NOAA's National Weather Service
California-Nevada River Forecast Center

Forecast Methods, Products, and Services for the San Joaquin River Basin

Rob Hartman
Hydrologist in Charge

Mission of NWS Hydrologic Services Program

- Provide river and flood forecasts and warnings for the protection of lives and property.
- Provide basic hydrologic forecast information for the nation's environmental and economic well being.

NWS River Forecast Centers

CNRFC Customers

- NWS Field Offices
- Federal Water Management Agencies
- State Water Management Agencies
- City / County Flood Control Operations
- Public / Private Utilities

Staffing

NWS/CNRFC

- Hydrologist in Charge
- DO Hydrologist
- 4 Senior Hydrologists
- 3 Hydrologists
- 1 Senior HAS Forecasters
- 2 HAS Forecasters
- 1 Information Tech. Officer
- Administrative Assistant

DWR/DFM

- Hydrology Branch Chief
- 7 Engineers/Forecasters

CNRFC Program Areas

- Flash Flood Support
- Dam Break Support
- Flood Forecasting
- Snowmelt Forecasting
- Water Supply Forecasting

CNRFC Hydrologic Modeling

Short Range … … … … … … Long Range

NWSRFS – OFS

6 hour time step
modular, deterministic

NWSRFS - ESP……..

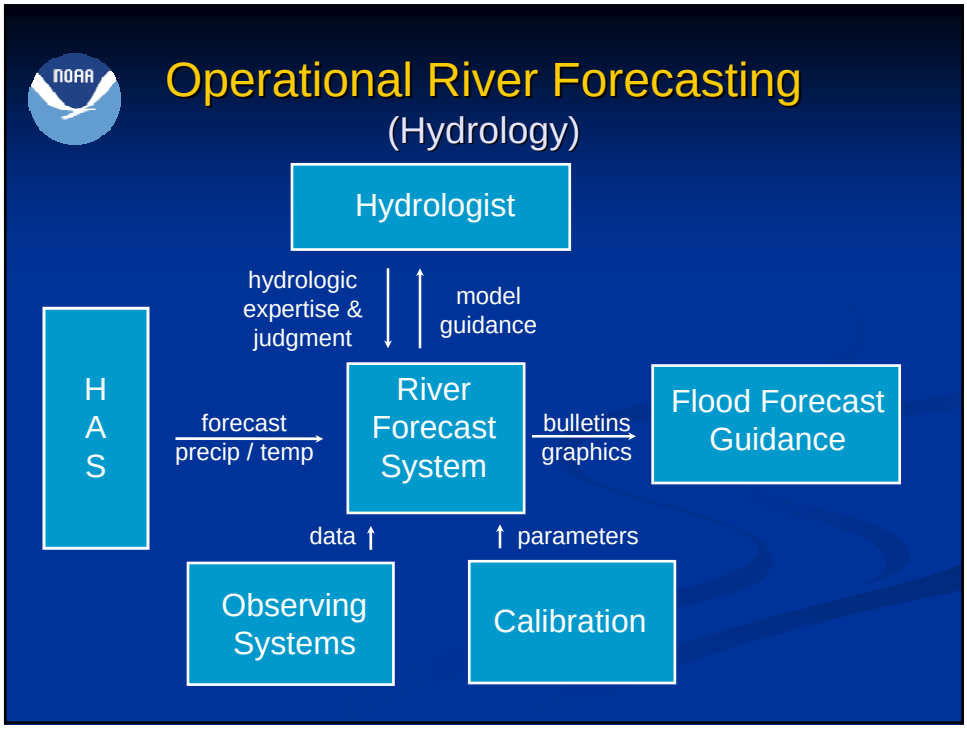
NWSRFS configuration
probablistic (ensemble)

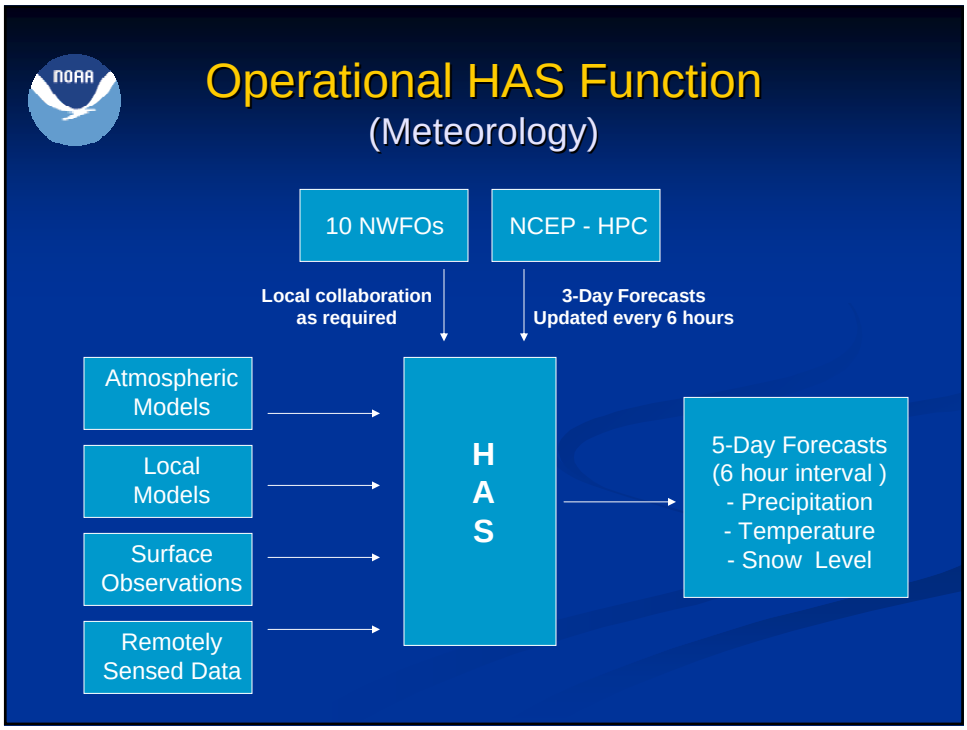
Statistical

simple, efficient, inflexible

Available CNRFC Forecasts

Forecast	Duration	Season	Frequency	Probabilities
Flood / Routine	5 Days	Year-round	Daily +	No
Ensemble Streamflow Prediction	User selectable to 1 year	Year-round	Daily	Yes
Spring Snowmelt	20 Days (4 x 5days)	Early April thru snowmelt peak	Weekly +	Yes
Water Supply	April - July	January – May	Monthly +	Yes


Operational River Forecasting
(Hydrology)
Hydrologist
hydrologic expertise & judgment
model guidance
H A S
forecast precip / temp
River Forecast System
bulletins graphics
Flood Forecast Guidance
data
parameters
Observing Systems
Calibration


Operational HAS Function
(Meteorology)
10 NWFOs
NCEP - HPC
Local collaboration as required
3-Day Forecasts Updated every 6 hours
Atmospheric Models
Local Models
Surface Observations
Remotely Sensed Data
H A S
5-Day Forecasts (6 hour interval)
- Precipitation
- Temperature
- Snow Level

Flood / Routine River Forecast Process

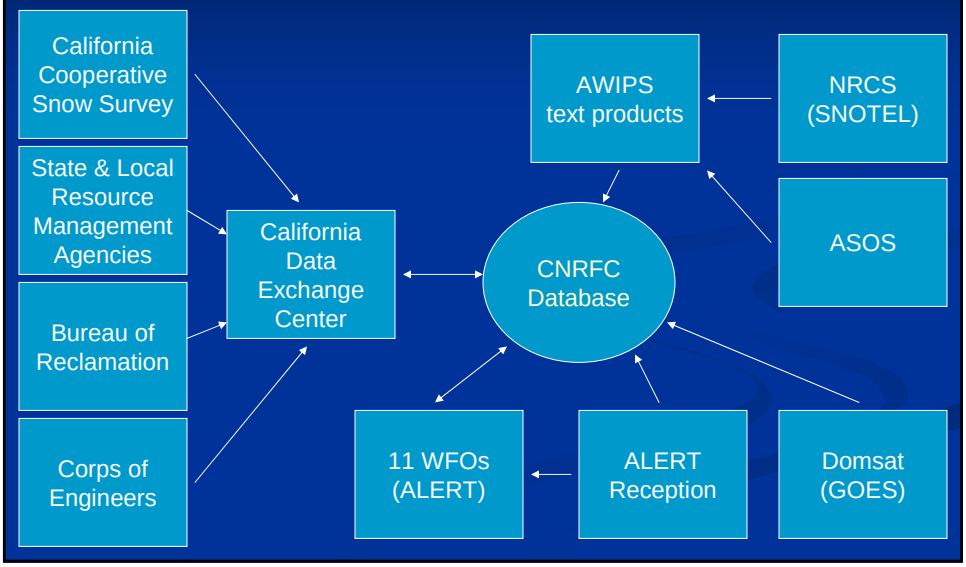
Preprocessing → **Processing** → **Post-processing**

- Data collection
- Data QC
- Mean Areal computations

- Run model(s)
- Make adjustments
- Move downstream

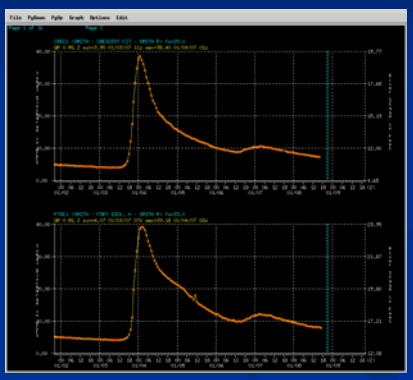
- Text Forecast
- Graphical Forecast

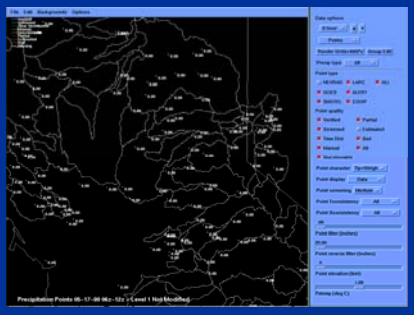
Preprocessing
Data Collection



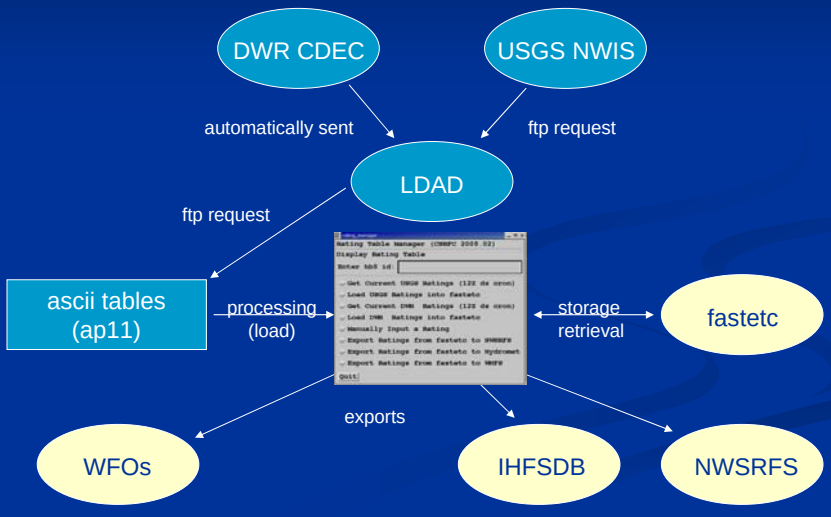
Preprocessing
Data Quality Control

- Precipitation
- Surface air temperature
- River stage and discharge
- Reservoir elevations and storage

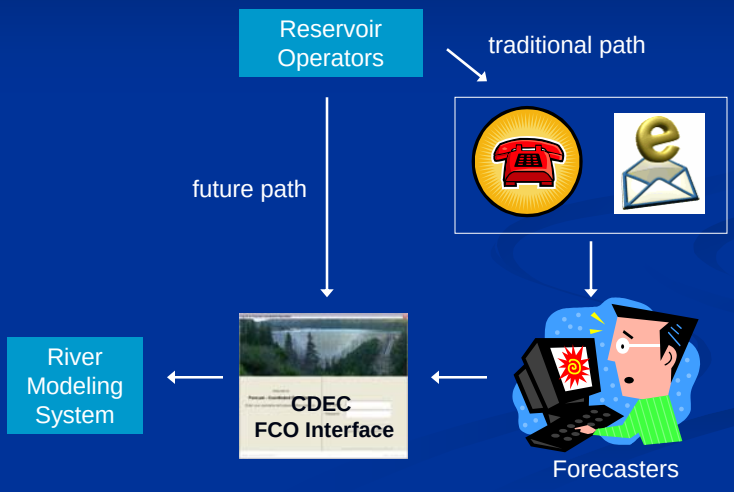




Preprocessing
Rating Table Management



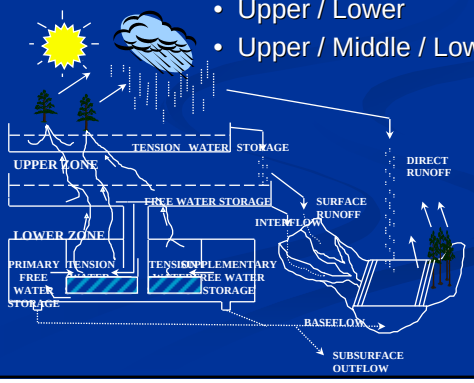
Preprocessing
Scheduled Reservoir Releases



Processing
NWSRFS Operations (Models)

- Rain-Snow Elevation
- Snow-17
- Soil Model (SAC-SMA)
- Unit Hydrograph
- Reservoir Models
- River Routing Models

- Lumped (not distributed)
- Mountainous basins
  - Subdivided into
    - Upper / Lower
    - Upper / Middle / Lower



Processing

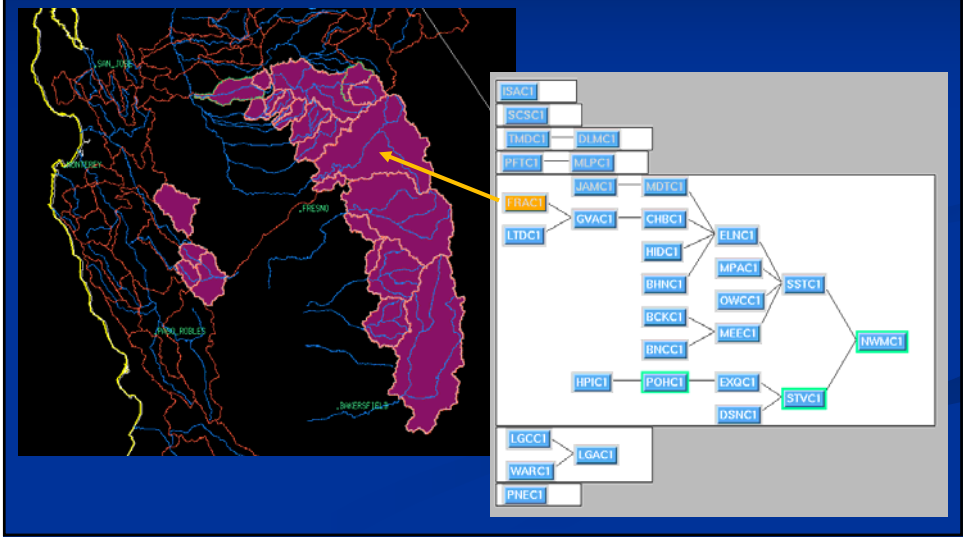
CNRFC's NWSRFS Implementation

- 250+ simulated watersheds
- ~90 flood forecast locations
- ~50 reservoir inflow locations

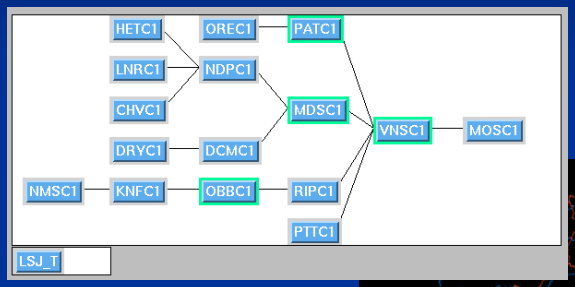
- Model time step = 6 hrs
  - Hourly discharge observations used in routings
- Routine forecast duration = 5 days
- Updates: every 6 hours during flood events

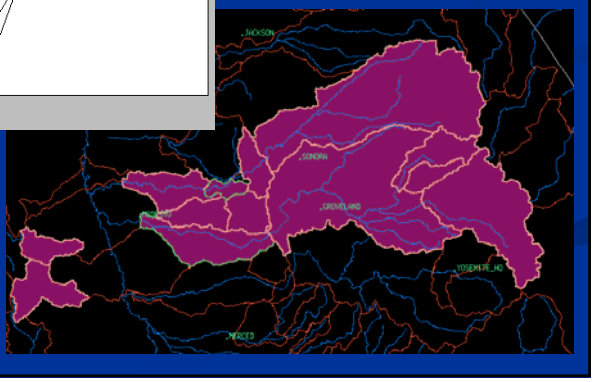
Processing

Upper San Joaquin Configuration



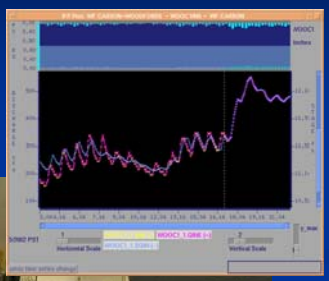
Processing
Lower San Joaquin Configuration

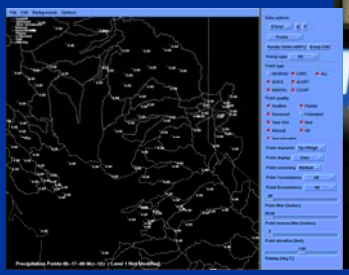




Processing
Forecaster Experience

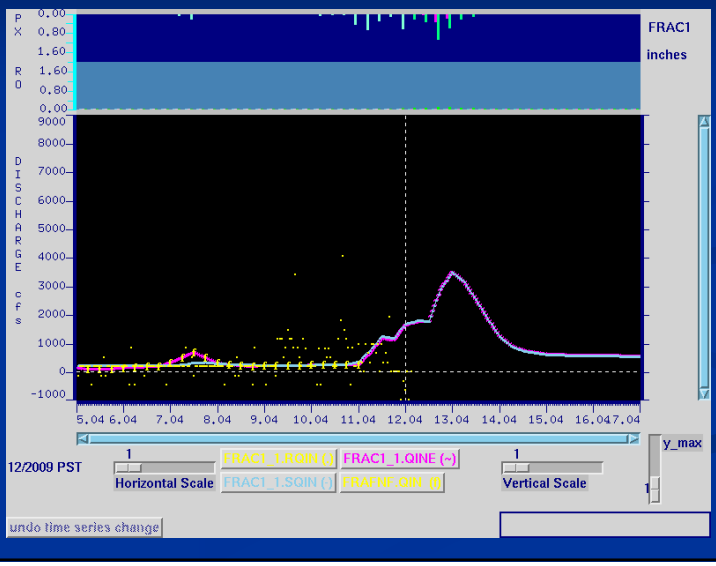
- Watershed characteristics
- Model idiosyncrasies
- Data and gage issues
- Customer and partner needs





Processing

San Joaquin – Millerton Inflow

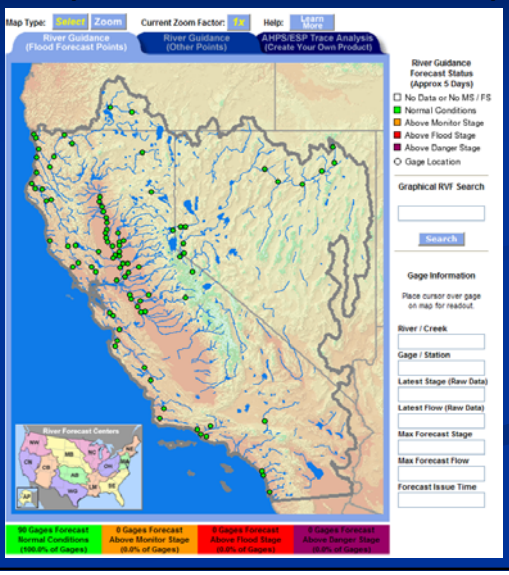


Post-processing

River Guidance (Flood Forecast Points)

- ~90 locations
- Updated w/each model run
  - 2x / day winter weekdays
  - 1x / day summer weekdays and weekends
  - 4x / day during flood events

(www.cnrfc.noaa.gov)

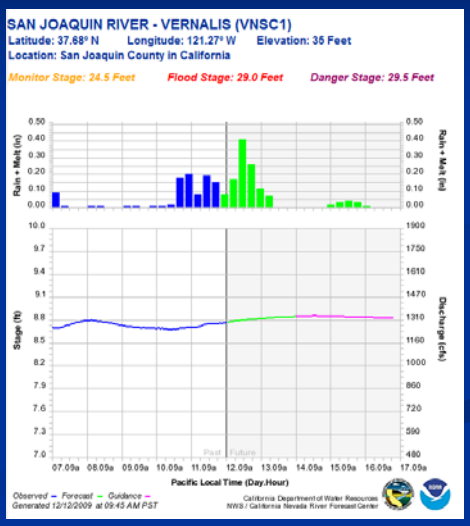


Post-processing

River Guidance (Flood Forecast Points)

- Graphical
  - -/+ 5 days
  - Obs + Forecast + Guidance
  - Available
    - CNRFC Website
    - CDEC Website
  - Interpretation
    - Online help
    - 1 page flier

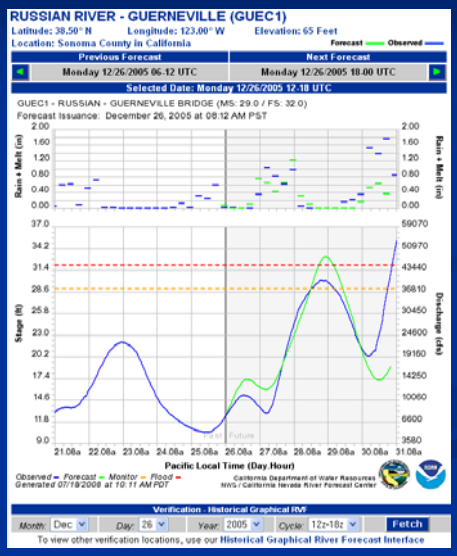
(www.cnrfc.noaa.gov)



Post-processing

River Guidance - Verification

- -/+ 5 days
- Observed and Forecast
  - precipitation
  - streamflow
- Select by
  - date
  - next/previous
  - looping
- Available
  - All flood forecast locations
  - CNRFC Website
- Interpretation
  - Online help
- All since Fall 2003



Post-processing
River Guidance (Flood Forecast Points)

- Text
  - New format this year
  - Issued with each model run
  - + 5 days
  - Summary table and shef encoded data
  - Available
    - CNRFC Website
    - CDEC Website
  - Basis of WFO issued flood warnings
  - Issued for 10 areas
  - Same frequency as graphics

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SAN JOAQUIN RIVER SYSTEM FORECAST
NATIONAL WEATHER SERVICE / CALIFORNIA-NEVADA RFC / SACRAMENTO CA
CALIFORNIA DEPARTMENT OF WATER RESOURCES / SACRAMENTO CA
947 AM PLT SAT DEC 12 2009

NEXT ISSUANCE:     SUNDAY, DECEMBER 13, 2009 AT  9AM PLT

FORECASTS THROUGH: THURSDAY, DECEMBER 17, 2009 AT  4AM PLT

.....................................................................
SITUATION SUMMARY:
ALL LOCATIONS ARE EXPECTED TO REMAIN BELOW CRITICAL LEVELS

.....................................................................
RIVER
   LOCATION                STAGE    FLOW      TIME    DATE          LEAD
   (NWSLI)                 (FT)     (CFS)     (PT)  (MM/DD/YY)      TIME
-------------------------  -----  ---------   ----  ----------      ------
SAN JOAQUIN RIVER     OBS   49.1       497 AT   9AM   12/12/09       (48)
   NEWMAN             >MS   63.0           NOT EXPECTED
   (NWMC1)            >FS   69.4           NOT EXPECTED
                      >DS   70.4           NOT EXPECTED
                      MAX   49.2       526 AT   1PM   12/12/09 IN    3 HRS

SAN JOAQUIN RIVER     OBS   32.0       547 AT   9AM   12/12/09       (48)
   PATTERSON          >MS   48.0           NOT EXPECTED
   (PATC1)            >FS   54.7           NOT EXPECTED
                      >DS   55.7           NOT EXPECTED
                      MAX   32.2       612 AT   5PM   12/16/09 IN 103 HRS

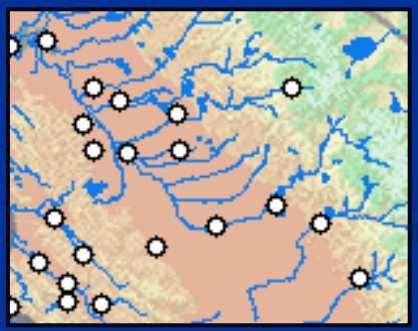
SAN JOAQUIN RIVER     OBS    8.8     1,310 AT   9AM   12/12/09       (48)
   VERNALIS           >MS   24.5           NOT EXPECTED
   (VNSC1)            >FS   29.0           NOT EXPECTED
                      >DS   29.5           NOT EXPECTED
                      MAX    8.8     1,310 AT  CURRENT TIME
```

(www.cnrfc.noaa.gov)

Post-processing
River Guidance (Other Points)

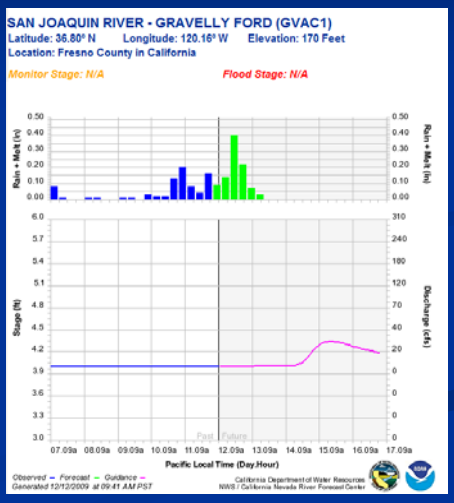
(www.cnrfc.noaa.gov)

- ~80 Non-flood locations



Post-processing
River Guidance (Other Points)

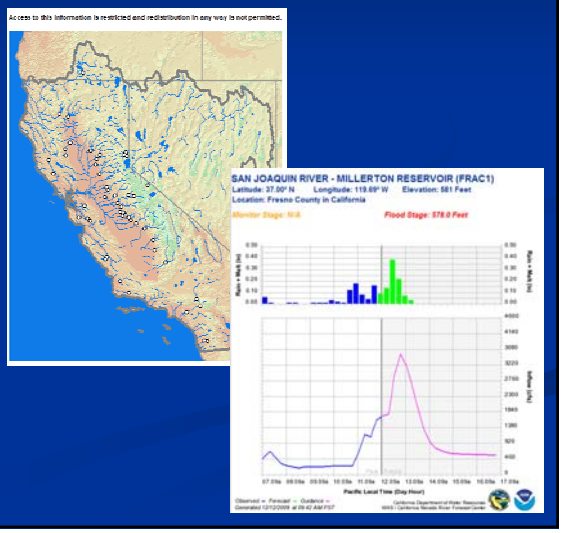
- Generated during normal forecast process
- Various uses
- Same format as flood points



(www.cnrfc.noaa.gov)

Post-processing
River Guidance (Reservoir Inflows)

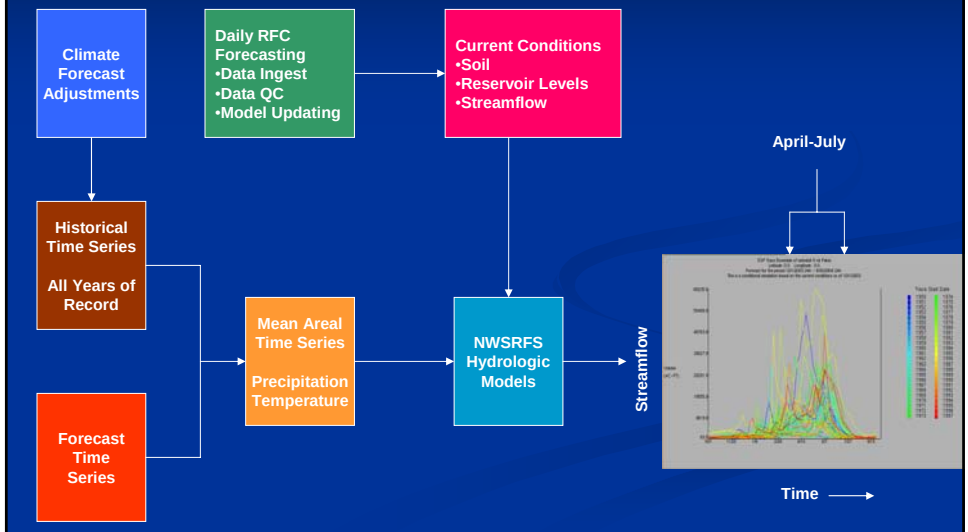
- 50 Reservoirs
- Restricted access
- Same format as river locations
- Updated w/ each model run
- Tabular data sent directly to operators



Ensemble Streamflow Prediction

- Use same forecasting infrastructure as Flood/Routine forecasts (NWSRFS)
  - Same models, observed data, model states
- Modeling system run with multiple scenarios of future precipitation and temperature
  - Scenarios are
    - Spatially and temporally coherent
    - Equally likely
- Resulting streamflow scenarios form a set that can be statistically sampled and analysed

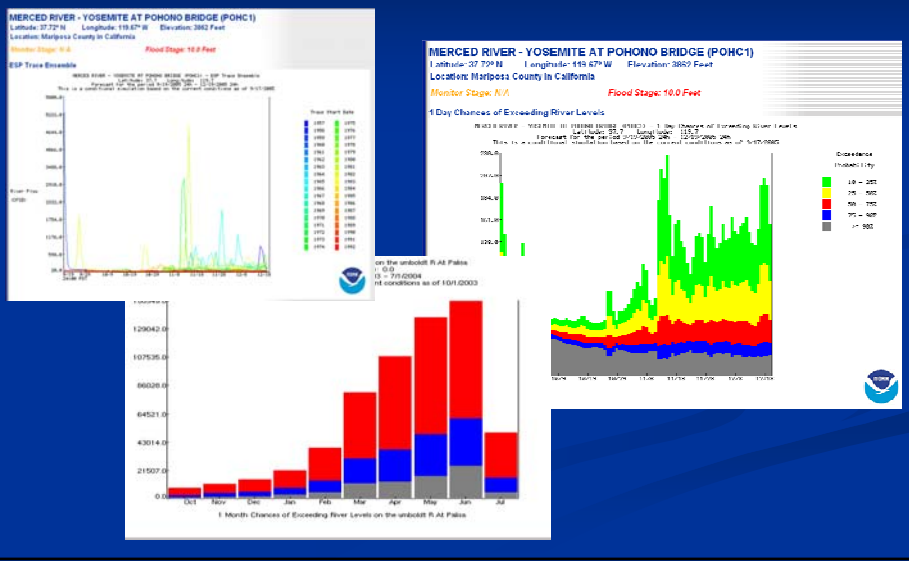
Ensemble Streamflow Prediction



ESP Product Generation

- Significant flexibility
  - User selectable time aggregation
    - 6 hrs to 1 year
  - User selectable window
    - Days, weeks, months or multiples there of
  - Information on
    - Peaks
    - Number of days to critical thresholds (e.g. Flood Stage)

Sample ESP Products



CNRFC Ensemble User Interface

- "Create Your Own"
- Ensembles run nightly
- Assumes knowledgeable user
- Online help and interpretive tools available

(www.cnrfc.noaa.gov)

20-Day Spring Snowmelt Forecasts

(www.cnrfc.noaa.gov/products/snowmelt/snowmelt.pdf)

- Issued on Wednesdays
  - Early April through the peak
  - Updates as requested
- Four 5-Day volume periods (20 days total)
  - 90%, 50%, 10% exceedance volumes (KAF)
- 1st period – primary use of single value forecast with QPF and forecast temperatures
- 2nd – 4th periods – primary use of ESP tools with blending of QPF and temperature forecasts into climatology
- 27 locations, 21 include peak forecasts

20-Day Spring Snowmelt Forecasts

(www.cnrfc.noaa.gov/products/snowmelt/snowmelt.pdf)

Forecast Runoff Volumes for the Snowmelt Season

Wednesday, April 29, 2009

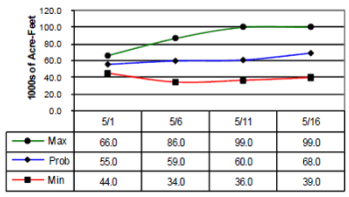
NWS California Nevada River Forecast Center and the California Dept. of Water Resources

Remarks: The initial synoptic conditions indicate an upper trough located over the Pacific Northwest inland toward the northern Rockies. This is resulting in cool temperatures across California and Nevada, near or slightly below normal. Late this week into this weekend (May 1 to May 3) a low pressure system will approach the west coast from the eastern Pacific. This will bring widespread precipitation across the entire region, greatest over the northern and central California coastal mountains, Shasta drainage, and the entire length of the Sierra Nevada. Overall amounts are still tough to pinpoint at this time. However, an early estimate is 0.25- to 0.75-inch across the lower elevations and 1.00- to 2.00-inches over the higher terrain. Amounts will be lighter across the s
temperatures, but near n
across the eastern Pacifi
while low temperatures
precipitation by the middl

Forecasts reflect predicte
shift from normal climato

Forecast Point	Peak 1-Day Volume (1000s of ac-ft)	Date (Month/Day)
American River - Folsom	17.5	5/10
Mokelumne River - Pardee	9.0	5/14
Stanislaus River - New Melones	12.0	5/14
Tuolomne River - New Don Pedro	22.0	5/18
Merced River - Pohono Bridge	7.0	5/15
Merced River – Lake McClure	11.0	5/15
Lake Tahoe Inflow	2.8	5/19
Truckee River – Tahoe to Farad	4.2	5/18
WF Carson River - Woodfords	1.0	5/19
EF Carson River - Gardnerville	3.2	5/19
Carson R – Carson City	3.0	5/20
San Joaquin River - Millerton	23.0	5/19
Kings River – Pine Flat	22.0	5/19
Kaweah River - Terminus	5.0	5/18
Tule River - Success	0.6	4/22
Kern River - Isabella	7.0	5/20
West Walker River - Coleville	2.4	6/5
East Walker River - Bridgeport	0.7	6/6
Humboldt River - Palisade	2.6	6/9
Marys River – Twin Buttes	0.8	5/24
Humboldt River - Elko	1.5	6/8

San Joaquin River at Millerton



	5/1	5/6	5/11	5/16
Max	66.0	86.0	99.0	99.0
Prob	55.0	59.0	60.0	68.0
Min	44.0	34.0	36.0	39.0

CNRFC Statistical Water Supply (SWS) Modeling

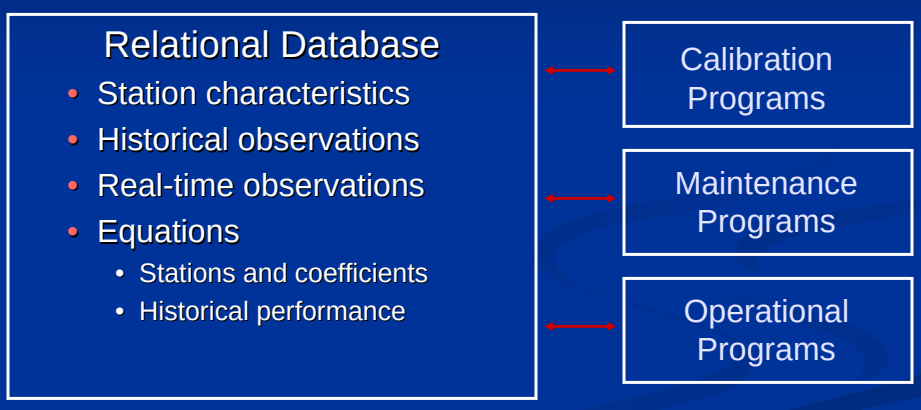
- Topics
  - Comparison of SWS and ESP attributes
  - Overview of CNRFC SWS environment
  - CNRFC SWS data requirements
  - CNRFC SWS calibration program and approach
  - CNRFC Operational process

  - Review of CNRFC Millerton Lake procedures
  - Description of CNRFC Water Supply products and locations

Statistical Models vs. Ensemble Techniques

- Statistical Models
  - Low data requirement
  - Easy to calibrate and maintain
  - Perform better for seasonal volume forecasts
  - Inflexible (use/output)
  - May have difficulty in extreme years
  - Difficult to integrate weather and climate forecasts
  - Dominate model in the past
- ESP Techniques
  - High data requirement
  - More difficult to calibrate and maintain ($$)
  - Perform better for partial season forecasts
  - Flexible (use/output)
  - Should work reasonably well in extreme years
  - Easier to integrate weather and climate forecasts
  - Dominate model in the future

CNRFC SWS System Design



CNRFC SWS Data Requirements

- Types
  - Adjusted monthly streamflow
    - Account for affects of diversions and reservoirs
    - Useful as a carryover term in some areas
  - Monthly precipitation
  - Snow course/pillow observations
  - Other
    - Climatic indexes, etc.

CNRFC SWS Calibration Program

- Developed by USDA/NRCS in late ‘80s

- Up to 49 “independent” variables
- Dependent variable transformation
- Principal components analysis (PCA)
- Cross validation standard error
- Combination analysis
- Yields “best” 20 equations (lowest CVSE)

SWS Calibration Approach

- Equations developed for each forecast month
  - Care taken to keep stations as consistent as possible from month to month
- No use of “future” data
  - Causes non-optimal coefficients (weights)
- Balance lower errors with good spatial distribution of stations
  - Attempt to introduce “some” hydrology
- Equations can be used in a mid-month mode
  - Estimate %normal to date and assume %normal to EOM
  - Use next month’s equation

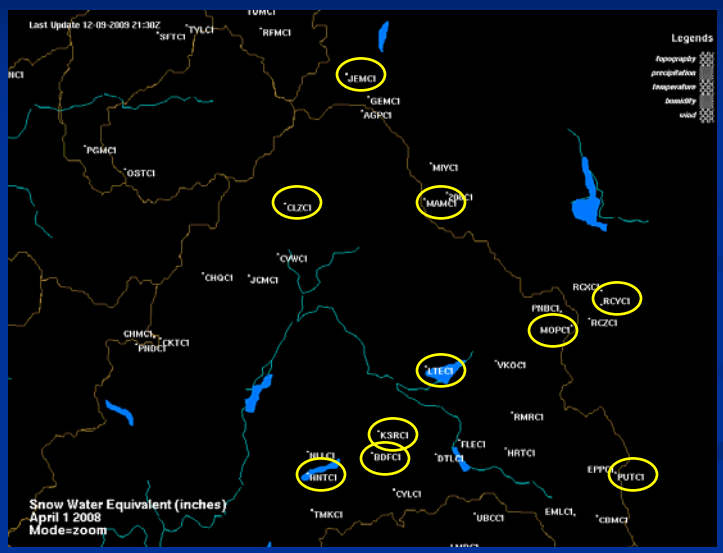
CNRFC Operational SWS Forecasting Process

- Monitor and quality control incoming data
- Run equations and make adjustments
  - Compare with ESP information
- Coordinate forecasts with other agencies
  - NRCS in Nevada and Southern Oregon
  - Comparison with CA DWR in California
- Publish forecasts on Internet

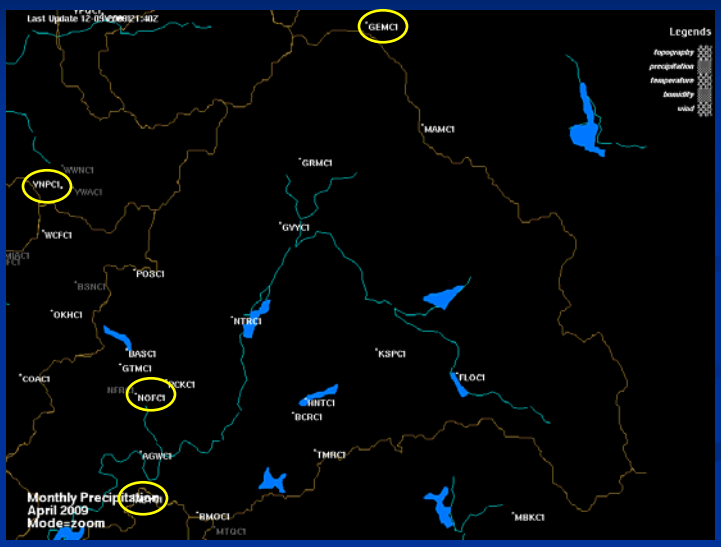
Statistical Procedures for
San Joaquin – Millerton Lake Inflow

- All forecasts are for April – July volume
- Maps of precipitation and snow course stations used in equations
- Monthly progression of SE and CV
- January 1 through May 1 equations
  - Scatter plots
  - Precipitation and Snow Courses used

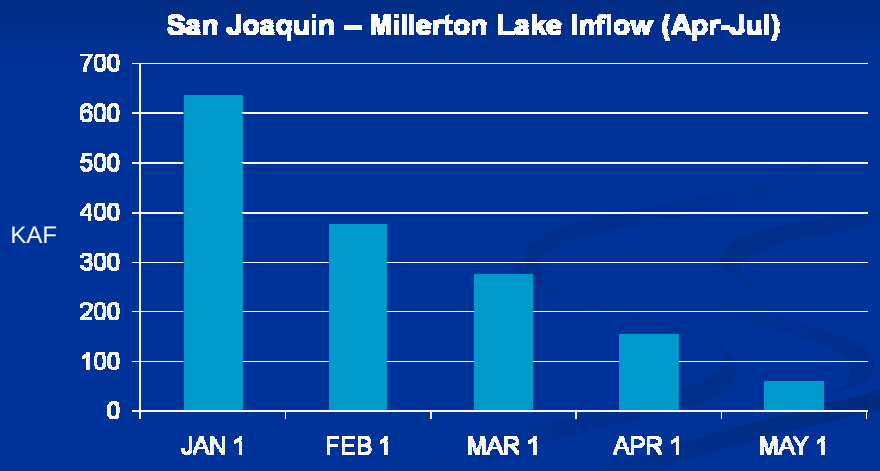
Utilized Snow Courses



Utilized Precipitation Gages

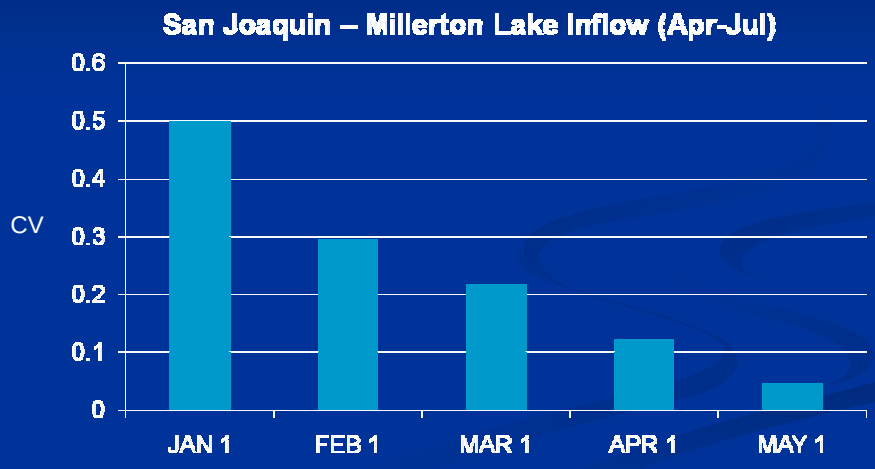


Monthly Standard Errors

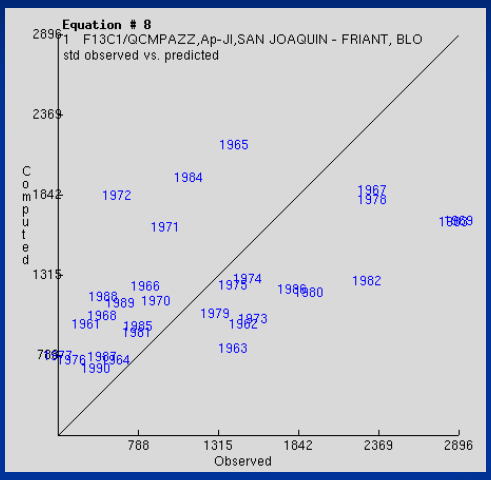


Monthly Coefficient of Variation

(Standard Error / Average)

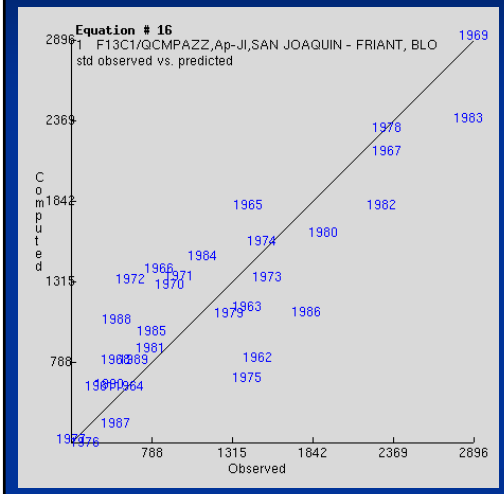


January Equation (Millerton, Apr-Jul)



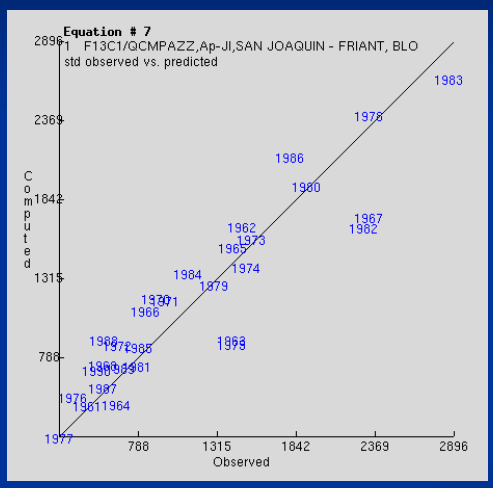
- Standard Error = 636 KAF
- December Precipitation
  - Gem Lake
  - South Entrance YNP
  - Auberry
  - North Fork Ranger Station

February Equation (Millerton, Apr-Jul)



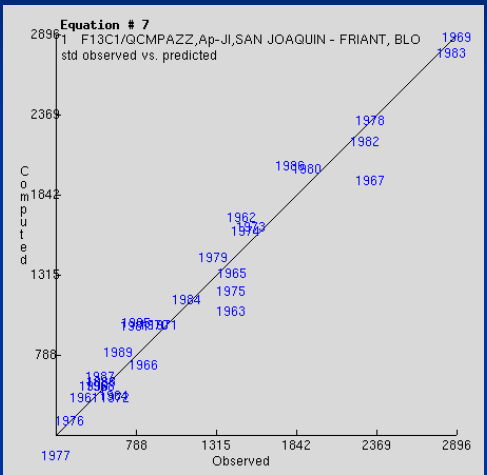
- Standard Error = 376 KAF
- Dec-Jan Precipitation
  - Auberry
  - North Fork Ranger Station
- Feb 1 SWE
  - Lake Thomas Edison
  - Rock Creek 1
  - Rock Creek 2

March Equation (Millerton, Apr-Jul)



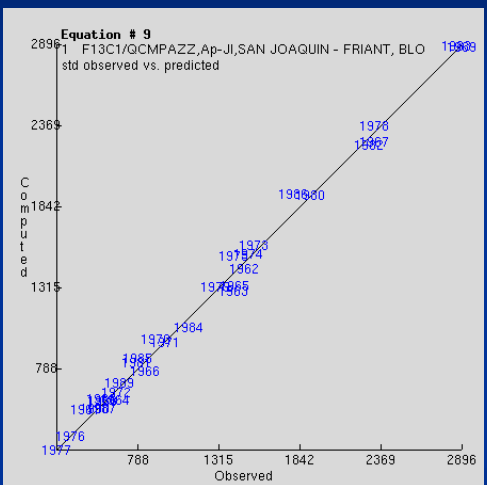
- Standard Error = 276 KAF
- Dec-Feb Precipitation
  - Auberry
  - North Fork Ranger Station
- Mar 1 SWE
  - Gem Pass
  - Mono Pass
  - Piute Pass

April Equation (Millerton, Apr-Jul)



- Standard Error = 155 KAF
- Dec-Mar Precipitation
  - Auberry
  - North Fork Ranger Station
- Apr 1 SWE
  - Gem Pass
  - Mono Pass
  - Piute Pass
  - Cora Lakes
  - Lake Thomas Edison
  - Rock Creek 2
  - Mammoth Pass

May Equation (Millerton, Apr-Jul)

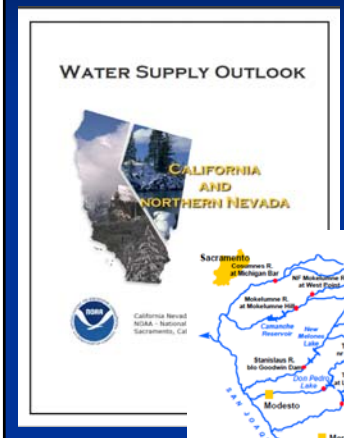


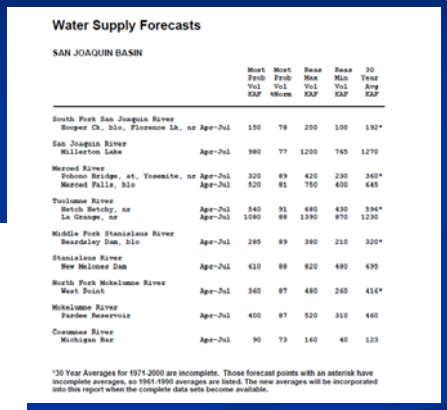
- Standard Error = 59 KAF
- Dec-Apr Precipitation
  - Auberry
  - North Fork Ranger Station
- Apr 1 SWE
  - Gem Pass
  - Mono Pass
  - Piute Pass
  - Cora Lakes
  - Rock Creek 2
- May 1 SWE
  - Lake Thomas Edison
  - Huntington Lake
  - Kaiser Pass
  - Badger Flat
  - Beard Meadow

CNRFC Water Supply Products and Services

- CNRFC Monthly Water Supply Outlook
  - www.cnrfc.noaa.gov/products/water_supply
- Westwide Water Supply Outlook
  - www.cbrfc.noaa.gov/wsup/westwide/westwide.cgi
- Western Water Supply Website
  - www.nwrfc.noaa.gov/westernwater

CNRFC Monthly Water Supply Outlooks





Water Supply Forecasts

SAN JOAQUIN BASIN

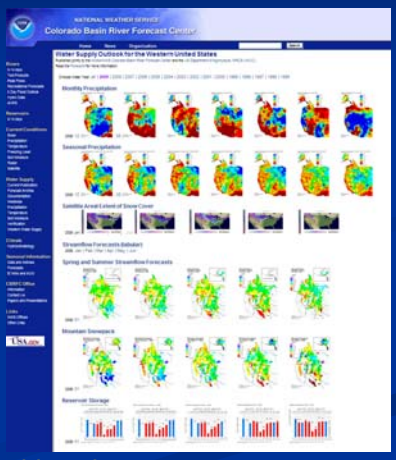
		Most Prob Vol KAF	Most Prob Vol %Norm	Reas Max Vol KAF	Reas Min Vol KAF	30 Year Avg KAF
South Fork San Joaquin River						
Hooper Ck, blo, Florence Lk, nr	Apr-Jul	150	78	200	100	192*
San Joaquin River						
Millerton Lake	Apr-Jul	980	77	1200	765	1270
Merced River						
Pohono Bridge, at, Yosemite, nr	Apr-Jul	320	89	420	230	360*
Merced Falls, blo	Apr-Jul	520	81	750	400	645
Tuolumne River						
Hetch Hetchy, nr	Apr-Jul	540	91	680	430	596*
La Grange, nr	Apr-Jul	1080	88	1390	870	1230
Middle Fork Stanislaus River						
Beardsley Dam, blo	Apr-Jul	285	89	380	210	320*
Stanislaus River						
New Melones Dam	Apr-Jul	610	88	820	480	695
North Fork Mokelumne River						
West Point	Apr-Jul	360	87	480	265	414*
Mokelumne River						
Pardee Reservoir	Apr-Jul	400	87	520	310	460
Cosumnes River						
Michigan Bar	Apr-Jul	90	73	160	40	123

*30 Year Averages for 1971-2000 are incomplete. Those forecast points with an asterisk have incomplete averages, so 1961-1990 averages are listed. The new averages will be incorporated into this report when the complete data sets become available.

www.cnrfc.noaa.gov/products/water_supply

Westwide Water Supply Forecasts

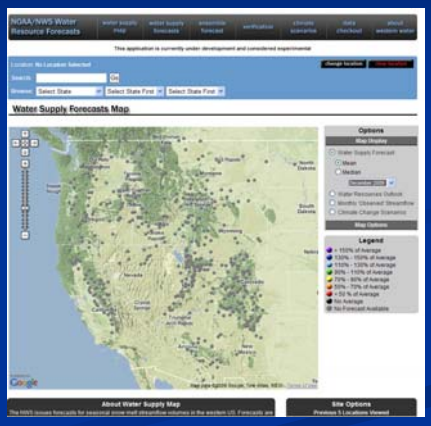
- Current and archive (‘95 on) of:
  - Monthly/Seasonal Precipitation
  - Snow water
  - Snow cover (satellite)
  - Reservoir storage
  - Streamflow forecasts



www.cbrfc.noaa.gov/wsup/westwide/westwide.cgi

Western Water Supply Website

- Stat-based forecasts
  - Monthly progression
- ESP-based forecasts
  - Monthly break-downs
- Verification information
- More…
- All points in Western US
  - Expanding Nation-wide



www.nwrfc.noaa.gov/westernwater

California-Nevada
River Forecast Center

Changes Are Coming!

- CHPS (Community Hydrologic Prediction System) to replace NWSRFS
  - Service oriented architecture
  - Delft FEWS + NWS models + custom development
  - Easier to integrate external models
  - Deployment at CNRFC underway now!
    - Massive migration effort
    - Started parallel operations in October 2009
    - Fully operational before October 2010
  - Fully operational across US by October 2011
  - See website NEWSLETTER for details…

Changes Are Coming!

- Hydrologic Ensemble Forecasting System
  - PROBABLISTIC FORECASTS
    - Short (hours), Medium(days), Long(weeks/months)
  - Requires CHPS
  - Many years in prototype development
  - Partial operational deployment planned for WY11
  - See website NEWSLETTER for details…

Future CNRFC Hydrologic Modeling

Short Range … … … … … … Long Range

CHPS

1-6 hour time step

Single value

HEFS……

probablistic (ensemble-based)

Statistical

simple, efficient, inflexible