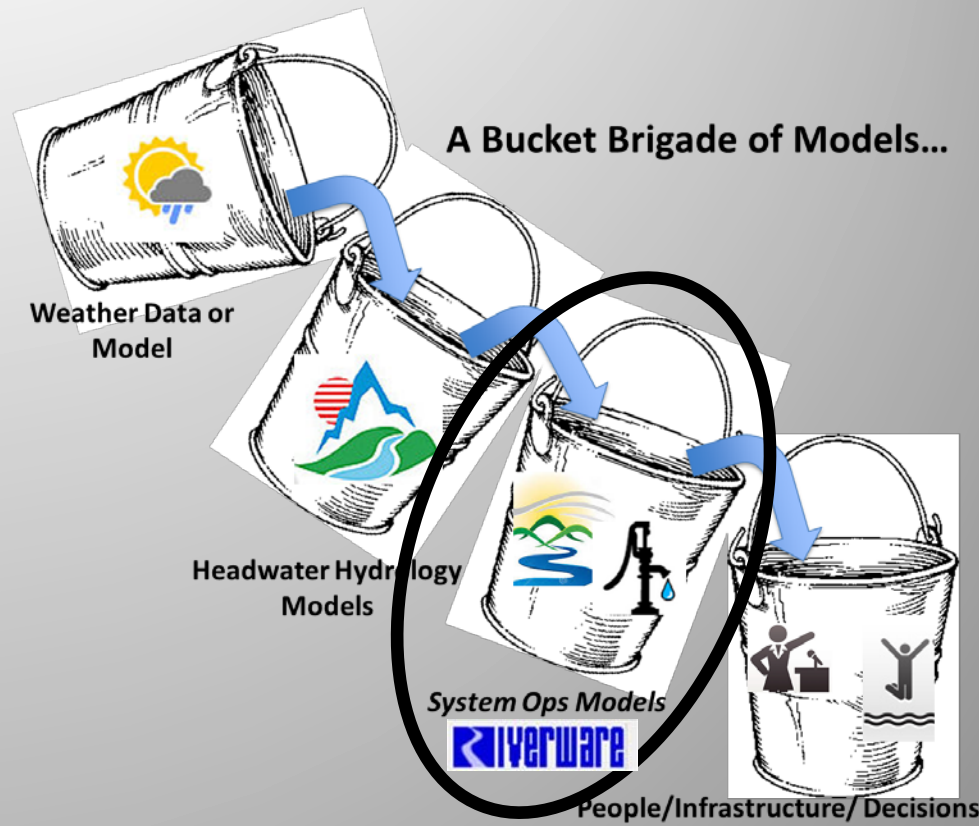


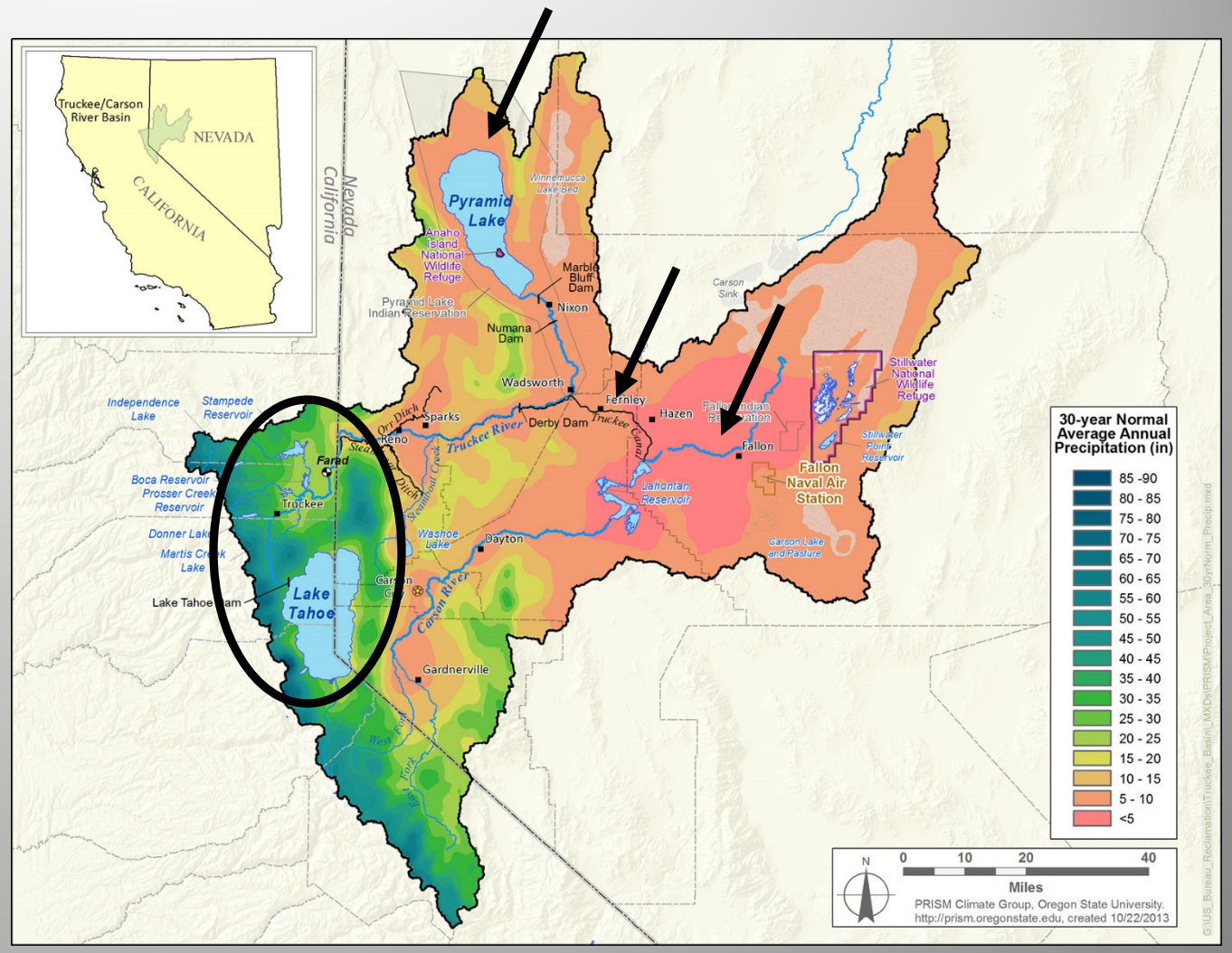
Figure courtesy of Mike Dettinger, USGS

PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Truckee–Carson Basin Introduction

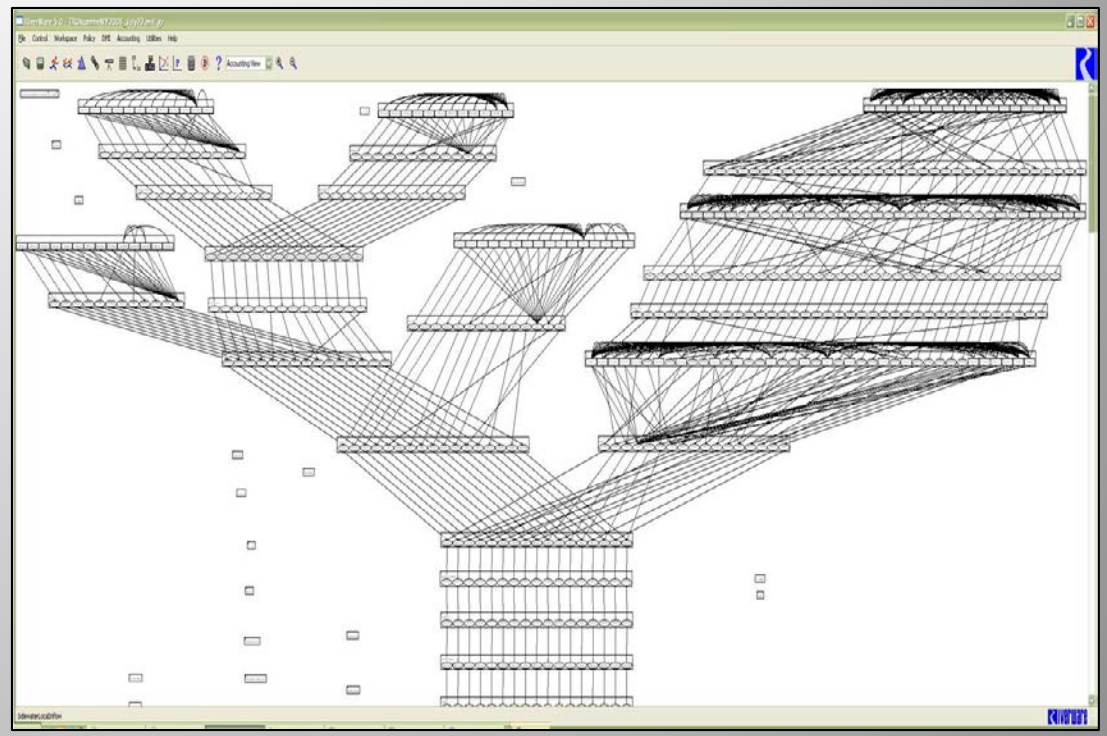
- Truckee River is ~100 miles long, flowing from Lake Tahoe to Pyramid Lake
- Seven upstream storage reservoirs that regulate ~70% of the basin water supply
- Majority of the water originates in California (Sierra Nevada Mountains)
- Majority of the water usage is in Nevada
- The river ends in a desert terminal lake, Pyramid Lake in the Great Basin
- Water is diverted from the Truckee Basin to the Carson basin via the Truckee Canal at Derby Dam
- The Newlands Project is served by the combined Truckee and Carson River in the lower Carson River basin



PWRE PRECISION WATER RESOURCES ENGINEERING

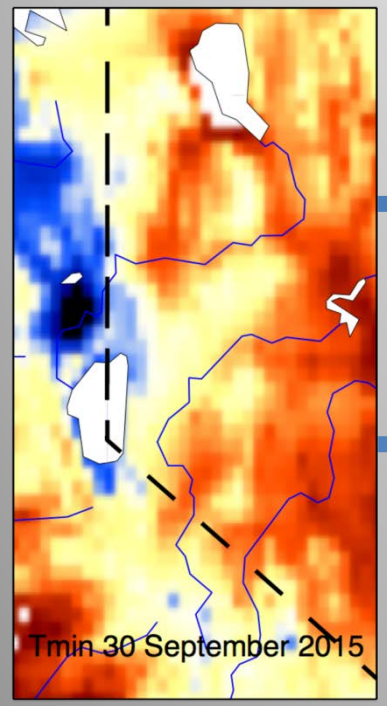
TROA Planning Model Summary

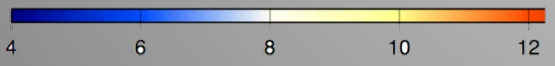
- Daily timestep RiverWare© model
- 100+ year runs possible
- Collaborative ongoing development by Truckee Basin stakeholders led by Reclamation since 2009
- Simulates all reservoir operations and diversions/uses in the basin according to TROA policy
- Tracks TROA accounting in all reservoirs and reaches
- Performs TROA accounting transactions
- Includes baseline characterization of individual party's operational strategies under TROA
- Used for planning studies by all major basin stakeholders



Water for the Seasons Integrated Models

Stakeholder informed climate scenario





4 km grid

Upper Truckee Watershed GSFLOW Model

Upper Carson Watershed PRMS Model

RiverWare

Truckee RiverWare TROA Planning Model

Fernley Groundwater MODFLOW Model

Carson Valley and Middle Carson Operations MODSIM Model

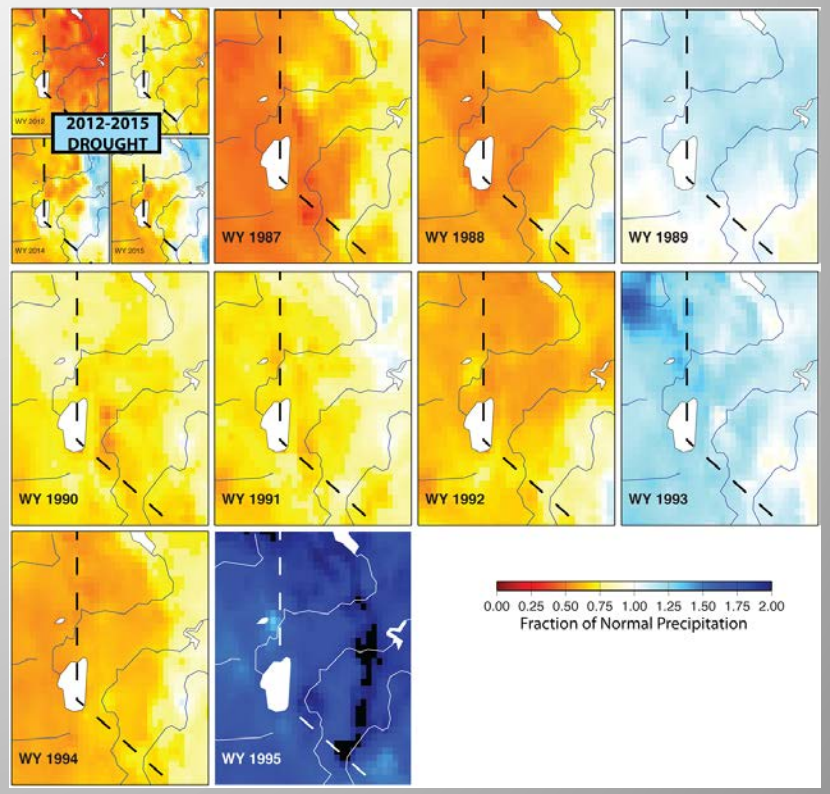
Carson Valley and Middle Carson Surface-Groundwater GSFLOW Model

PWRE PRECISION WATER RESOURCES ENGINEERING

WATER for the SEASONS

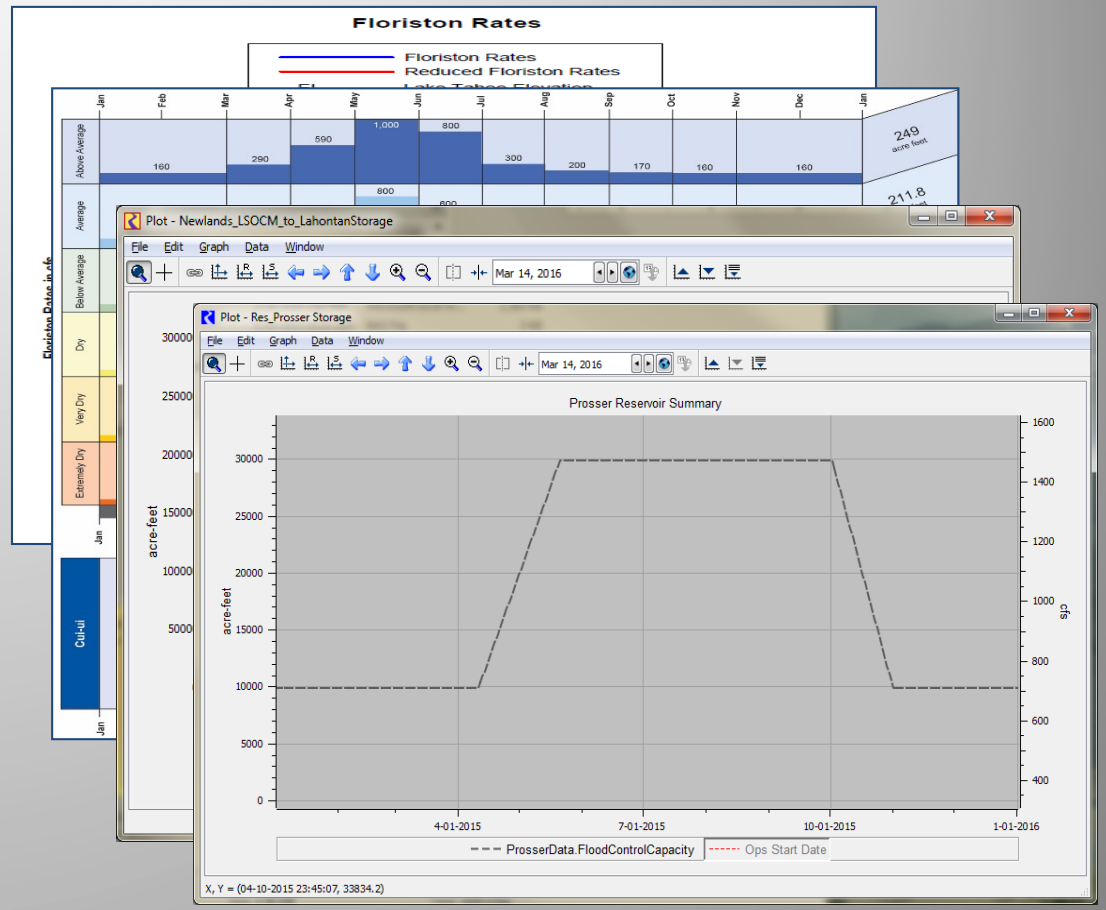
Climate Scenarios Developed

- Extended Drought– 2012-2015 followed by 1987 – 1994 climate. Small temperature shift for early period for temperature parity with late period
- Extended Drought Warmer Temperature – same concatenated drought as above +2.5C
- Historical Plus Warming – 1980–2015 hydrology with uniform 4.3C warming
- Low Frequency – 20-year GCM climate trace that showed the largest standard deviation of annual precipitation values
- High Frequency – 20-year GCM climate trace with the lowest standard deviation of annual precip. Total annual precip very similar to low frequency
- These scenarios provide the basis for exploring some very important "What if" questions about the future of the Truckee-Carson system



Fixed Calendar Dates in Operational Policy

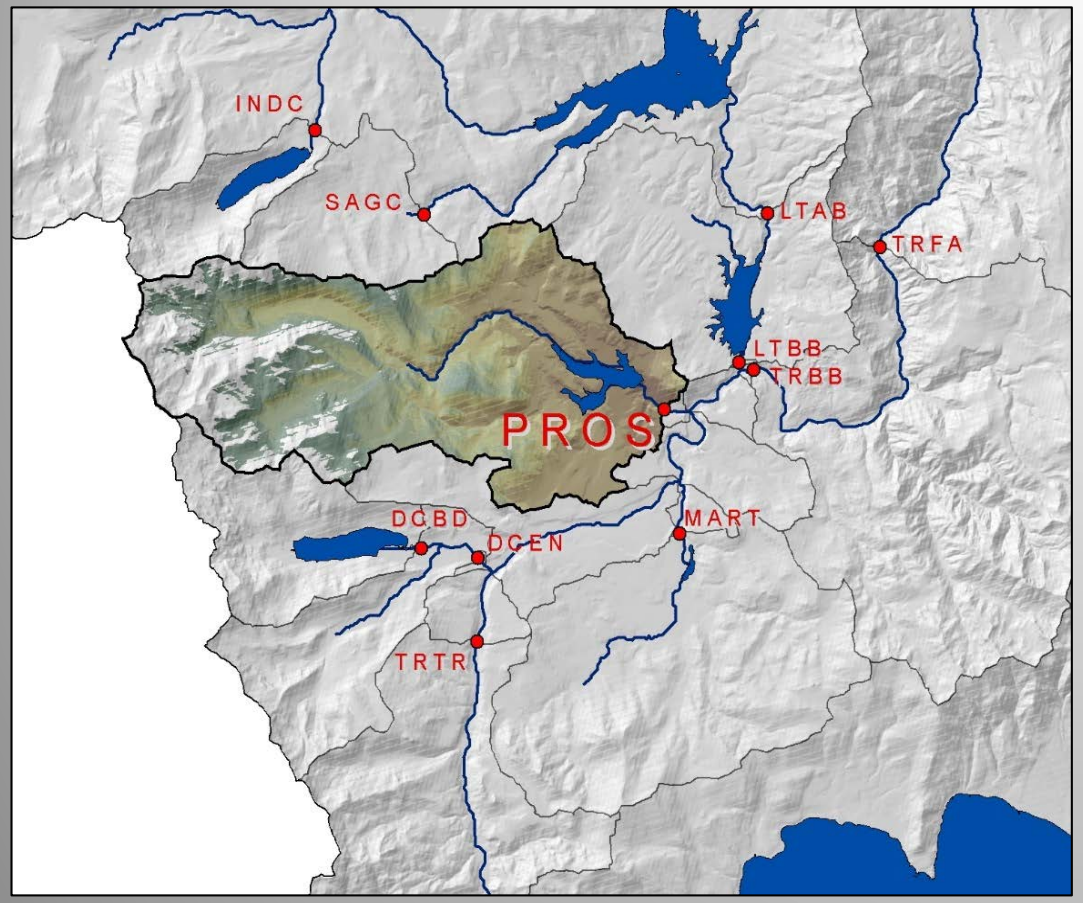
- Many operations in the basin are tied to fixed calendar dates
- These dates are based on historical snow accumulation and runoff seasonal timing
- What are the impacts of operating the Truckee-Carson system under rigid calendar-based constraints if the actual seasonal cycle is changing?
  - Floriston Rates
  - Fish Flow Regimes
  - Lahontan Storage Targets (OCAP)
  - USACE Flood Space Requirements



PRECISION WATER RESOURCES ENGINEERING

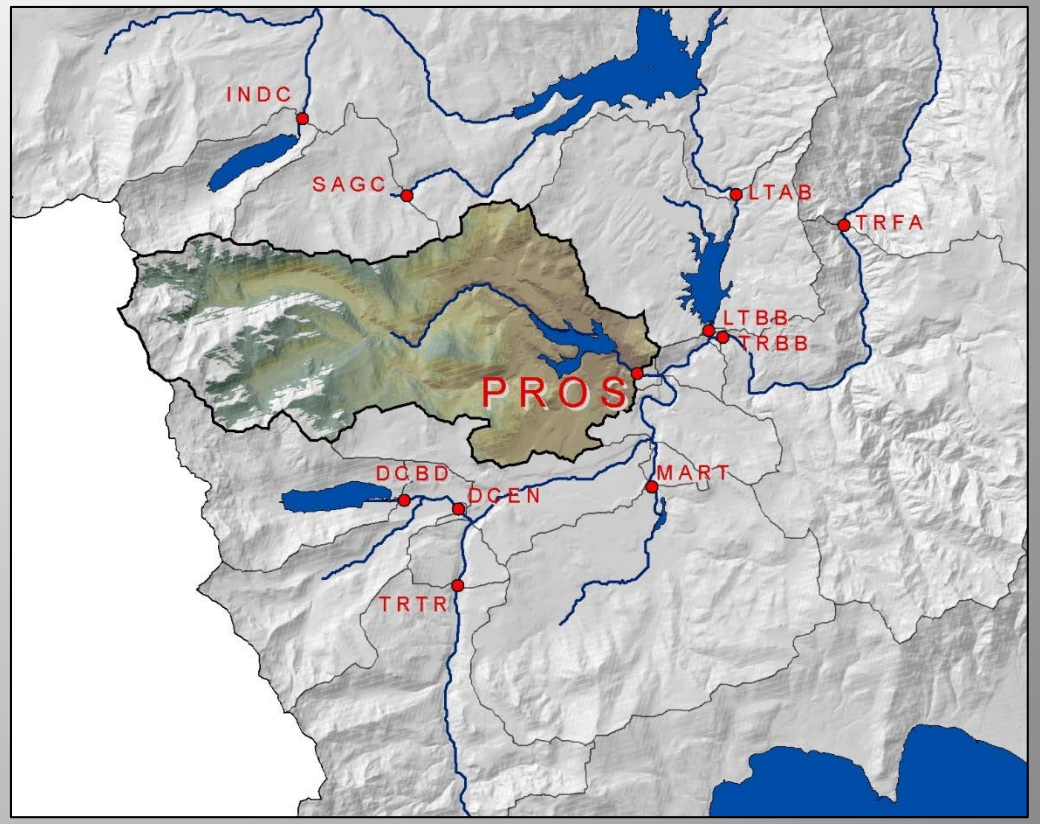
WATER For The SEASONS

Water Supply Impacts



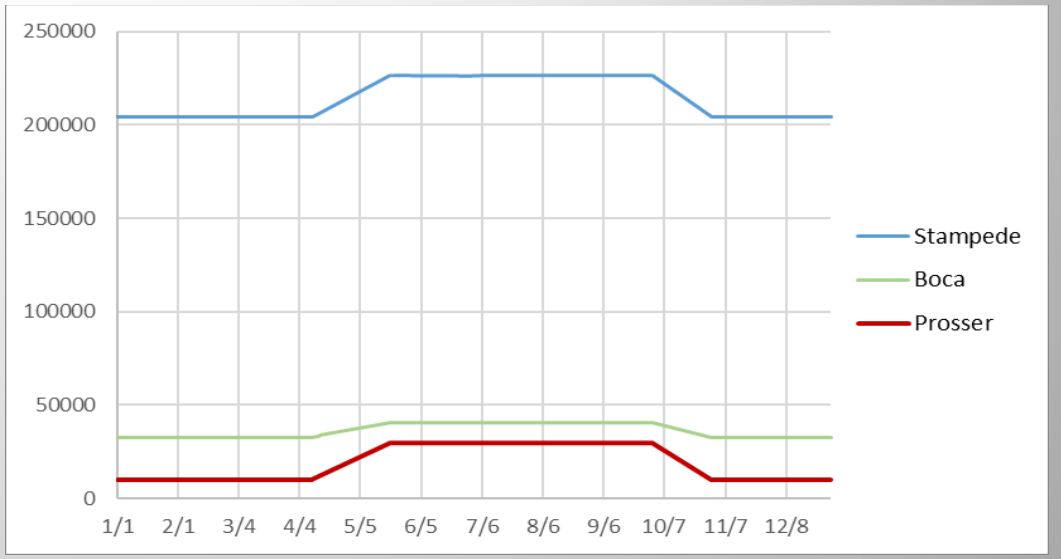
Prosser Creek Reservoir Operations

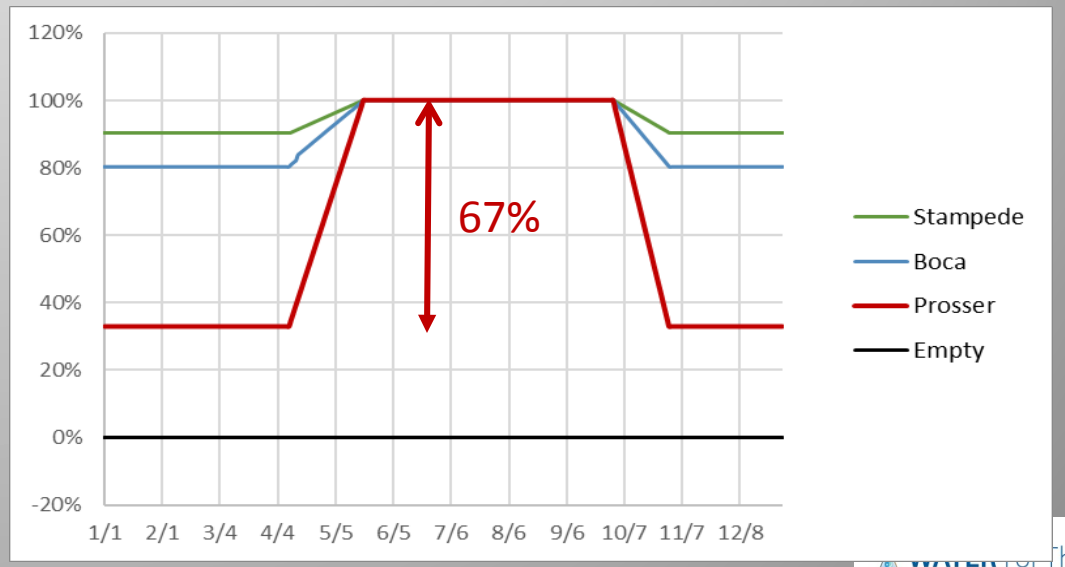
- Prosser is owned by the Bureau of Reclamation and is operated by the Federal Watermaster
- Reservoir Capacity 29,800 AF
- Reservoir allowed to start filling as early as April 10th according to USACE flood guide limitations
- Reservoir can be full as early as May 5th (29,800 af)
- Reservoir must be drawn down to 9,800 AF by October 31st (20,000 AF flood space is reserved)



Prosser Creek Reservoir Storage Utilization

- Prosser Creek Reservoir is smallest of the three BOR reservoirs in the basin
  - Prosser Creek – 29,800 acre-ft
  - Boca – 40,100 acre-ft
  - Stampede – 226,500 acre-ft
- Prosser's effectiveness is most impacted by current flood control operations
  - ~10% of Stampede's capacity must be evacuated for flood control each year
  - ~20% of Boca's capacity must be evacuated for flood control each year
  - ~67% of Prosser's contents must be evacuated every year for flood control space requirements





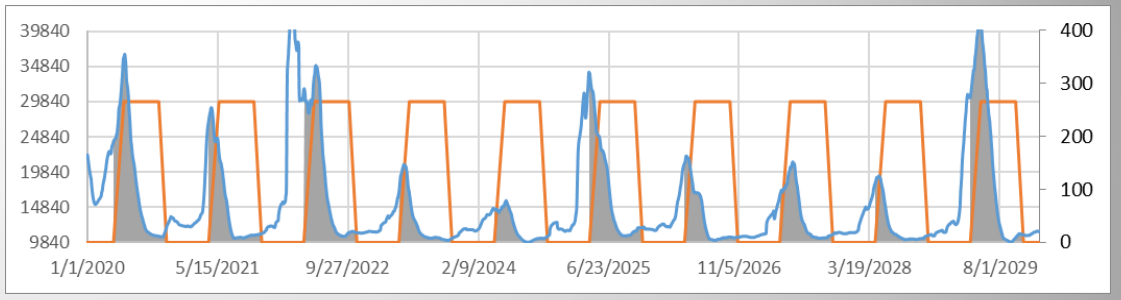
PRECISION WATER RESOURCES ENGINEERING

The SEASONS

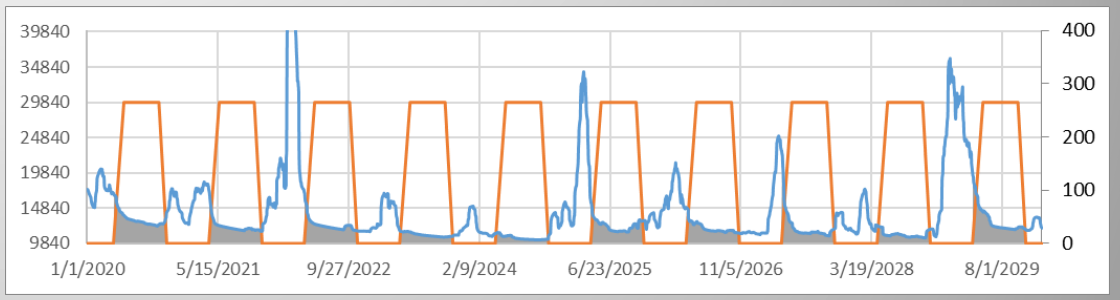
Adaptation Measures Modeled

- Relax the Fixed Date Operations on flood control reservoirs to allow for storage before April 10th
- No Offset – Current fixed date operations
- Static Offset – Allow storage one month earlier, i.e. March 10th
- Dynamic Offset – Determine Offset based on inflows to Boca, Stampede and Prosser, no earlier than Feb 1
- Offsets based on inflows is simplistic, and other factors like snow melt parameter could be considered
- This is advantageous from water supply standpoint. Further study is required to address flood control issues

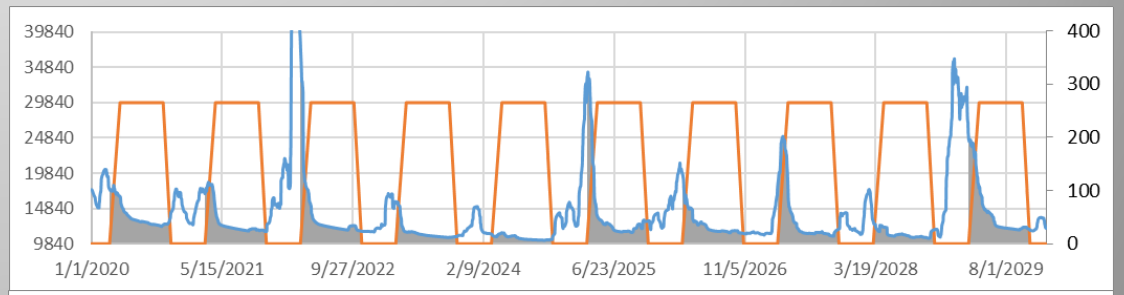
Historical



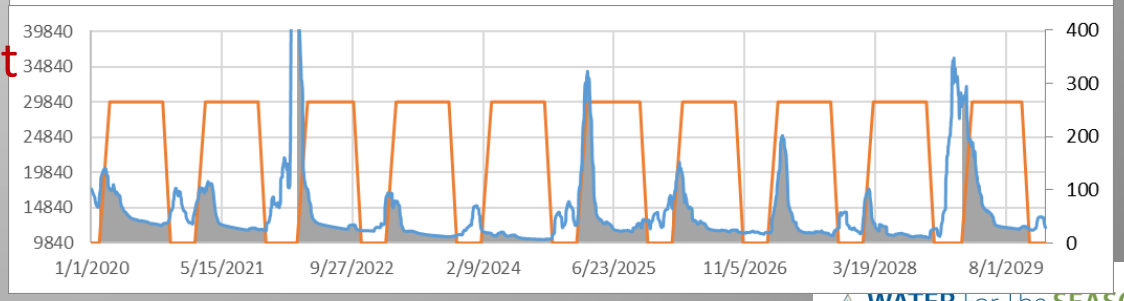
No Offset



Static Offset



Dynamic Offset

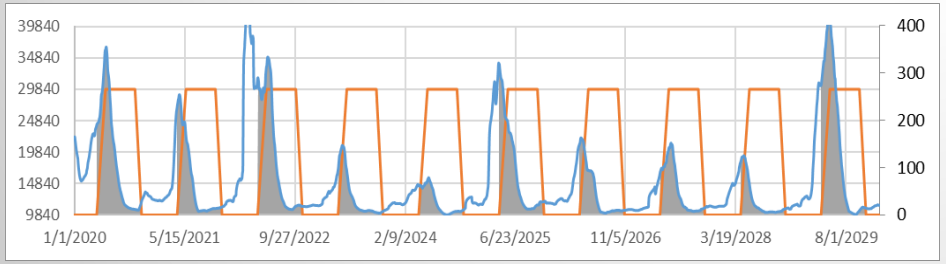


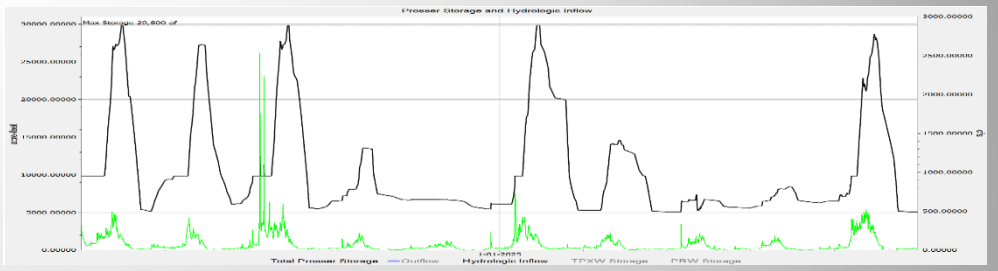
PWRE PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

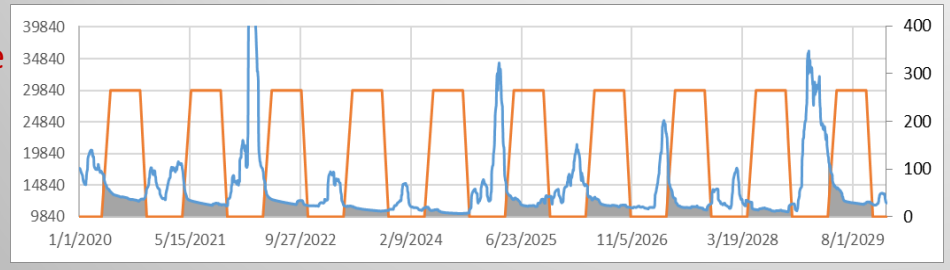
Prosser Storage Utilization

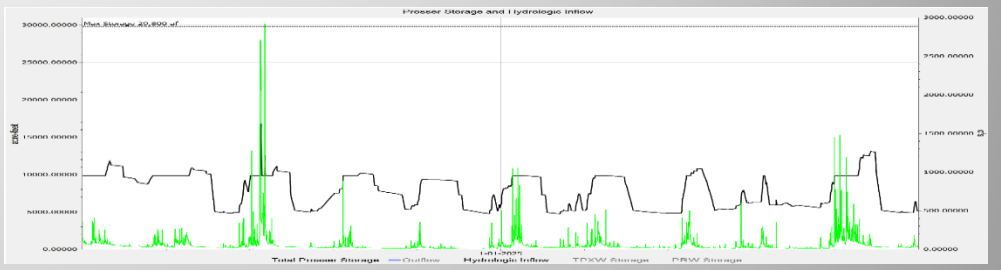
Historical Average Storage
76% of capacity
22,500 acre-ft



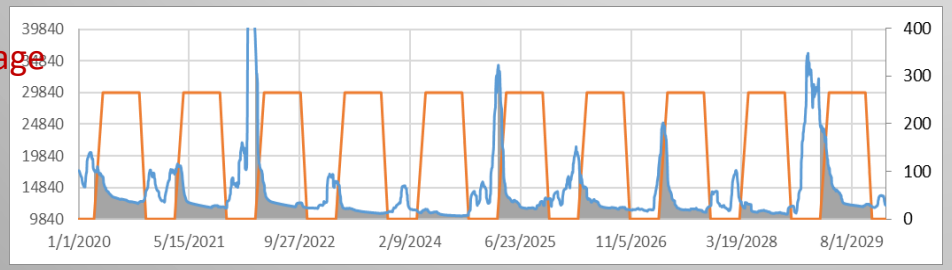


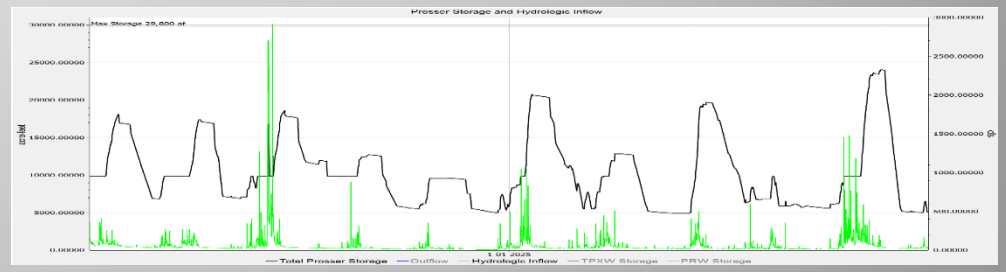
No Offset Average Storage
46% of capacity
13,800 acre-ft



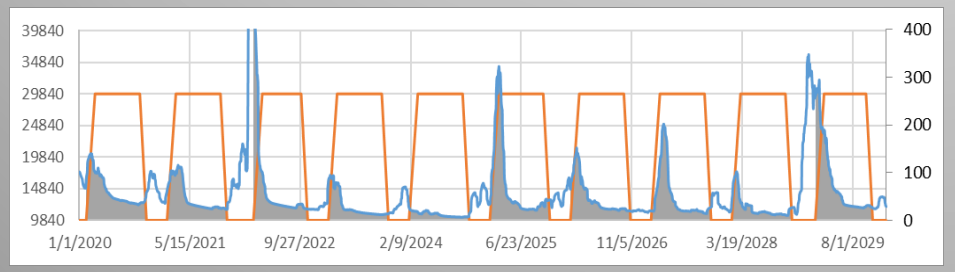


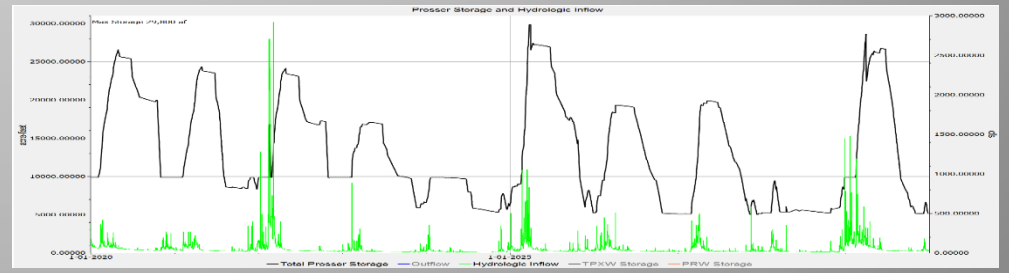
Static Offset Average Storage
64% of capacity
19,200 acre-ft)





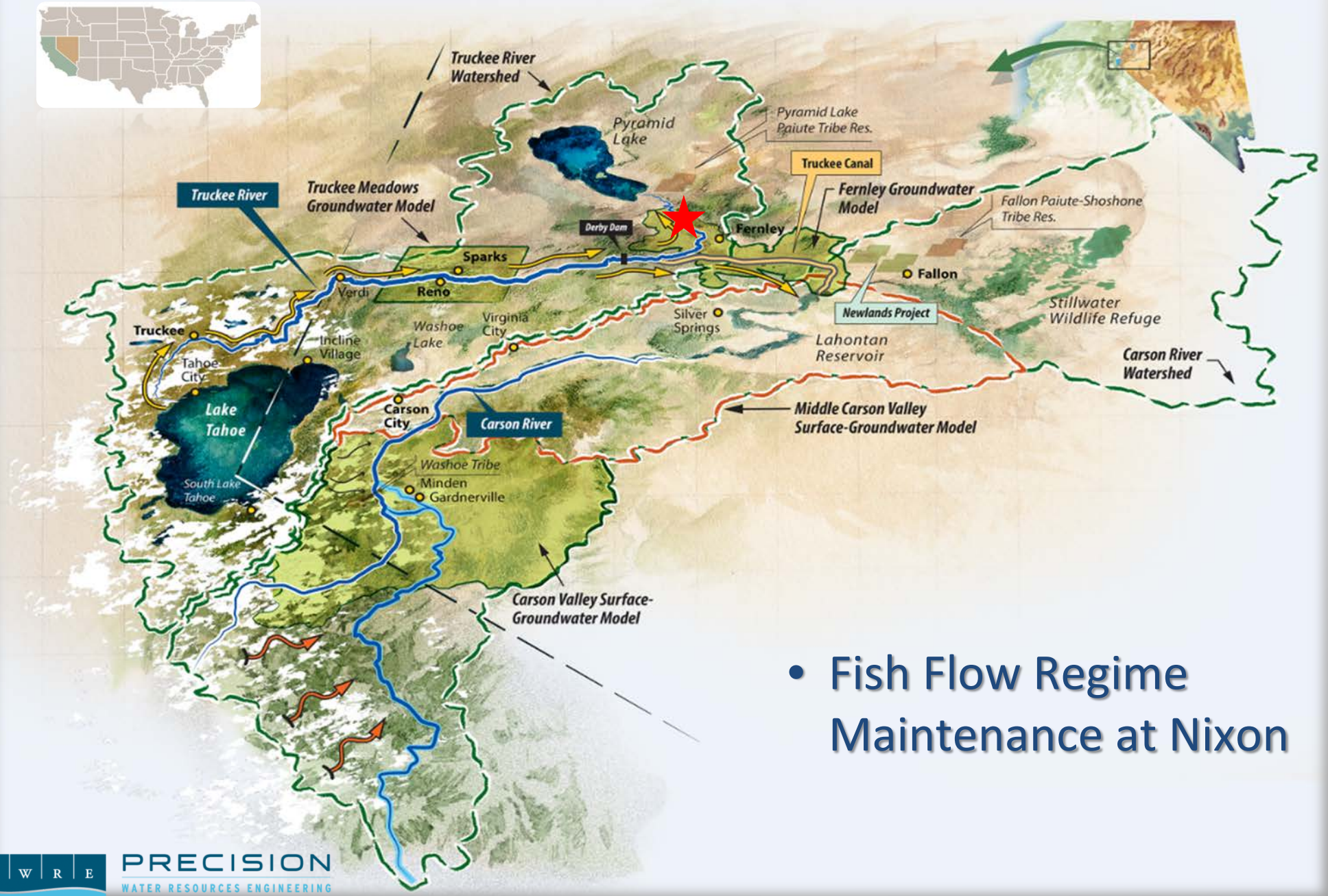
Dynamic Offset Average Storage
76% of capacity
22,500 acre-ft





PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS



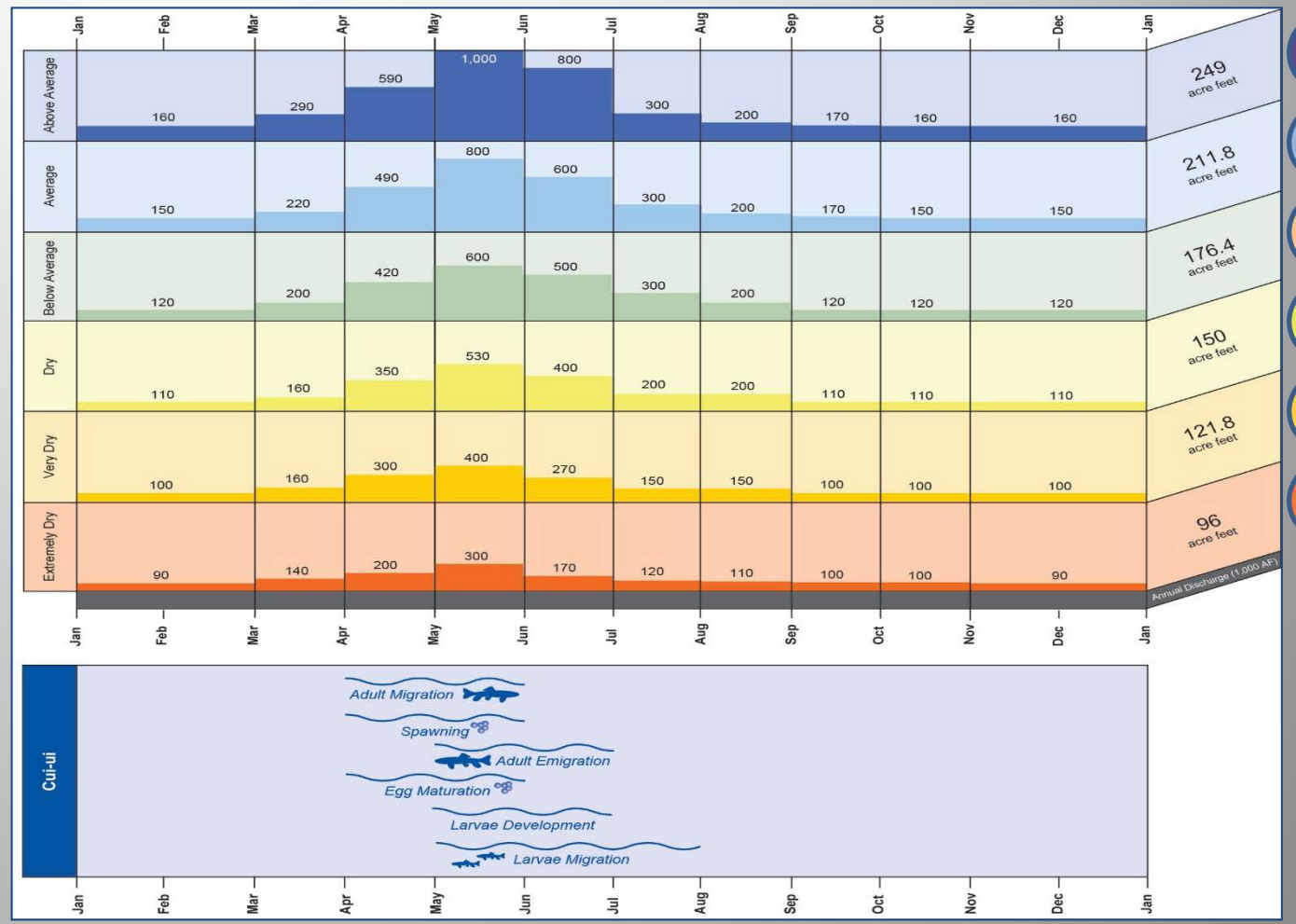
- Fish Flow Regime Maintenance at Nixon

PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Fish Flow Regime Target Attainment - Background

- Waters stored in Stampede and Prosser Creek Reservoirs are designated for the Pyramid Lake Fishes
- Six flow regimes (monthly flow targets) for the Lower Truckee River for the benefit of the threatened and endangered fish species
- Flow regime selection is made on March 1st based on
  - Stampede storage volume
  - Forecasted inflows into Stampede Reservoir
- Goal is to mimic the natural hydrograph (magnitude) and to optimally utilize Stampede Reservoir storage for extended droughts
- System has been implemented with a rigid date structure

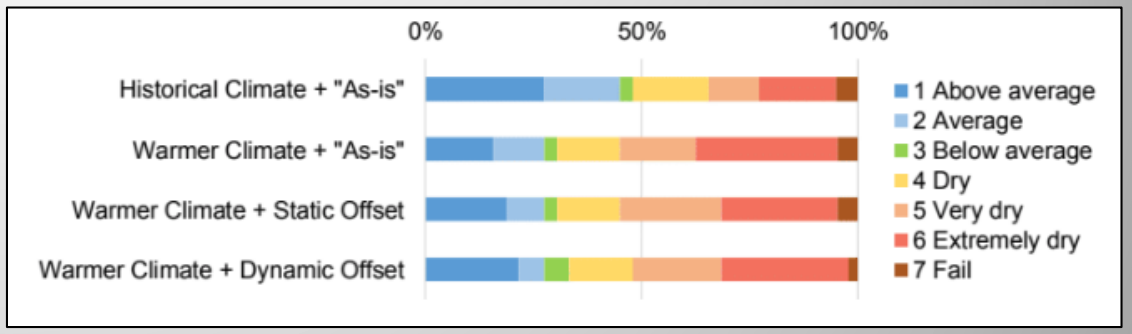


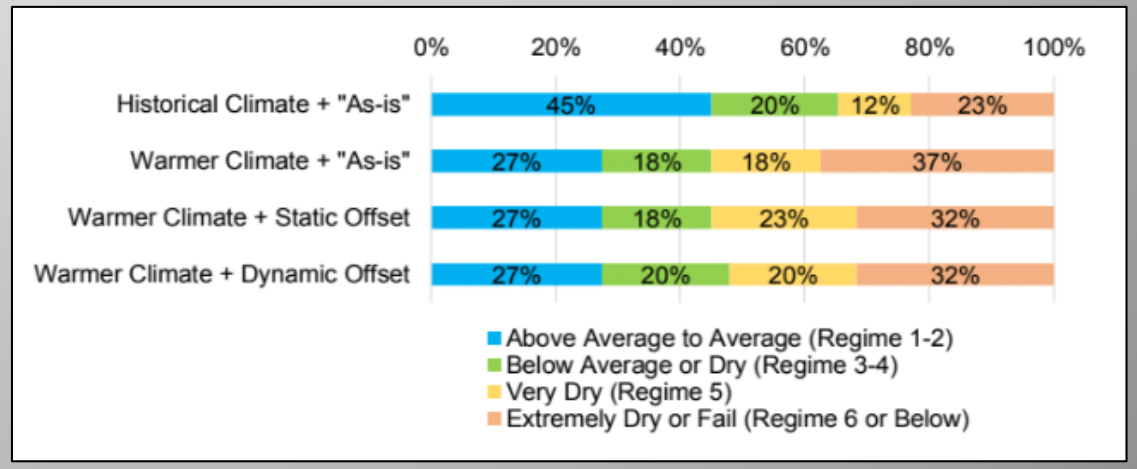
PWRE PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Fish Flow Regime Target Attainment - Results

- In a warm climate scenario, for all three reservoir operations scenarios, the flow regime distribution is lower. Lower flow Flow Regimes happen more often
- Shifting the flood space requirements to allow earlier storage improves the flow regime distribution
- With the dynamic offset, Flow Regime 1 happens 6% more often
- With dynamic offset, Flow Regime 6 happens 4% less often
- With dynamic offset, failure (7) happens 3% less often





PWRE PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Water Balance Visualization Tool

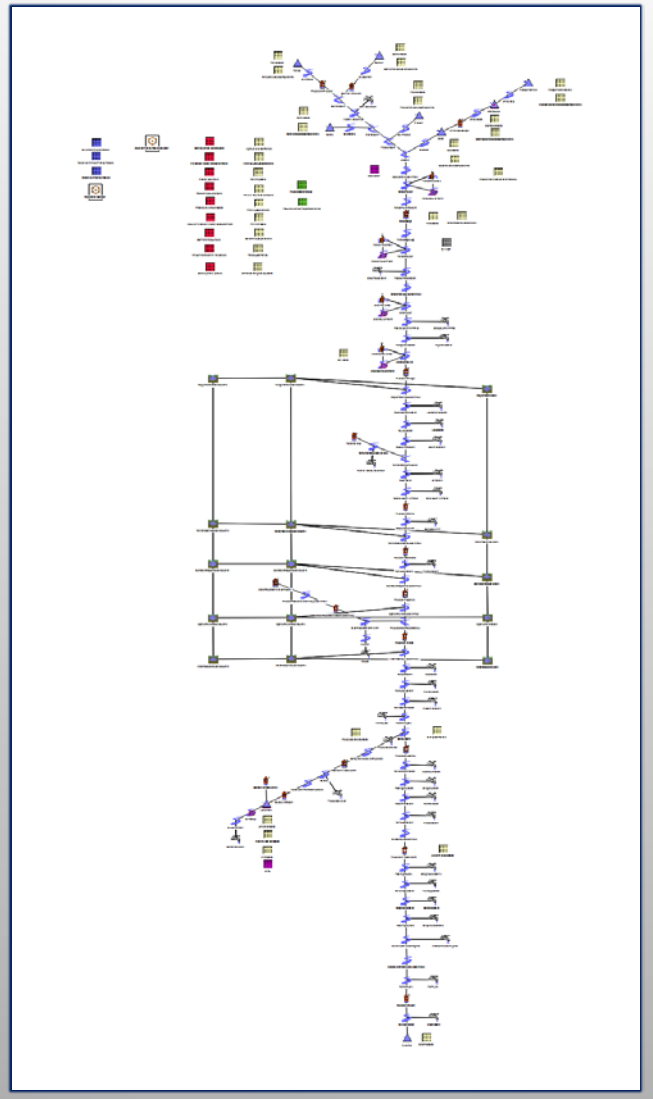
- RiverWare models can get large and complicated with lots of output data
- Extracting “the story” from a run or from a comparison of runs can be difficult and laborious
- But no matter how complicated, a RiverWare model simply evaluates a water balance
- A visualization tool was developed for the WftS project that helps make “the story” more accessible to everyone
- Typically a planning study consists of altering a subset of the water balance in some way and then seeing how the rest of the balance is impacted
  - Climate Change vs. Historical Climate
  - Future Demands vs. Current Demands
  - New Operating Policy vs. Current Operating Policy

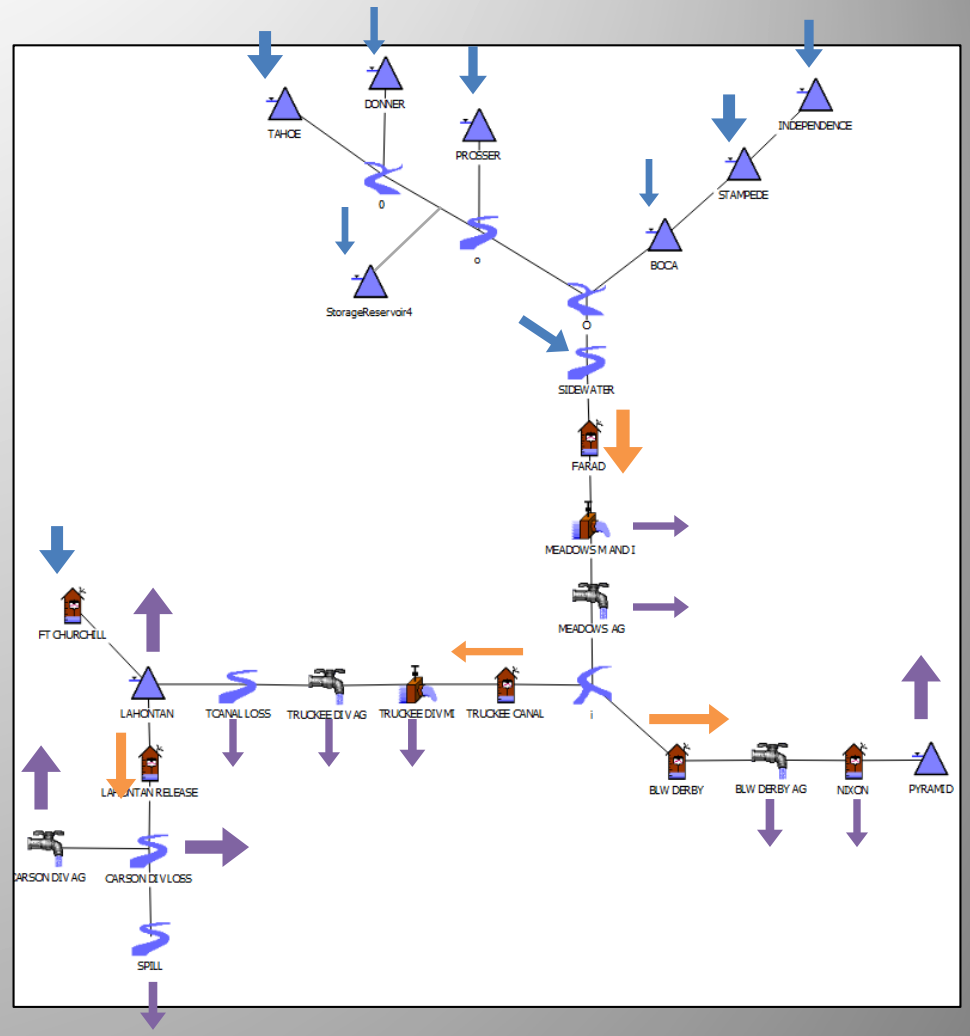
PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS

Water Balance Visualization Tool

- Simplifies the model water balance
  - Every inflow and outflow in model is included
- Visualizes the water balance
  - flows into the system
  - flows out of the system
  - flows through the system
- The balance can be viewed on a variety of time scales (annual averages, averages by month, etc.)
- Visualizes the comparison between two runs to quickly show the story of how changes propagate throughout the system

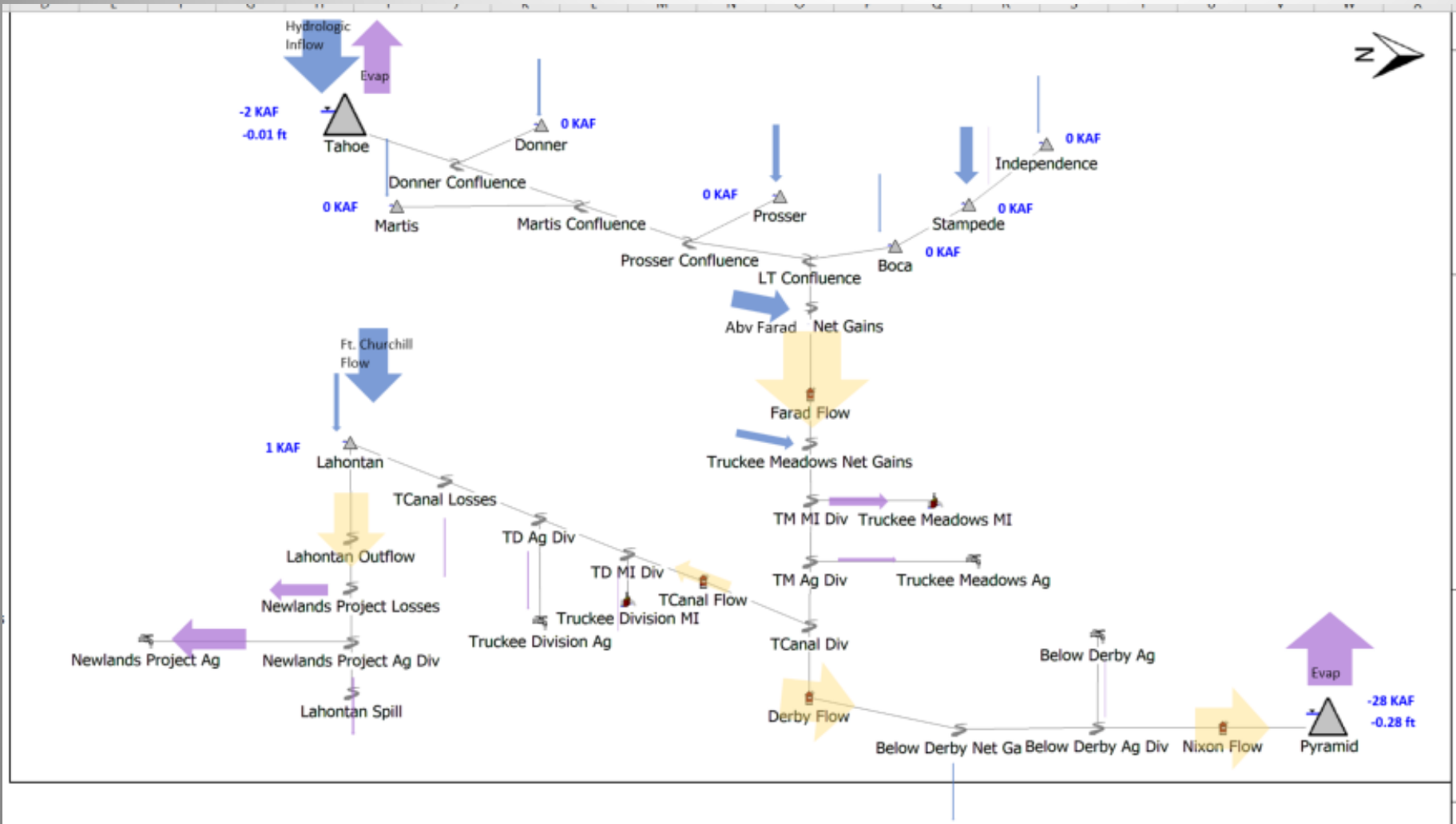




PRECISION WATER RESOURCES ENGINEERING

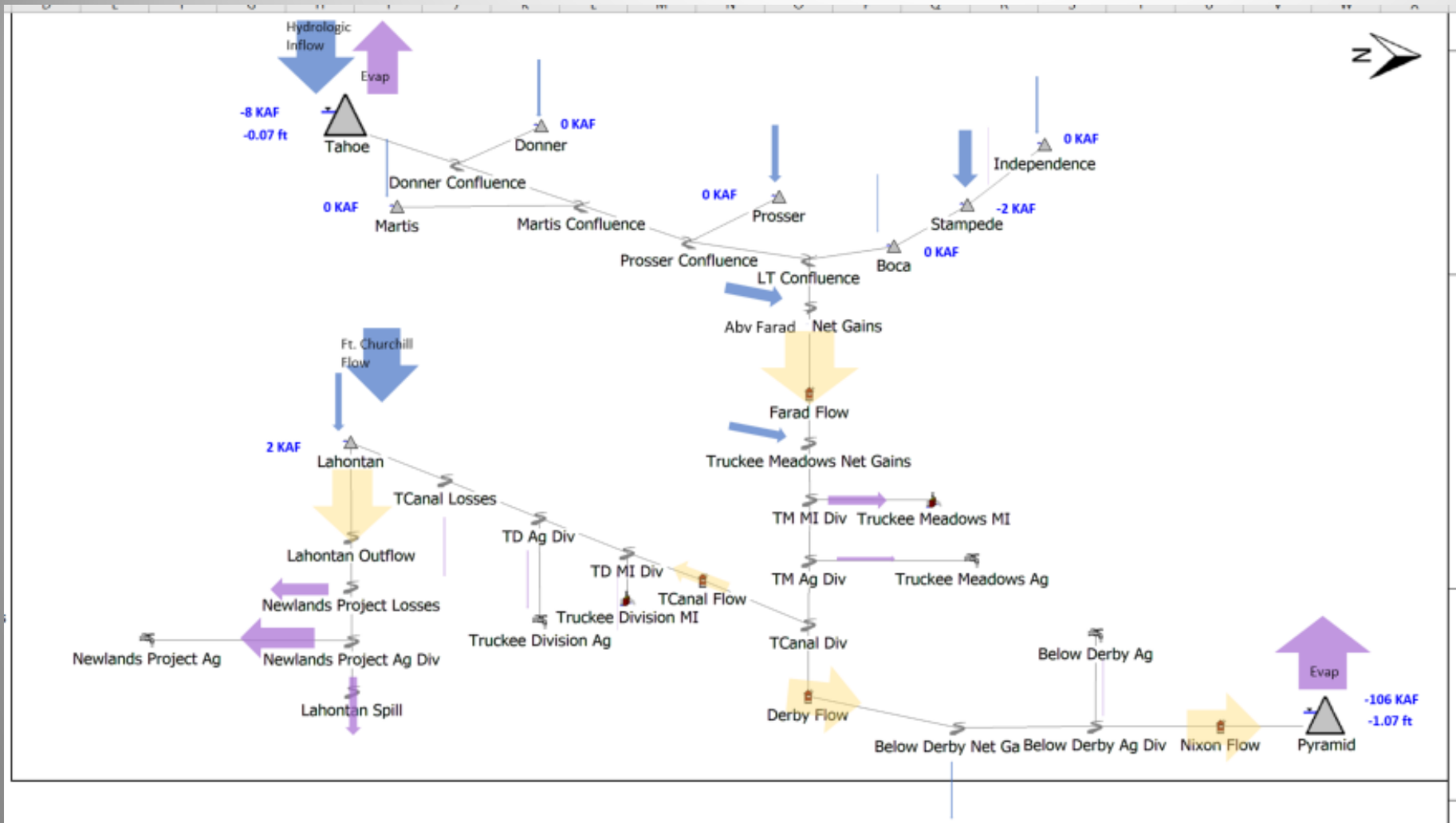
WATER For The SEASONS

Scenario 1 – Annual Average



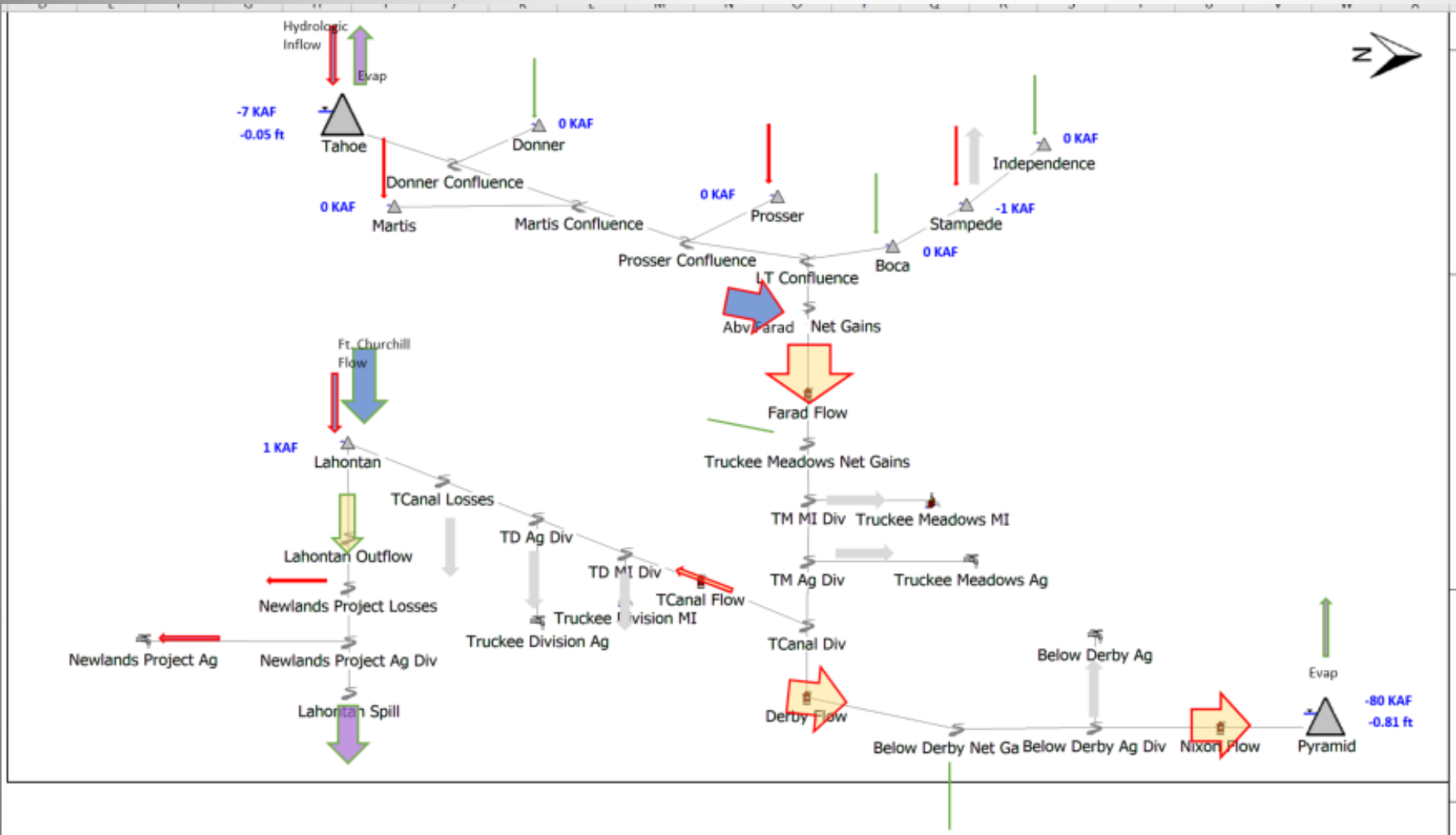
		Average Annual Values (KAF)			
		Scenario 1	Scenario 2	Magnitude of Change	% Change
Delta Storages	Tahoe	(1.52)	-8.16	-6.64	436.69%
	Stampede	-0.34	-1.58	-1.24	363.65%
	Independence	-0.05	-0.05	0.00	0.00%
	Boca	-0.19	-0.19	0.00	-0.68%
	Donner	0.00	0.00	0.00	-16.70%
	Prosser	-0.23	-0.22	0.01	-5.81%
	Martis	0.00	0.00	0.00	0.00%
	Pyramid	-28.18	-108.52	-80.34	285.06%
	Lahontan	1.03	1.67	0.64	61.70%
	Tahoe.Pool Elevatio	-0.01	-0.07	-0.05	437.88%
	Pyramid.Pool Elevat	-0.28	-1.09	-0.81	285.08%
Inflows	Donner.Hydrologic I	25.42	26.02	0.60	2.36%
	Tahoe.Hydrologic In	326.88	316.59	-10.29	-3.15%
	Independence.Hydr	16.31	17.03	0.71	4.38%
	Stampede.Hydrologi	106.96	105.80	-1.17	-1.09%
	Prosser.Hydrologic I	57.82	54.47	-3.35	-5.79%
	Martis.Hydrologic In	17.54	15.50	-2.03	-11.60%
	Boca.Hydrologic Infl	16.31	17.03	0.71	4.38%
	BlwDonner.Local Inf	24.06	24.68	0.63	2.61%
	BlwTahoe.Local Infl	65.32	65.68	0.36	0.56%
	SidewaterNetLocalIr	58.66	0.11	-58.54	-99.80%
	Farad to Derby Net	66.83	66.83	0.00	0.00%
	Below Derby Local I	12.10	12.10	0.00	0.00%
	Lahontan.Hydrologi	-38.67	-49.32	-10.65	27.55%
	Ft. Churchill	249.80	297.07	47.27	18.92%
Outflows	Tahoe Net Evap	221.80	245.80	24.00	10.82%
	Stampede Net Evap	2.03	1.58	-0.44	-21.83%
	Pyramid Net Evap	377.64	387.57	9.93	2.63%
	Truckee Division MI	3.15	2.55	-0.60	-19.01%
	Truckee Division Ag	10.60	8.35	-2.25	-21.23%
	Truckee Canal Losse	11.97	10.92	-1.05	-8.77%
	Farad to Derby Ag	28.01	28.01	0.00	0.00%
	Farad to Derby M&I	74.88	74.88	0.00	0.00%
	Below Derby Ag	7.58	7.58	0.00	0.00%
	Newlands Project Lc	98.22	94.36	-3.86	-3.93%
	Newlands Project Ag	174.62	167.76	-6.86	-3.93%
Intermediate Flo	Farad Flow	488.60	398.95	-89.64	-18.35%
	Derby Flow	345.75	276.23	-69.52	-20.11%
	Tcanal Flow	106.78	98.42	-8.36	-7.83%
	Lahontan Outflow	291.19	322.73	31.54	10.83%
	Lahontan Spill	18.34	60.61	42.26	230.44%
	Nixon Flow	354.23	285.44	-68.79	-19.42%

Scenario 2 – Annual Average



		Average Annual Values (KAF)			
		Scenario 2	Scenario 4	Magnitude of Change	% Change
Delta Storages	Tahoe	(8.16)	-8.16	0.00	0.00%
	Stampede	-1.58	-1.57	0.01	-0.49%
	Independence	-0.05	-0.05	0.00	0.00%
	Boca	-0.19	-0.20	-0.01	3.21%
	Donner	0.00	0.00	0.00	0.00%
	Prosser	-0.22	-0.22	0.00	0.00%
	Martis	0.00	0.00	0.00	0.00%
	Pyramid	-108.52	-106.41	2.12	-1.95%
	Lahontan	1.67	1.67	0.00	0.01%
	Tahoe.Pool Elevatio	-0.07	-0.07	0.00	0.00%
	Pyramid.Pool Elevat	-1.09	-1.07	0.02	-1.96%
Inflows	Donner.Hydrologic I	26.14	26.14	0.00	0.00%
	Tahoe.Hydrologic In	316.59	316.59	0.00	0.00%
	Independence.Hydr	17.03	17.02	0.00	-0.01%
	Stampede.Hydrologi	105.80	105.80	0.00	0.00%
	Prosser.Hydrologic I	54.47	54.47	0.00	0.00%
	Martis.Hydrologic In	15.50	15.50	0.00	0.00%
	Boca.Hydrologic Infl	10.39	10.38	-0.01	-0.06%
	BlwDonner.Local Inf	24.68	24.68	0.00	0.00%
	BlwTahoe.Local Infl	65.68	65.68	0.00	0.00%
	SidewaterNetLocalIr	0.11	0.11	0.00	-0.09%
	Farad to Derby Net	66.83	66.83	0.00	0.00%
	Below Derby Local I	12.10	12.10	0.00	0.00%
	Lahontan.Hydrologi	-49.32	-49.88	-0.56	-1.14%
	Ft. Churchill	297.07	302.56	5.49	1.85%
Outflows	Tahoe Net Evap	245.80	245.80	0.00	0.00%
	Stampede Net Evap	1.58	1.60	0.02	0.98%
	Pyramid Net Evap	387.57	387.94	0.37	0.10%
	Truckee Division MI	2.55	2.56	0.01	0.27%
	Truckee Division Ag	8.35	8.37	0.02	0.22%
	Truckee Canal Losse	10.92	10.67	-0.25	-2.26%
	Farad to Derby Ag	28.01	28.01	0.00	0.00%
	Farad to Derby M&I	74.88	74.88	0.00	0.00%
	Below Derby Ag	7.58	7.58	0.00	0.00%
	Newlands Project Lc	94.36	94.88	0.51	0.54%
	Newlands Project Ag	167.76	168.67	0.91	0.54%
Intermediate Fl	Farad Flow	398.95	398.93	-0.03	-0.01%
	Derby Flow	276.23	278.65	2.42	0.88%
	Tcanal Flow	98.42	95.75	-2.67	-2.71%
	Lahontan Outflow	322.73	325.21	2.48	0.77%
	Lahontan Spill	60.61	61.66	1.06	1.75%
	Nixon Flow	285.44	287.86	2.42	0.85%

Scenario 1 vs 2 – Annual Average



		Average Annual Values (KAF)			
		Scenario 1	Scenario 2	Magnitude of Change	% Change
Delta Storages	Tahoe	(1.52)	-8.16	-6.64	436.69%
	Stampede	-0.34	-1.58	-1.24	363.65%
	Independence	-0.05	-0.05	0.00	0.00%
	Boca	-0.19	-0.19	0.00	-0.68%
	Donner	0.00	0.00	0.00	-16.70%
	Prosser	-0.23	-0.22	0.01	-5.81%
	Martis	0.00	0.00	0.00	0.00%
	Pyramid	-28.18	-108.52	-80.34	285.06%
	Lahontan	1.03	1.67	0.64	61.70%
	Tahoe.Pool Elevatio	-0.01	-0.07	-0.05	437.88%
	Pyramid.Pool Elevat	-0.28	-1.09	-0.81	285.08%
Inflows	Donner.Hydrologic I	25.42	26.02	0.60	2.36%
	Tahoe.Hydrologic In	326.88	316.59	-10.29	-3.15%
	Independence.Hydr	16.31	17.03	0.71	4.38%
	Stampede.Hydrologi	106.96	105.80	-1.17	-1.09%
	Prosser.Hydrologic I	57.82	54.47	-3.35	-5.79%
	Martis.Hydrologic In	17.54	15.50	-2.03	-11.60%
	Boca.Hydrologic Infl	16.31	17.03	0.71	4.38%
	BlwDonner.Local Inf	24.06	24.68	0.63	2.61%
	BlwTahoe.Local Infl	65.32	65.68	0.36	0.56%
	SidewaterNetLocalIr	58.66	0.11	-58.54	-99.80%
	Farad to Derby Net I	66.83	66.83	0.00	0.00%
	Below Derby Local I	12.10	12.10	0.00	0.00%
	Lahontan.Hydrologi	-38.67	-49.32	-10.65	27.55%
	Ft. Churchill	249.80	297.07	47.27	18.92%
Outflows	Tahoe Net Evap	221.80	245.80	24.00	10.82%
	Stampede Net Evap	2.03	1.58	-0.44	-21.83%
	Pyramid Net Evap	377.64	387.57	9.93	2.63%
	Truckee Division MI	3.15	2.55	-0.60	-19.01%
	Truckee Division Ag	10.60	8.35	-2.25	-21.23%
	Truckee Canal Losse	11.97	10.92	-1.05	-8.77%
	Farad to Derby Ag	28.01	28.01	0.00	0.00%
	Farad to Derby M&I	74.88	74.88	0.00	0.00%
	Below Derby Ag	7.58	7.58	0.00	0.00%
	Newlands Project Lc	98.22	94.36	-3.86	-3.93%
	Newlands Project Ag	174.62	167.76	-6.86	-3.93%
Intermediate Fl	Farad Flow	488.60	398.95	-89.64	-18.35%
	Derby Flow	345.75	276.23	-69.52	-20.11%
	Tcanal Flow	106.78	98.42	-8.36	-7.83%
	Lahontan Outflow	291.19	322.73	31.54	10.83%
	Lahontan Spill	18.34	60.61	42.26	230.44%
	Nixon Flow	354.23	285.44	-68.79	-19.42%

Questions?

PRECISION WATER RESOURCES ENGINEERING

WATER For The SEASONS