Colorado Basin River Forecast Center (CBRFC) Overview

Kevin Werner

NWS Colorado Basin River Forecast Center

MWD
May 8, 2012

Outline

Colorado River Overview

2011 vs 2012

CBRFC Forecasts and Services

Who we are…

Mission: To understand and predict changes in the Earth's environment … to meet our Nation's economic, social, and environmental needs

Mission: The NWS provides weather, hydrologic, and climate forecasts and warnings … for the protection of life and property and the enhancement of the national economy

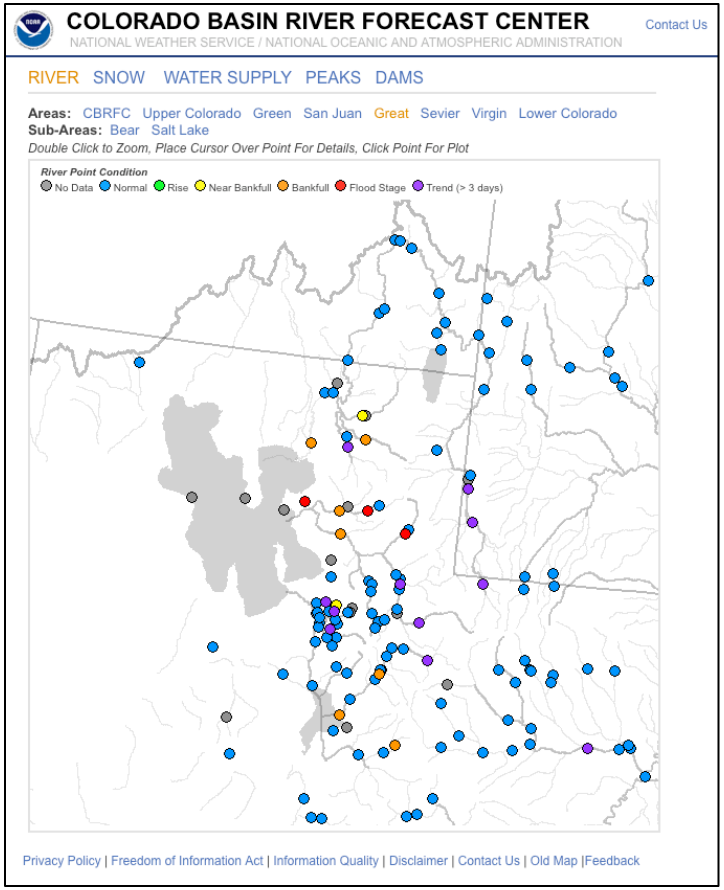
The Colorado Basin River Forecast Center generates streamflow forecasts and related datasets for the Colorado and eastern Great Basins

Colorado Basin River Forecast Center

The Colorado Basin River Forecast Center (CBRFC) generates streamflow forecasts across the Colorado Basin and Utah. The latest forecasts, data, and more are available online:

- **Daily streamflow forecasts**
- **Long lead peak flow forecasts**
- **Water supply forecasts**
- **Webinar briefings**
- **Email updates**
- **And More….**

www.cbrfc.noaa.gov



Why the Colorado River Stopped Flowing -All Things Considered, July 14, 2011

Colorado River

- 25 million people in US rely on Colorado River water
- 3.5 million acres of irrigation in US
- 85% of runoff comes from above 9000 feet
- Total mean annual flow is 15 MAF
- Storage capacity is about 60 MAF (4 times mean annual flow)
- River is fully used and little flows to ocean

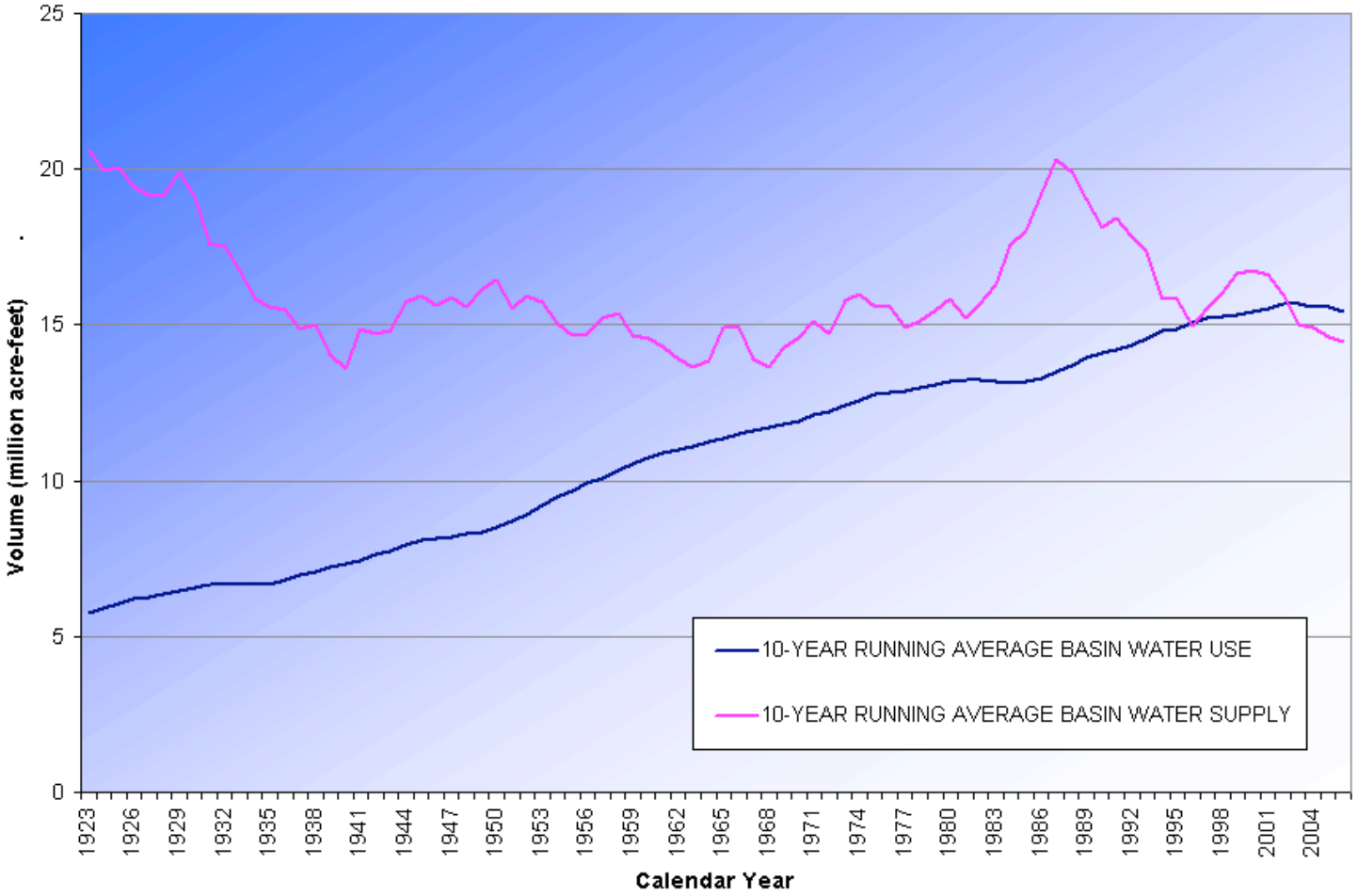
Upper Basin

- Distribution of Average Runoff in Lake Powell:
  - ½ Upper Colorado including Gunnison, Dolores
  - 1/3 Green River including Yampa, Duchesne
  - 1/6 San Juan River

Colorado River Allocation

- Colorado Compact (1922) divided water between the upper basin and lower basin – 7.5 MAF each
- Mexican Water Treaty (1944) allocated Mexico 1.5 MAF
- Arizona v. California (1964) allocated water among lower basin states
- Interim Guidelines (2007) specify shortages and surpluses through 2026 that are tied to forecasts
- Key facts:
  - River is over-allocated: original allocation (16.5 MAF) was based on a series of wet years. Actual average flow is ~15 MAF
  - Lower basin states (AZ, CA, NV) use full 7.5 MAF each year
  - Mexico uses its full 1.5 MAF
  - Upper basin states (CO, WY, UT, NM) are still “developing” their 7.5 MAF
  - No shortage has ever been declared on the river
  - Shortages would affect lower basin states first (and AZ first of all)

Long Term Supply / Demand



Interim Operating Guidelines

- Guidelines specify how shortages and surpluses will be distributed among the basin states
- USBR directed to operate reservoirs based, to a large extent, on CBRFC/NRCS official forecasts
- Most years 8.23 MAF released from Lake Powell to Lake Mead
- In wet years when Lake Mead is low (such as 2011), “extra” water can be released. This is called equalization and/or balancing.

Lake Powell

Elevation (feet)	Opertaions According to Interim Guidelines	Live Storage (MAF)
3,700	**Equalization Tier** Equalize, Avoid Spills or Release 8.23 MAF	24.3
3,636 - 3,666 (2008-2026)		15.5 - 19.3 (2008-2026)
	Upper Elevation Balancing Tier[1] Release 8.23 MAF; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 MAF	
3,575		9.5
	Mid-Elevation Release Tier Release 7.48 MAF; if Lake Mead < 1,025 feet, Release 8.23 MAF;	
3,525		5.9
3,490	**Lower Elevation Balancing Tier** Balance contents with a min/max release of 7.0 and 9.5 MAF	
3,370		

15.5 MAF
3,636
4/1/2012

Lake Mead

Elevation (feet)	Opertaions According to Interim Guidelines	Live Storage (MAF)
1,220	Flood Control, 70R or ICS Surplus	25.9
1,200		22.9
	Domestic or ICS Surplus	
1,145		15.9
1,105	Normal Operations or ICS Surplus	11.9
1,075		9.4
	Shortage 333 KAF[2]	
1,050		7.5
	Shortage 417 KAF[2]	
1,025		5.8
	Shortage 500 KAF[2] and Consultation[3]	
1,000		4.3
895		0

14.5 MAF
1,129
4/1/2012

Value

Damage from 1/10 AZ storm:	$11m[a]
Damage from 6/10 UT flooding:	$6.5m[a]
Damage from 12/10 UT/NV storm:	$35m[a]
Damage from spring 2011 UT/CO/WY flooding:	<$200m

Colorado River average runoff: 12.4 MAF

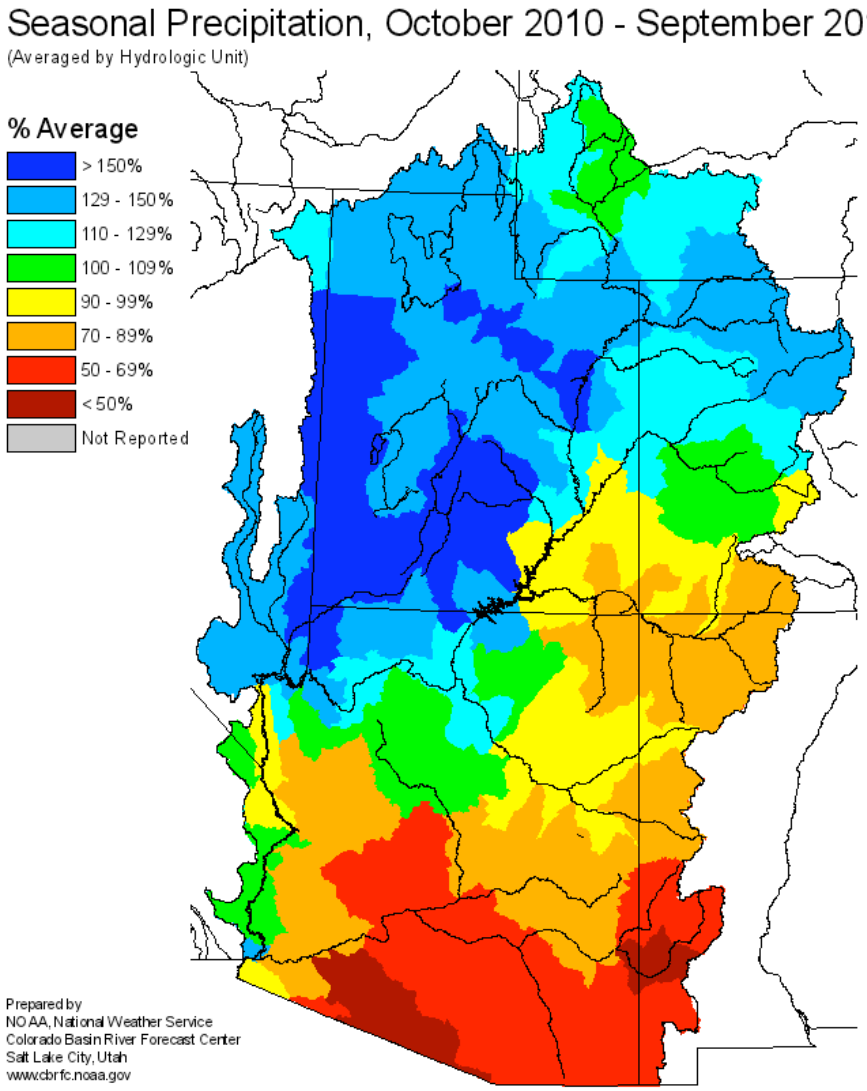
Replacement value of $330/AF -> $4b[b]

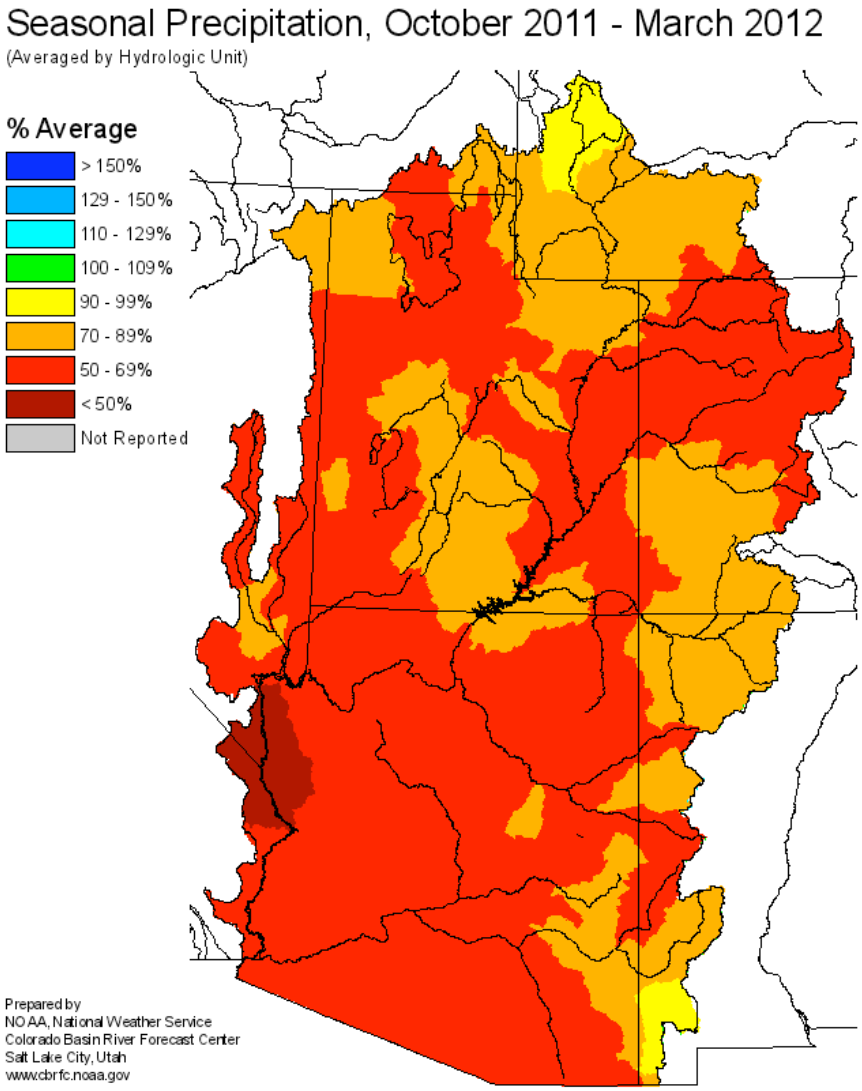
**Economic value of water resources far greater than flooding damages

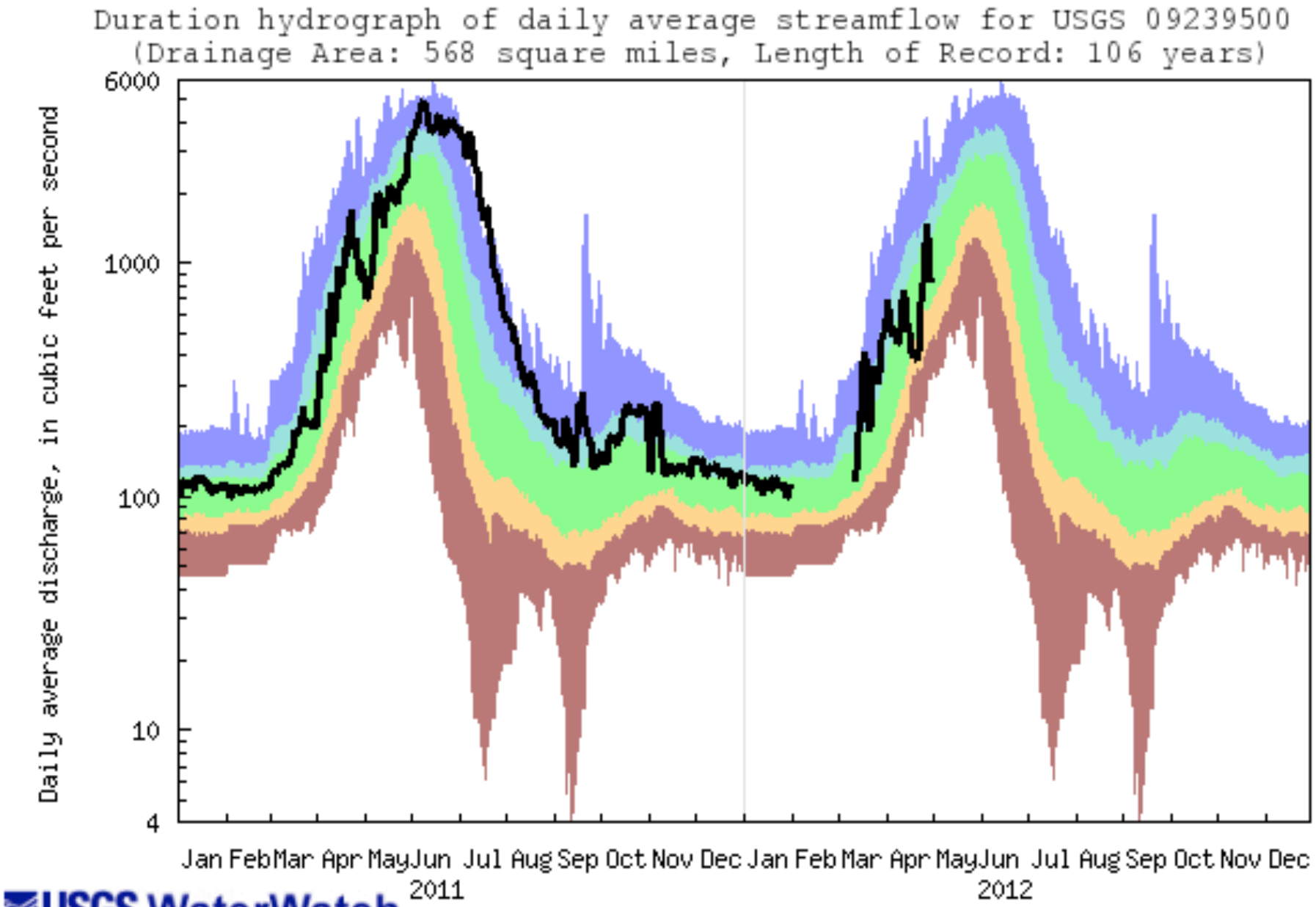
Sources:

a: WFO, FEMA (via stormdata); b: MWD (via Hasencamp, private communication

2011 vs 2012: Both Extremes






Duration hydrograph of daily average streamflow for USGS 09239500
(Drainage Area: 568 square miles, Length of Record: 106 years)
Daily average discharge, in cubic feet per second
6000
1000
100
10
4
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2011
2012
USGS WaterWatch
Last updated: 2012-05-01

Late 2010

October 18, 2010, 2:05 PM

Lake Mead Hits Record Low Level

By FELICITY BARRINGER

Jim Wilson/The New York Times

Bleached rock indicating a former high-water mark on outcroppings surrounding Lake Mead.

Living

Sometime between 11 and noon on Sunday, the water level in Lake Mead, the massive reservoir whose water fills the taps of millions of people across the Southwest, fell lower than it ever has since it was filled 75 years ago.

The New York Times

LAS VEGAS REVIEW-JOURNAL

Drought-stricken Lake Mead falls to a level not seen since 1937

K.M. CANNON/LAS VEGAS REVIEW-JOURNAL

An aerial photo taken Saturday shows the marina operations in Lake Mead's Hemenway Harbor, just down the hill from Boulder City. All of the docks shown used to be located elsewhere but had to be moved to their present locations because of the reservoir's falling water level. » Buy this photo

BY HENRY BREAN
LAS VEGAS REVIEW-JOURNAL

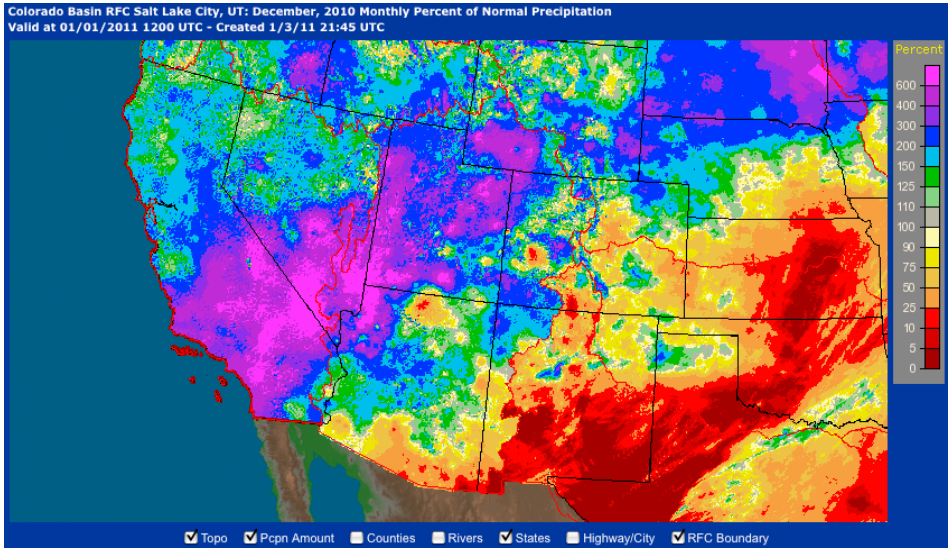
Posted: Oct. 19, 2010 | 12:00 a.m.
Updated: Oct. 19, 2010 | 7:17 a.m.

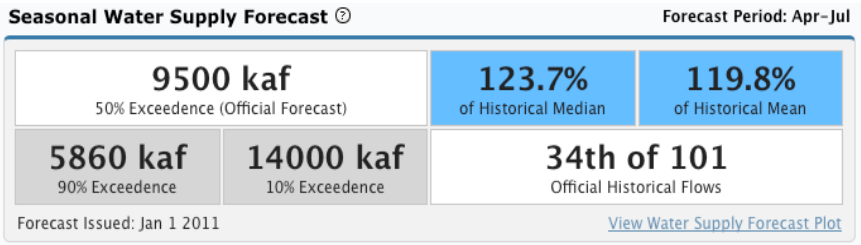
Oddly, the drought's latest milestone arrived on a rainy day.

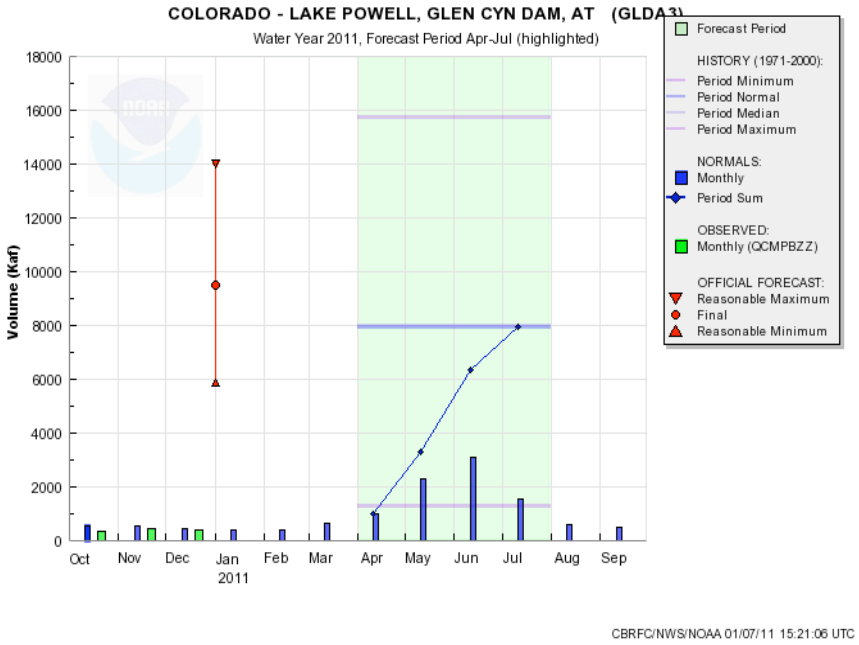
Tools

183 Like 28 Tweet Email Print Share

Early 2011







Pre Holiday Storm:

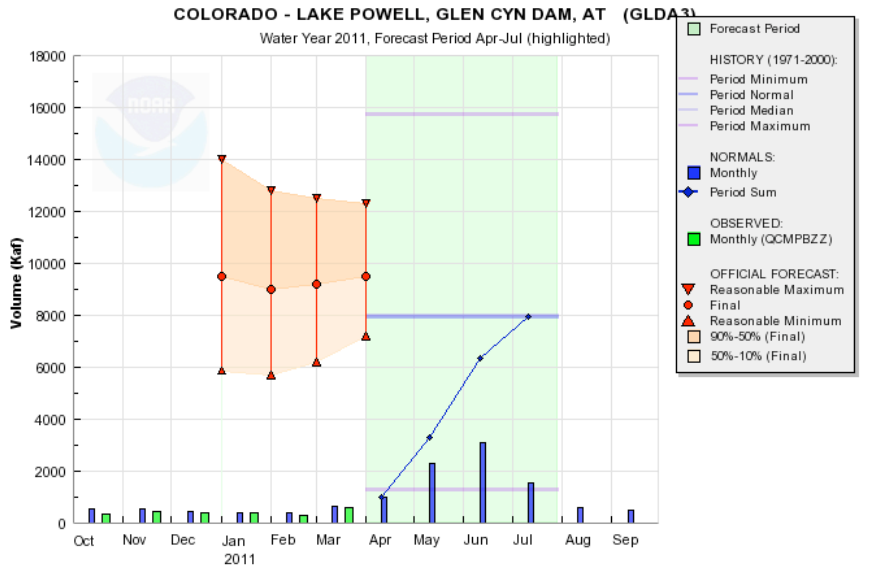
- Lake Mead up ~2 feet from local runoff
- Large snow accumulation
- Forecasts reflected that….

Irrational Exuberance?

Seasonal Water Supply Forecast ⓘ — **Forecast Period: Apr–Jul**

9500 kaf 50% Exceedence (Official Forecast)	**123.7%** of Historical Median	**119.8%** of Historical Mean
7200 kaf 90% Exceedence	**12300 kaf** 10% Exceedence	**34th of 102** Official Historical Flows

Forecast Issued: Apr 1 2011 — View Water Supply Forecast Plot

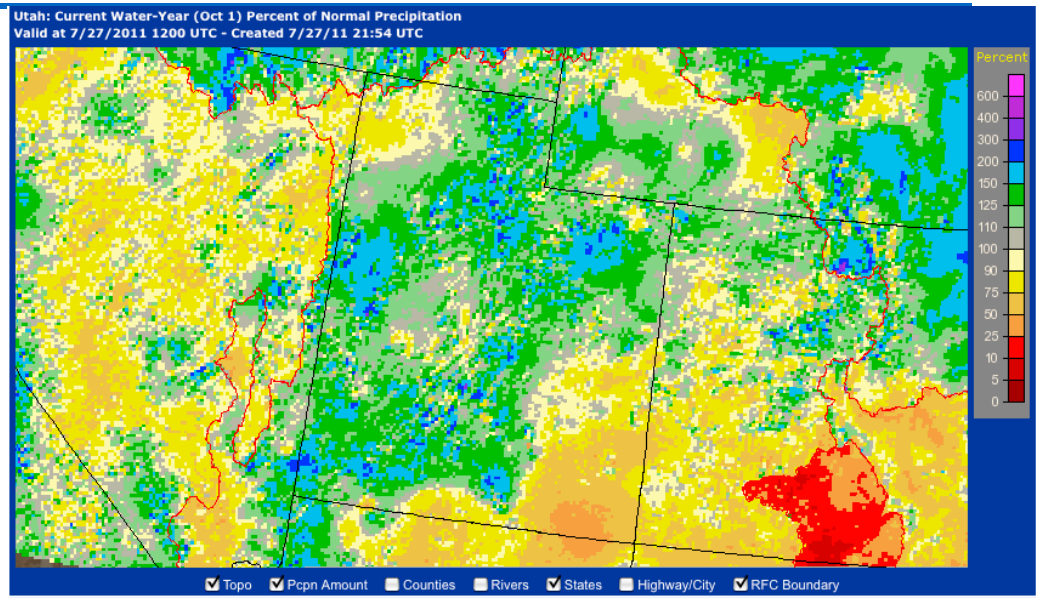


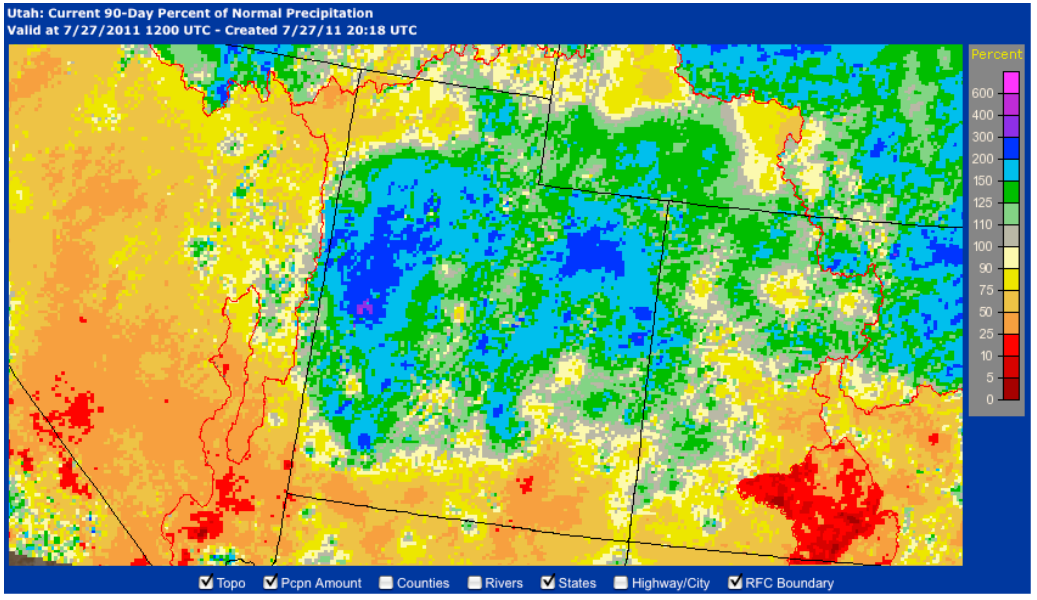
CBRFC/NWS/NOAA 04/07/11 00:16:40 UTC

Web Reference: www.cbrfc.noaa.gov/gmap/gmapm.php?wcon=checked

Spring 2011

- Winter and Spring 2011 were much wetter than normal for most of Utah – especially the months of March/April/May
- Spring was very cold across Utah
- Snowpack accumulated to record or near record amounts at most SNOTEL sites
- Snow melt was delayed – and largely tempered by cool May/ June weather
- Flood did occur in low elevation basins (May/June) and high elevation basins (late June/July)





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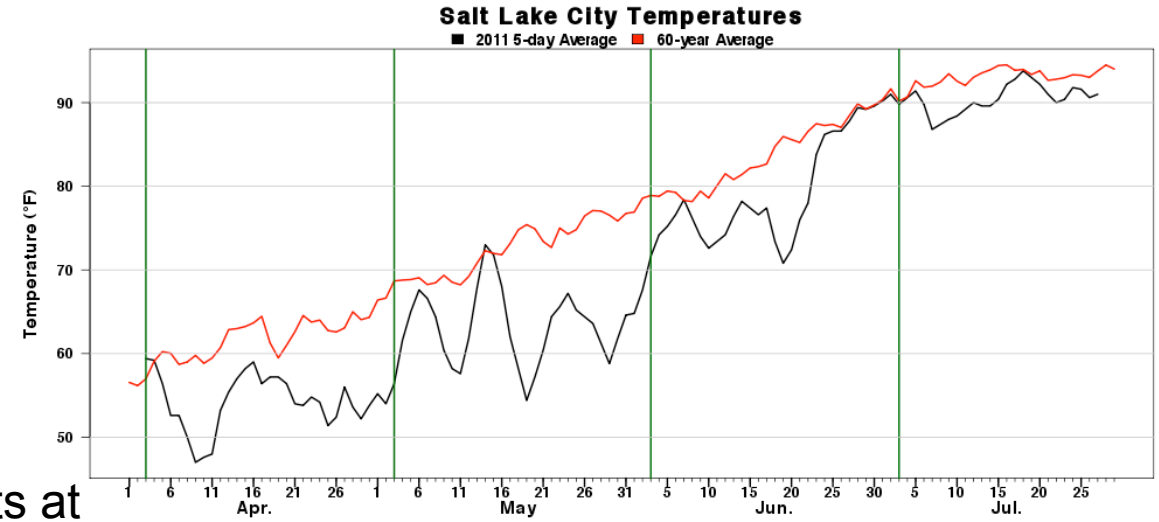

Number of Days Below 60-yr Average (April 1 – July 29)

Year	Number of Days Below Normal	Standard Deviation of Below Normal Days
2011		
1998		
1995		
1983		
1953		
1999		
1991		
1975		
1993		
1982		
2010		
1965		

Spring 2011

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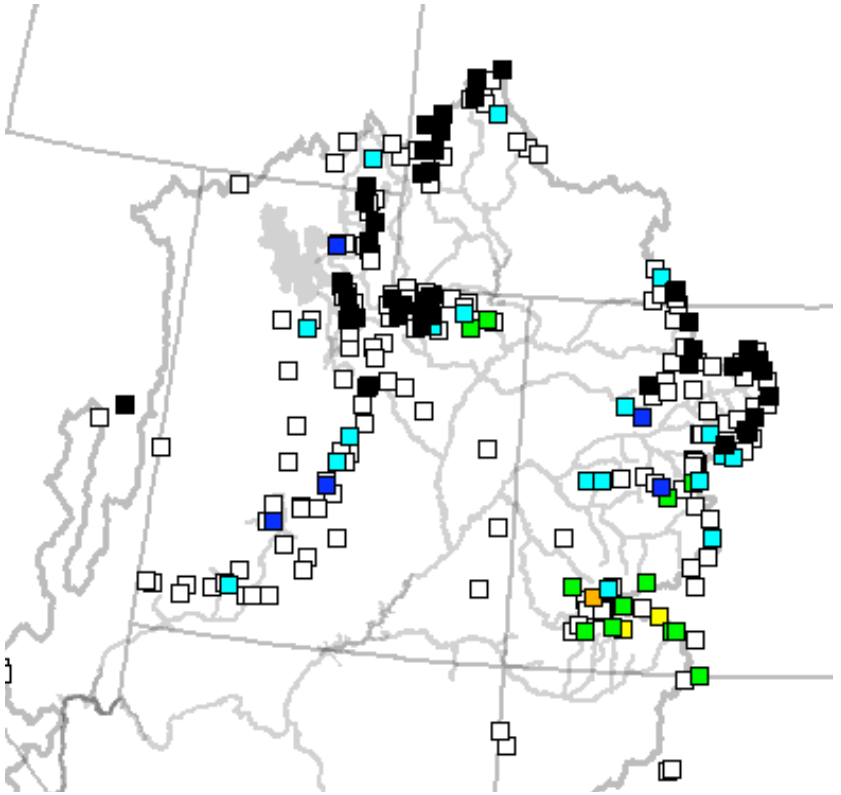


Flooding and High Flows

denverpost.com

Yampa River remains steady at Steamboat Springs; flood stage hits Monday

BOOKMARK PRINT EMAIL 0 COMMENTS

By Matt Stensland
Steamboat Pilot

POSTED: 06/02/2011 11:09:02 AM MDT
UPDATED: 06/02/2011 11:10:57 AM MDT

Recommend One person recommends this.

The height of the Yampa River remained steady overnight through Steamboat Springs, but it's expected to rise during the course of the day today and peak at about 7 feet tonight at the Fifth Street bridge measuring site, according to the National Weather Service in Grand Junction.

The Yampa River flows by Fish Creek Mobile Home Park on Thursday morning. Sandbags line the banks. (STEAMBOAT TODAY | Matt Stensland)

A similar trend is expected to continue into Monday, with the forecast calling for high temperatures in the 70s.

The Yampa is forecast to reach 7.7 feet at Fifth Street by 6 a.m. Monday. The flood stage at that location is 7.5 feet. The third highest recorded height at that location is 7.65 feet, set on June 3, 1997. The record crest was June 8, 1905, when the river reached 8.9 feet. A year ago the Yampa peaked at 6.72 feet on June 7.

11NEWS

Colorado River still running high, causing flooding in some areas

Parts of the Colorado River are still swollen, overflowing it's banks in some spots.

Posted: 8:45 AM Jun 9, 2011
Reporter: Cecile Juliette
Email Address: cecile.juliette@nbc11news.com

Story | 0 Comments

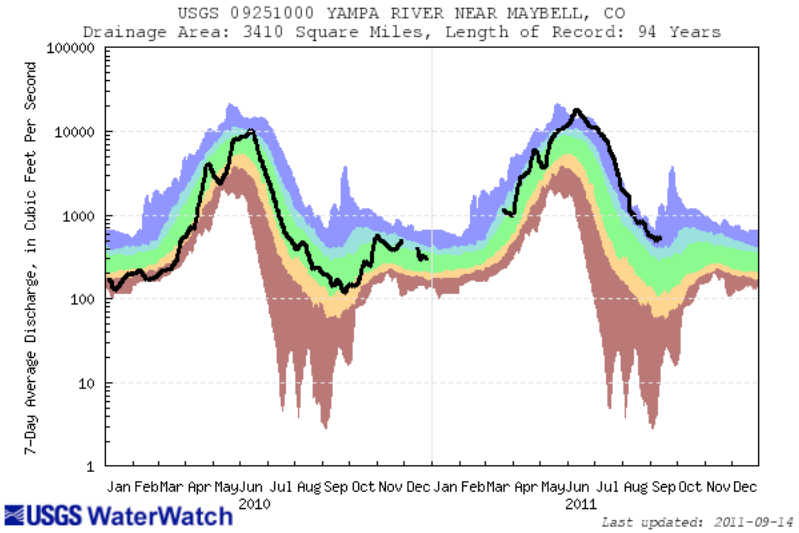
Font Size: A A A

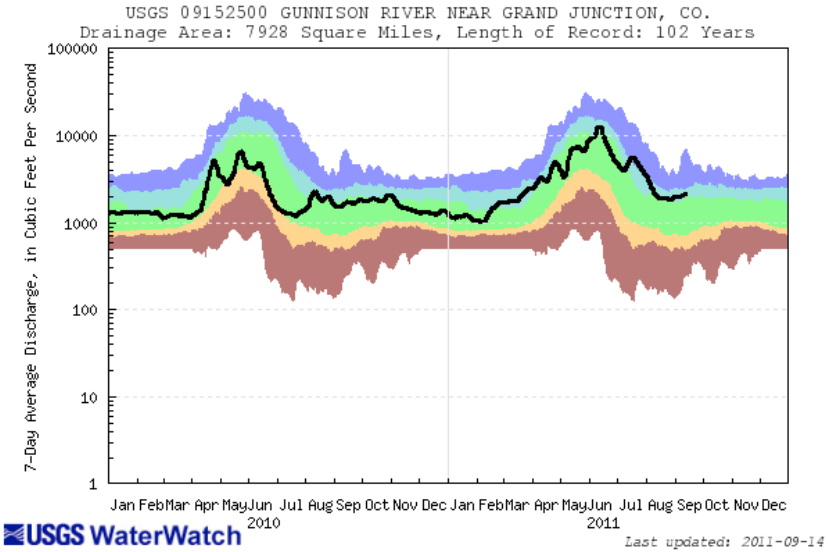
MESA COUNTY, Colo. (KKCO) - The Colorado River is still cresting in parts of Mesa County, according to the National Weather Service.

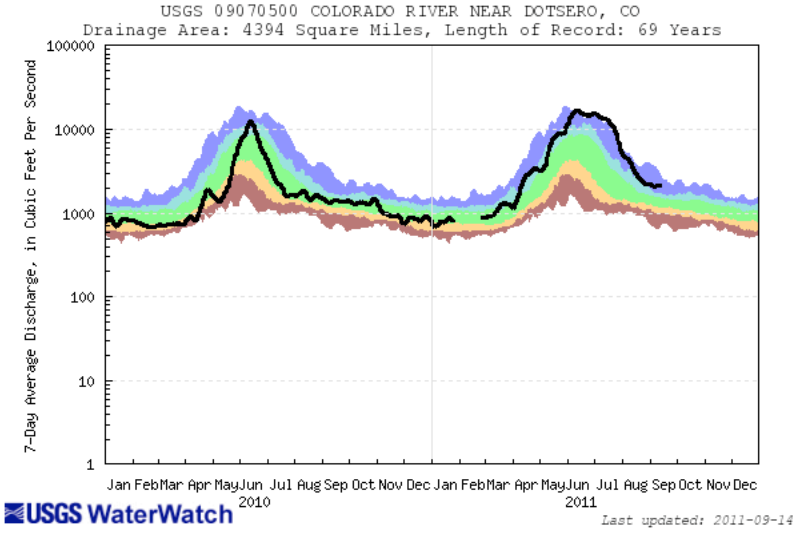
An early morning check of the Cameo gauge on Thursday revealed that the Colorado River had receded slightly. On Wednesday it was recorded at 13.4 feet, and on Thursday it measured 13.1 feet.

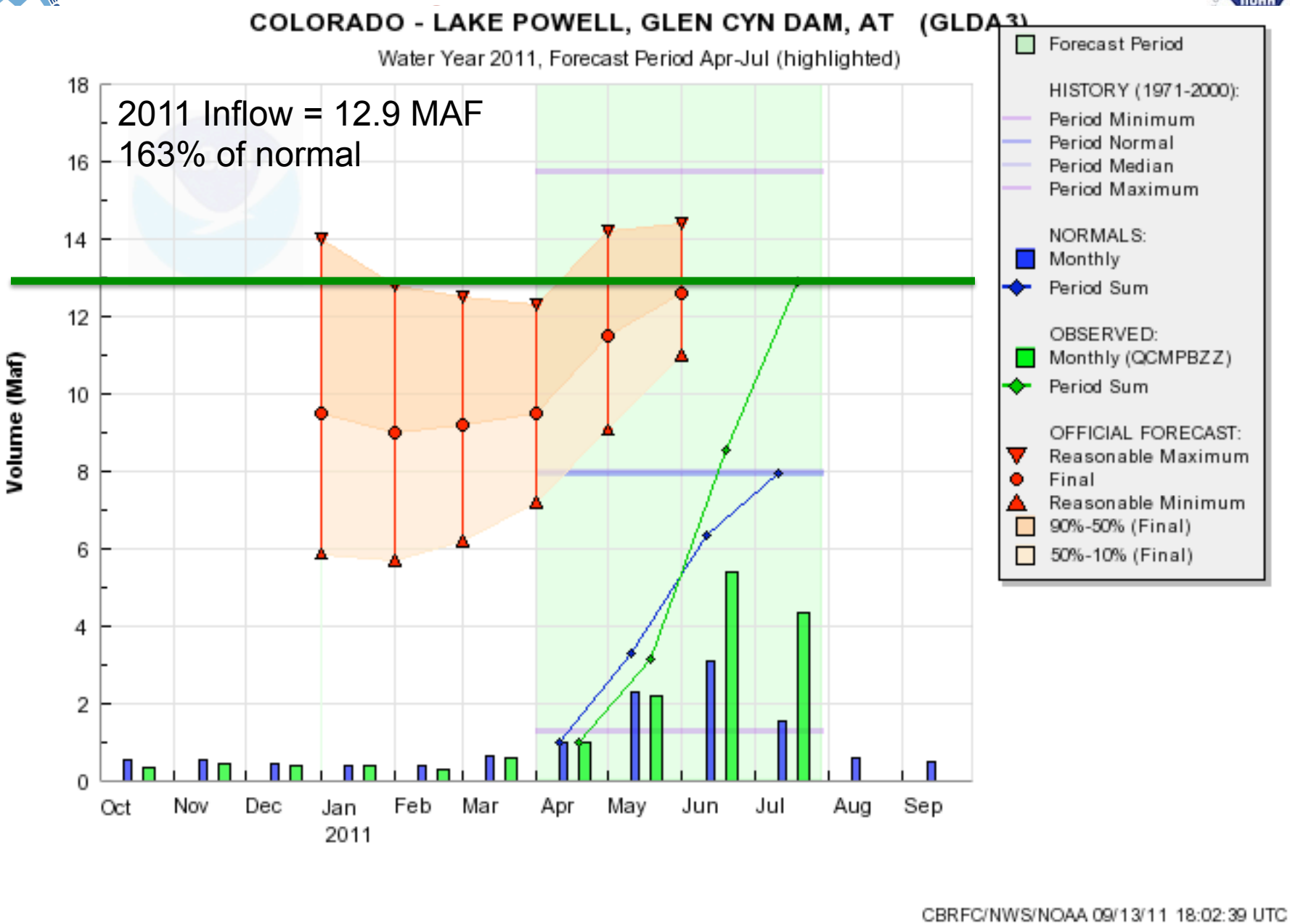
Flooding and High Flows

- Wettest area was northern Colorado
- Upper Colorado also quite wet
- Gunnison divided web from normal
- Dolores, San Juan basins nearer normal







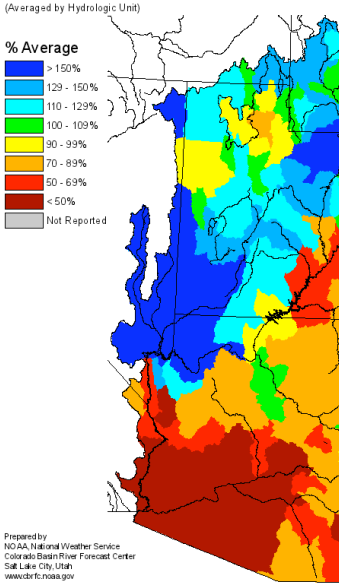


CBRFC/NWS/NOAA 09/13/11 18:02:39 UTC

2012

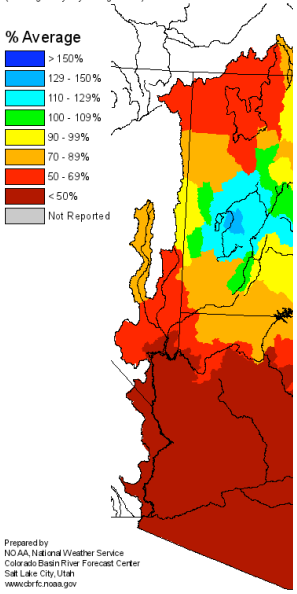
Seasonal Precipitation, October 2011 - April 2012

(Averaged by Hydrologic Unit)



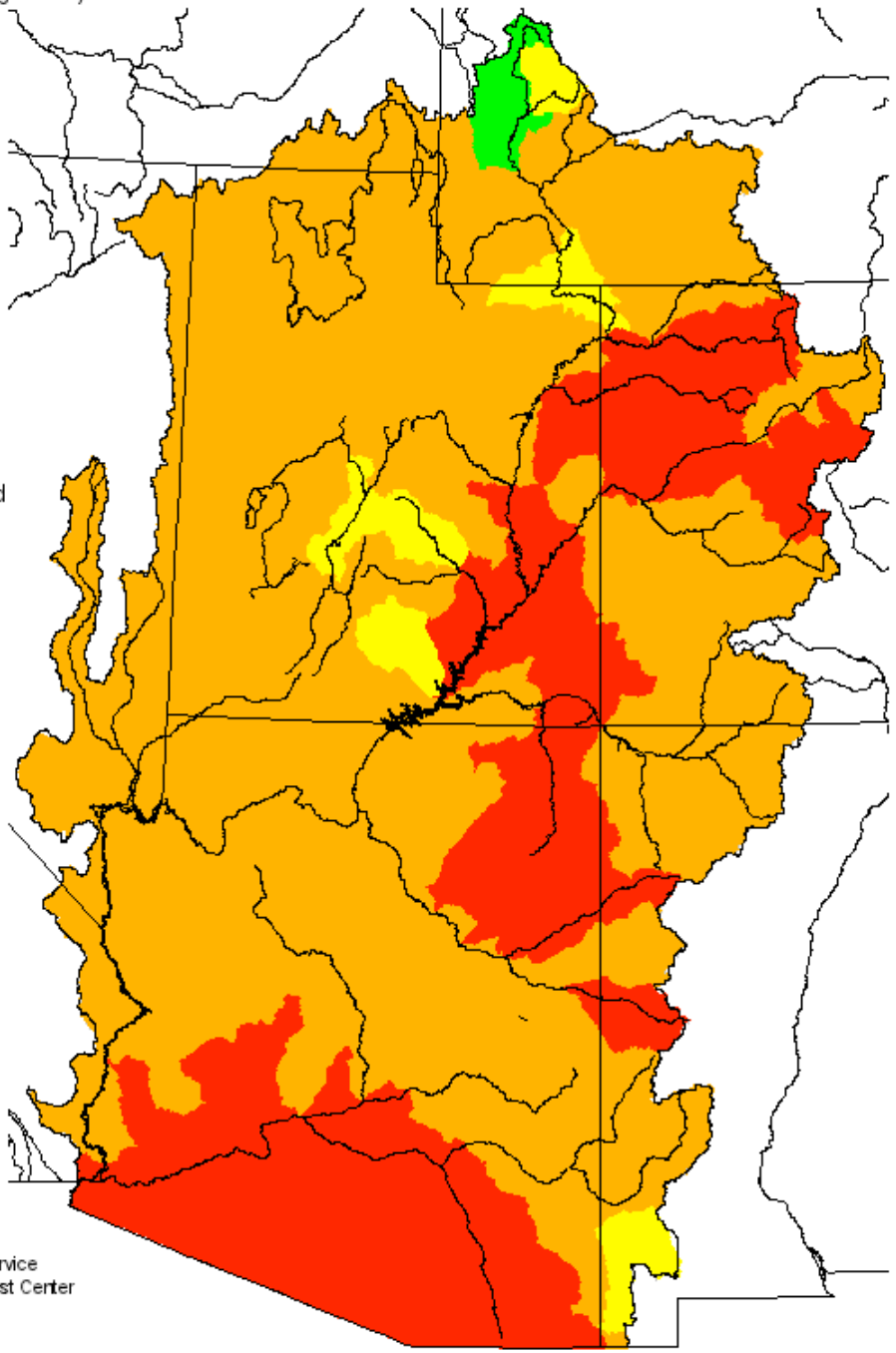
Monthly Precipitation for October 201

(Averaged by Hydrologic Unit)



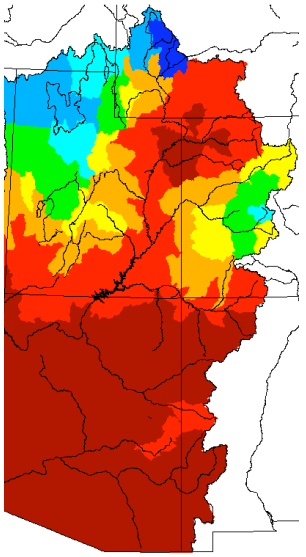
Monthly Precipitation for Februa

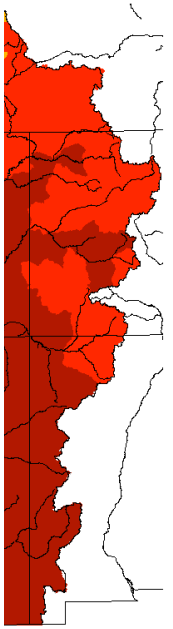
(Averaged by Hydrologic Unit)



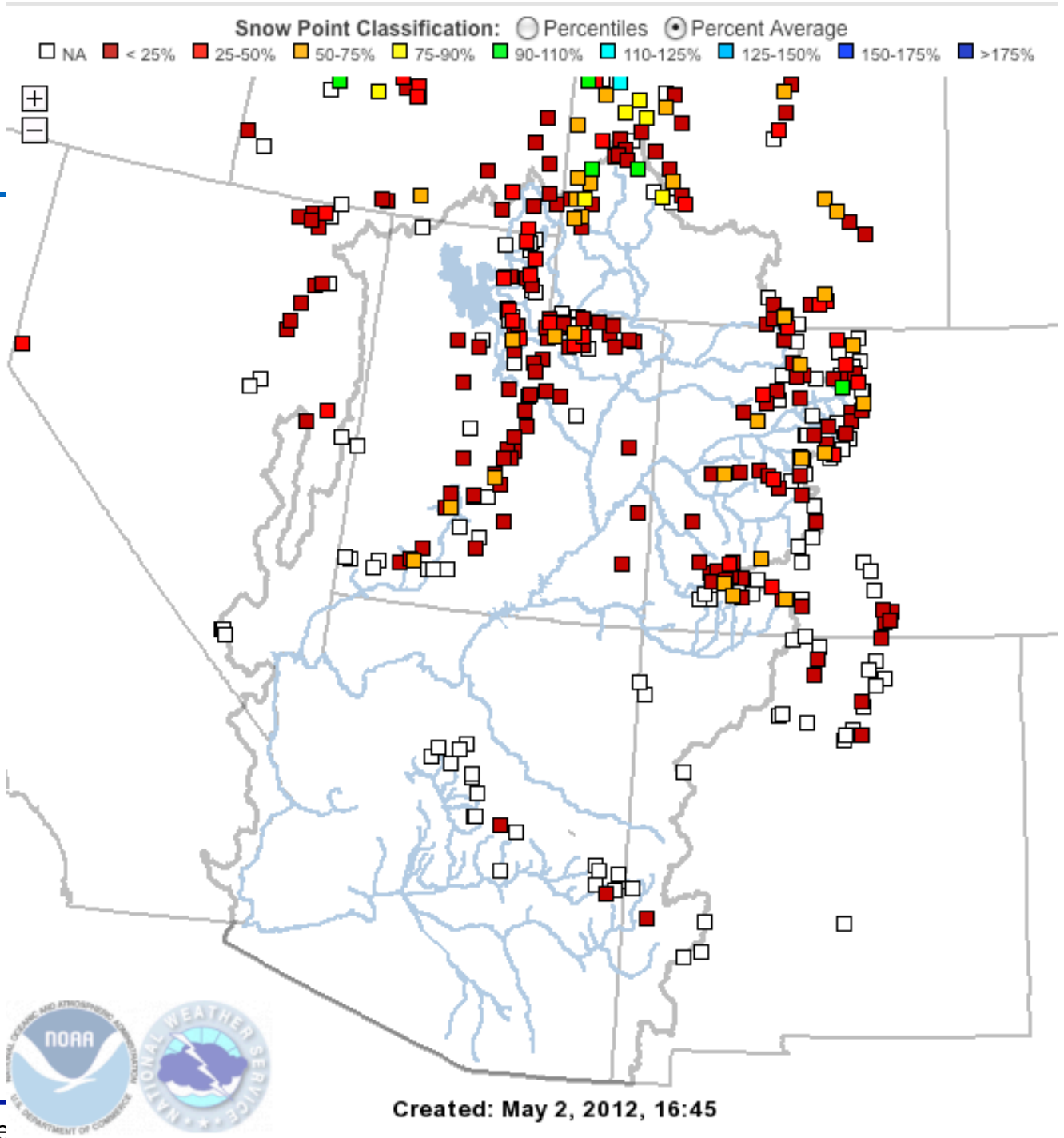
Prepared by
NOAA, National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
www.cbrfc.noaa.gov

on for January 2012





Snow



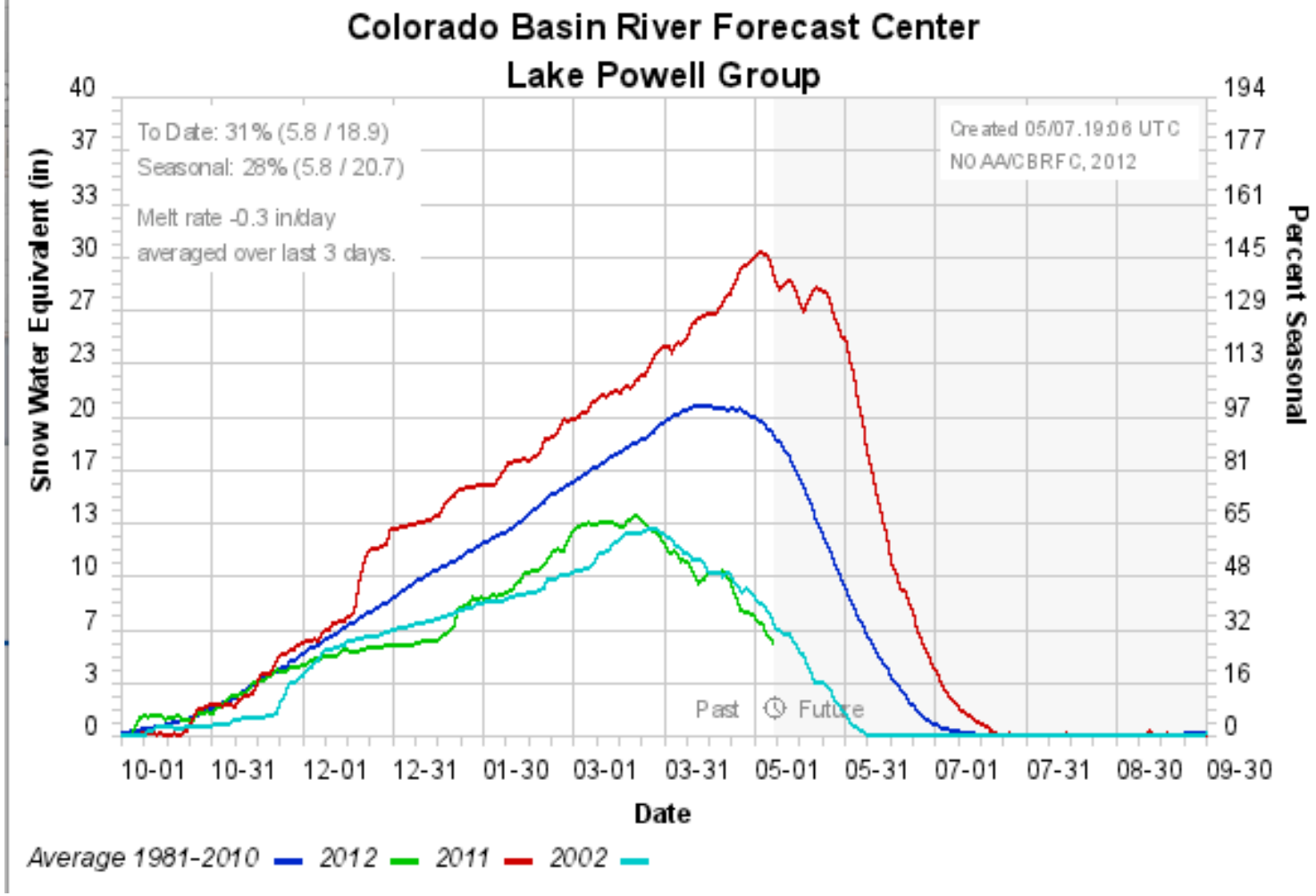
Web Reference

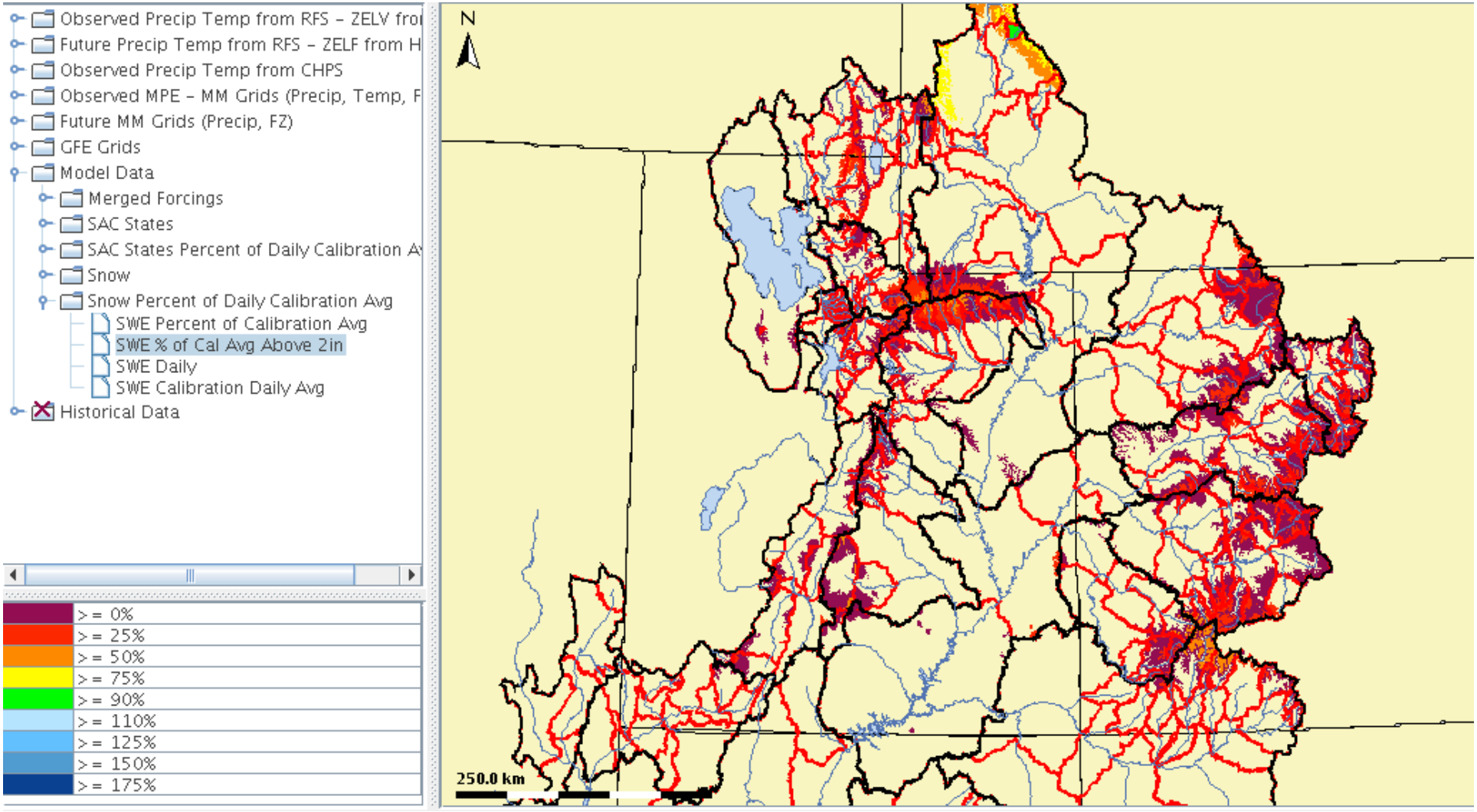
Snow

Lake Powell Snotel Group

View station in google maps or google earth

The current time is: 05/07.19:06 UTC




Observed Precip Temp from RFS – ZELV fro
Future Precip Temp from RFS – ZELF from H
Observed Precip Temp from CHPS
Observed MPE – MM Grids (Precip, Temp, F
Future MM Grids (Precip, FZ)
GFE Grids
Model Data
Merged Forcings
SAC States
SAC States Percent of Daily Calibration A
Snow
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Historical Data
>= 0%
>= 25%
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>= 110%
>= 125%
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2012

Tuesday, May 1st 41° F | 7-day forecast Contribute | Steal The Deal | Advertise | Place a Classified Ad |

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Drought: Will there be a call on the Colorado River?

Send us your news

Saturday, April 28, 2012

By Janice Kurbjun
Summit Daily News

Email Print

ENLARGE

The reduction in water levels due to drought on Lake Mead can be seen by the white ring around the shore at Hoover Dam in this Friday, July 21, 2006 file photo in Boulder City, Nev.
APfile photo

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Bloomberg Businessweek

Global Economics | Companies & Industries | Politics & Policy | Technology | Markets & Finance | Innovation | Lifestyle

THE ASSOCIATED PRESS April 24, 2012, 11:34AM ET text size: T | T

Colorado gearing up for possible summer drought

DENVER

Colorado is preparing to tap a law that allows a water trust to lease water from willing water users to preserve wildlife and plants.

The Natural Resources Conservation Service is warning stream flows are likely to be low across the state this summer.

The law was passed in 2003 to protect waterfowl, wildlife, fish, bugs and plants.

The Colorado snowpack is down to 35 percent of the statewide average, as of Monday. The North Platte and South Platte basins in northern Colorado were in the best shape, at 48 percent of average.

MORE FROM BUSINESSWEEK

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Indicated Dividend Yield Rankings of S&P 500 Companies

S&P 500 Analyst Estimate Revisions for April 30

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WEEKLY AD SPECIALS FROM THE DENVER POST

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STORY STAT

Rafting Colorado rivers not so wild in 2012: Water levels could be just right for first-timers, families

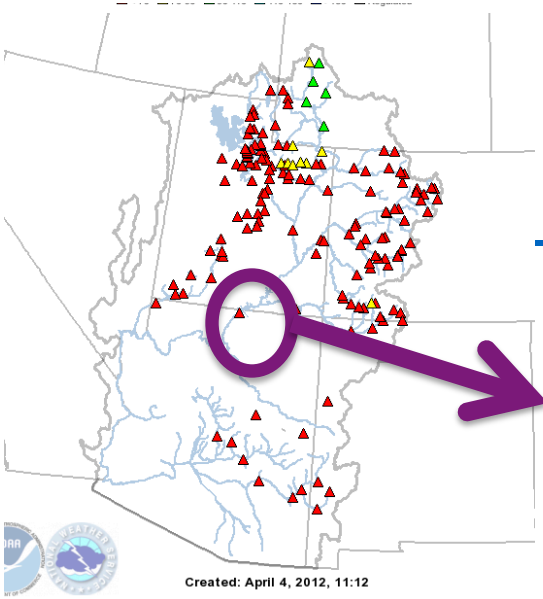
By Kyle Wagner
The Denver Post

POSTED: 05/01/2012 01:00:00 AM
UPDATED: 05/01/2012 10:52:22 AM

Boaters with Kodi Rafting ride the rapids into Seidel's Suckhole on the Arkansas River through Brown's Canyon Thursday. (*Mark Fox, Summit Daily file*)

So, Goldilocks, last year you said you didn't want to go whitewater rafting because the rivers' water levels were too high.

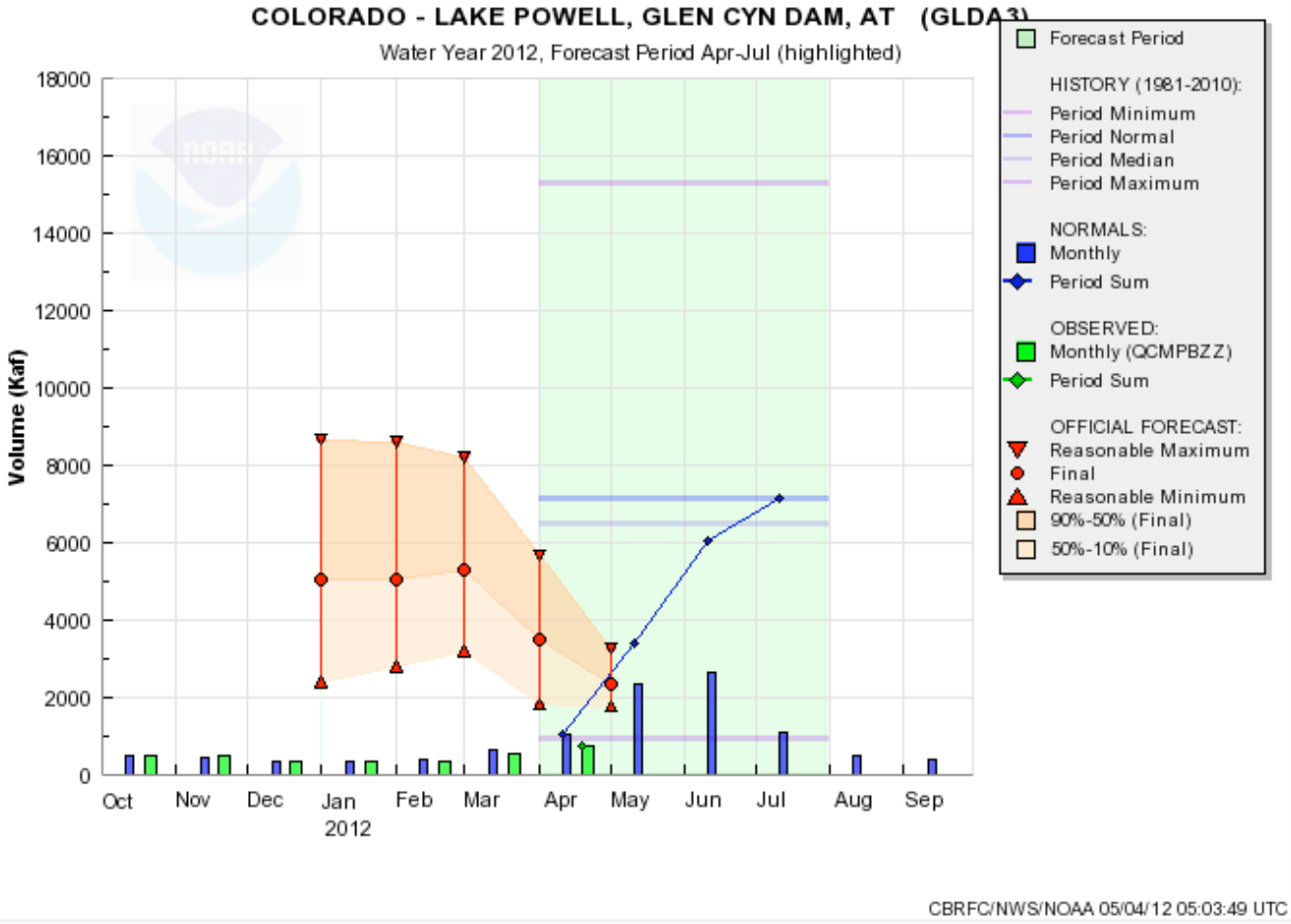
What's your excuse this year?



Seasonal Water Supply Forecast ⓘ — **Forecast Period: Apr-Jul**

2360 kaf	36%	33%
50% Exceedence (Official Forecast)	of Historical Median	of Historical Mean
1760 kaf	**3260 kaf**	**100th of 103**
90% Exceedence	10% Exceedence	Official Historical Flows

Forecast Issued: May 1 2012 — View Water Supply Forecast Plot



CBRFC/NWS/NOAA 05/04/12 05:03:49 UTC

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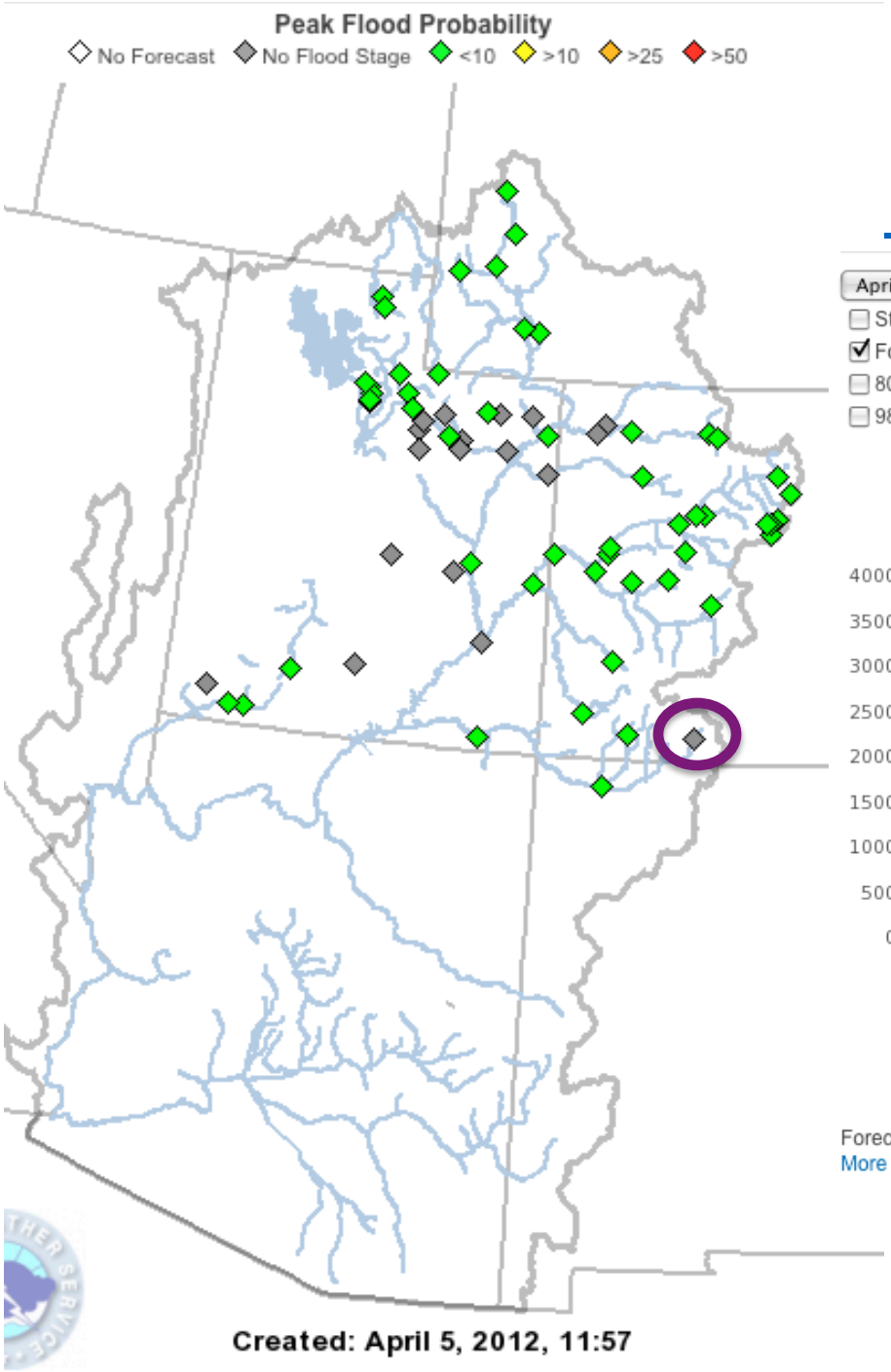
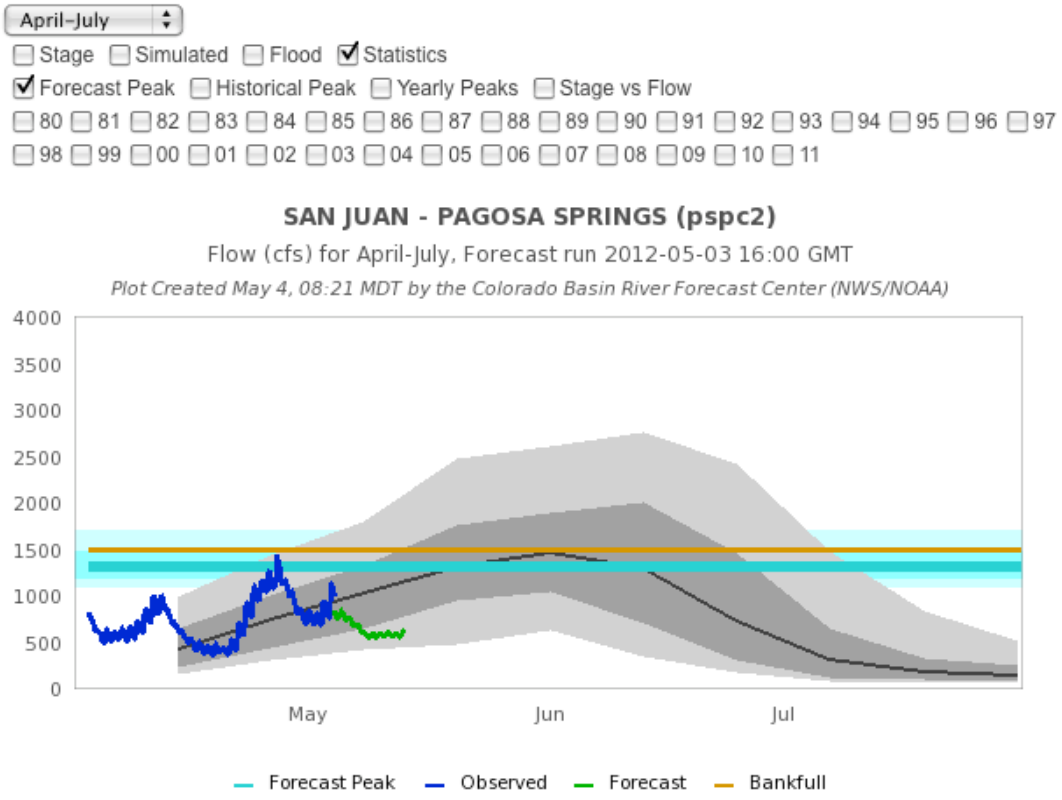




Forecast Peaks are Mean Daily. Historical and Yearly Peaks are Instantaneous.
More Plot Options

Forecast Methodology

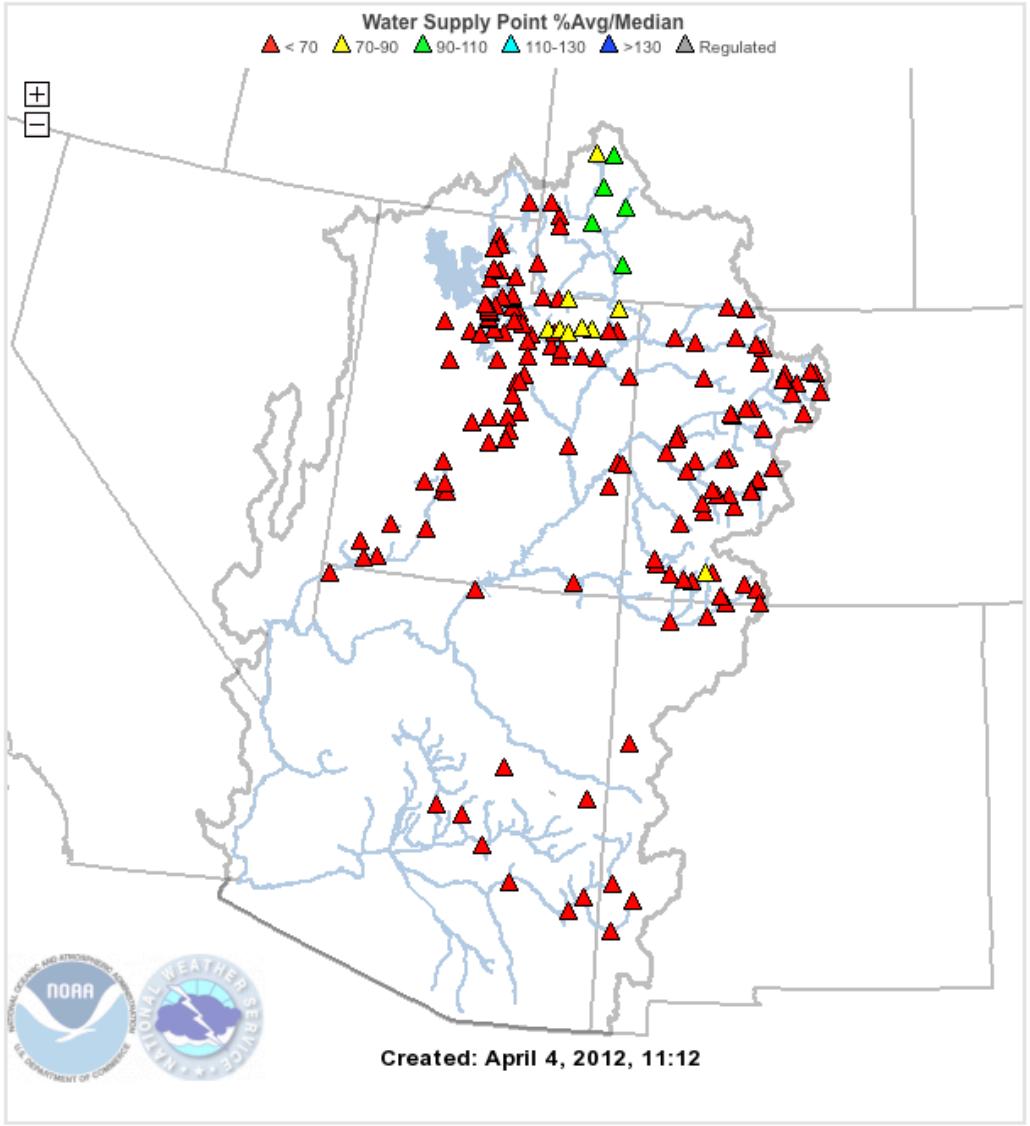
Water Supply Forecasts

Generated seasonally
•Typically January through June
•Updated monthly or as needed

Forecast runoff volume (usually April – July)

Probabilistic

Increasingly doing year round forecasts to support USBR and others



Water Supply Forecast Methods

➢ Statistical Forecasting (SWS)

- Statistical Regression Equations
- Primary NOAA/RFC forecast method from 1940's to mid 1990's.
- Primary NRCS/NWCC forecast method
- Historical Relationships between flow, snow, & precipitation (1971-2000+)
- Tied to a fixed runoff period (inflexible)

➢ Ensemble Streamflow Prediction (ESP)

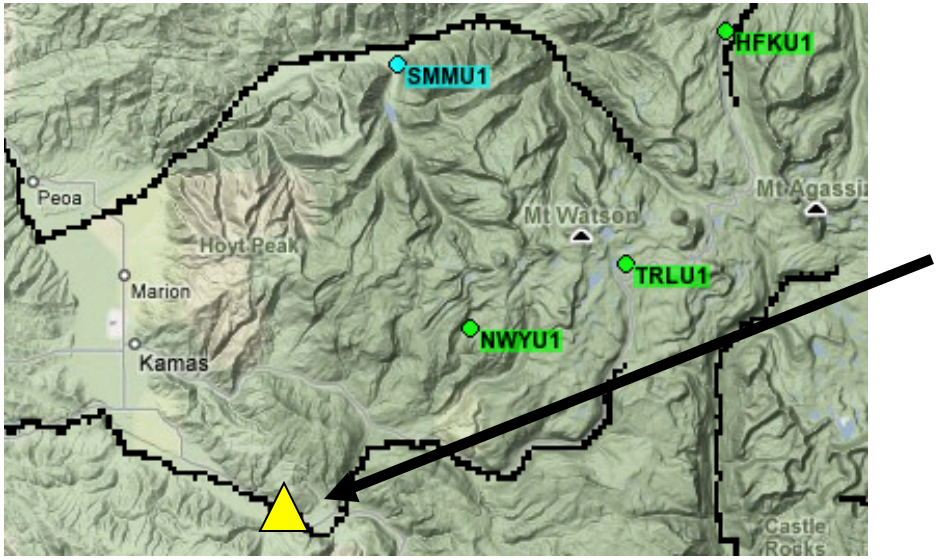
- A component of a continuous conceptual model
- Continuous *real time* inputs (temperature, precipitation, forecasts)
- **Hydrologic Model** (SAC-SMA) accounts for soil moisture states and drives runoff efficiency
- **Snow Model** (Snow-17) Builds and melts snowpack
- Flexible run date, forecast period, forecast parameters.
- Evolving toward ESP as primary forecast tool at NOAA/RFCs

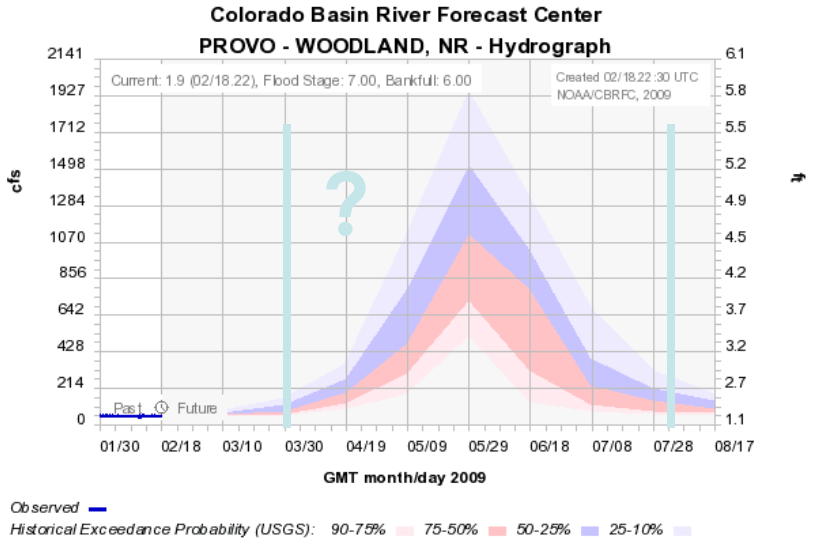
Statistical Water Supply (SWS)

Equations built on relationships between the inputs and the output

Output Variable:

April-July streamflow volume at Provo-Woodland

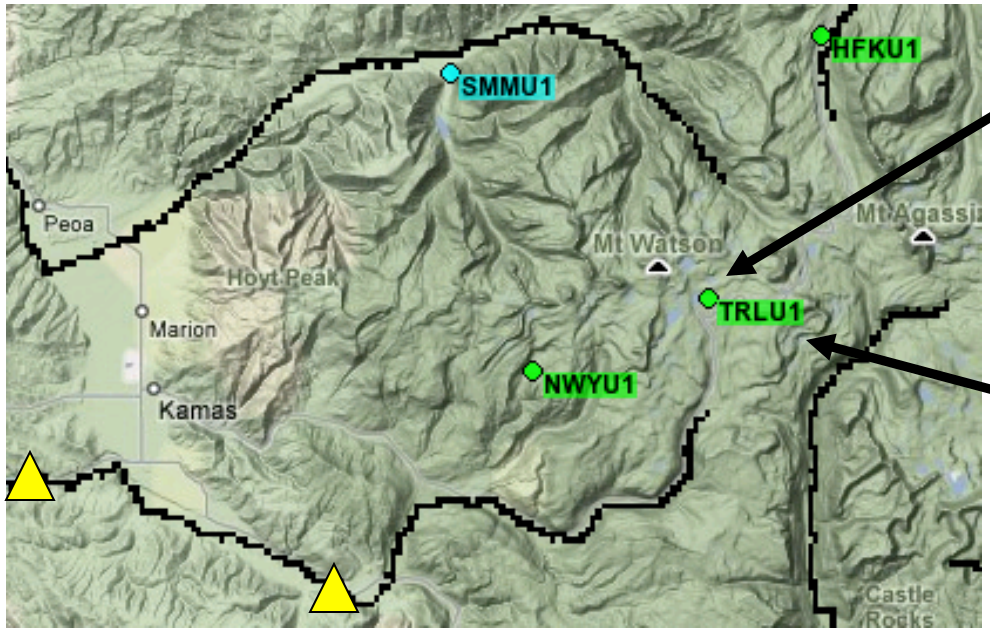


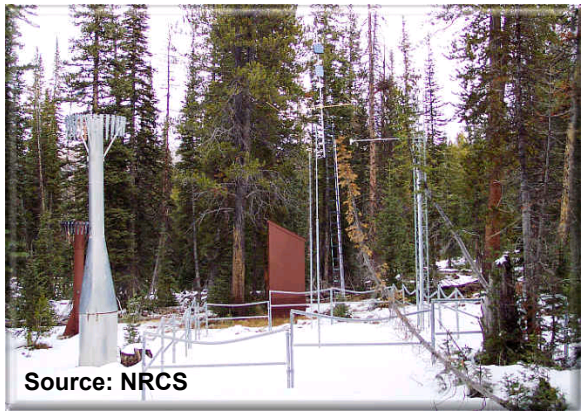


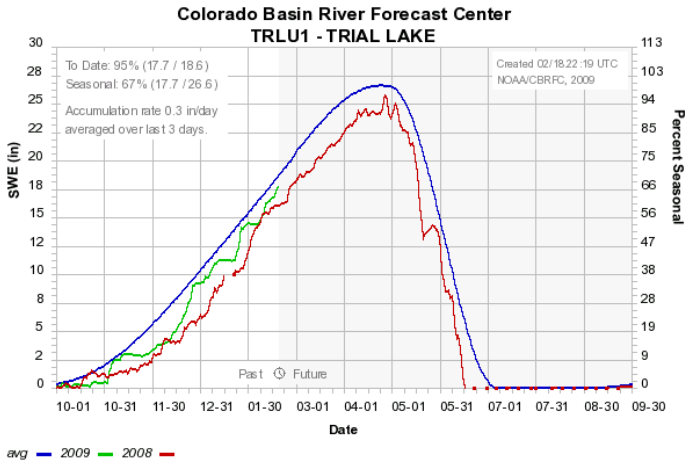
Statistical Water Supply (SWS)

Equations built on relationships between the inputs and the output

Input Variable: Trial Lake Snow







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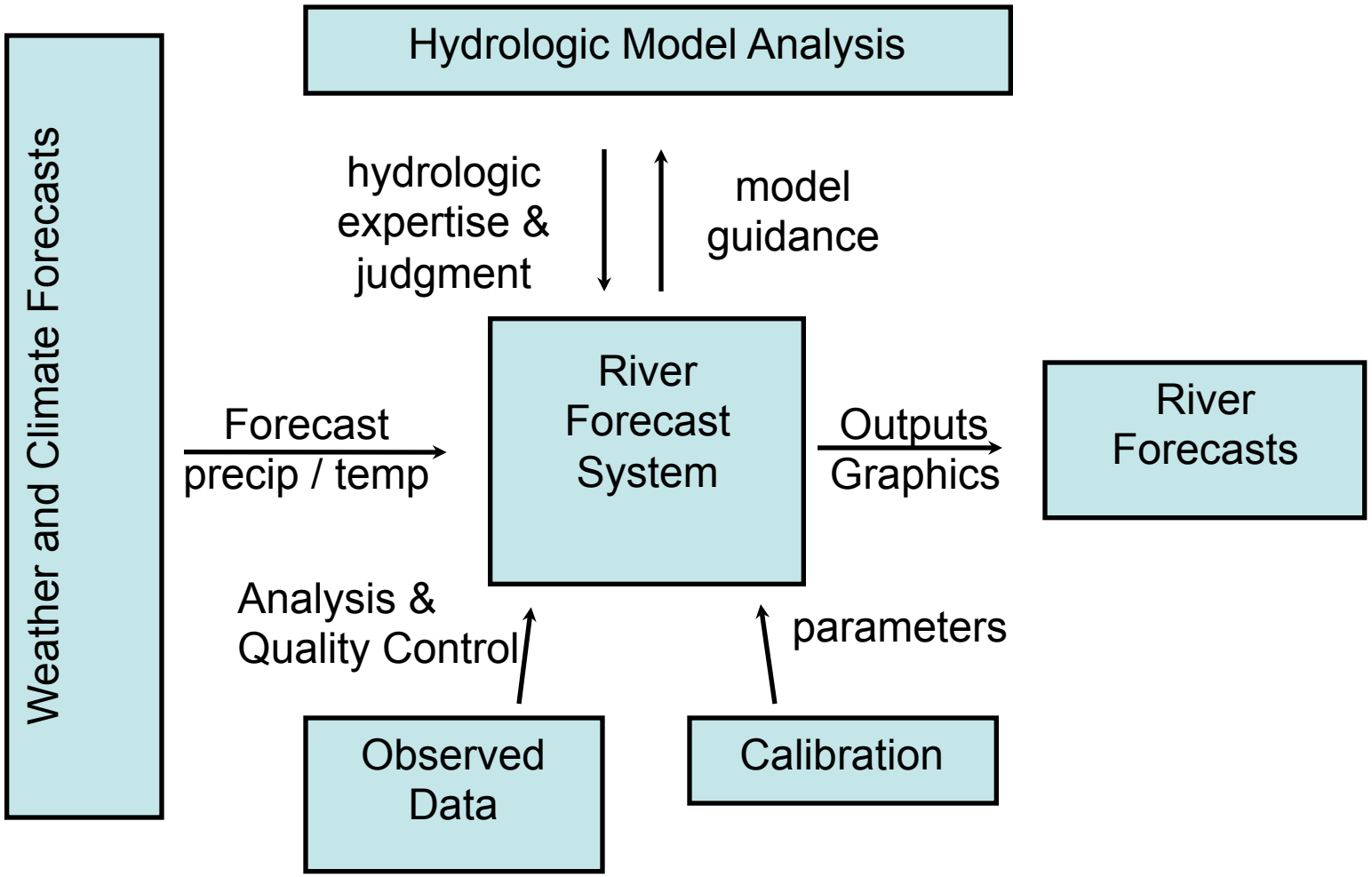
General RFC Model

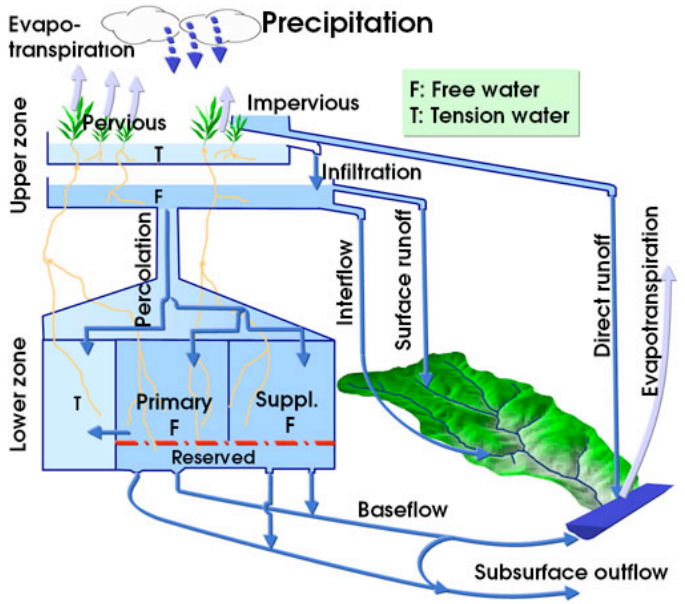


RFC Models

RFC forecast uses a snow model and a rainfall-runoff model:

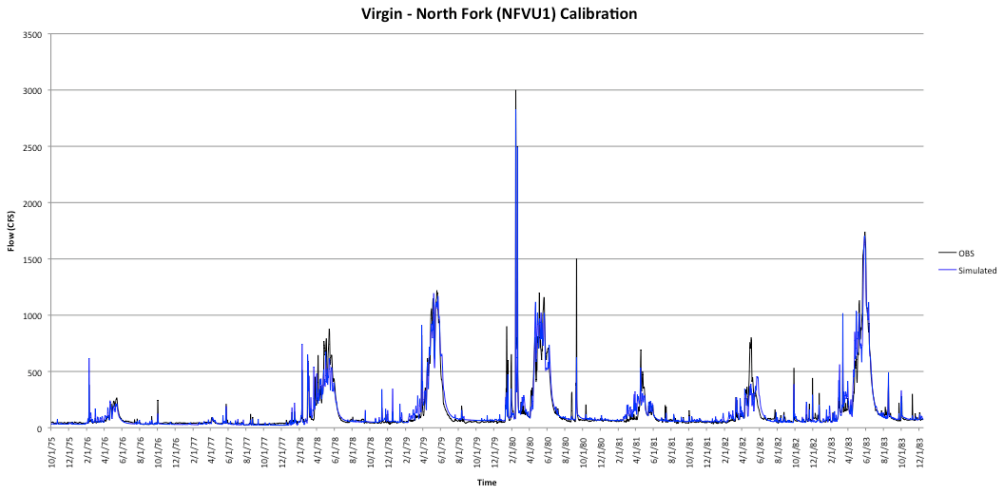
- SNOW-17: Temperature index model for simulating snowpack accumulation and melt
- Sacramento Soil Moisture Accounting Model: Conceptual hydrologic model used to generate runoff

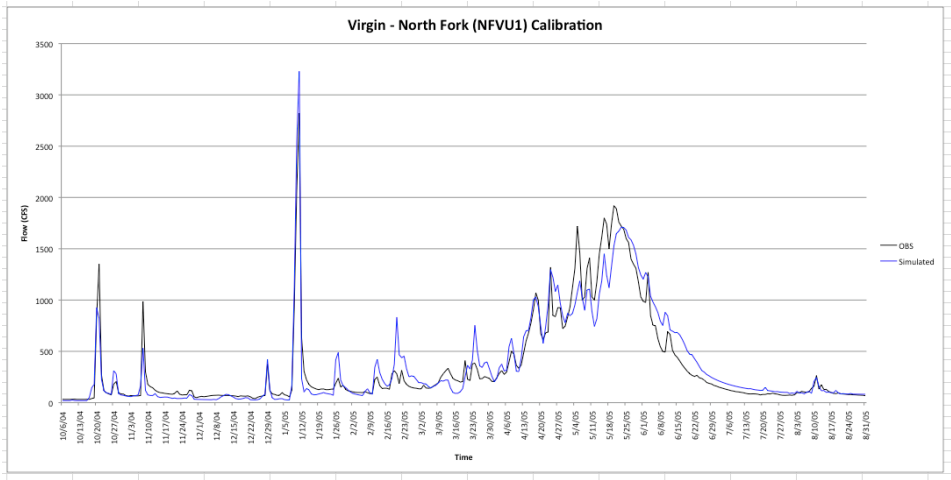
Snow Model: SNOW-17
Temperature Index Snow model



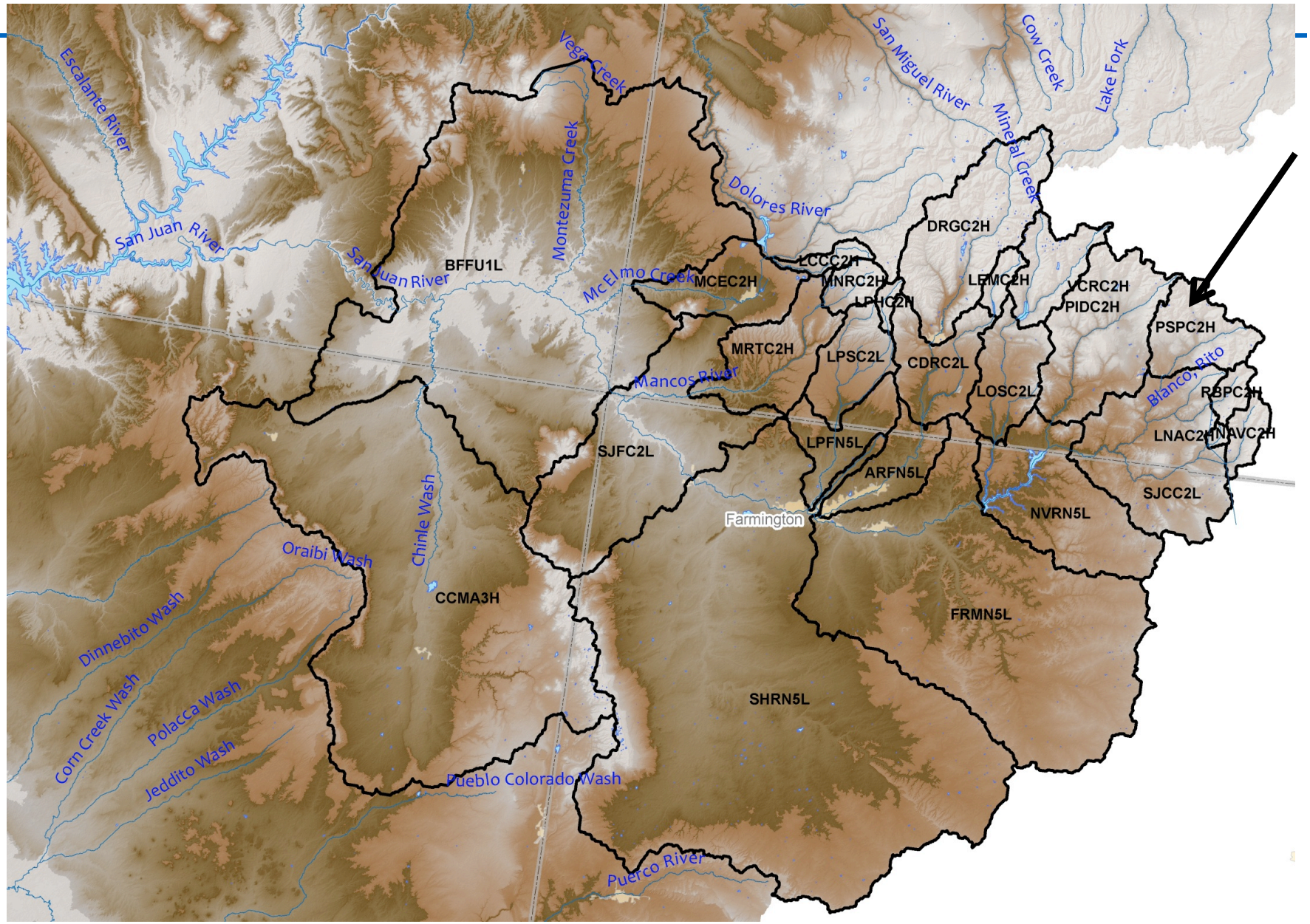
Calibration

- Process to assign parameter values to the runoff and snow modules within the model. Unique set for each basin (and sub-basin)
- Quality of calibration can vary greatly from basin to basin depending on data availability, period or record, quality of data, hydrology of the basin, etc.

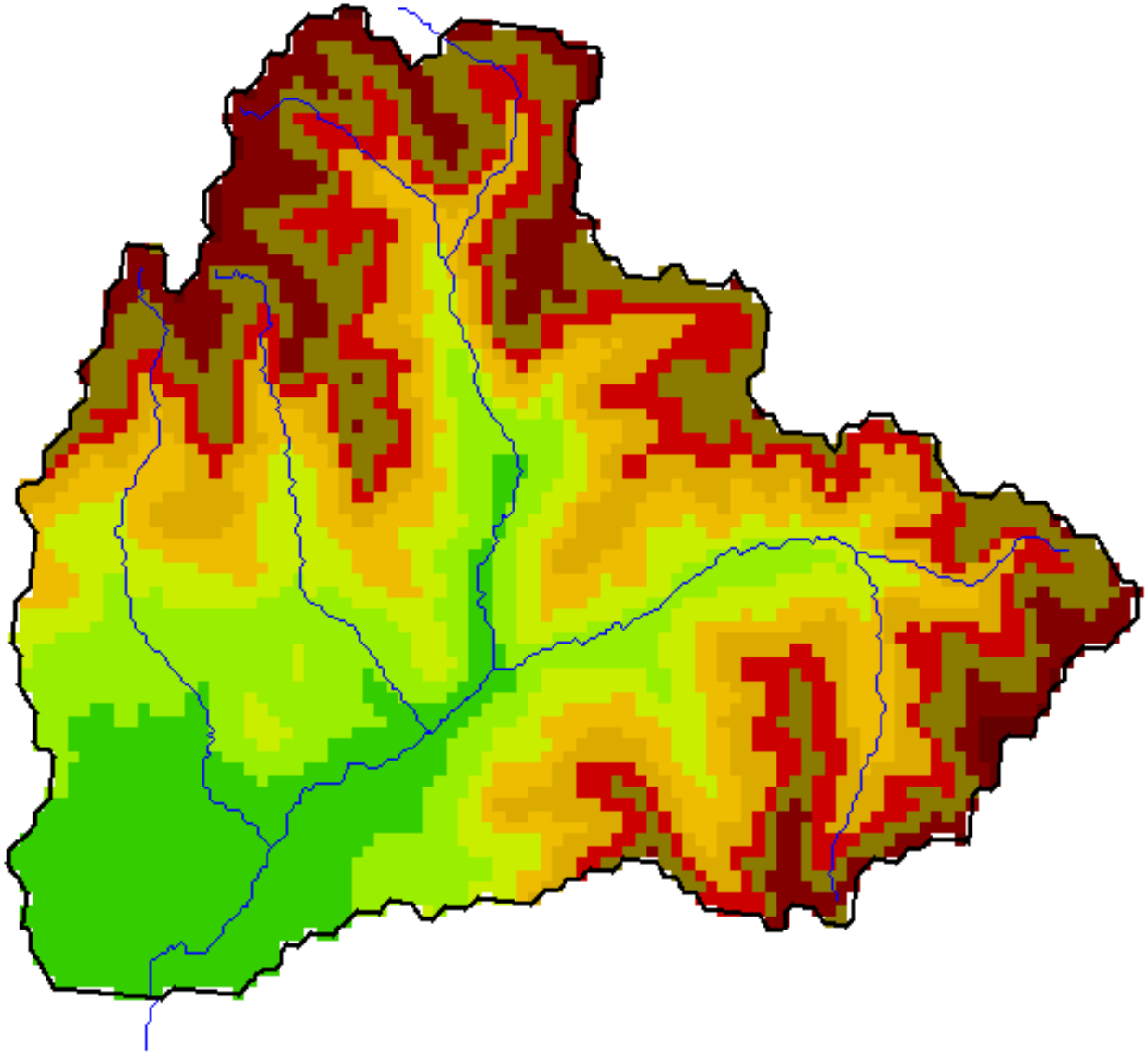




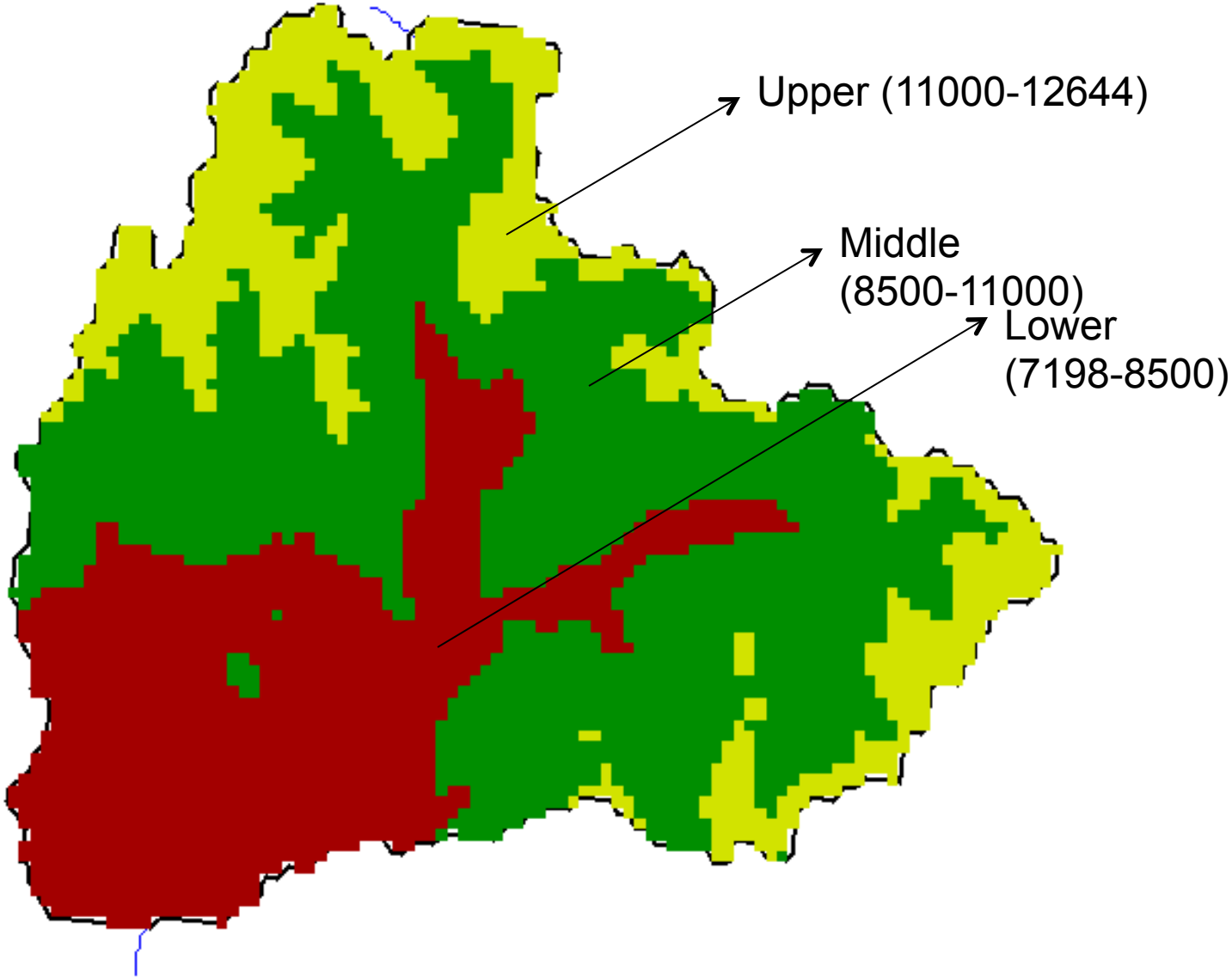
San Juan Basin

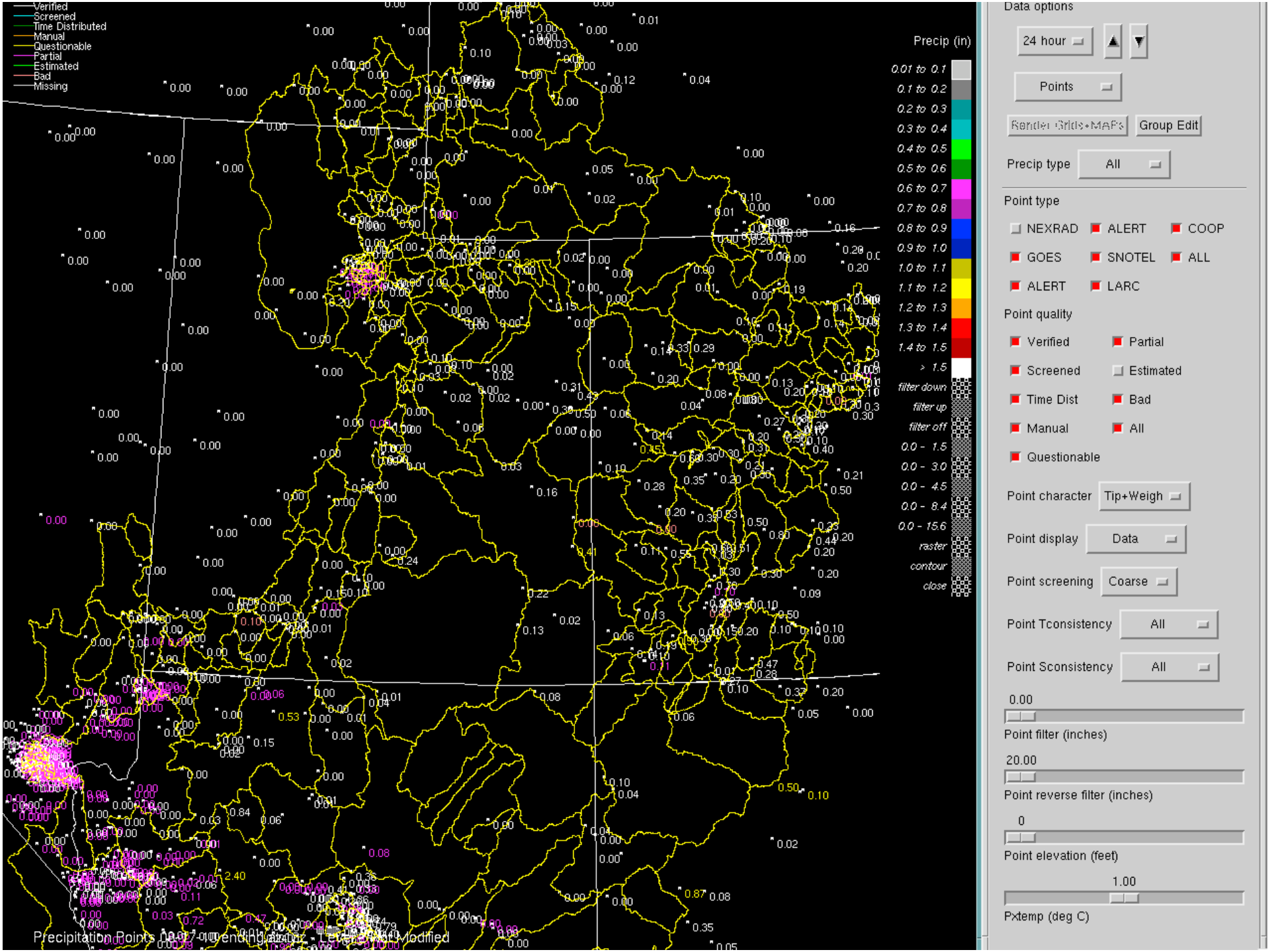


San Juan-Pagosa Springs(PSPC2)



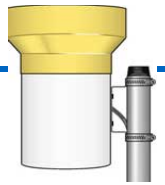
San Juan-Pagosa Springs(PSPC2)



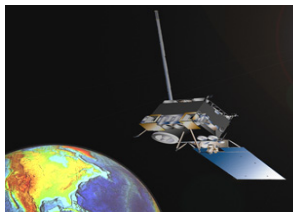

Verified
Screened
Time Distributed
Manual
Questionable
Partial
Estimated
Bad
Missing
Precip (in)
0.01 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8
0.8 to 0.9
0.9 to 1.0
1.0 to 1.1
1.1 to 1.2
1.2 to 1.3
1.3 to 1.4
1.4 to 1.5
> 1.5
filter down
filter up
filter off
0.0 - 1.5
0.0 - 3.0
0.0 - 4.5
0.0 - 8.4
0.0 - 15.6
raster
contour
close
Data options
24 hour
Points
Render Grids+MAPs
Group Edit
Precip type
All
Point type
NEXRAD
ALERT
COOP
GOES
SNOTEL
ALL
ALERT
LARC
Point quality
Verified
Partial
Screened
Estimated
Time Dist
Bad
Manual
All
Questionable
Point character
Tip+Weigh
Point display
Data
Point screening
Coarse
Point Tconsistency
All
Point Sconsistency
All
0.00
Point filter (inches)
20.00
Point reverse filter (inches)
0
Point elevation (feet)
1.00
Pxtemp (deg C)
Precipitation Points

Quantitative Precipitation Estimates (QPE)

Rain Gage Measurement

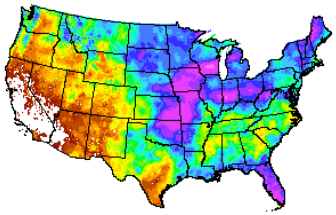


GOES Satellite Estimate

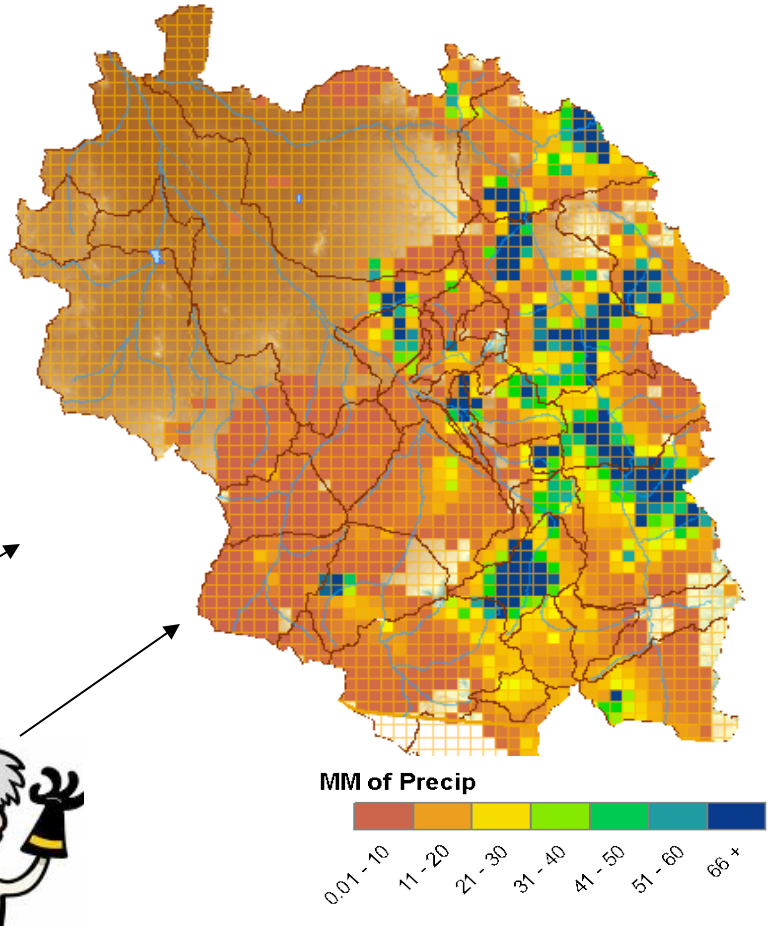


Radar Estimate

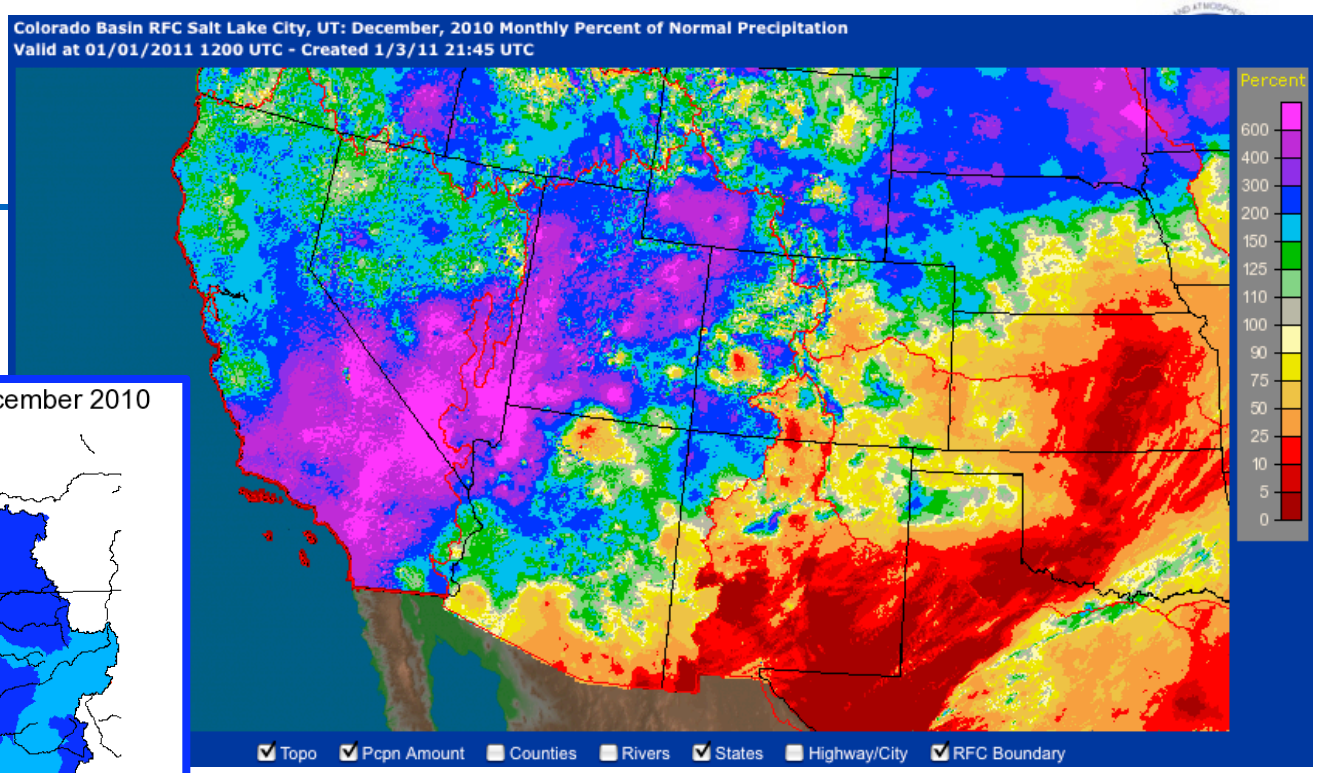
Climate patterns



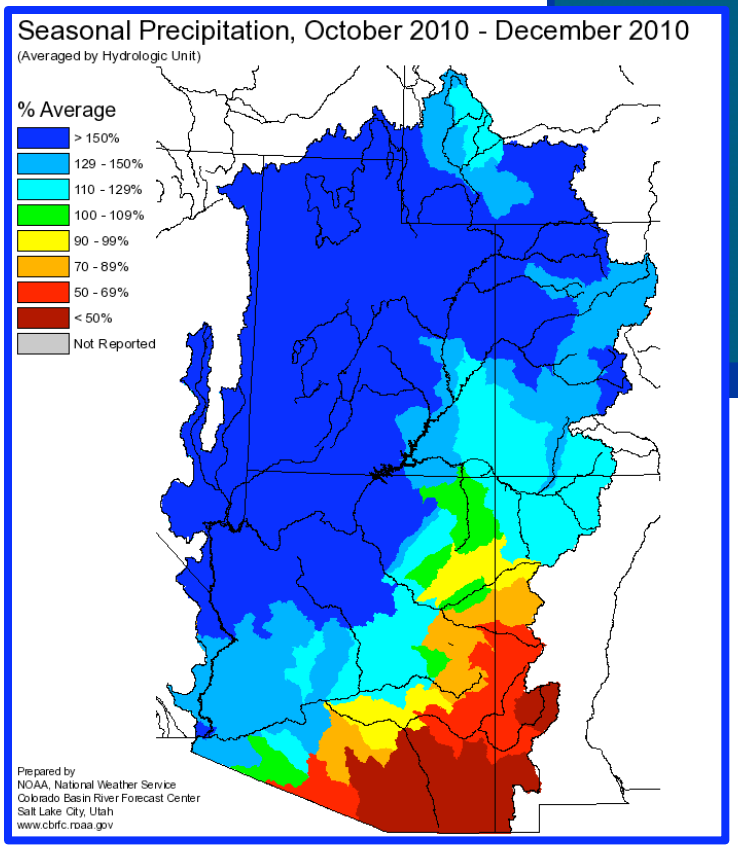
Gridded Precipitation Estimate



Forecaster Analysis



Source: water.weather.gov

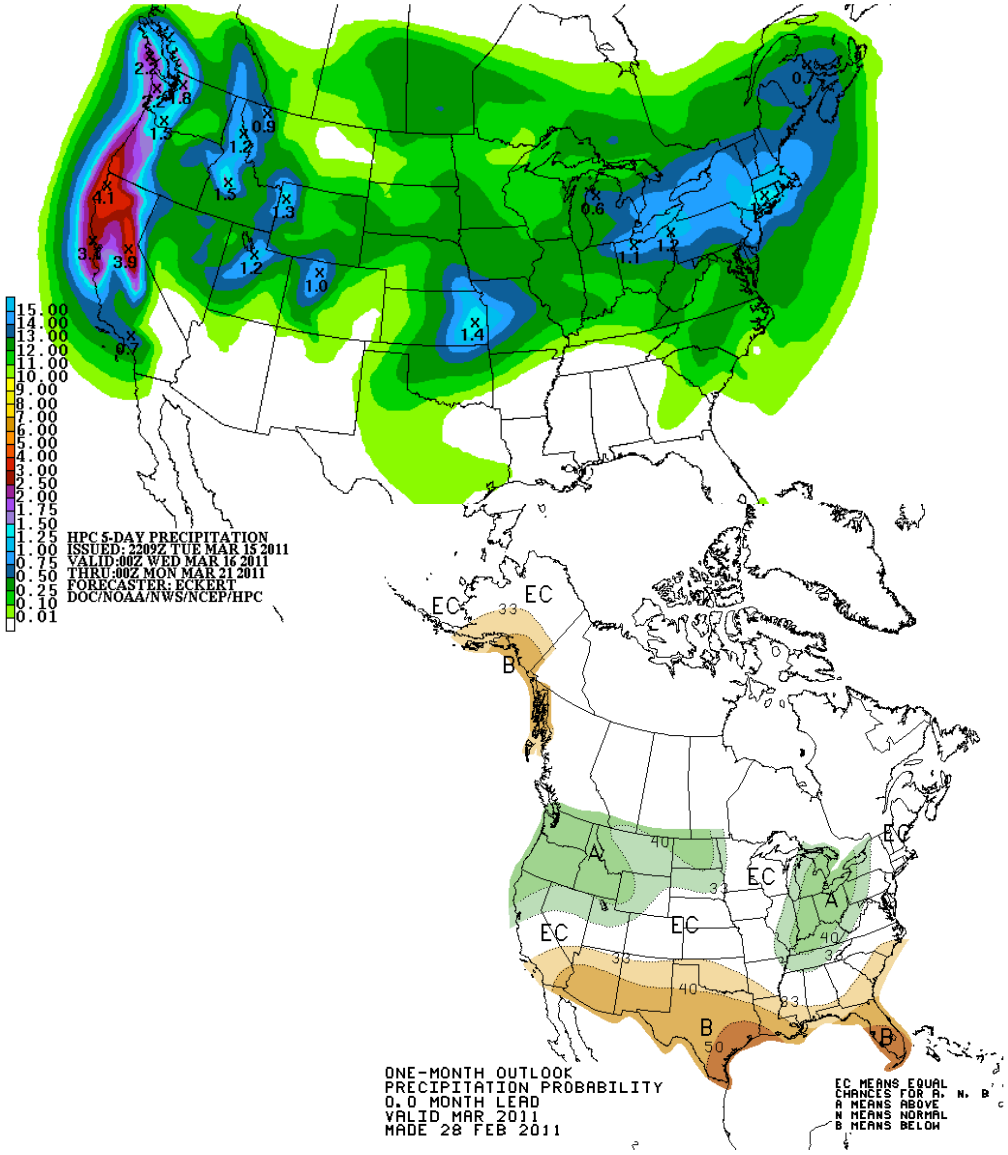


Source: www.cbrfc.noaa.gov

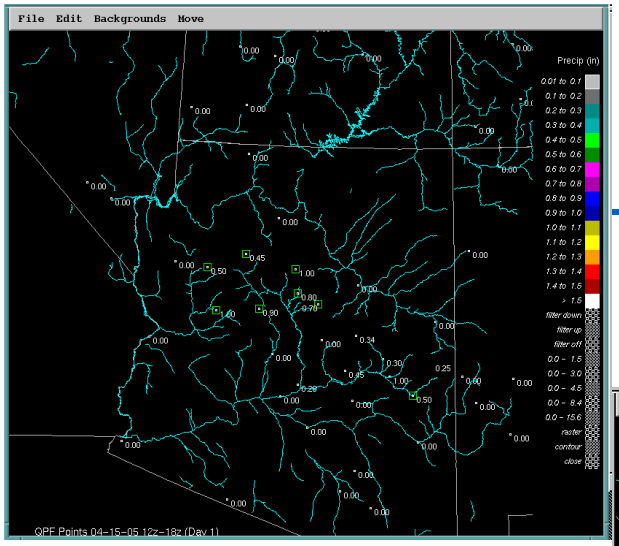
Weather and Climate Forecasts

RFC forecast system incorporates both weather and climate forecasts:

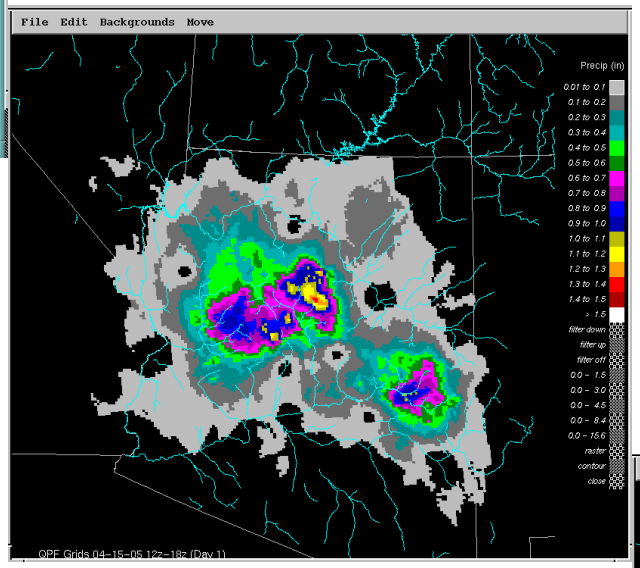
- Weather forecasts integrated into daily operations with forecaster control over point and basin average values
  - Water supply forecasts typically only use QPF during late season or in lower basin
  - When QPF is used, it is used in a deterministic manner
- Climate forecasts integrated into seasonal water supply forecasts through probability shifts of forcing ensemble
  - Climate forecasts are typically only considered in lower basin and only in ENSO years



Forecast Precipitation (QPF)

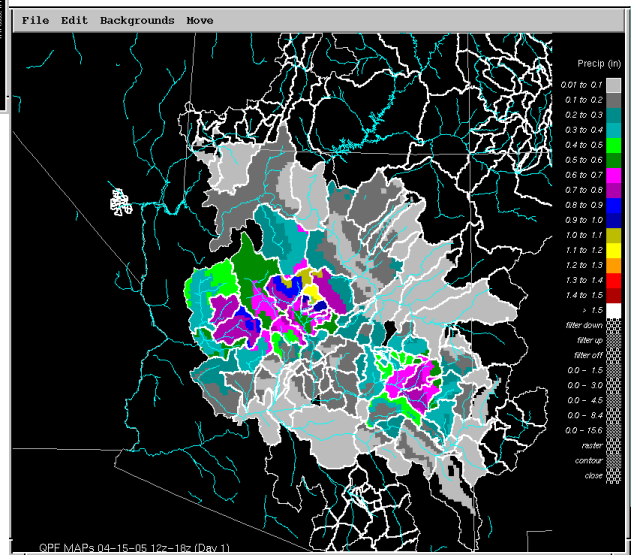


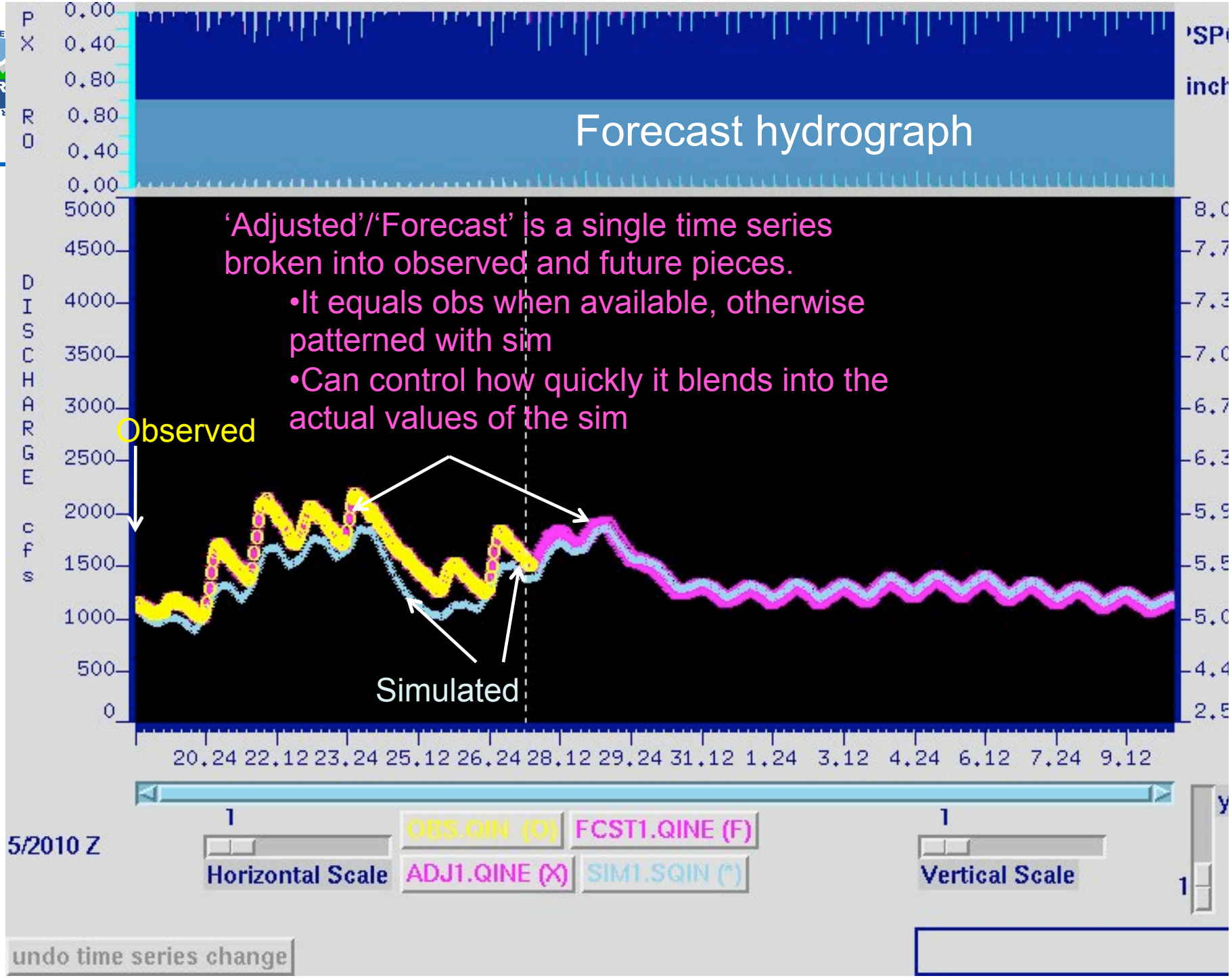
Point Values
(HPC)



Grid Values
(Prism
Scaling)

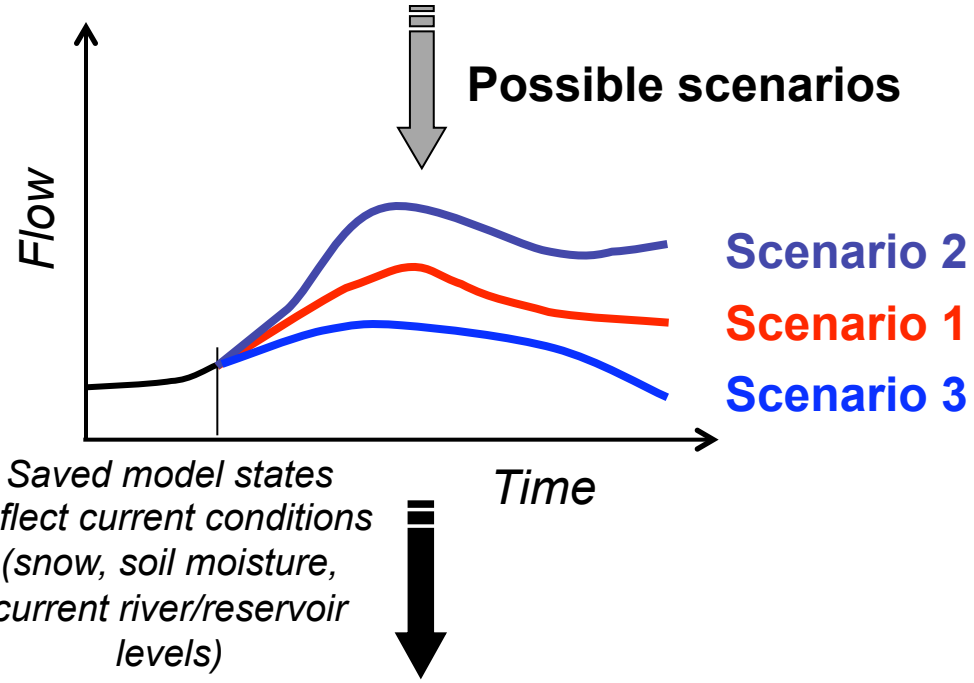
Basin Values




Forecast hydrograph
'Adjusted'/'Forecast' is a single time series broken into observed and future pieces.
•It equals obs when available, otherwise patterned with sim
•Can control how quickly it blends into the actual values of the sim
Observed
Simulated
DISCHARGE cfs
PX ROO
inch
0.00
0.40
0.80
0.80
0.40
0.00
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
8.0
7.7
7.3
7.0
6.7
6.3
5.9
5.5
5.0
4.4
2.5
20.24 22.12 23.24 25.12 26.24 28.12 29.24 31.12 1.24 3.12 4.24 6.12 7.24 9.12
5/2010 Z
Horizontal Scale
OBS.QIN (O)
FCST1.QINE (F)
ADJ1.QINE (X)
SIM1.SQIN (*)
Vertical Scale
undo time series change

ESP Technique

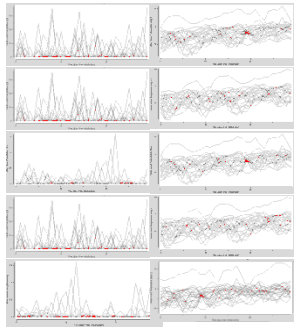
Multiple streamflow scenarios with historic meteorological or forecast weather/climatic data



Results used in statistical analysis to produce forecasts with probabilistic values

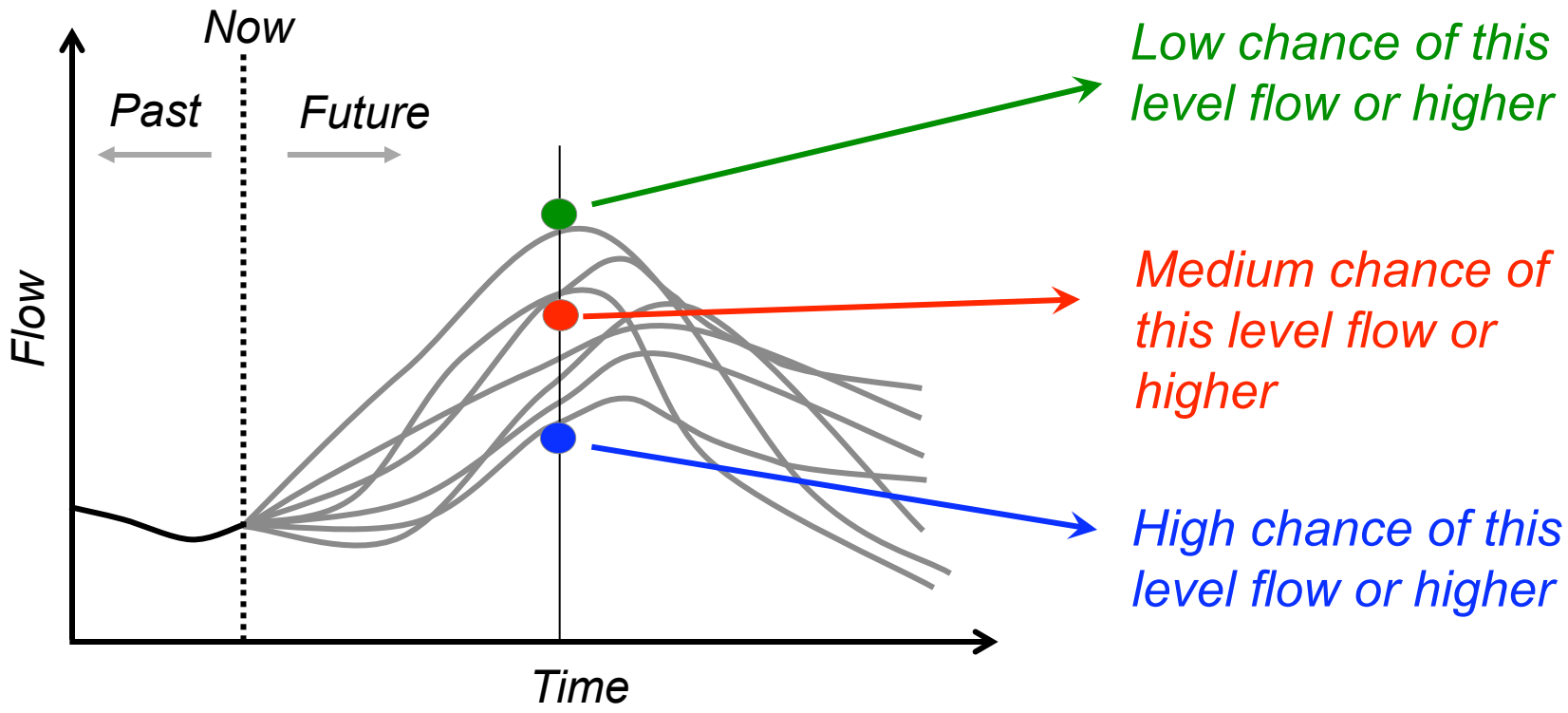
Historical time series of precipitation and temperature

81
82
83
84
85

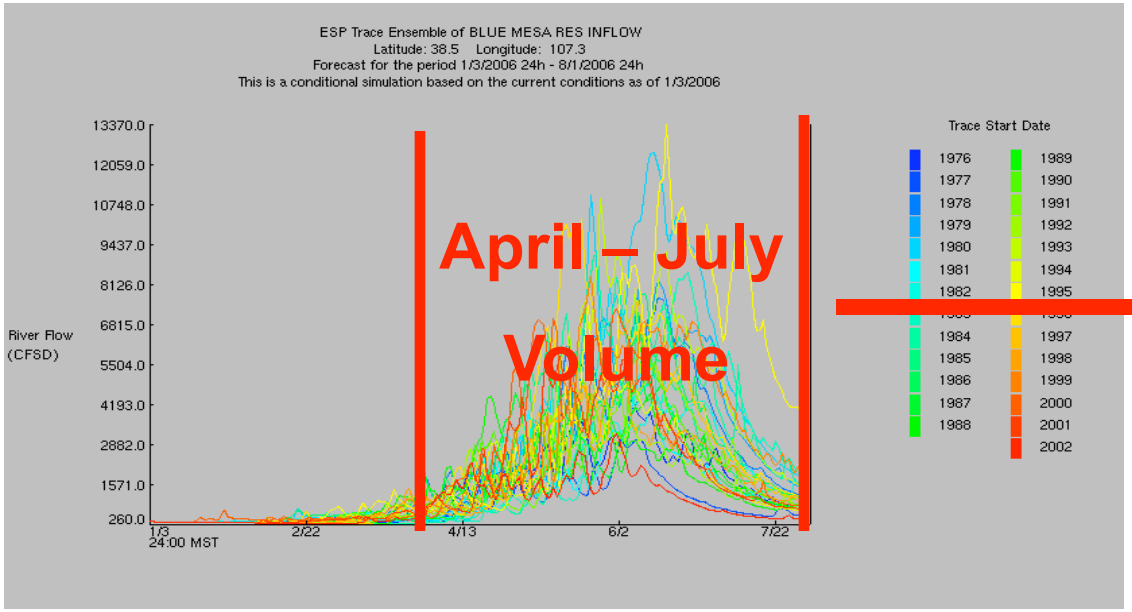


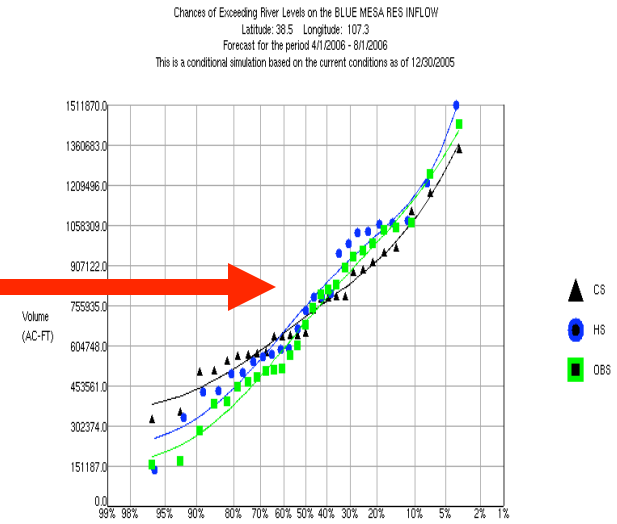
Forecast weather (at CBRFC):
- Use 10 days of forecast max/min temperatures.
- Two runs –
  - 5 days of forecast precipitation
  - 0 days of forecast precipitation

ESP Technique (cont.)



ESP Analysis





1. Select a forecast window
2. Select a forecast variable (e.g. max flow, volume, time to peak, etc)
3. Model derives a probability distribution function

```
# Statistics based on all years.
#
# Exceedance    Conditional     Historical      Historical
# Probabilities Simulation      Simulation      Observed
#
  0.900         438320.500      328520.656      262730.375
  0.750         552369.562      499977.531      435810.375
  0.500         711742.375      751782.938      691946.625
  0.250         877104.812      973699.188      935549.938
  0.100         1080490.375     1170393.125     1157333.250
```

ESP 'Modes'

UNREGULATED

(Water Supply Volume Forecasts)

Not what will be observed in the rivers.

No diversions (for places we have historical/real time measurements).

- Trans-basin diversions.

No water held by reservoirs (passes through).

Consumptive Use operation still in effect.

REGULATED

(Peak Flow Forecasts)

Observed mean daily peak.

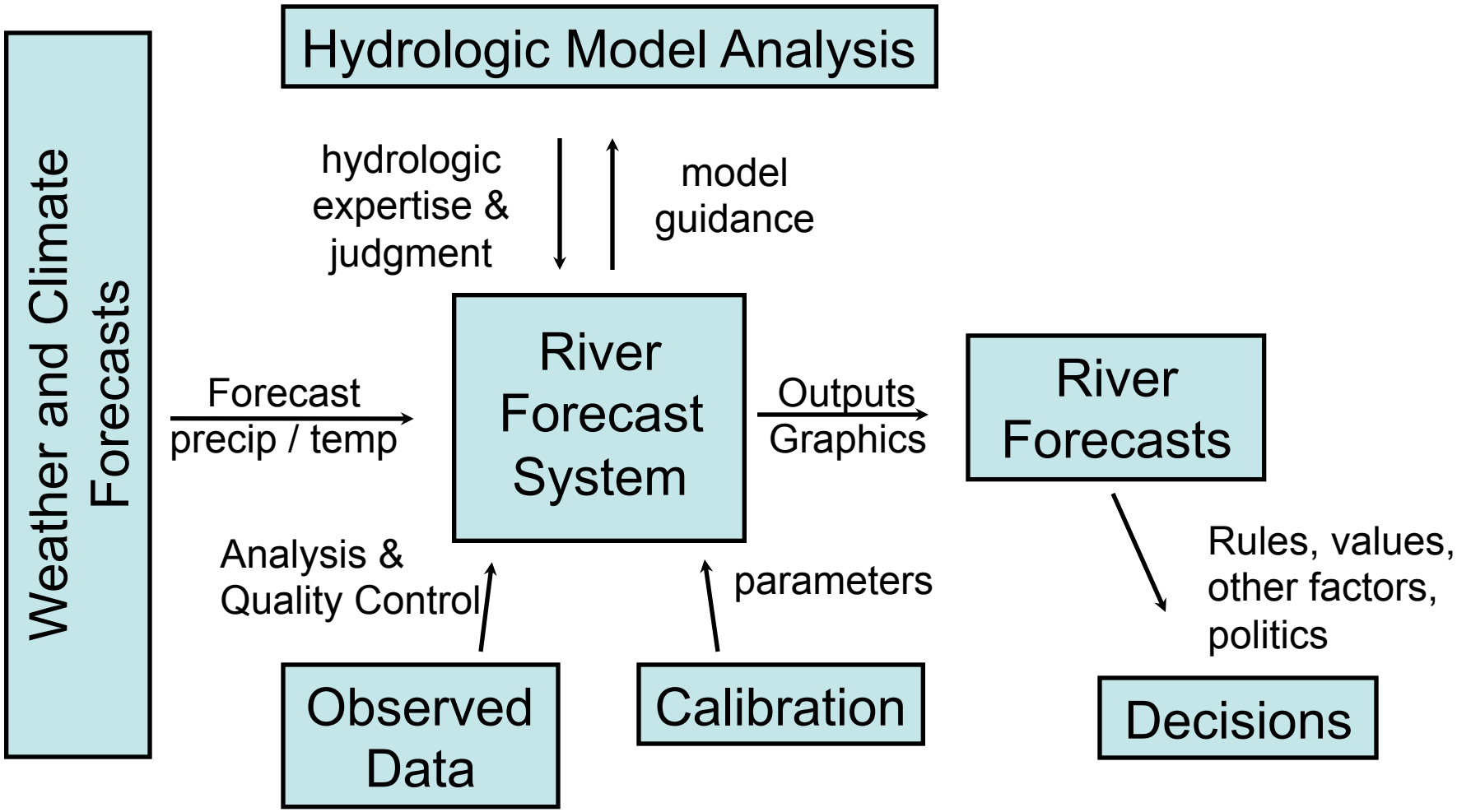
Historical diversion data used in calculation of each year's hydrograph.

Reservoirs operated based on a set of 'rules'.

- Time of year or elevation.

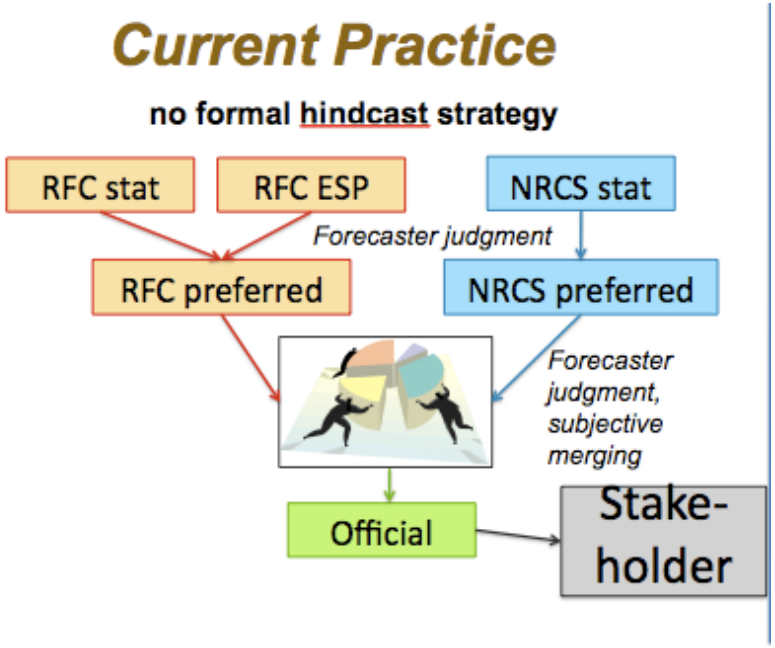
Similar to daily forecast methodology.

Forecast Process



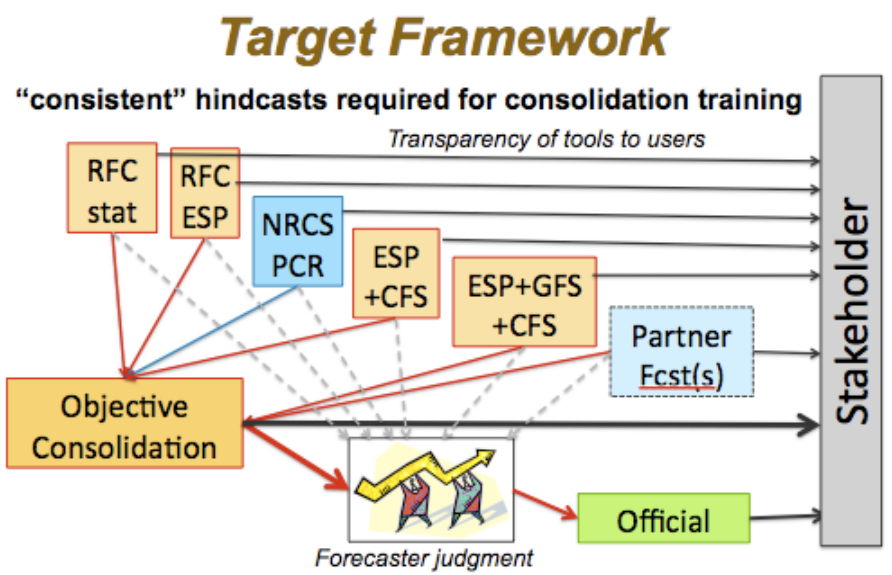
Past CBRFC Methods

- Official forecasts coordinated each month with NRCS/NWCC
- Skill primarily from accumulating snow pack
- Updated monthly or semi-monthly
- Probabilistic but not ensemble based
- Not repeatable
- Subjective
- Forecaster Role:
  - Monitor forecast process and system
  - Add judgement to forecast process



Future CBRFC Methods

- Objective, repeatable ensemble forecasts
- Integrate skill from weather and climate predications
- Tailor to stakeholder thresholds and concerns
- Forecaster role:
  - Monitor forecast process and system
  - Apply judgement (less frequently?)
  - Decision support
  - Work to improve forecast system and processes based on objective standards
  - Follow best practices identified by CPC



Water Supply Decision Support

The past

Seasonal water resources forecasting and modeling in the Colorado Basin
circa 1980 - 2010

Coordinated Forecast (single number) → 24 month study → Stakeholders

The future

Seasonal water resources forecasting and modeling in the Colorado Basin
Near future

Hydrologic Ensembl Forecast System → Mid-Term Probabilistic Model → Stakeholders

Efforts in parallel --

- CBRFC working to improve probabilistic flow forecasts
- BOR working to implement probabilistic water management model

Summary

Colorado Basin Primer

2011 vs 2012

CBRFC Forecast Methods Overview

Questions?

Kevin Werner

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Phone: 801.524.5130
Email: kevin.werner@noaa.gov