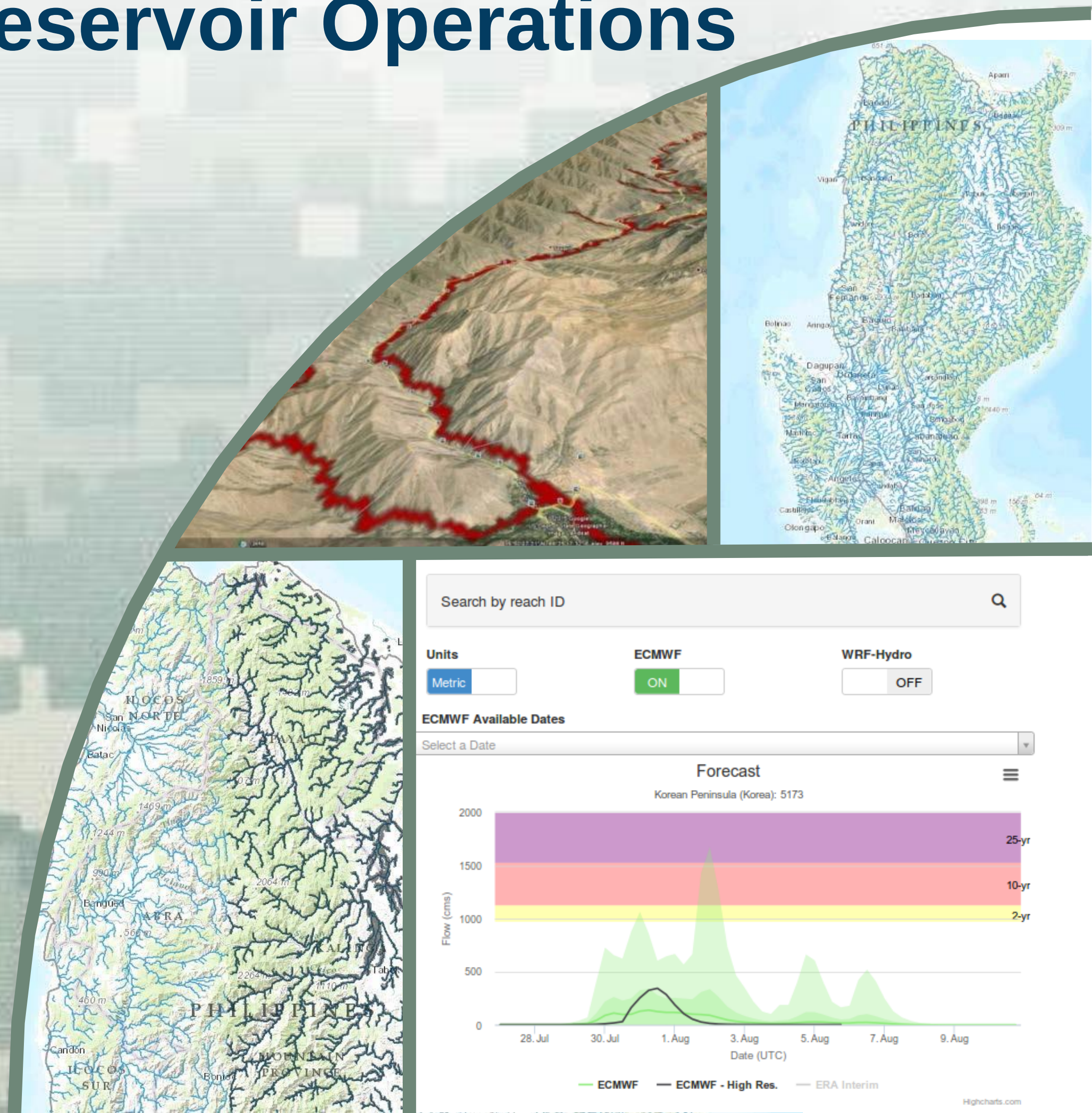
Forecast Informed Reservoir Operations (FIRO)

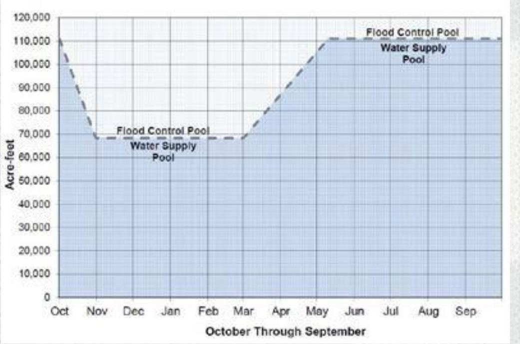
ERDC Hydrologic Investigations

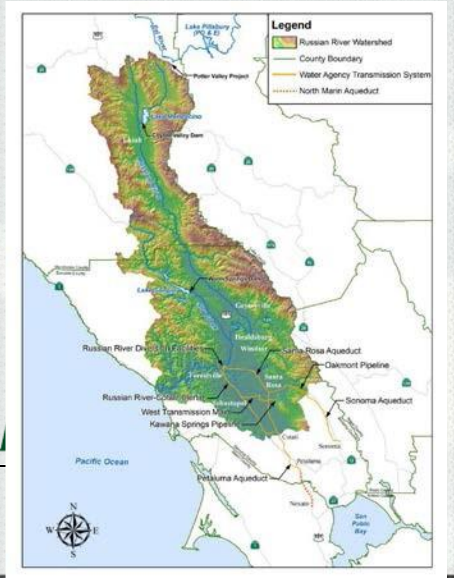


Briefing,
May 31, 2017

Background

- The US Army Corps of Engineers (USACE) operates reservoirs primarily for flood control, with recreation, water supply, and power generation being authorized uses for many reservoirs.
- USACE reservoirs are typically operated according to rule curves, which specify yearly stage variations of the reservoir.
- The operations manual may allow for variations in the rule curve.
- In the Russian River Valley, variations may could possibly increase critical water supplies
- Simulations tools can be used to explore possible variations.





Purpose

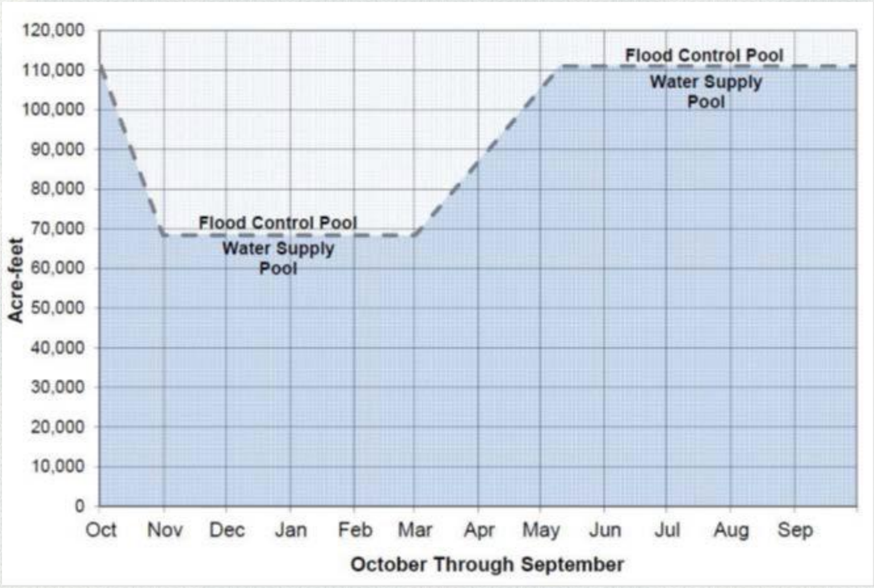
- Identify important factors and technology gaps in simulating flows and reservoir response in the Russian River Valley utilizing forecasted weather products for the purposes of assessing the effect of variations in reservoir operating rules on water supply and flood control.

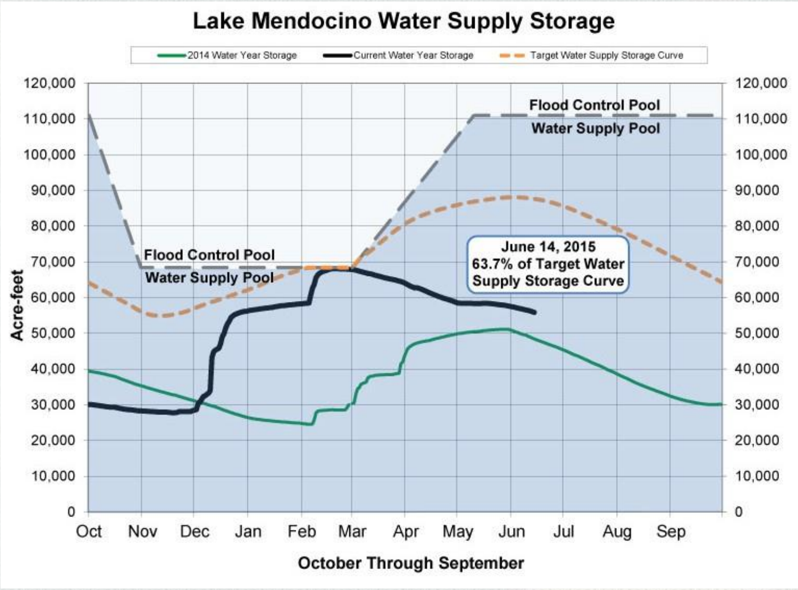
Objectives

- Understand the processes that control runoff in Russian River Valley.
- Assess the ability to simulate flows and reservoir levels in the Russian River Valley with an integrated physics-based watershed model.
  - Advantages/disadvantages to standard methods
  - Effects of scale
- Incorporate forecasted weather products into the watershed model for short term, days to weeks, predictions of flows and reservoir levels.
  - Standard method for incorporation into USACE models.
  - Assess current utility of forecasted models.
  - Attempt to define required weather forecast capability with current state of the art hydrologic models.

Objectives

- Utilize available observed data to improve forecast of flows and reservoir stages – data assimilation.
- Game different operational schemes, adjustments, etc., to attempt to define potential types of improved operational rules, methods, and schemes that might increase water supply, without affecting flood protection.





Work Plan

- Utilize the GSSHA hydrologic model
- Build models of various resolution to assess issues of model scale
  - Start with Lake Mendocino
  - Expand to Lake Sonoma
  - Entire Russian River Valley
- Asses impact of other factors
  - Temporal resolution of precipitation
    - Impact on parameter values
  - Reservoir operations

Work Plan

- Incorporate weather forecast into GSSHA
  - Getting the data into GSSHA
  - Different models/output/resolutions/ensembles
- Data Assimilation
  - Precipitation
  - Flows
  - Soil Moisture
- Explore "optimal" rule curves for Lake Mendocino and Lake Sonoma

Work Plan

- Disseminate results
  - Reports
  - Journal Articles
  - CWMS (Corp Water Management System)
  - ERDC Tethys based platform

Time Line

- Year 1 (2015)
  - ▸ Develop work plan
- Year 2 (2016)
  - ▸ Develop varying scale GSSHA models of Lake Mendocino
- Year 3 (Current FY)
  - ▸ Incorporate groundwater into GSSHA models
  - ▸ Incorporate advance operating rules into GSSHA
  - ▸ Begin incorporating weather forecast products into GSSHA
  - ▸ Begin working on data assimilation
  - ▸ Begin Lake Sonoma Model

Time Line

- Year 4
  - Continue with incorporating weather forecast into GSSHA
  - Continue with data assimilation
  - Explore alternate routing methods in GSSHA
  - Complete Lake Sonoma model
  - Begin Russian River model
  - Begin exploring “optimal” rule curve
- Year 5
  - Complete weather forecasting tasks
  - Complete data assimilation tasks
  - Complete Russian River model
  - Disseminate Information

Progress To Date

- Three GSSHA models of Lake Mendocino
  - ► 30m model of East Fork of the Russian down to Ukiah
  - ► 50m model of Russian River to Hopland
  - ► 270 m model of the Russian River to Hopland
- Data processed for period of record
  - ► Precipitation
  - ► Inflows
  - ► Hydrometeorological
- Calibration to observed data in progress
- Coupled to CW3E West WRF model for selected events

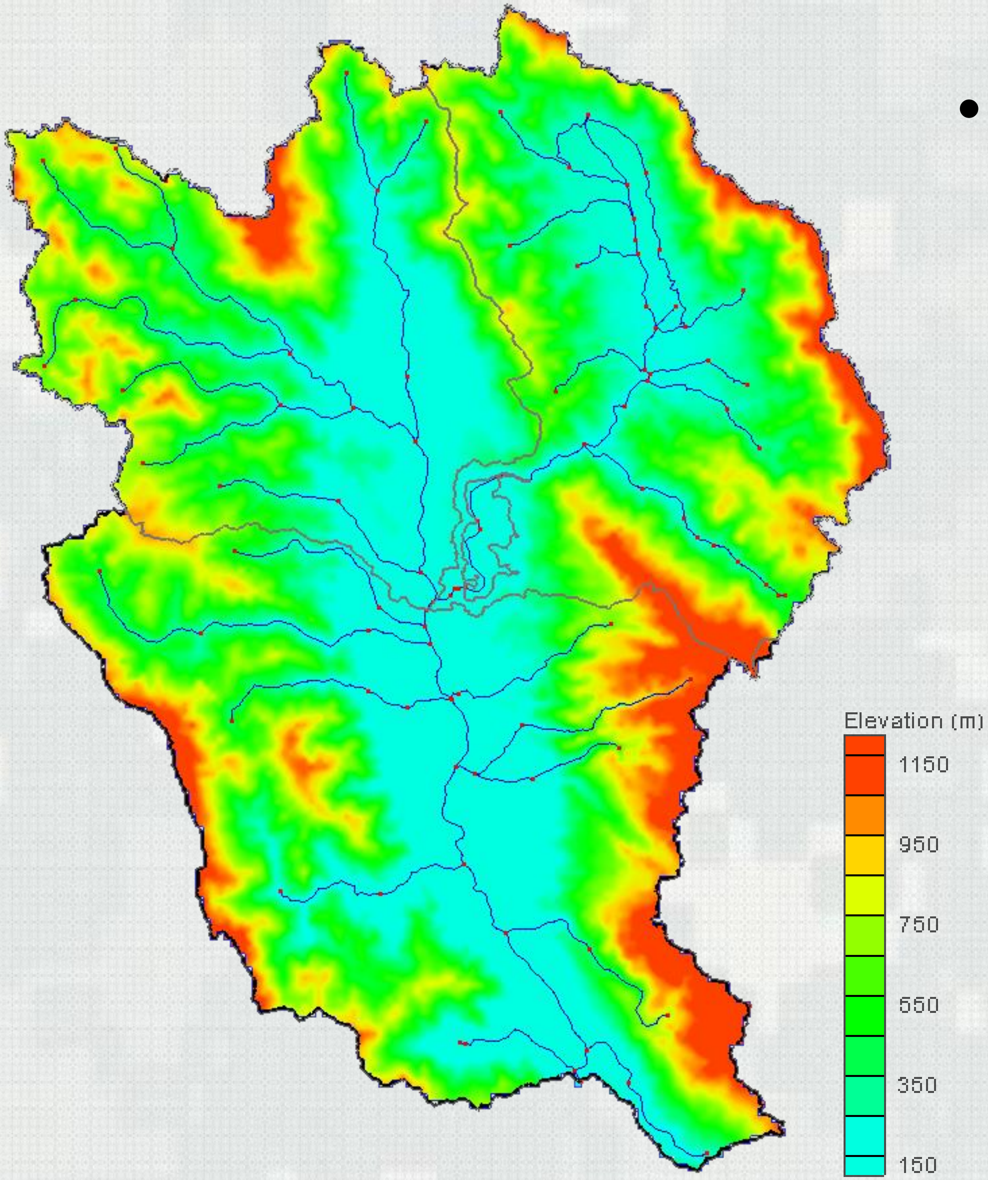
Important Factors to Consider

- Hydrologic simulator
  - Processes
    - Infiltration
    - Evapotranspiration
    - Overland flow
    - Stream flow
    - Groundwater interaction
    - Basin transfers
  - Methods
- Scale issues
  - Spatial and Temporal
  - Parameter values
- Reservoir Operations
- Data Assimilation

Overall Watershed Modeling Approach using GSSHA

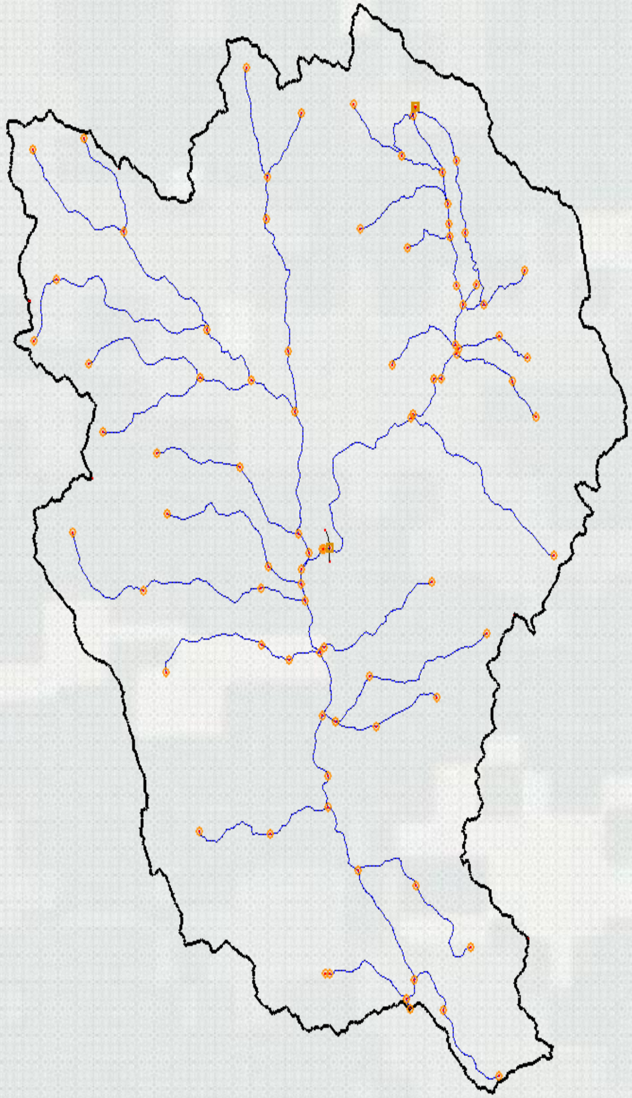
- Watershed Modeling System (WMS) developed by Aquaveo, Inc. used to create GSSHA input files.
- GSSHA uses multiple ASCII text files as input that allow for review of model input parameters.
- Distributed data input from GIS shapes files and topographic data: land use (http://sonomavegmap.org), SSURGO soils, 10 m DEM, LiDAR, lake bottom surveys.
- Infiltration and roughness parameters from literature and previous GSSHA modeling efforts (gsshawiki.com).
- Incorporate newly collected hydrology field data from 2017-2019 wintertime wet seasons in the Russian River Valley.

GSSHA Model Input Data



- Topography:
  - Stream Network built from 10 m DEM elevations. Lake bottom elevations from LiDAR data (SCWA) merged with 10 m DEM.
  - Created a DEM for Russian River Valley down to Hopland, CA, used for various model grids (at this point).

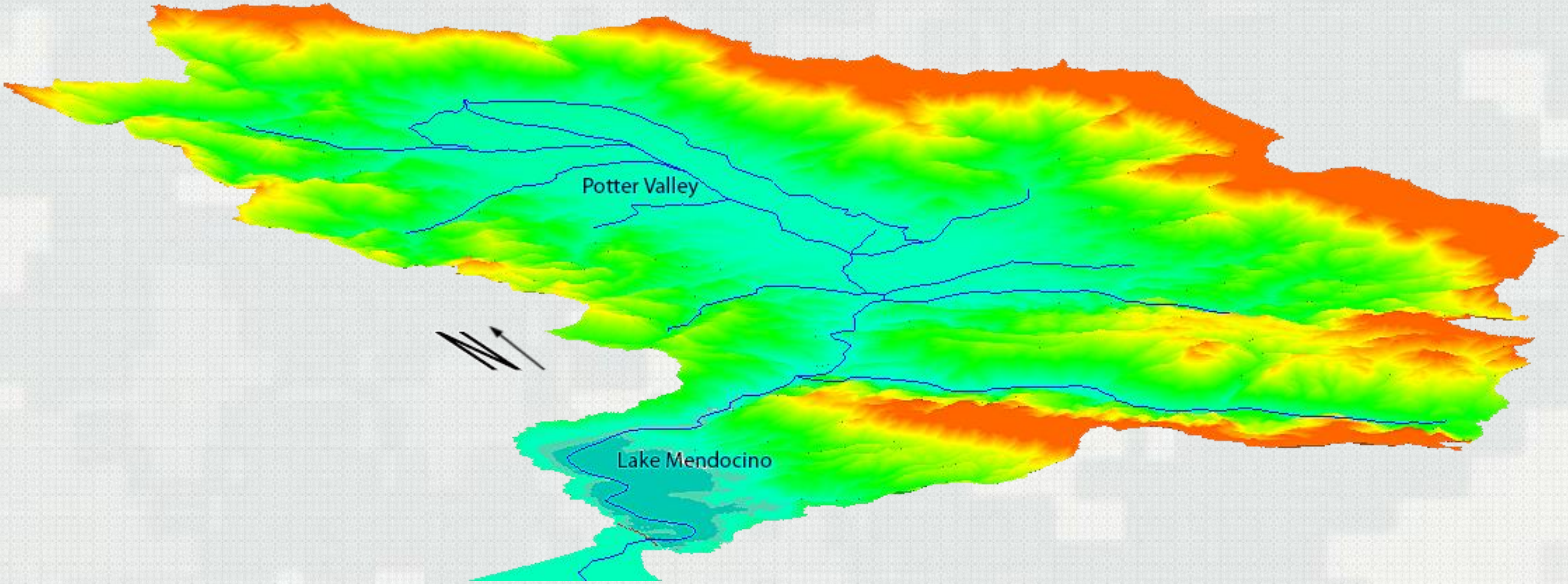
GSSHA Model Input Data



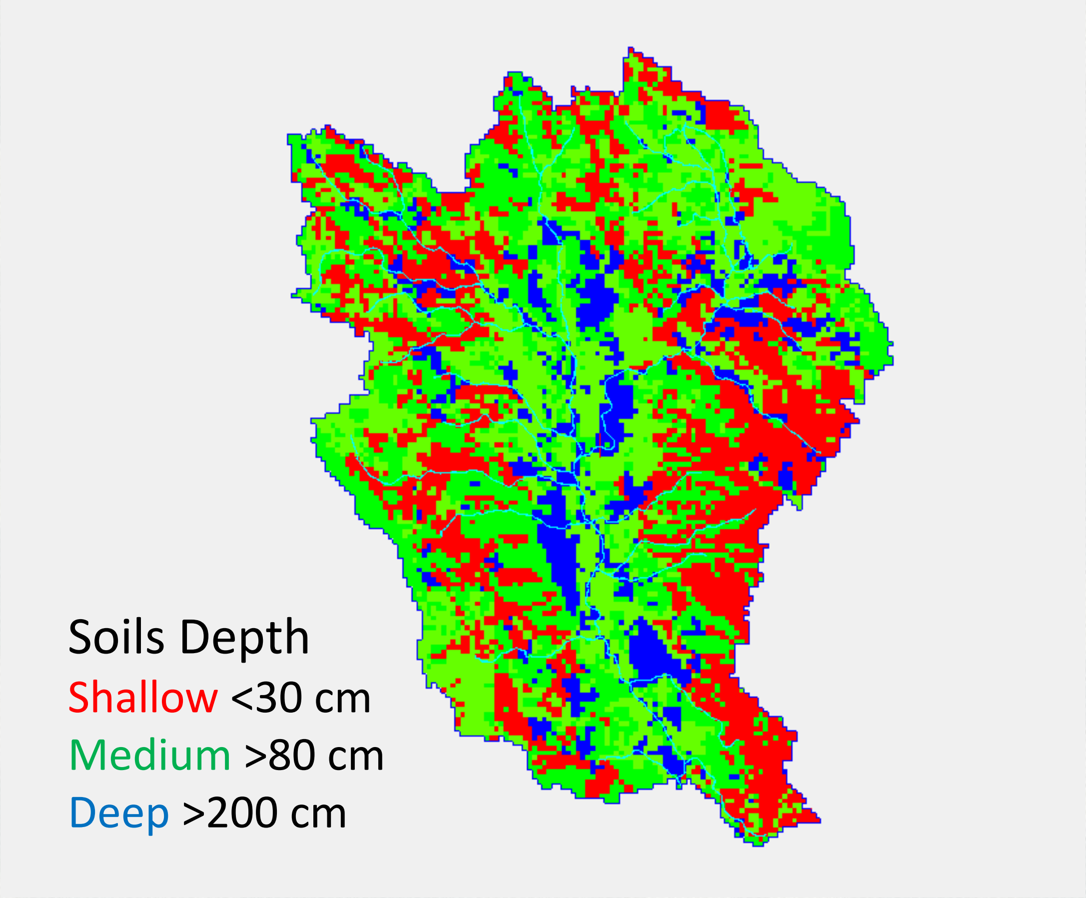
- Streams
  - Created initially using WMS processor (TOPAZ) from the DEM.
  - Modified and checked manually using WMS, validating stream elevation and slope, distribution of 1-D link and nodes.
  - Available river cross sections from DEM and field surveys done by CHL (mostly above Lake Mendocino).
  - Prescribed stream flows from Eel River diversion.

GSSHA Model Input Data

- Mendocino Lake
  - Lake is defined in GSSHA model with min, max, and initial elevations which determines initial area of the lake.
  - Outlet structure is Coyote Valley Dam with a hourly scheduled discharge curve.
  - During a long term model simulation, lake elevation is calculated based on inflow and outflow and a lake volume/area curve.
  - Recoding GSSHA to more accurately simulate lakes.

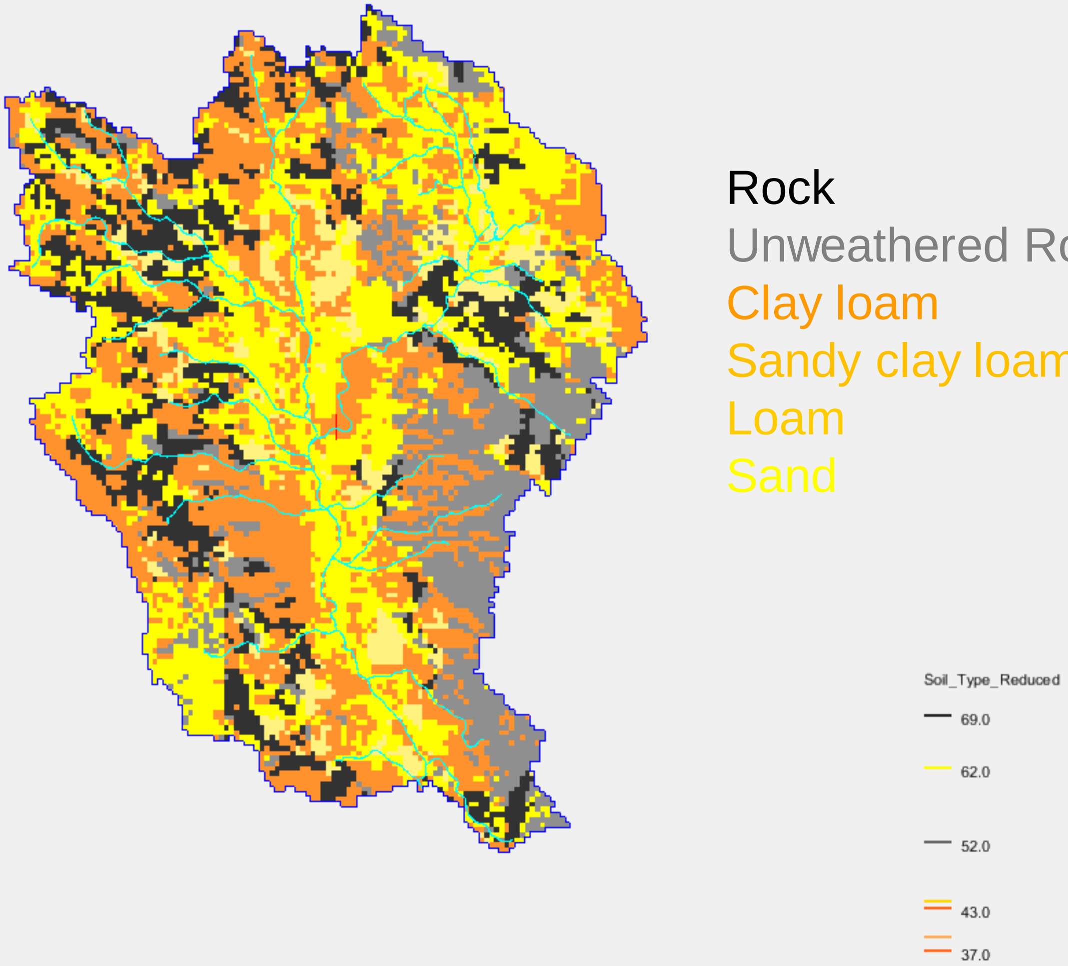


Factors – Soil Depth



- Soils Input Data
  - Index map method allows for either a unique value for each cell, all the same, or any variation.
  - Soil parameters for Green and Ampt infiltration (saturated hydraulic conductivity, effective porosity, residual moisture content).
  - Soils from SSURGO website from SCWA and USGS discussions.
  - Input parameters soil permeability, etc. from USGS, COE, SCWA, and literature sources and discussions with FIRO partners.

Factors – Soil Texture



Soil Hydrologic Considerations

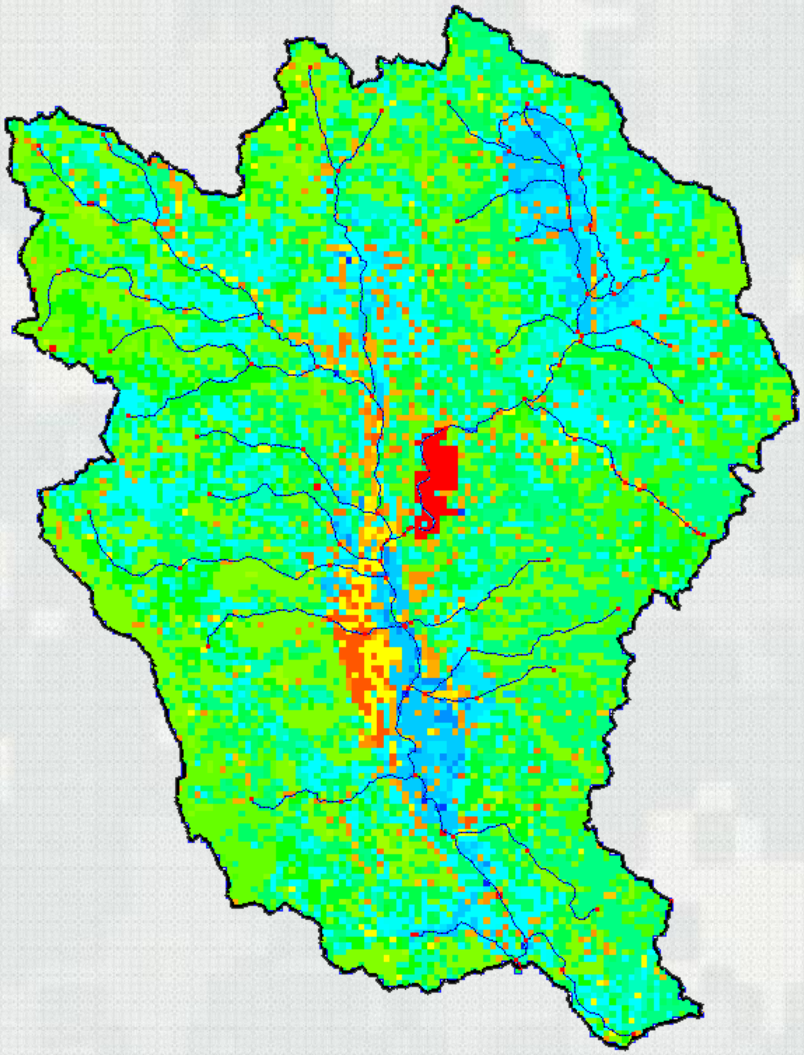
- Many soils are shallow with bedrock underneath
- Simulations with multi-layer Green and Ampt model allow proper system response to be captured from all types.

Well drained soils (sands and loams) over confining layers provide storage that must be filled before runoff occurs

Well drained deep soils may not produce surface runoff. May contribute to base flow.

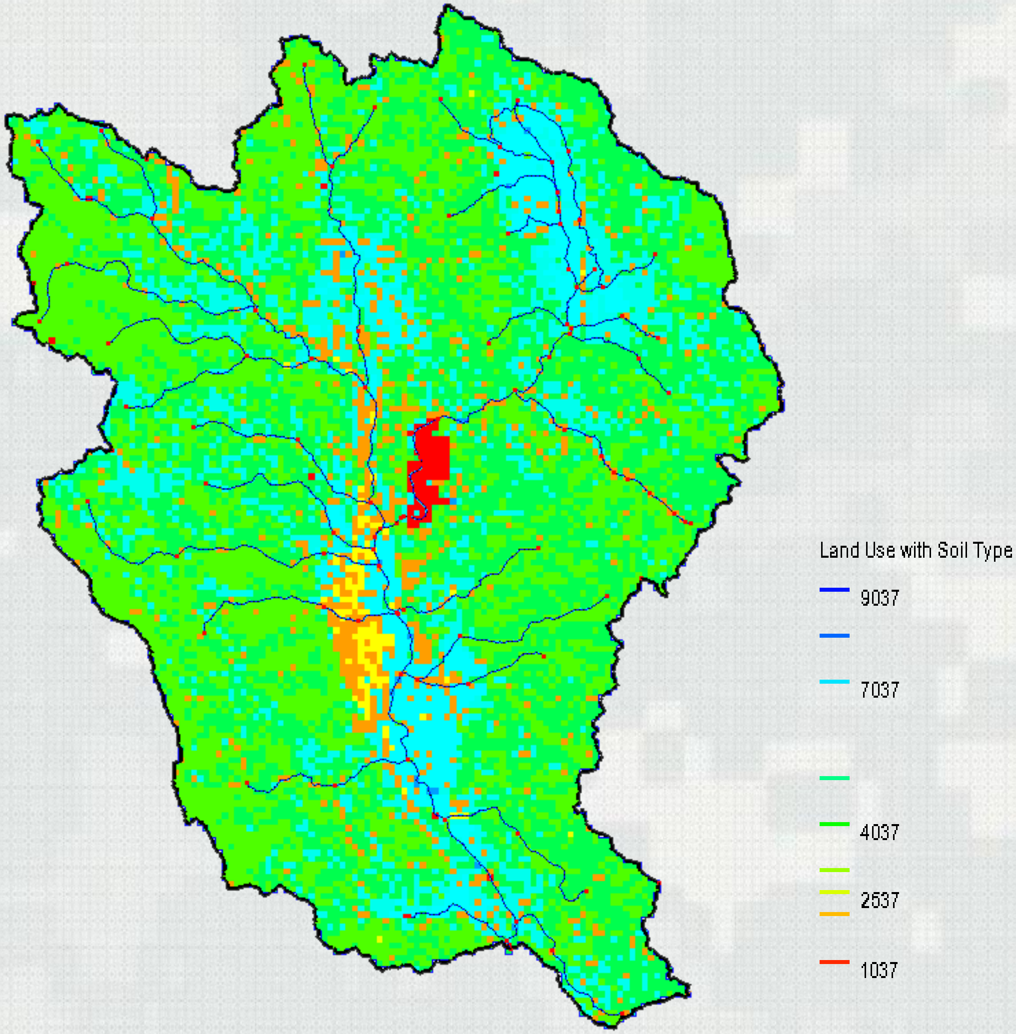
Clayey soils and exposed bedrock may produce rapid surface runoff

Land Use



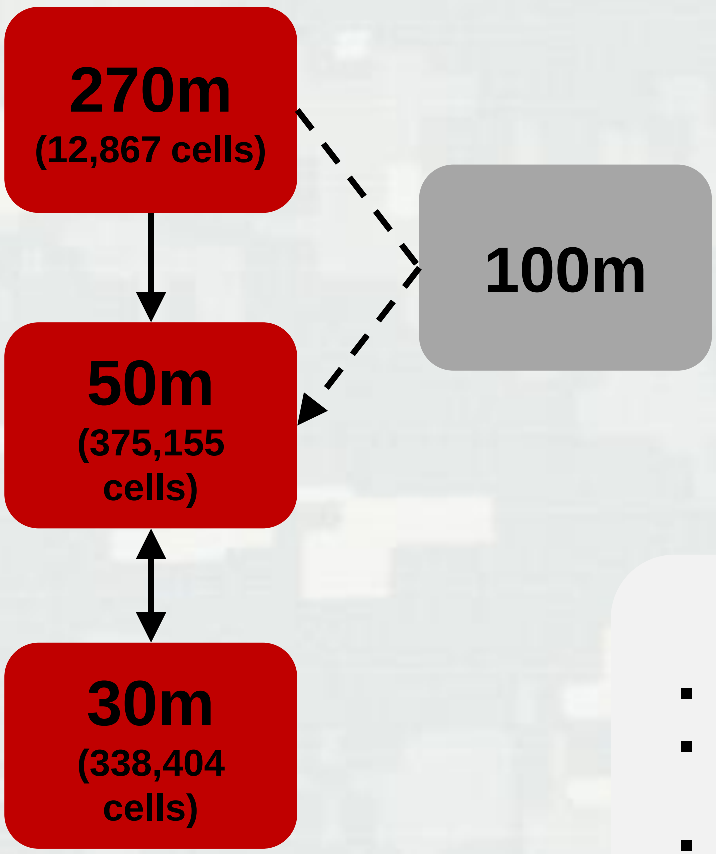
Code	Land Use	Domain Percentage
11	Water	1%
21	Developed Open space	6%
22	Developed Low Intensity	1%
23	Developed Medium Intensity	1%
24	Developed High Intensity	< 1%
31	Barren Land	<1%
41	Deciduous Forest	2%
42	Evergreen Forest	19%
43	Mixed Forest	11%
52	Shrub	38%
71	Grassland	14%
81	Pasture	<1%
82	Crops	6%
90	Woody Wetlands	<1%
95	Emergent Herbaceous Wetlands	<1%

- **Land Use/Soil Type Intersection - joint land use/soils coverage**



Code	Land Use	Soil Type
1002	LU: Water	ST: Clay Loam
1037	LU: Water	ST: Clay Loam
1039	LU: Water	ST: Clay Loam
1043	LU: Water	ST: Clay Loam
1044	LU: Water	ST: Clay Loam
1052	LU: Water	ST: Clay Loam
1062	LU: Water	ST: Clay Loam
1069	LU: Water	ST: Clay Loam
2002	LU: DevLow	ST: Gravely Sandy Loam
2037	LU: DevLow	ST: Water (Clay Loam)
2039	LU: DevLow	ST: Sandy Clay Loam
2043	LU: DevLow	ST: Clay Loam
2044	LU: DevLow	ST: Loam
2052	LU: DevLow	ST: Sandy Loam
2062	LU: DevLow	ST: Very Gravely Sandy Loam
2069	LU: DevLow	ST: Loam
2502	LU: DevHigh	ST: Gravely Sandy Loam
2537	LU: DevHigh	ST: Water (Clay Loam)
2539	LU: DevHigh	ST: Sandy Clay Loam
2543	LU: DevHigh	ST: Clay Loam
2544	LU: DevHigh	ST: Loam
2552	LU: DevHigh	ST: Sandy Loam
2562	LU: DevHigh	ST: Very Gravely Sandy Loam
2569	LU: DevHigh	ST: Loam
3002	LU: Barren	ST: Gravely Sandy Loam
3037	LU: Barren	ST: Water (Clay Loam)
3039	LU: Barren	ST: Sandy Clay Loam
3043	LU: Barren	ST: Clay Loam
3044	LU: Barren	ST: Loam
3052	LU: Barren	ST: Sandy Loam
3062	LU: Barren	ST: Very Gravely Sandy Loam
3069	LU: Barren	ST: Loam
4002	LU: Forest	ST: Gravely Sandy Loam
4037	LU: Forest	ST: Water (Clay Loam)
4039	LU: Forest	ST: Sandy Clay Loam
4043	LU: Forest	ST: Clay Loam

Modeling strategy



270m (938 km^2)

- Trades accuracy for fast solution times
  - Physics/data debugging
  - Calibration
- Short term forecasting
- Same scale at USGS' California Basin Characterization Model (BCM)

50m (938 km^2)

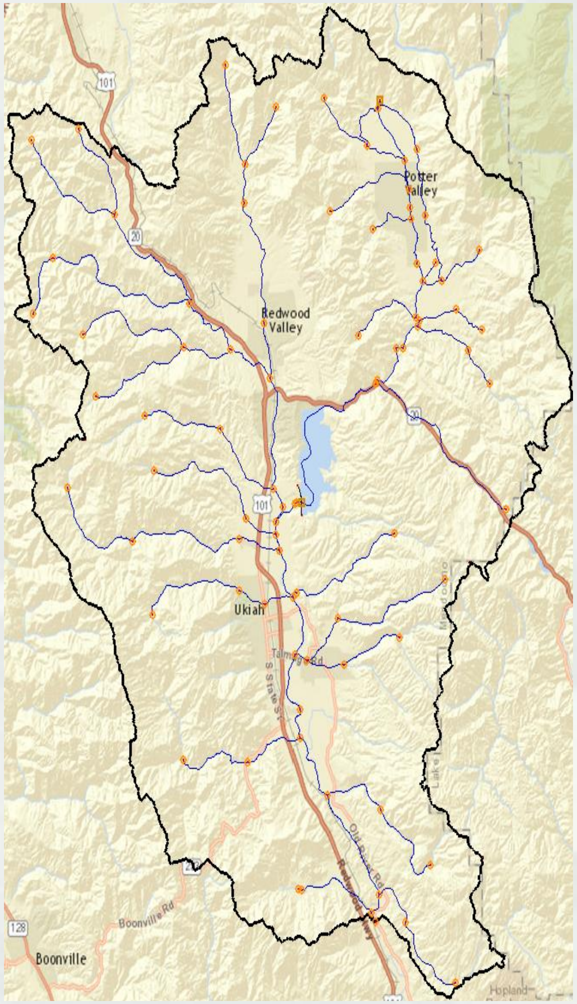
- Detailed model of full watershed
- Full GSSHA accuracy with increased computational time
- Mid/long term forecasting

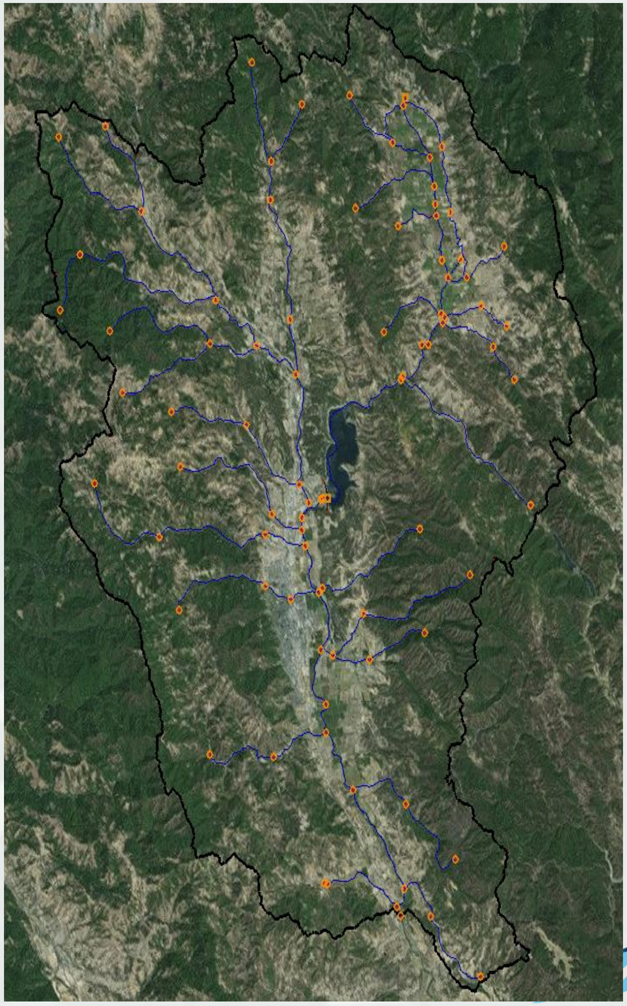
30m (304 km^2)

- Detailed model of east fork watershed
- Focus on reservoir level in Lake Mendocino
- Dam operational focus

Model - 270m

(river down to Hopland, CA)





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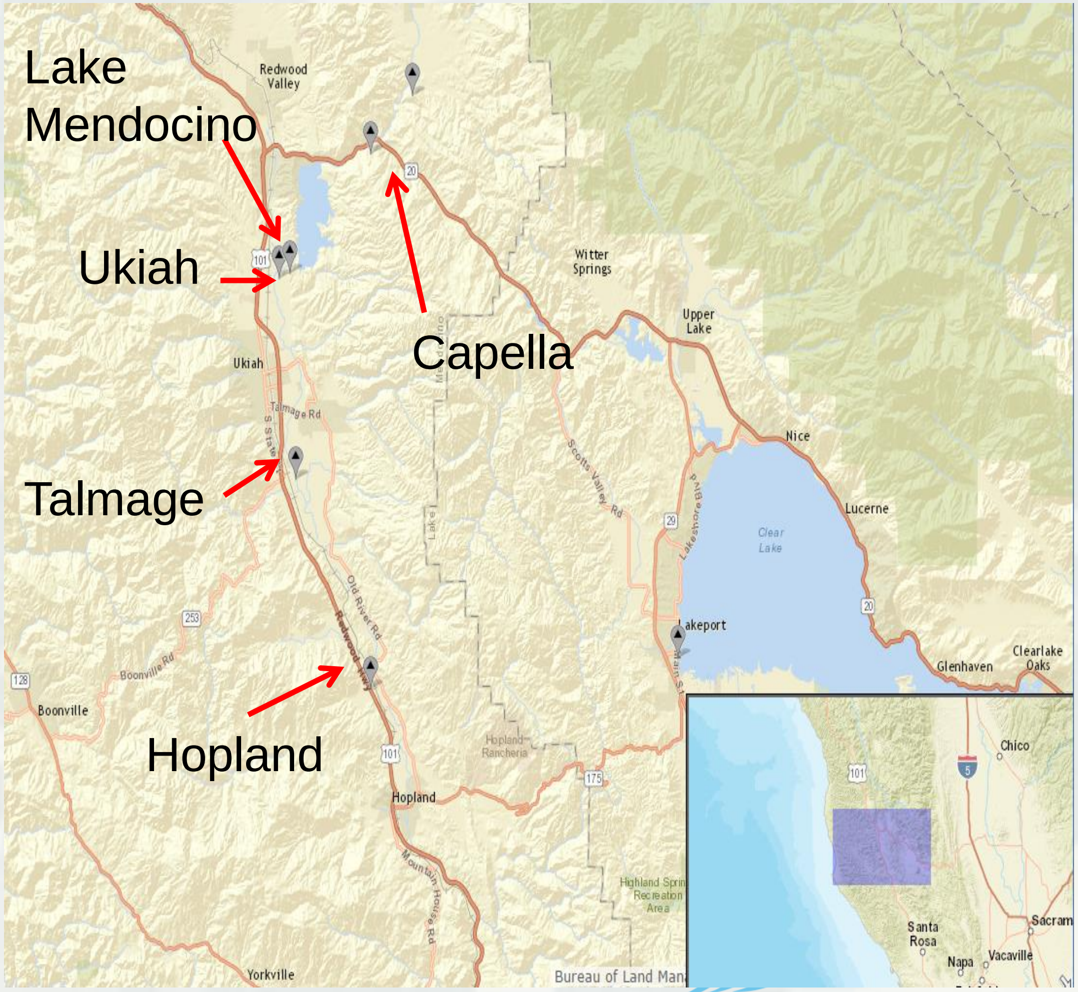
Calibration strategy

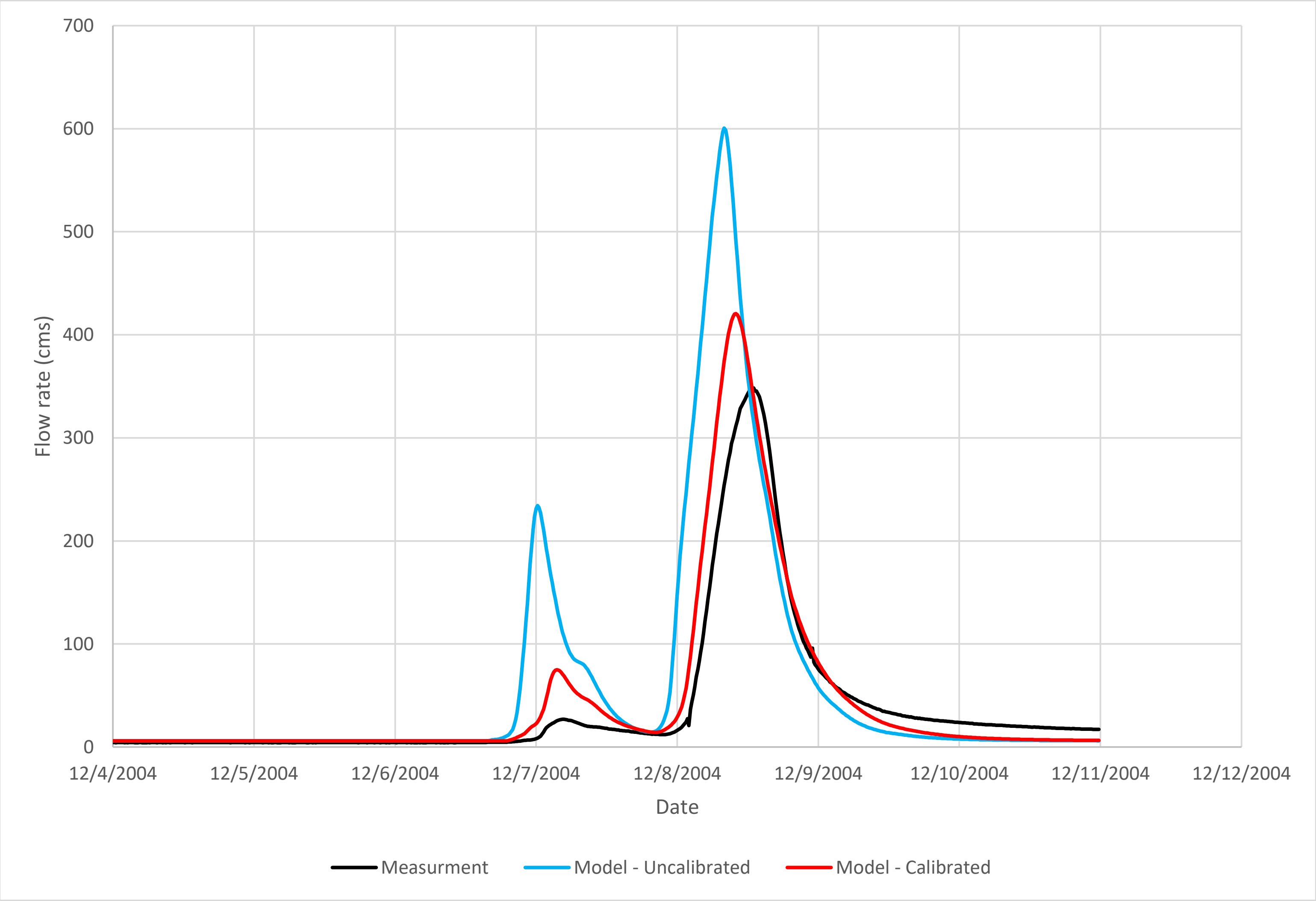
- Initially isolated event Oct – Dec 2004 using Efficient Local Search/PEST on 270m.
- Perform Shuffled Complex Evolution (SCE) method (SCE) over multiple events on the 270 m model.
- Narrow parameters values – year run long term simulation or longer periods for all models (270, 50, 30m)
- Verify using additional year or years.
- Run the entire or large portion of record.

Calibration Locations

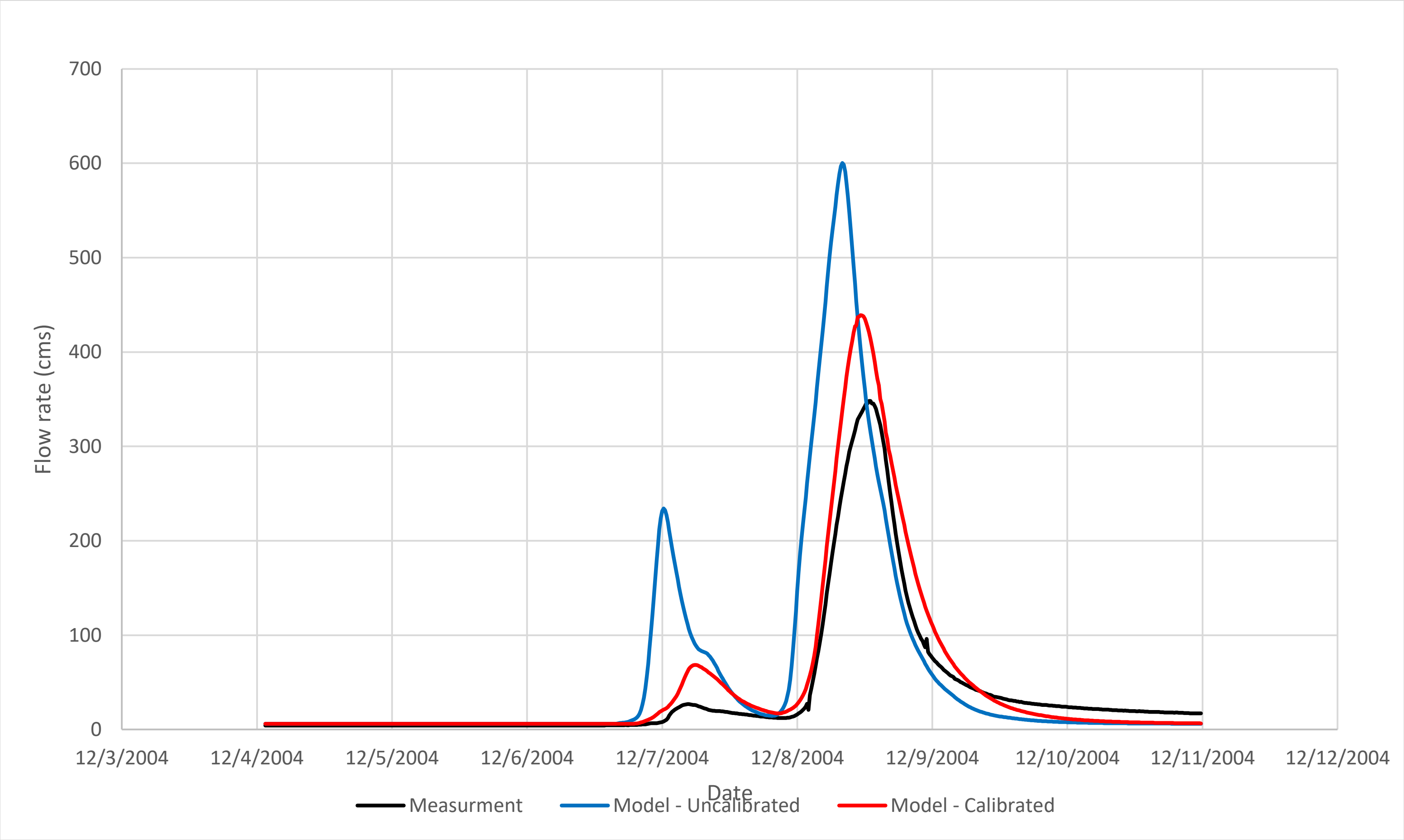
- Five available gages for comparison of simulated versus measured:
  - Discharge: Ukiah (*west fork*)
  - Discharge: Capella (*east fork*)
  - Discharge: Talmage (*main channel*)
  - Discharge: Hopland (*outlet*)
  - Water surface elevation: Lake Mendocino
- Efficient Local Search (PEST) calibration method used to date.



Initial Calibration – Hopland Gage – In Progress

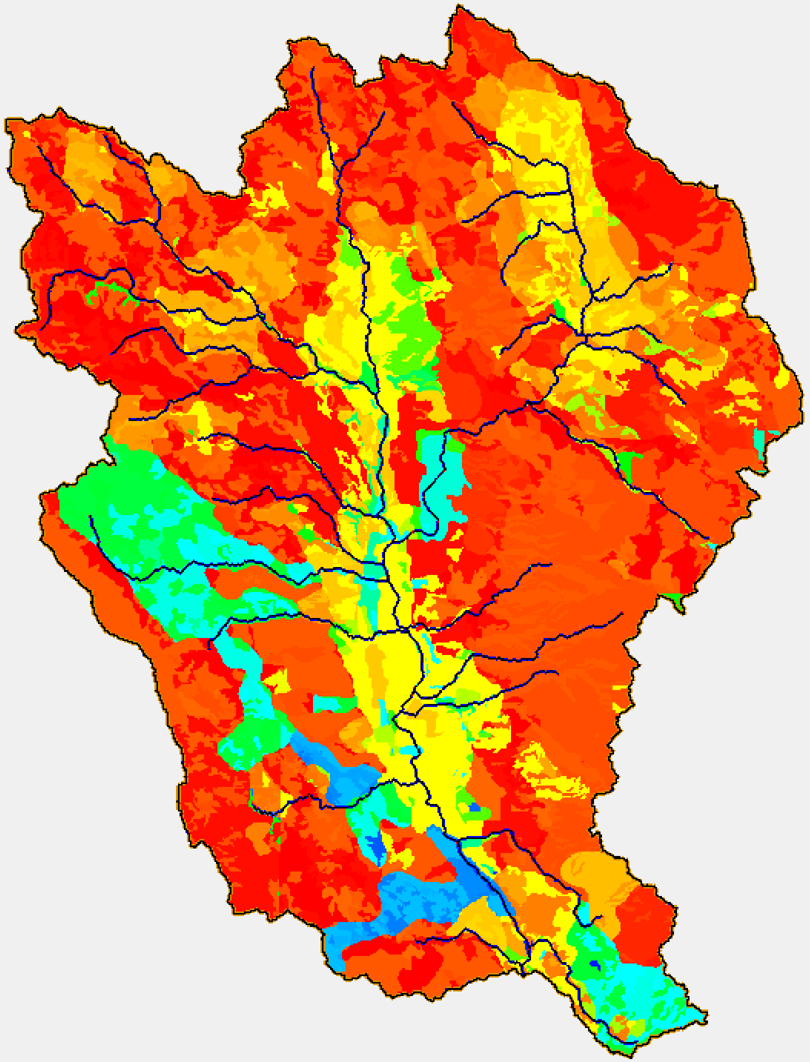


Extended Calibration – Hopland Gage – In Progress

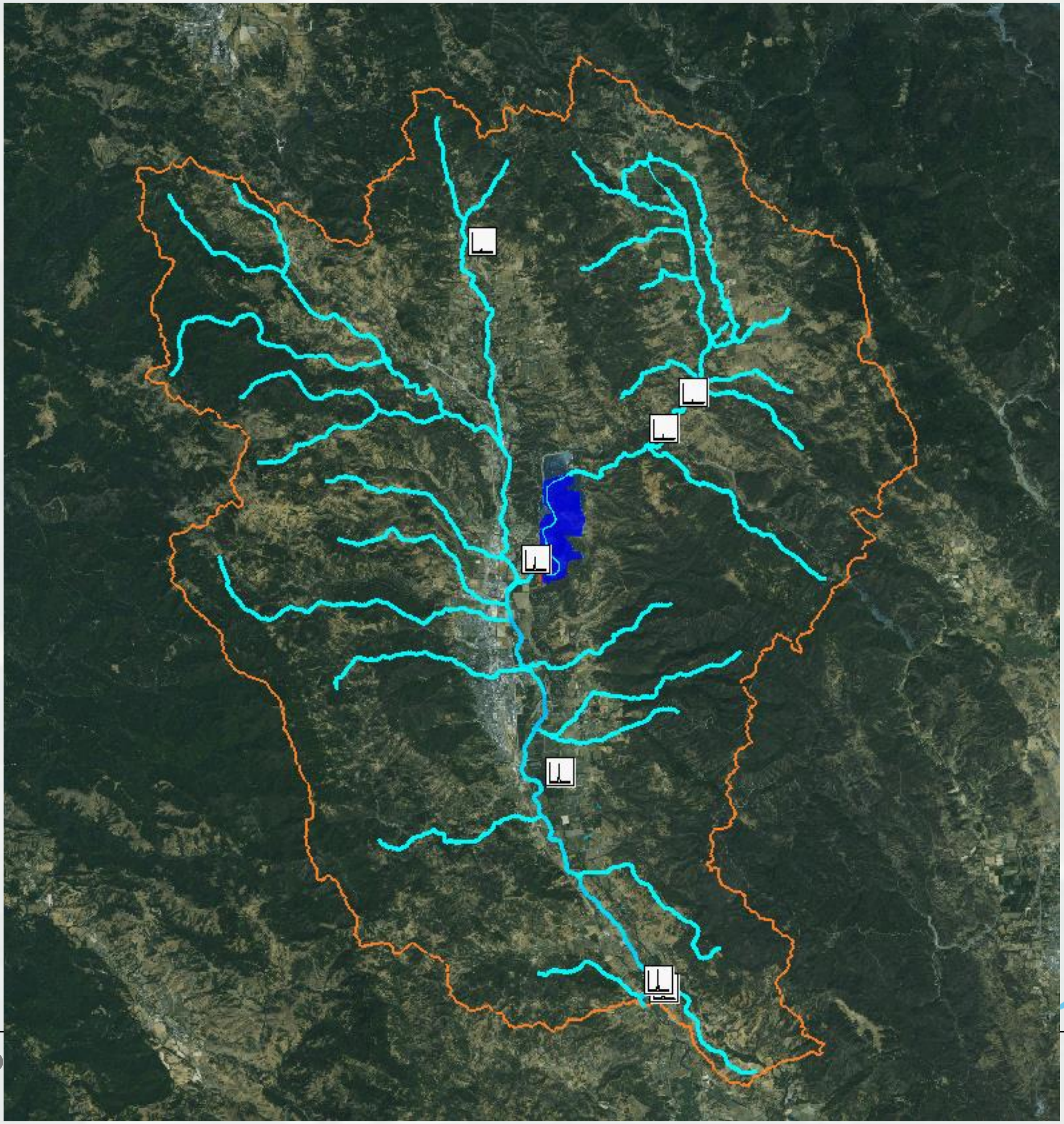


50 meter GSSHA model

- Cell resolution: 50X50 m
- No. cells: 375,155 compared to ~13,000 for 270m model.
- Awaiting results of 270 m calibration for refining of parameters before initiating calibration.



50 m GSSHA Model

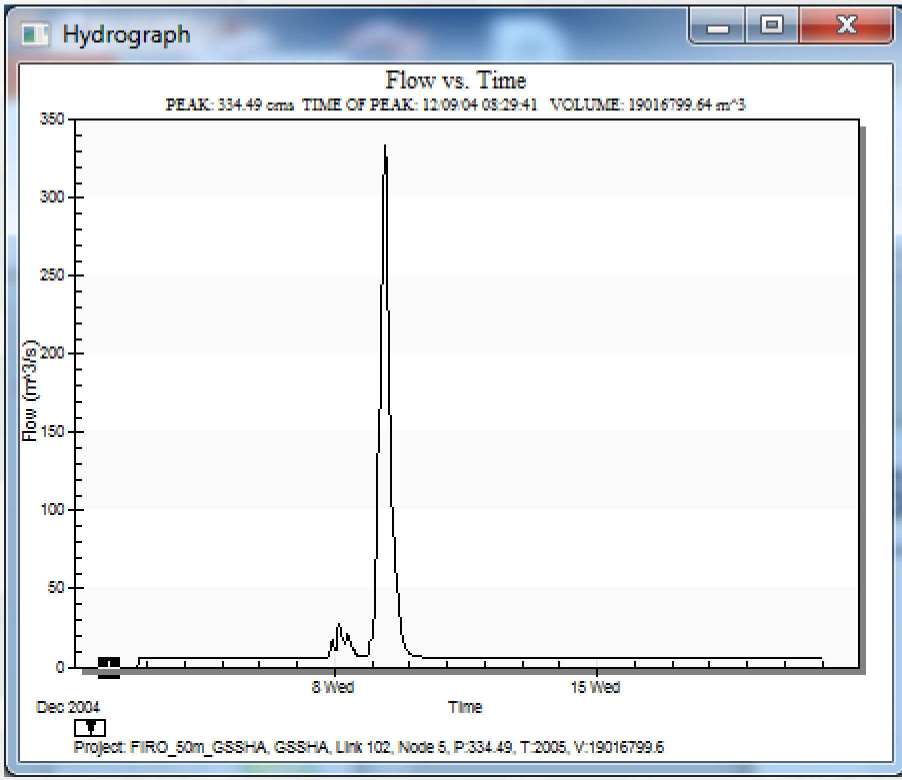


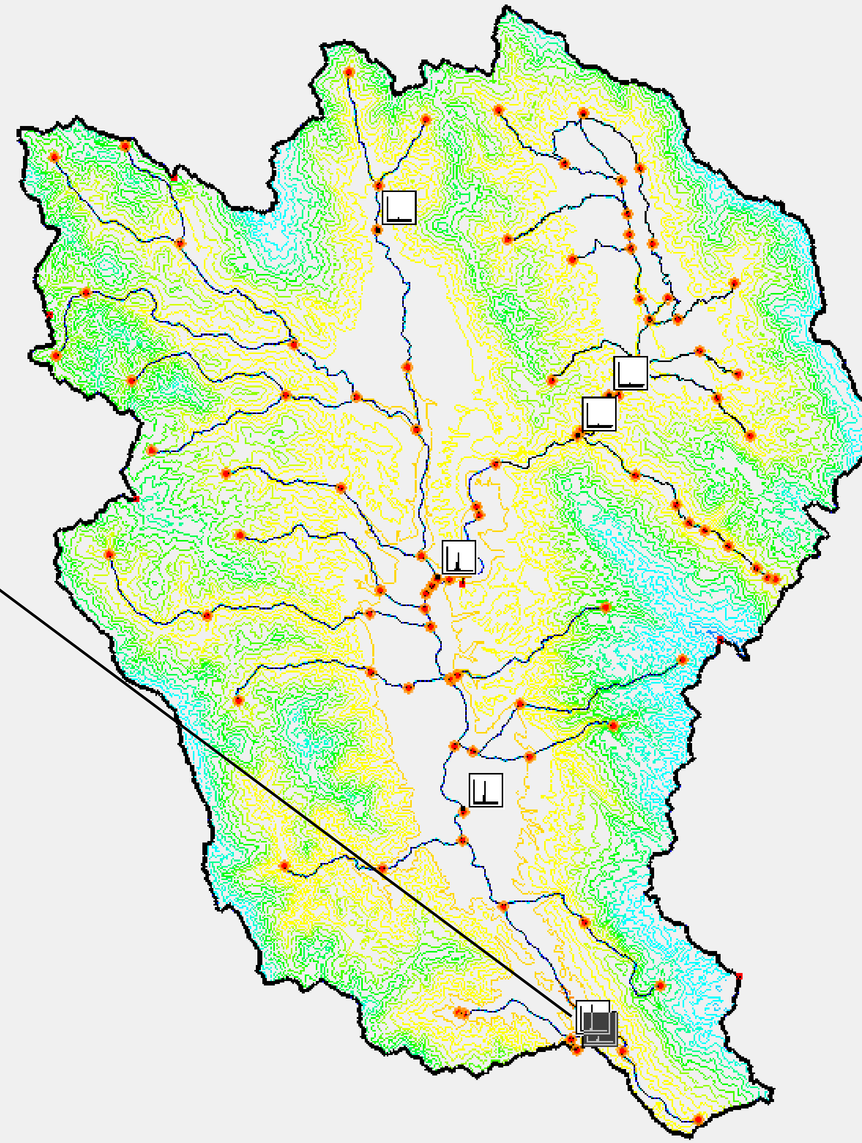
GSSHA simulation with channel depth and overland flow

08-12 Dec 2014

GSSHA 50 m model

- Gage locations with Model Outlet Flow Hydrograph.

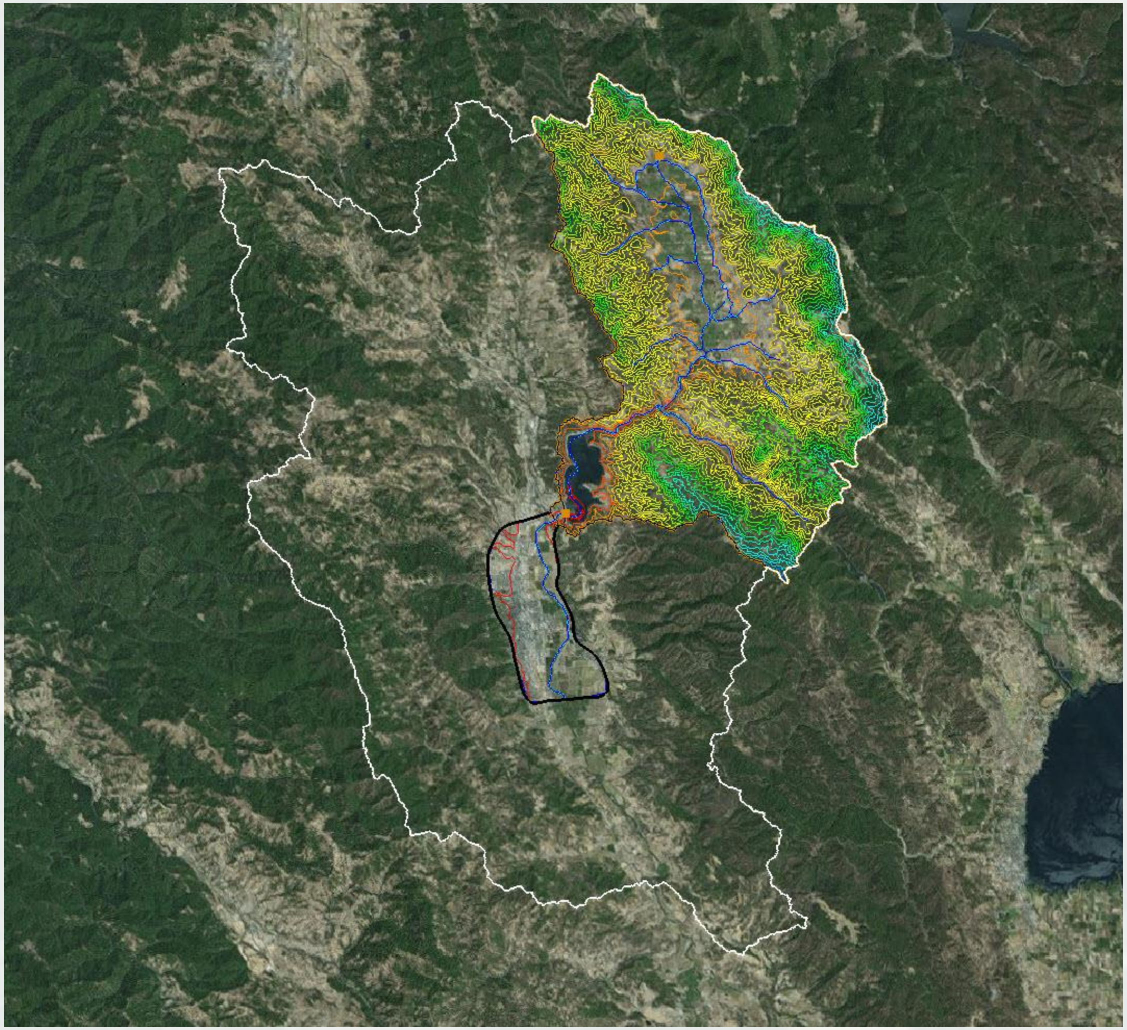




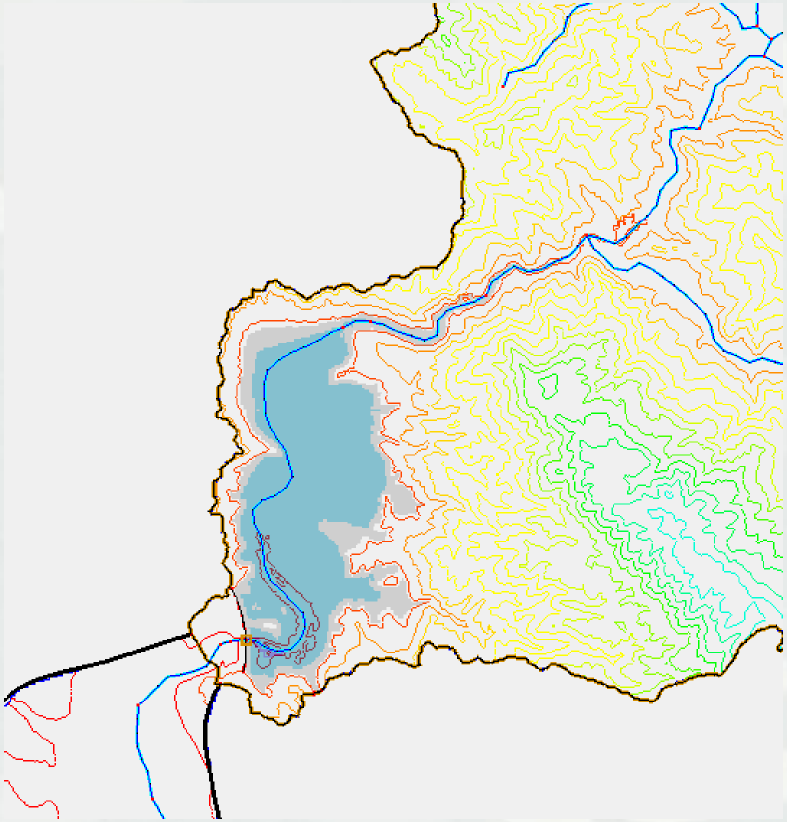
30 m GSSHA Model

- Smaller area than either the 270 or 50 m models, total model domain is 304 km^2
- Designed for greater accuracy of Lake Mendocino.
- Smaller grid sections below the Coyote Valley Dam and more detail in Potter Valley.
- Calibration pending 270m model results.

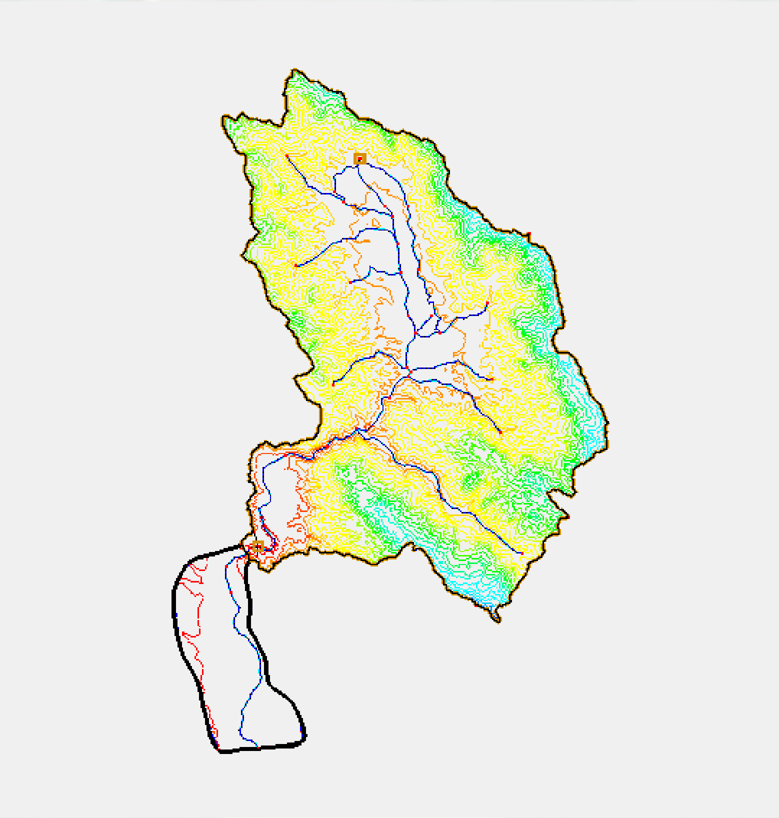
30 m GSSHA Model



30 m GSSHA Model (con't)



Mendocino Lake



Model Domain

Spring/Summer Efforts – Once Funding is Secured

- Additional calibration methods of 270, 50, and 30 m models
  - SCE (Shuffled Complex Evolution)
  - Efficient Local Search (PEST)
- Further refine GSSHA data inputs based on additional data from USGS, SCWA, others.
- Incorporating groundwater
- Operating rules of Coyote Valley Dam into the GSSHA model.
- Assisting with field data collection in Lake Mendocino Area.