Groundwater Flow Model for Evaluation of Hydrologic Effects of the San Joaquin River Restoration

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SAN JOAQUIN RIVER RESTORATION PROGRAM

USGS science for a changing world

Overview

* San Joaquin River Restoration Program (SJRRP)
* What is the concern?
* Model purpose
* Model overview
* Model surface hydrology
* Model results and applications
* Uncertainty analysis

SJRRP Overview

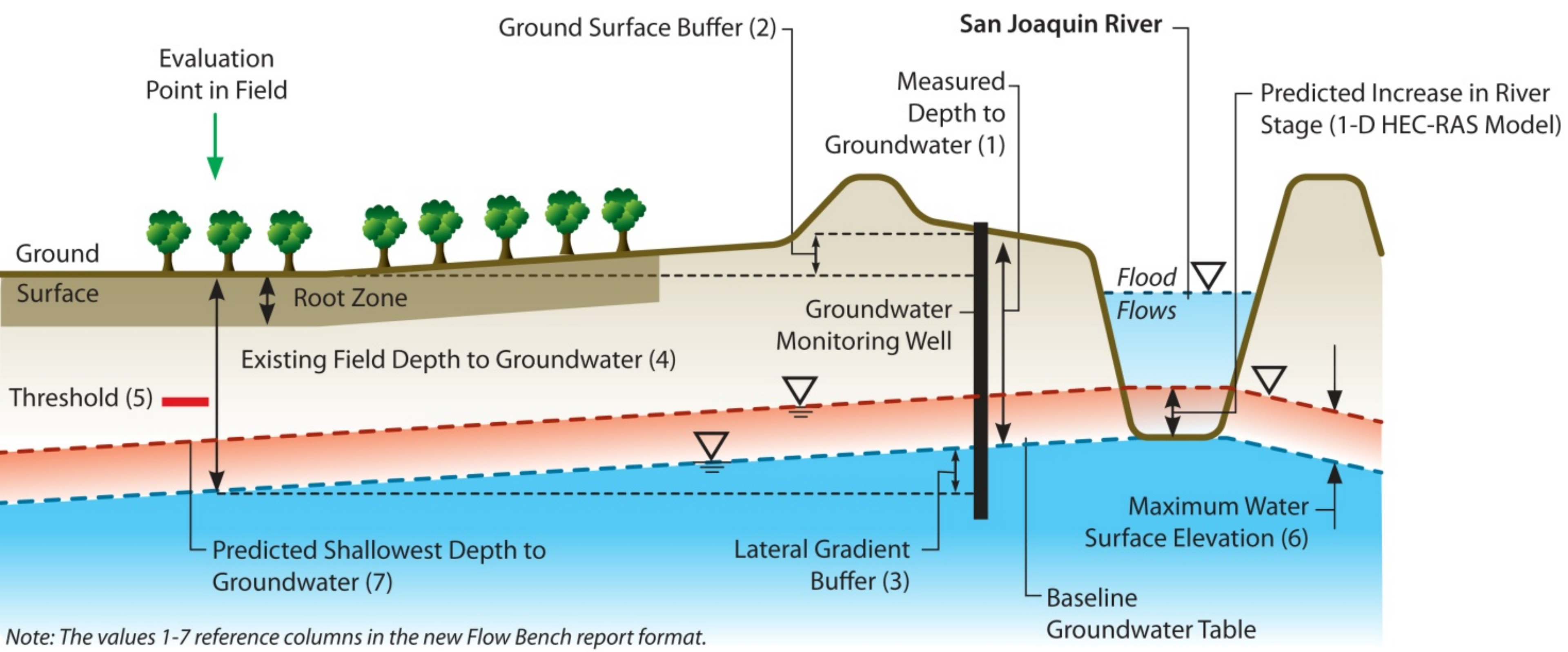
- Restoration Goal
  - To restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.
- Water Management Goal
  - To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

What is the Concern?

* Increased river seepage and higher groundwater levels adjacent to the river

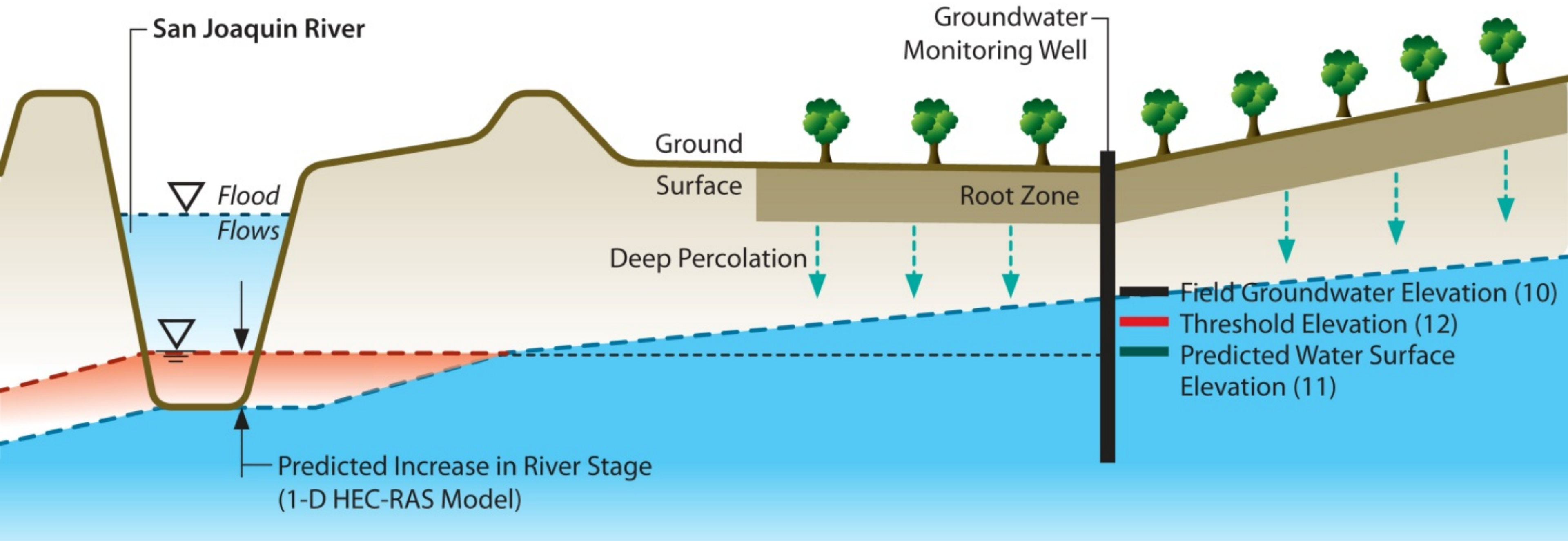
Adjacent to Losing Portions of River

* Higher river stage increases seepage from the river



Adjacent to Gaining Portions of the River

* Higher river stage reduces seepage back to the river



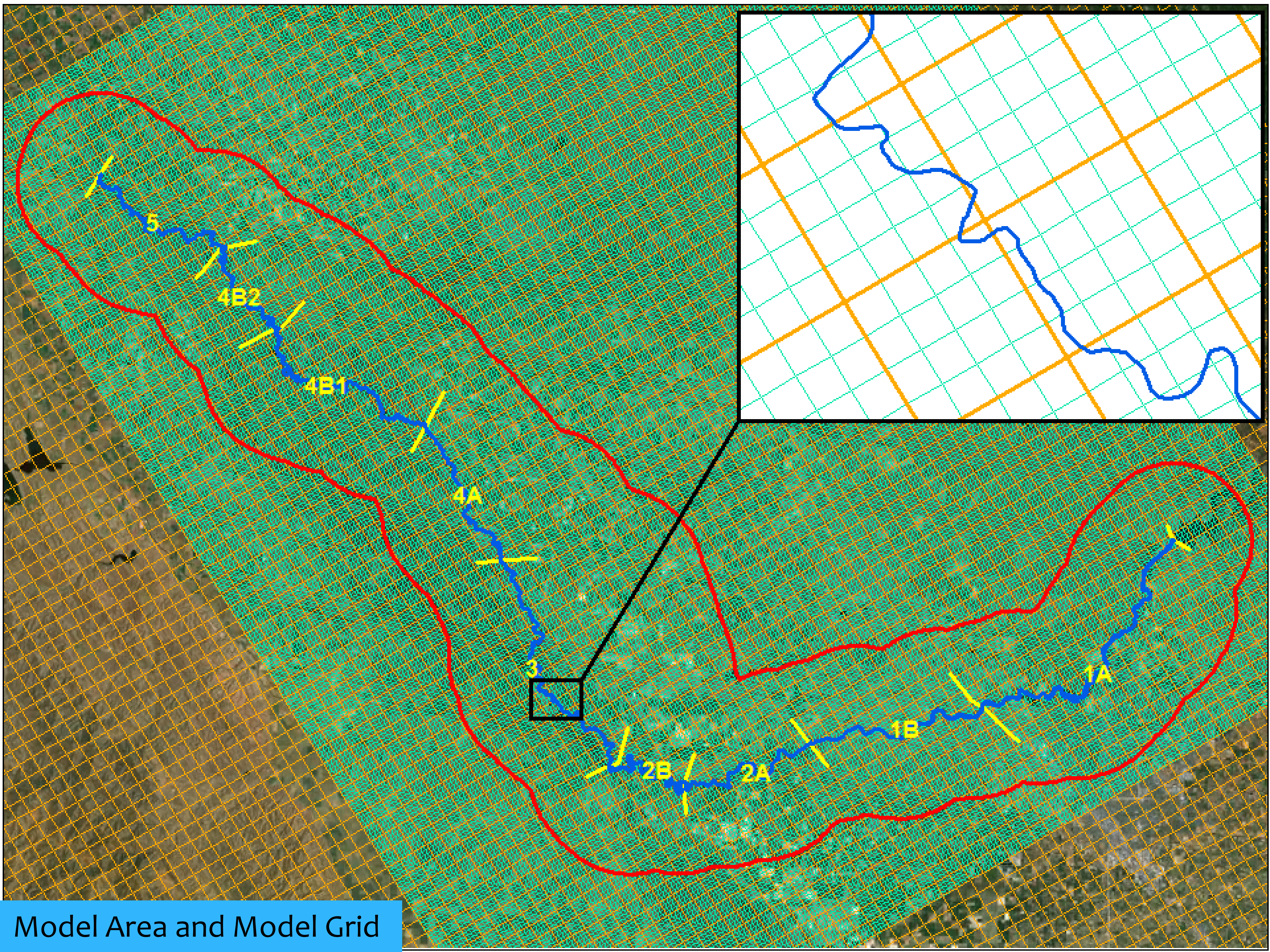
Note: The values 1-7 reference columns in the new Flow Bench report format.

Model Purpose

* Predict change in seepage due to SJRRP flows
* Evaluate effectiveness of potential management actions
* Determine areas susceptible to developing high water-table conditions
* Provide quantitative information about groundwater flow system

Model Overview

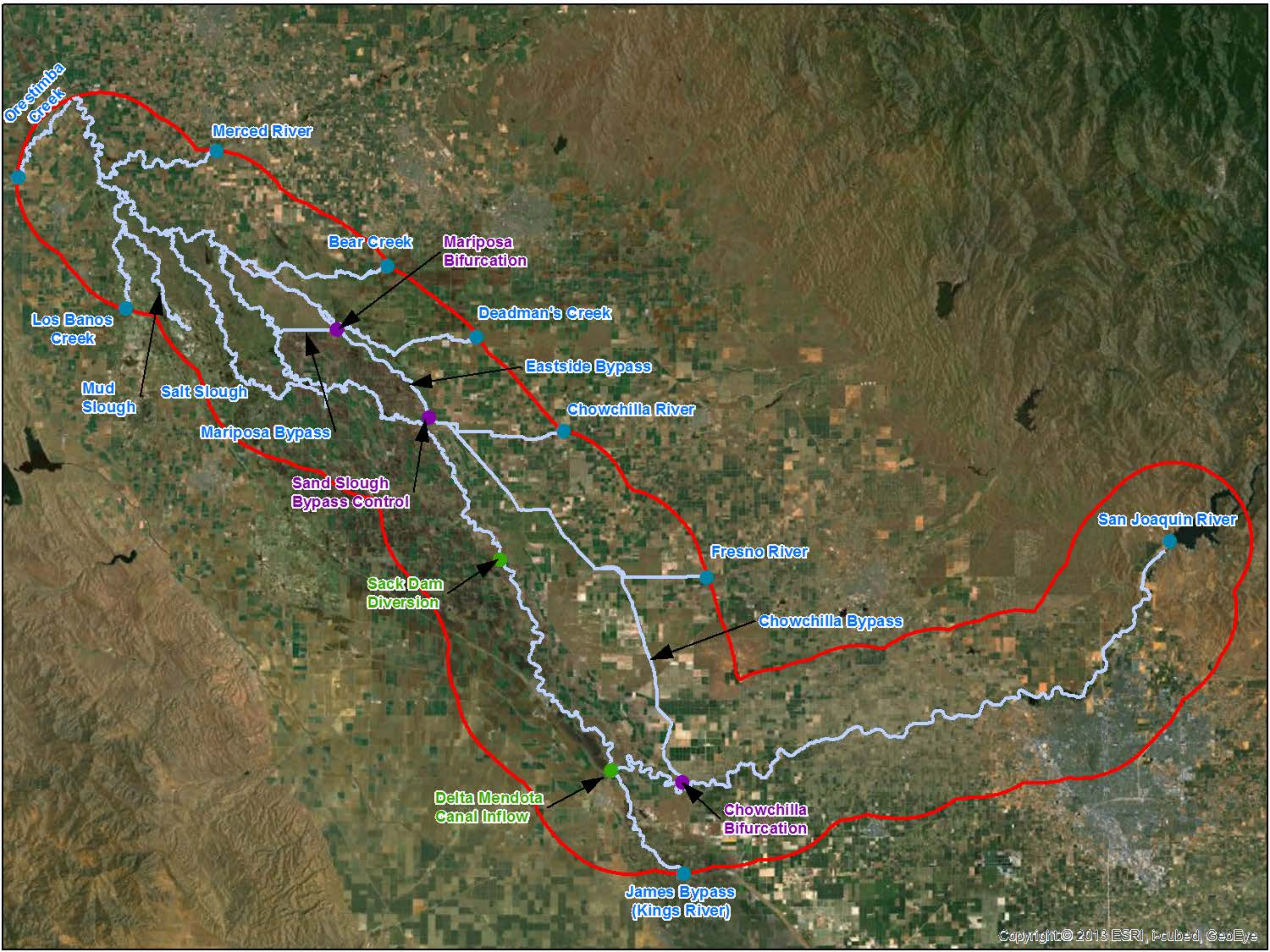
* Published USGS SIR: http://pubs.usgs.gov/sir/2014/5148/
* Developed using MODFLOW Farm Process
* 1,300-square-mile area
* 150-mile reach of the San Joaquin River
* April 1961 – September 2003
* Weekly stress periods
* Simulated features include
  * 3-D aquifer sediment texture
  * Surface-water flow and stream-aquifer interaction
  * Agricultural supply and demand



Model Area and Model Grid

Model Surface Hydrology

* Simulated streamflow network
  * San Joaquin River
  * Chowchilla, Eastside, and Mariposa Bypasses
  * 10 other tributaries
* Simulated bypass structures
* Simulated irrigation diversion
* Streambed elevation and streamflow rating tables based on HEC-RAS model (Tetra Tech, 2009)


Orestimba Creek
Merced River
Bear Creek
Mariposa Bifurcation
Los Banos Creek
Deadman's Creek
Eastside Bypass
Mud Slough
Salt Slough
Chowchilla River
Mariposa Bypass
Sand Slough Bypass Control
San Joaquin River
Fresno River
Sack Dam Diversion
Chowchilla Bypass
Delta Mendota Canal Inflow
Chowchilla Bifurcation
James Bypass (Kings River)
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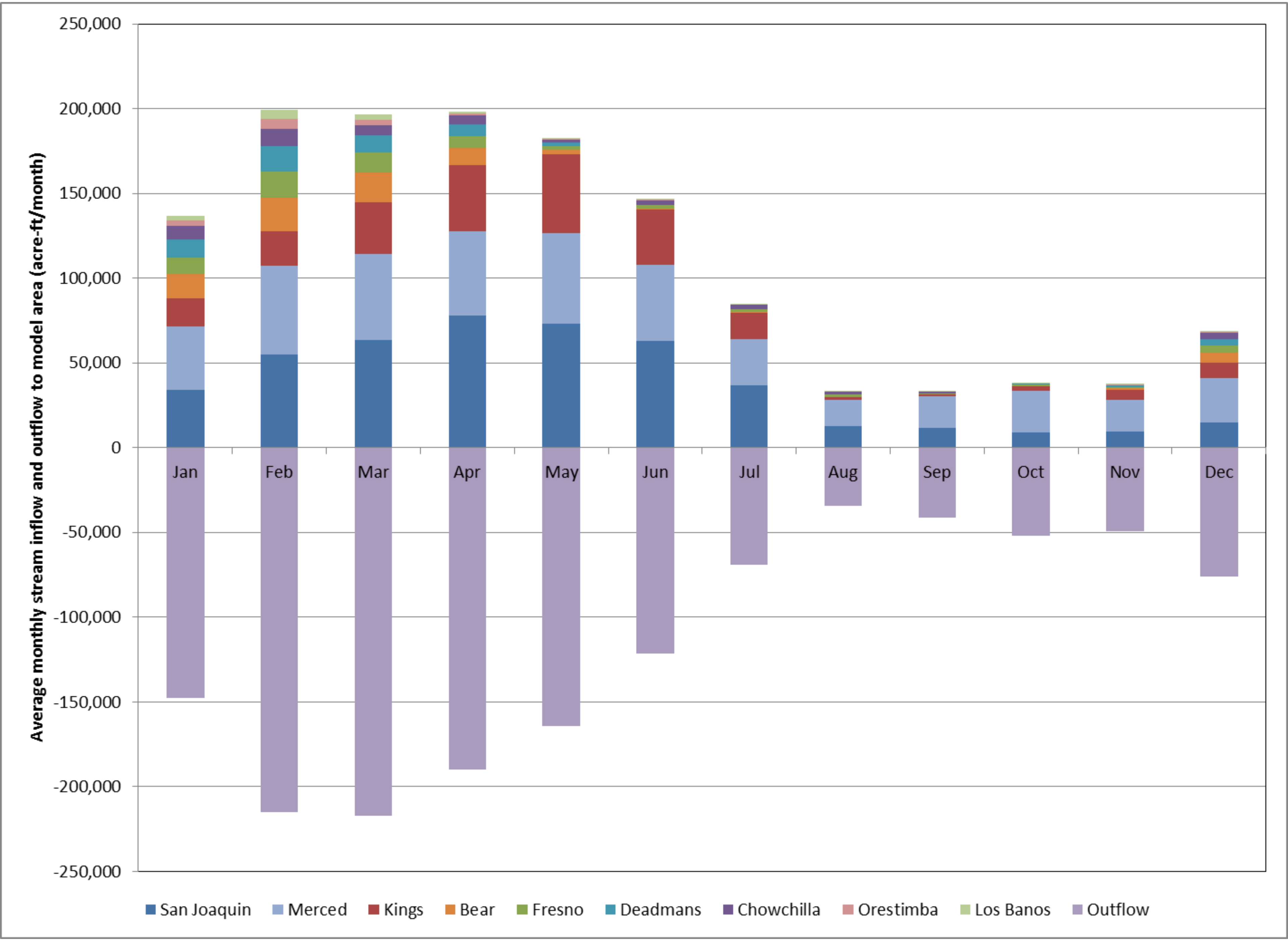
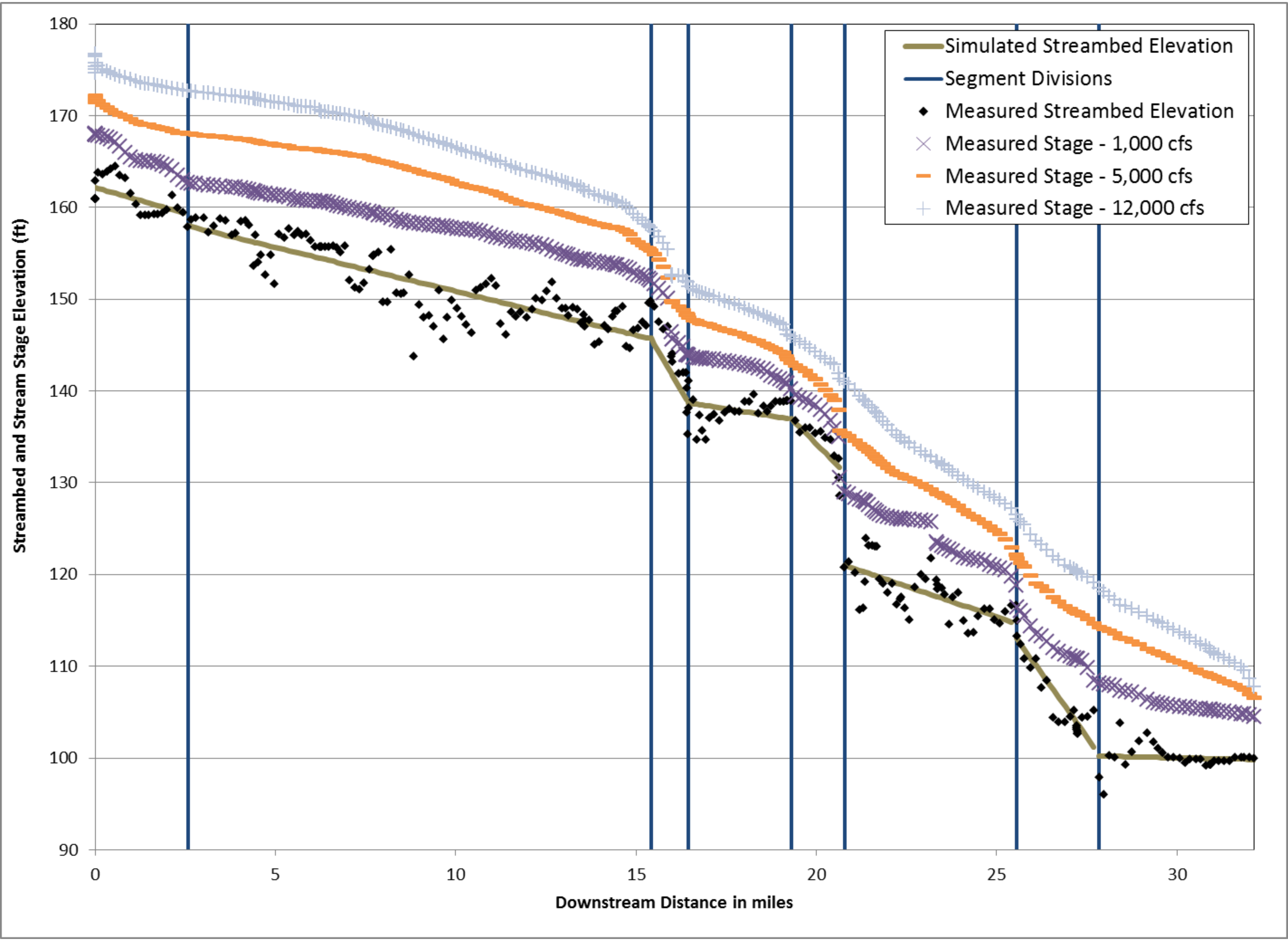
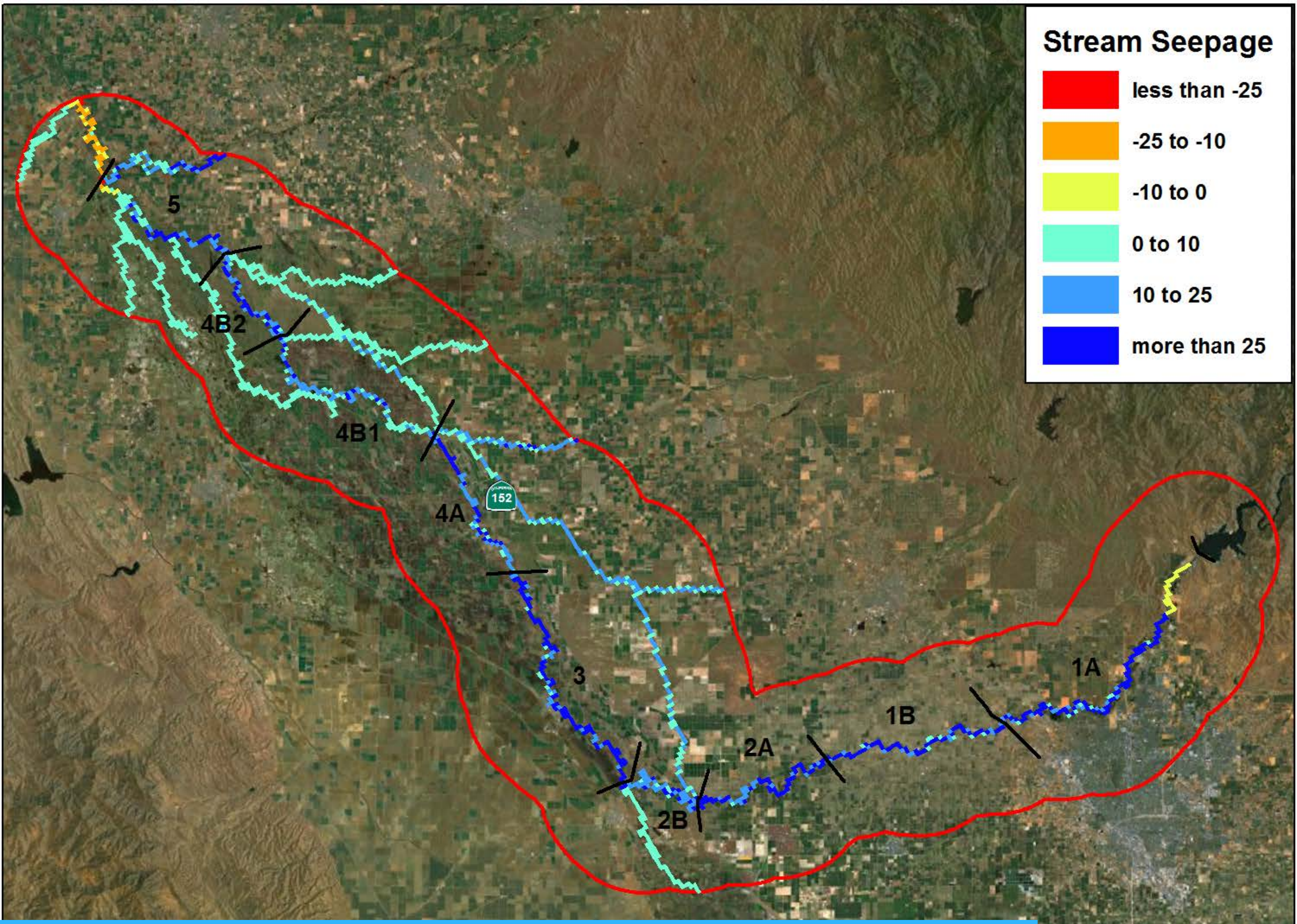
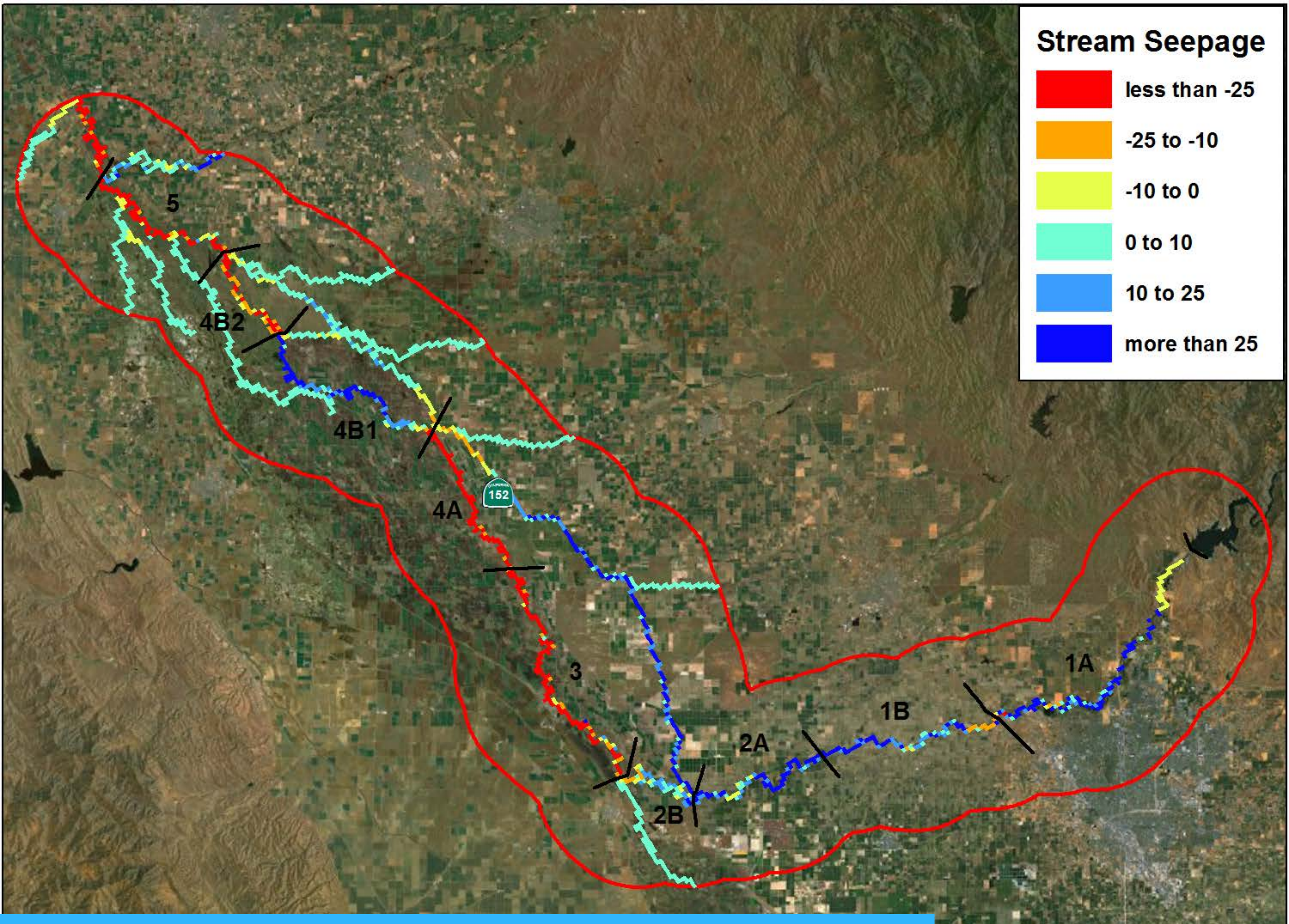

250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
Average monthly stream inflow and outflow to model area (acre-ft/month)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
San Joaquin
Merced
Kings
Bear
Fresno
Deadmans
Chowchilla
Orestimba
Los Banos
Outflow

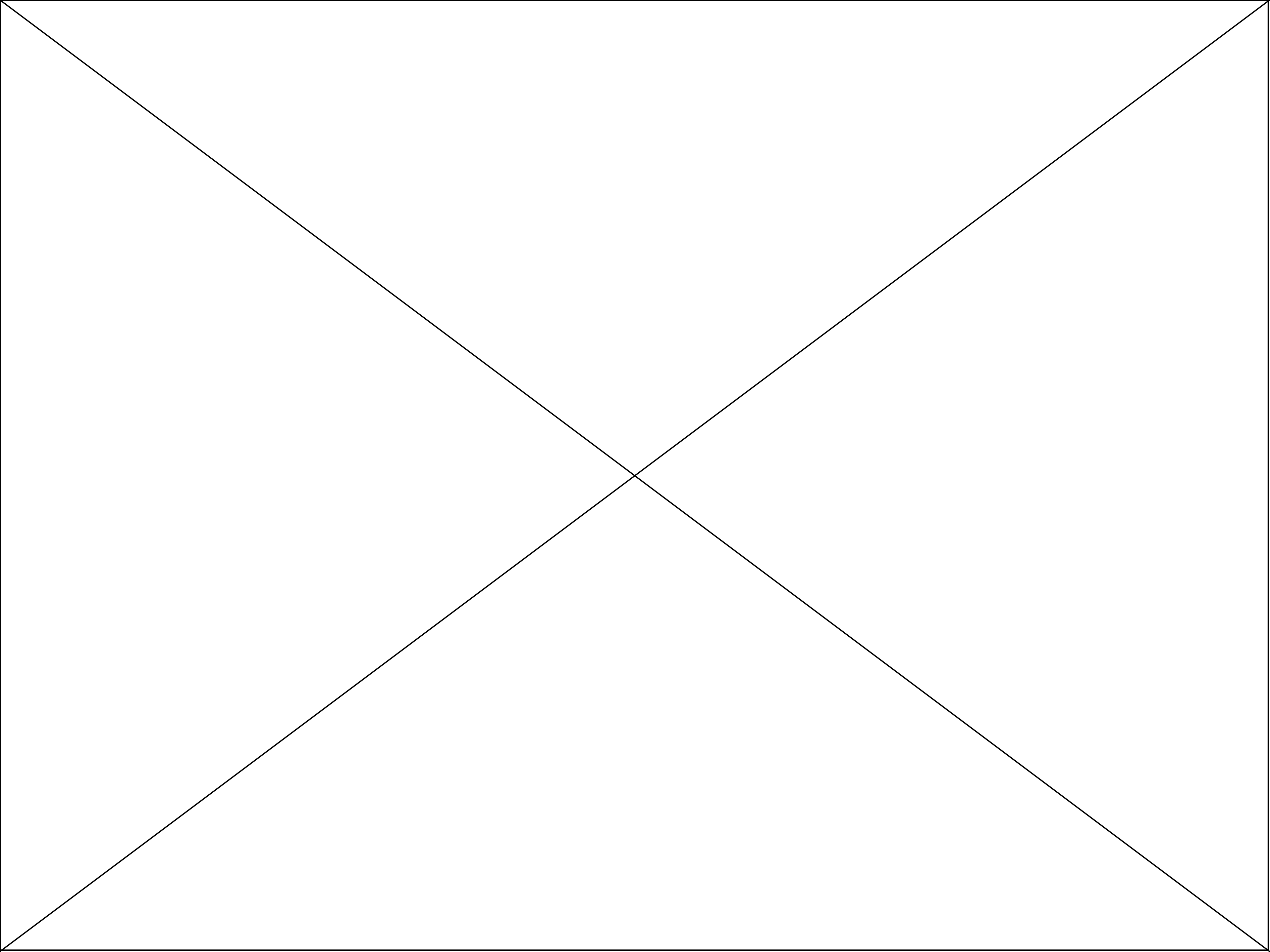

Simulated Streambed Elevation
Segment Divisions
Measured Streambed Elevation
Measured Stage - 1,000 cfs
Measured Stage - 5,000 cfs
Measured Stage - 12,000 cfs
Streambed and Stream Stage Elevation (ft)
Downstream Distance in miles
180
170
160
150
140
130
120
110
100
90
0
5
10
15
20
25
30

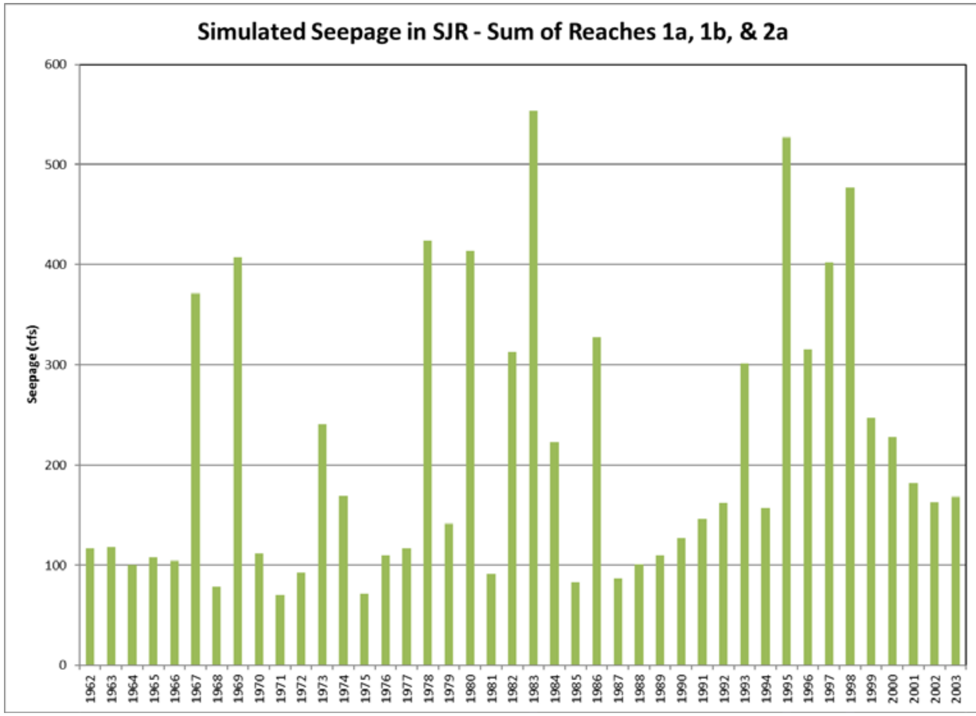


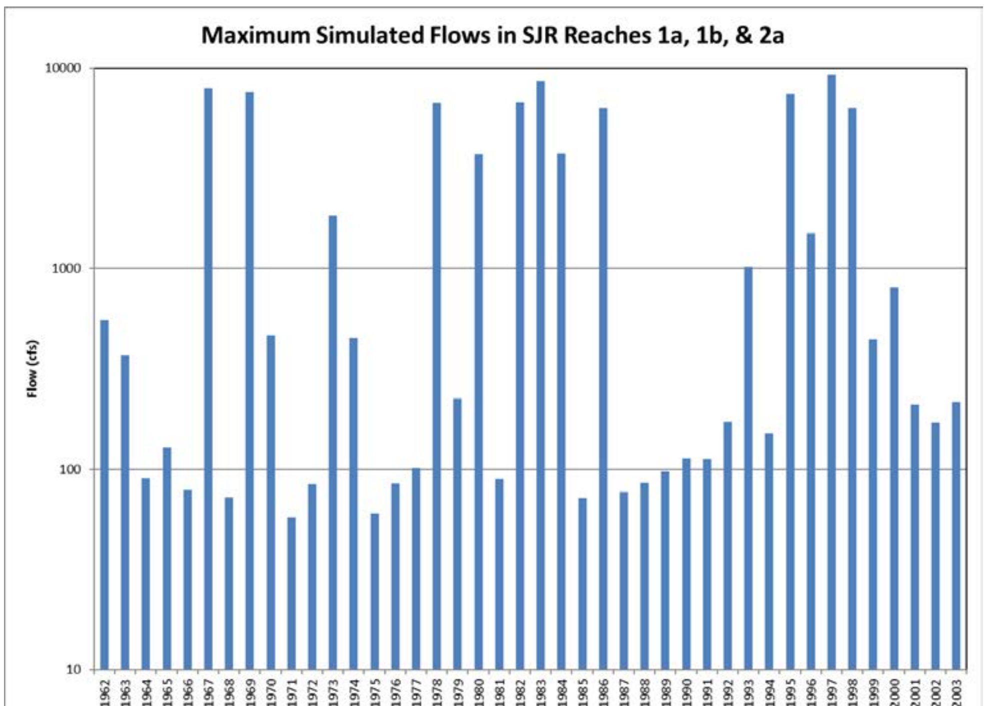
Stream-aquifer interaction – 1961 to 2003 average (acre-ft/month per cell)



Stream-aquifer interaction – February 1984 (acre-ft/month per cell)





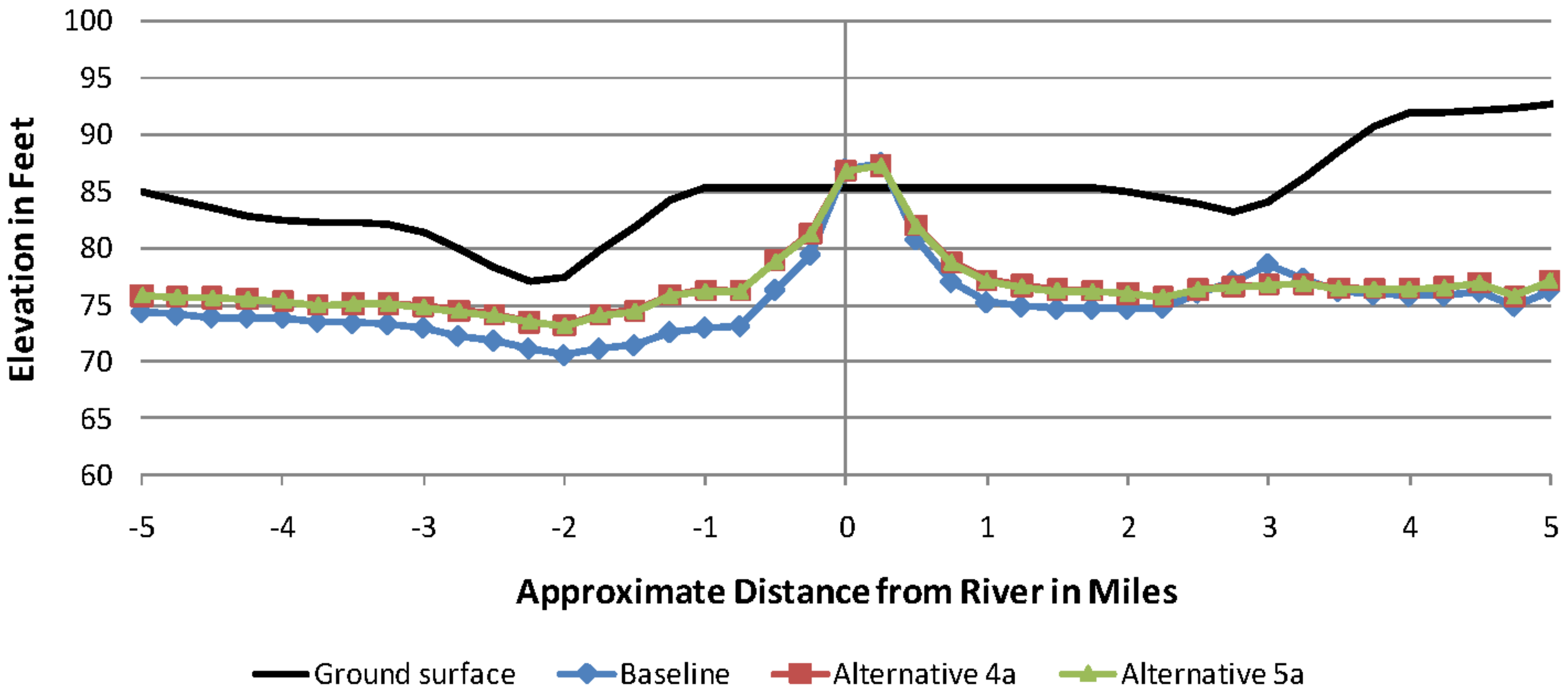


- In normal to drier years, the only flows in the San Joaquin River are to meet flow targets at Gravelly Ford
- During the 1987 to 1992 drought (a mix of normal-dry and dry years), seepage increased each year from 90 cfs in 1987 to 160 cfs in 1992
- Additional groundwater seepage is induced by declines in groundwater levels near the San Joaquin River
- In dry years with limited water supplies, additional seepage losses are a concern

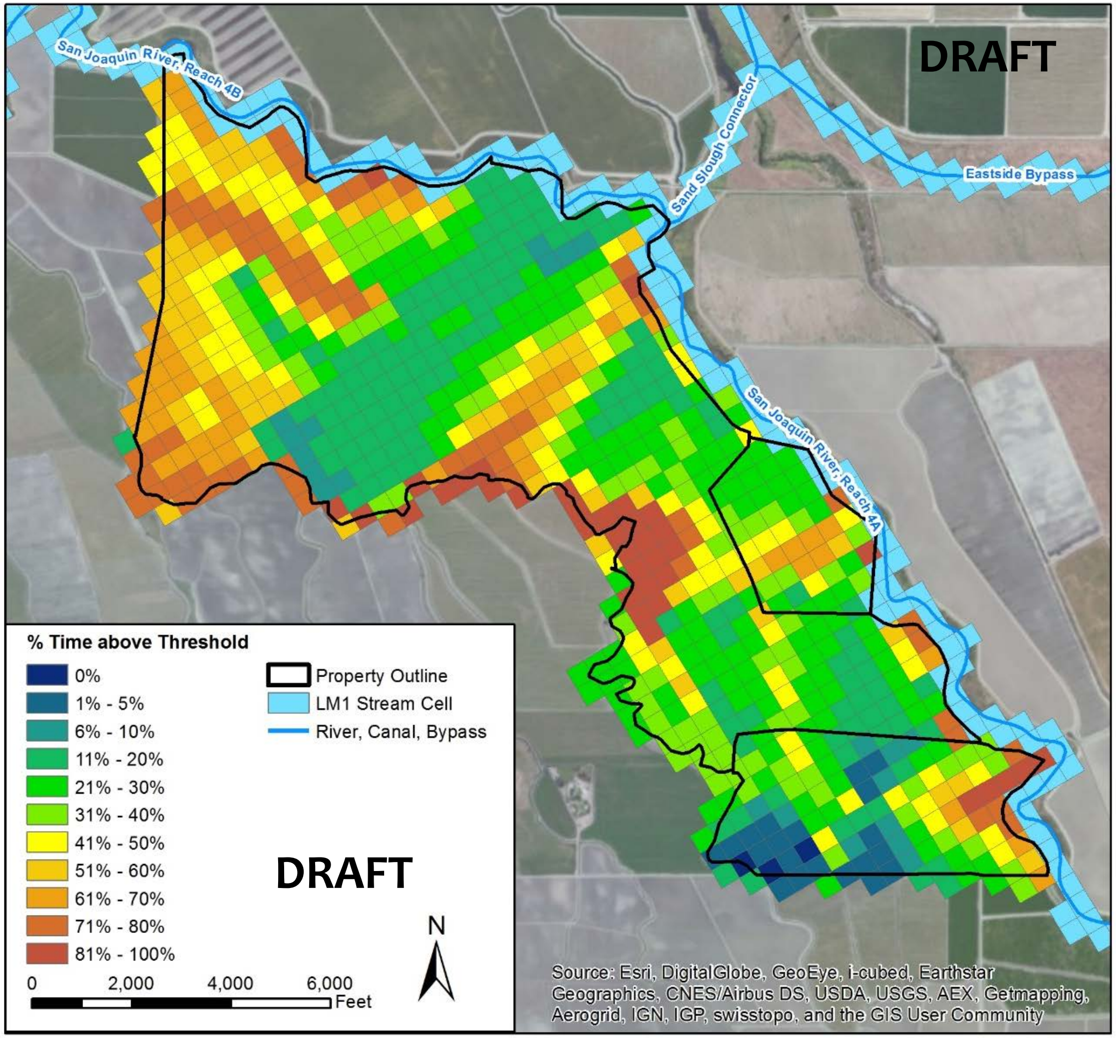
Model Application
Impacts of SJRRP Flows

* Baseline
  * No SJRRP flows
  * Historical conditions and hydrology
* Several scenarios with different SJRRP flow routing and timings
* Inflows set in the SJRRPGW at four locations based on SJRRP RiverWare model output
  * Lake Millerton
  * Chowchilla Bypass
  * Sand Slough Control Structure
  * Mariposa Bypass

Groundwater Level Cross Section at Mariposa Bypass – January 1997

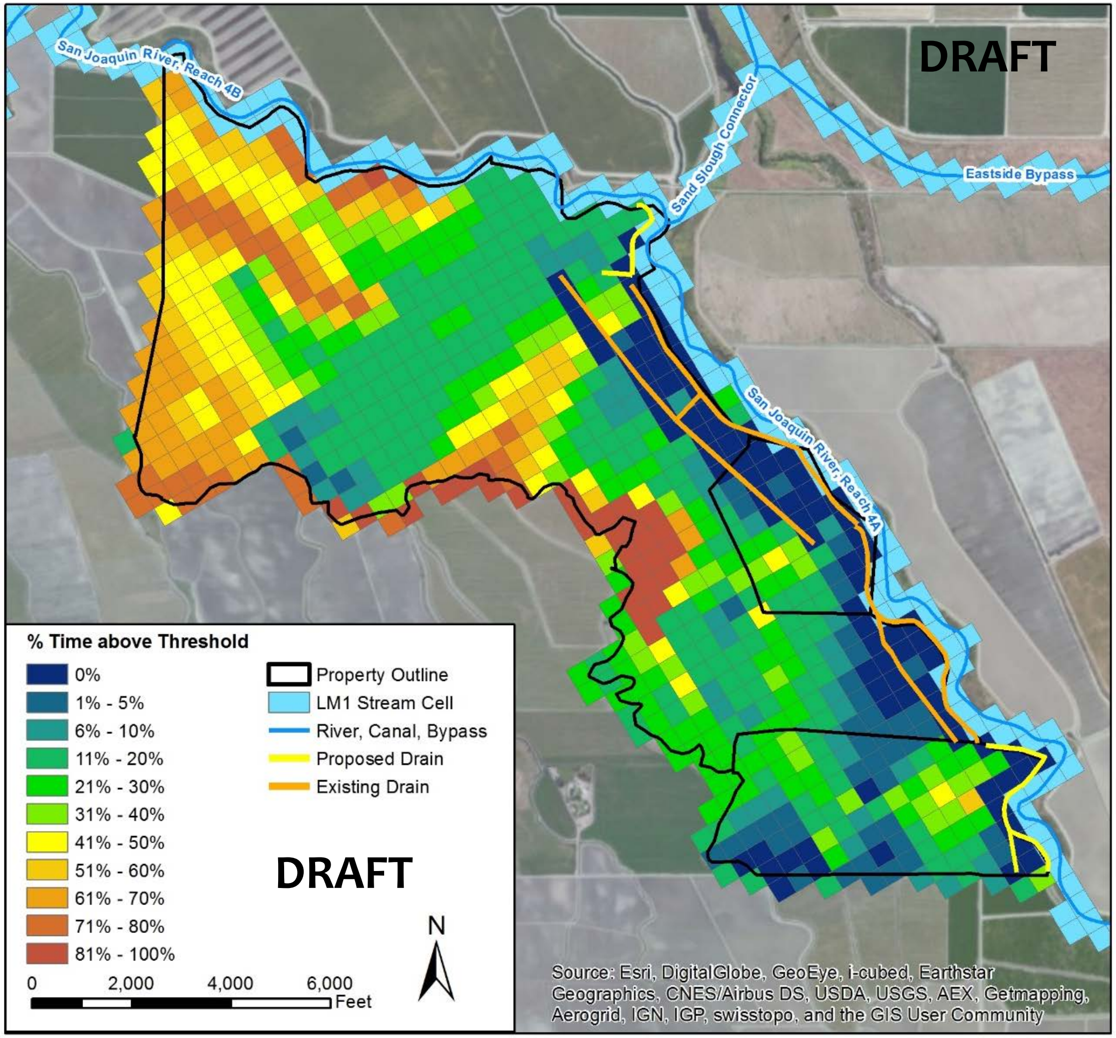


Comparison with Thresholds



- Percent of time above threshold
- No Drains

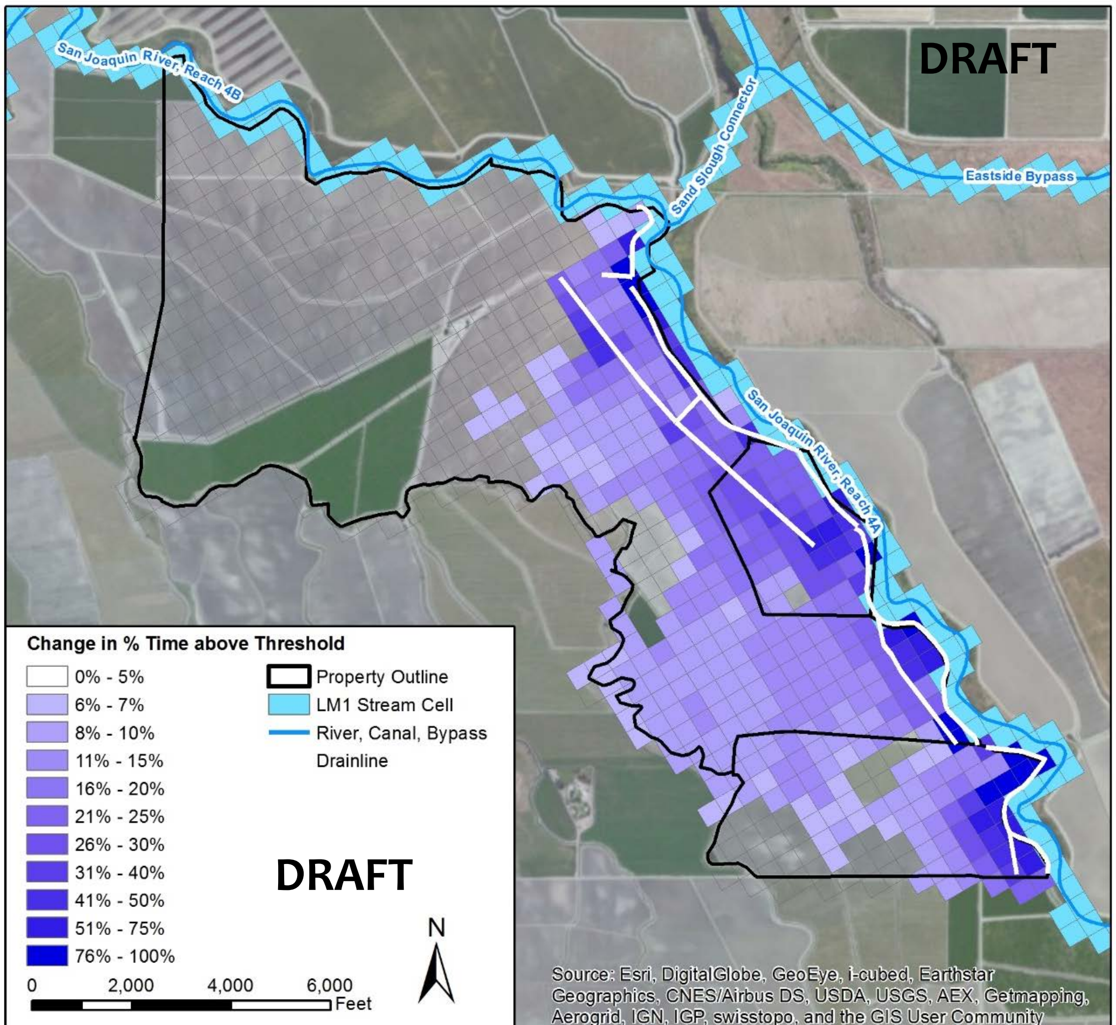
Comparison with Thresholds



* Percent of time above threshold
* With Drains

Preliminary draft – subject to change

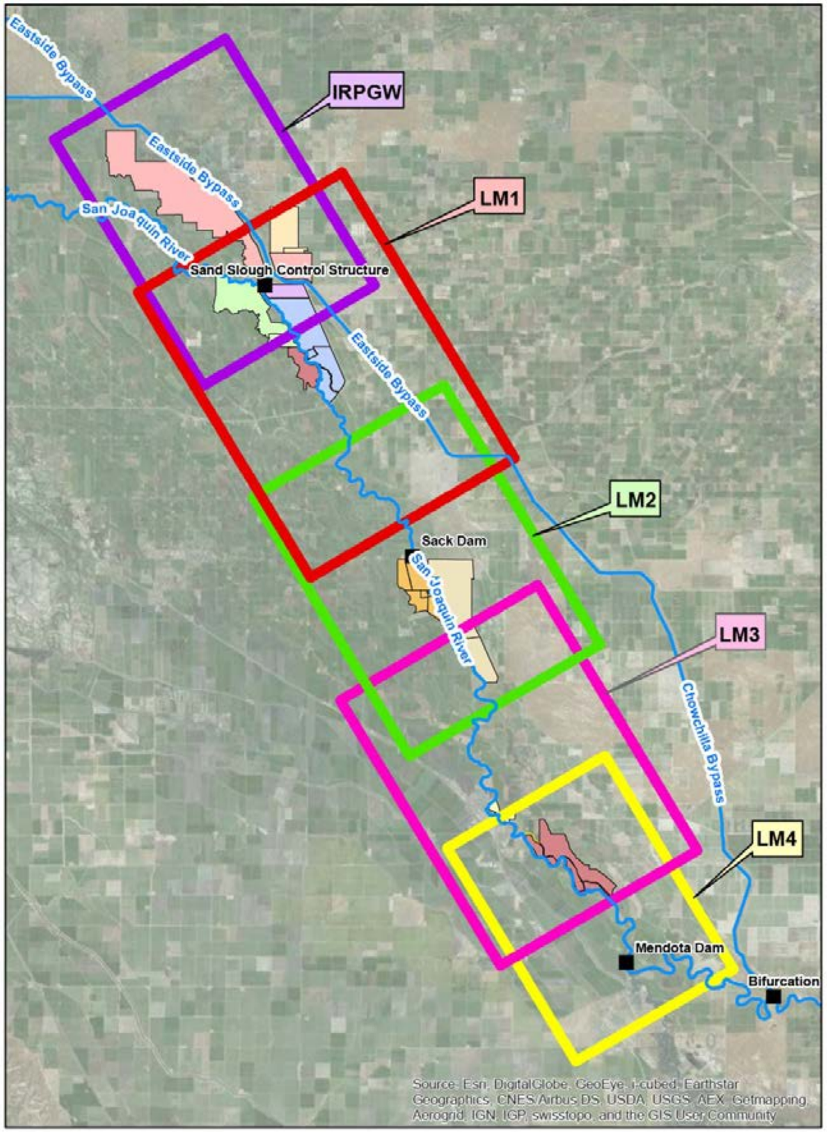
Comparison with Thresholds



* Percent of time above threshold
* Difference between "no drains" and "with drains"

Local Models ("LM")

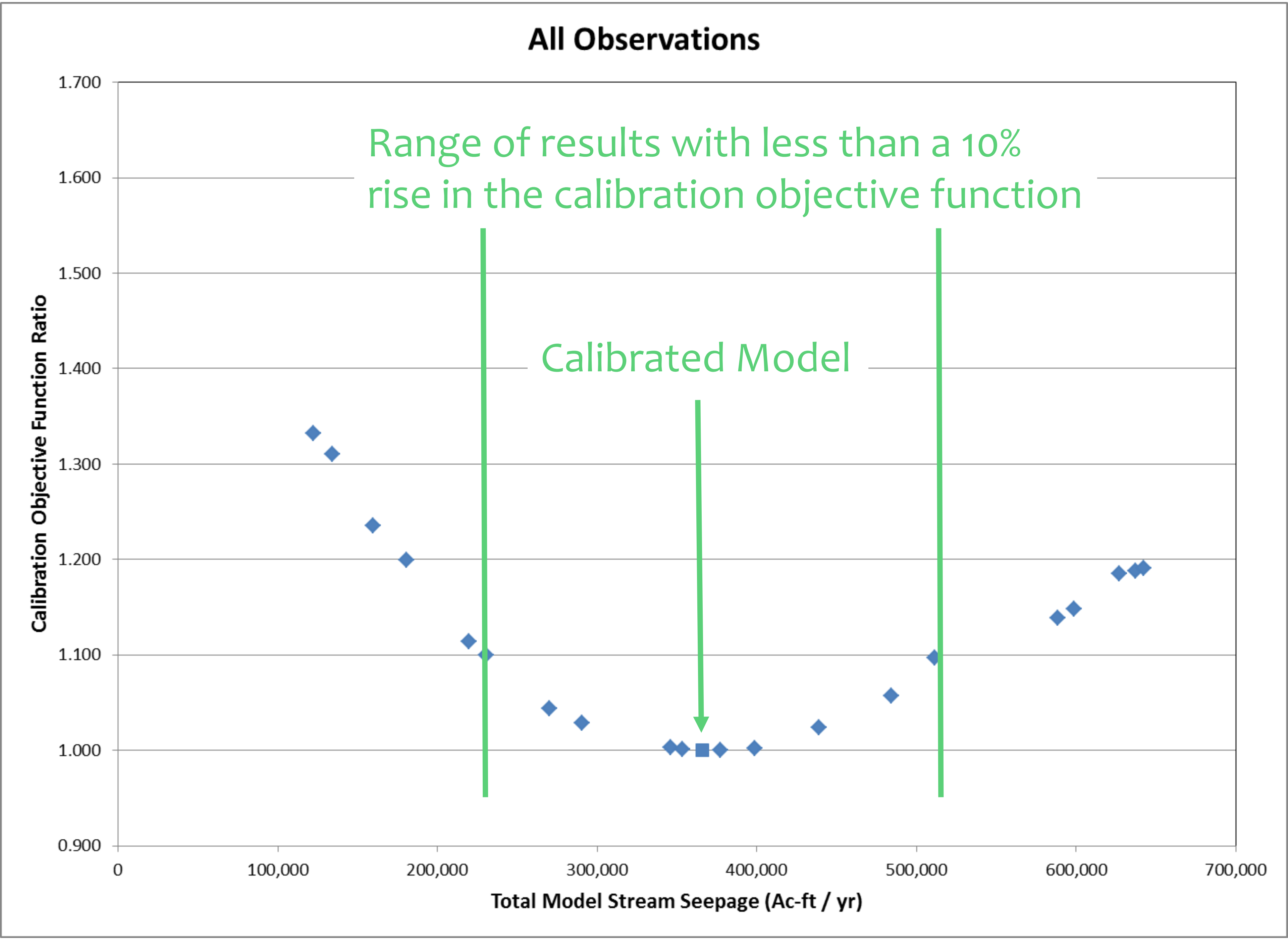
* Reaches 3, 4A
* Development of local scale models from SJRRPGW



Preliminary draft – subject to change

Model Predictive Uncertainty - Pareto Optimization

- Technique used to analyze the tradeoff between two different optimization objective functions
- For this study two objective functions
  - Calibrate the model
  - Maximize the simulated seepage rate
- The Pareto front is a set of points where one optimization objective cannot improve without worsening the other optimization objective


All Observations
Range of results with less than a 10% rise in the calibration objective function
Calibrated Model
Calibration Objective Function Ratio
Total Model Stream Seepage (Ac-ft / yr)
1.700
1.600
1.500
1.400
1.300
1.200
1.100
1.000
0.900
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000

Model Predictive Uncertainty - Results

* Annual seepage rate ranges from 230,000 acre-feet per year to 520,000 acre-feet per year with less than a 10% rise in the calibration objective function
* Uncertainty of 290,000 acre-feet per year
* Matches well with previous qualitative estimates of seepage rates for the study area