Woodard & Curran

YUBA WATER AGENCY

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Application of IWFM's MultiModel Package in the Sacramento Valley

Leveraging Local Scale Models and Reducing Uncertainty Related to Boundary Conditions

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Acknowledgements

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Interbasin Flows - Background

SGMA Undesirable Results

Lowering of groundwater levels

Reduction in groundwater storage

Surface water depletion

*Sustainable groundwater use can't be achieved by increasing groundwater inflow from neighboring basins (**interbasin flows**)*

Subbasins are often bounded by streams – better simulation of interbasin flows improves our understanding of stream-aquifer interaction across boundaries

Regional Modeling with the Best Local Tools

Many of the most detailed, best calibrated models in the Central Valley are localized models of one or a few subbasins

Larger, valley-wide modeling spanning basins can improve estimates of:

- Stream aquifer interaction
- Interbasin flows
- Recharge operations

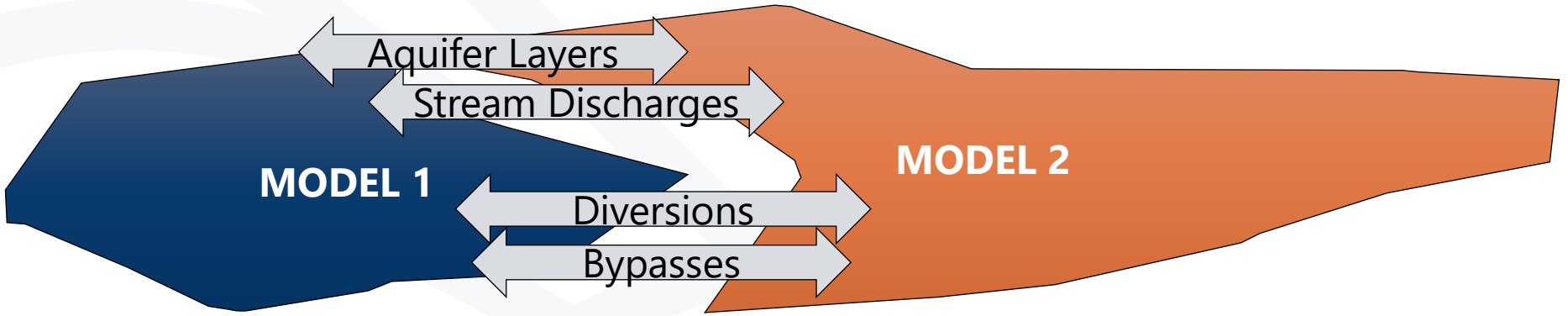
So, how can we leverage local models in a regional way to improve estimates of stream/aquifer interaction and interbasin flows?

SOLUTION
IWFM MultiModel Package

Terminology

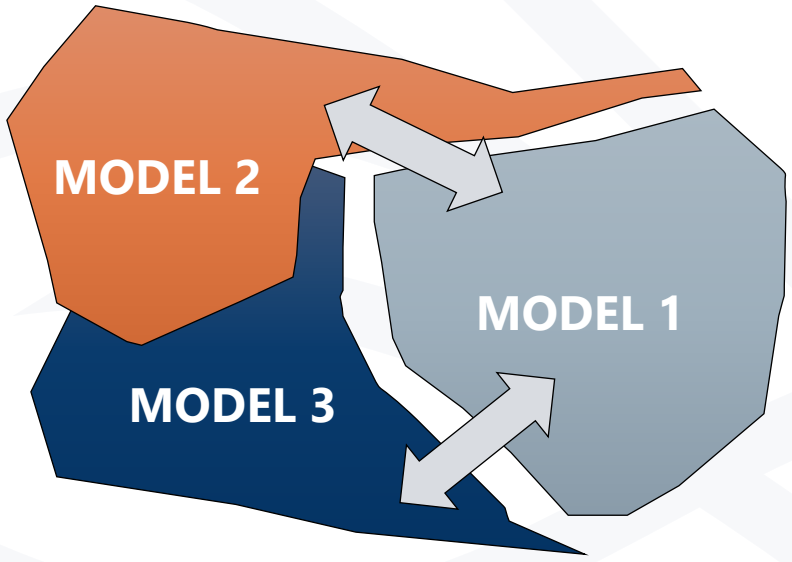
→ *MultiModel*

- A suite of directly adjacent/overlapping IWFM models combined into a contiguous simulation
  - » Up to 8 models can be linked

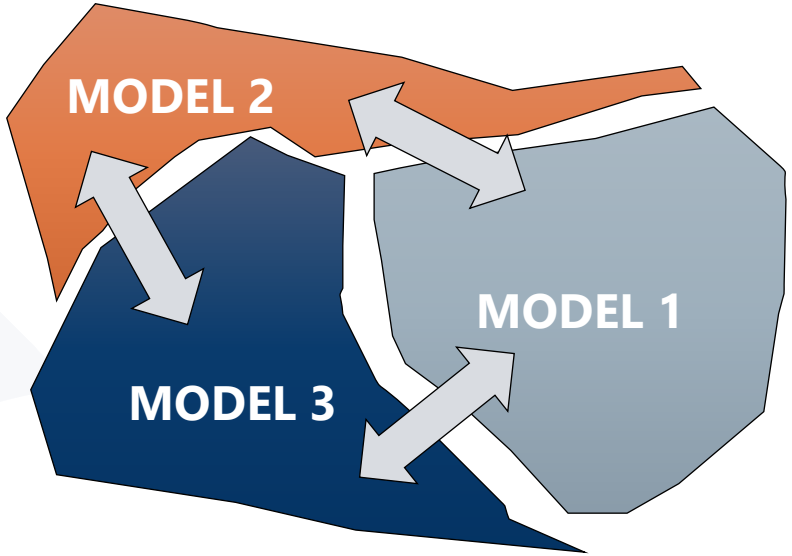


Conceptualizing the MultiModel

Simple Case
Each model is linked only to a main model of interest

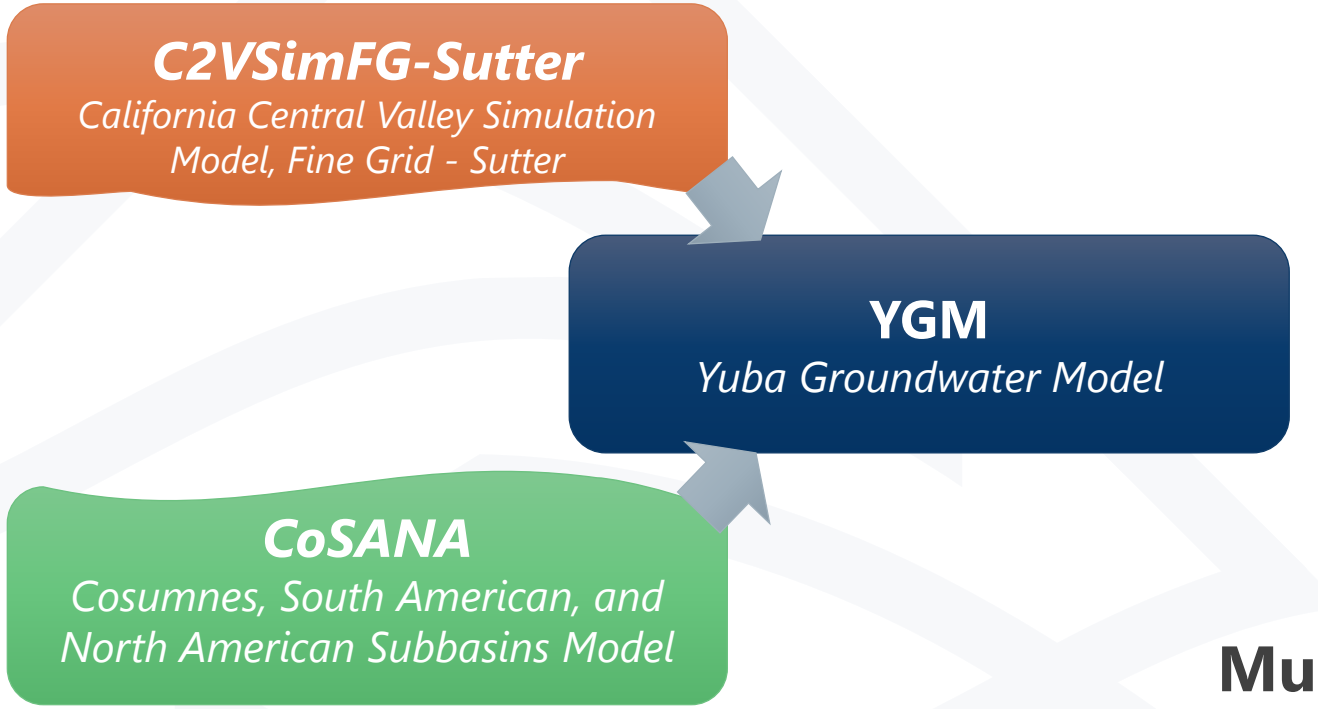


Complex Case
Each model is linked to all adjacent/overlapping models

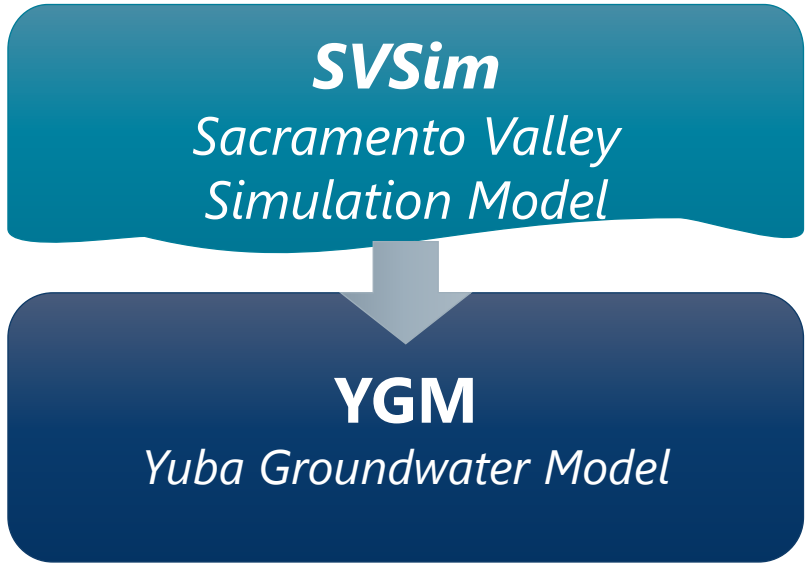


MultiModel Applications
Introduction

MultiModel Scenario 1 (MM1)
(Simple Case)



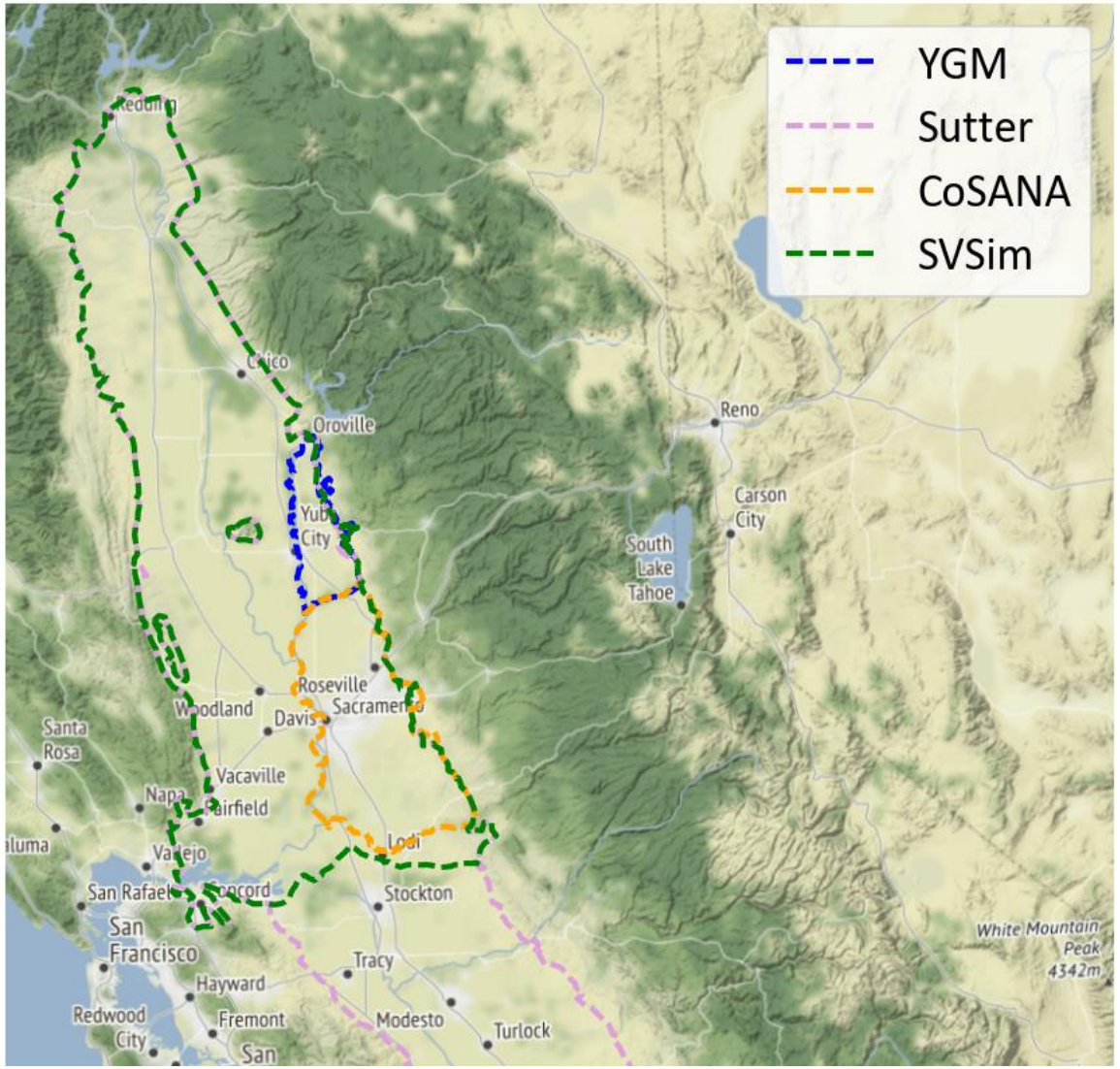
MultiModel Scenario 2 (MM2)



MultiModel Scenario 3 (MM3)
YGM + C2VSim (coming soon?)

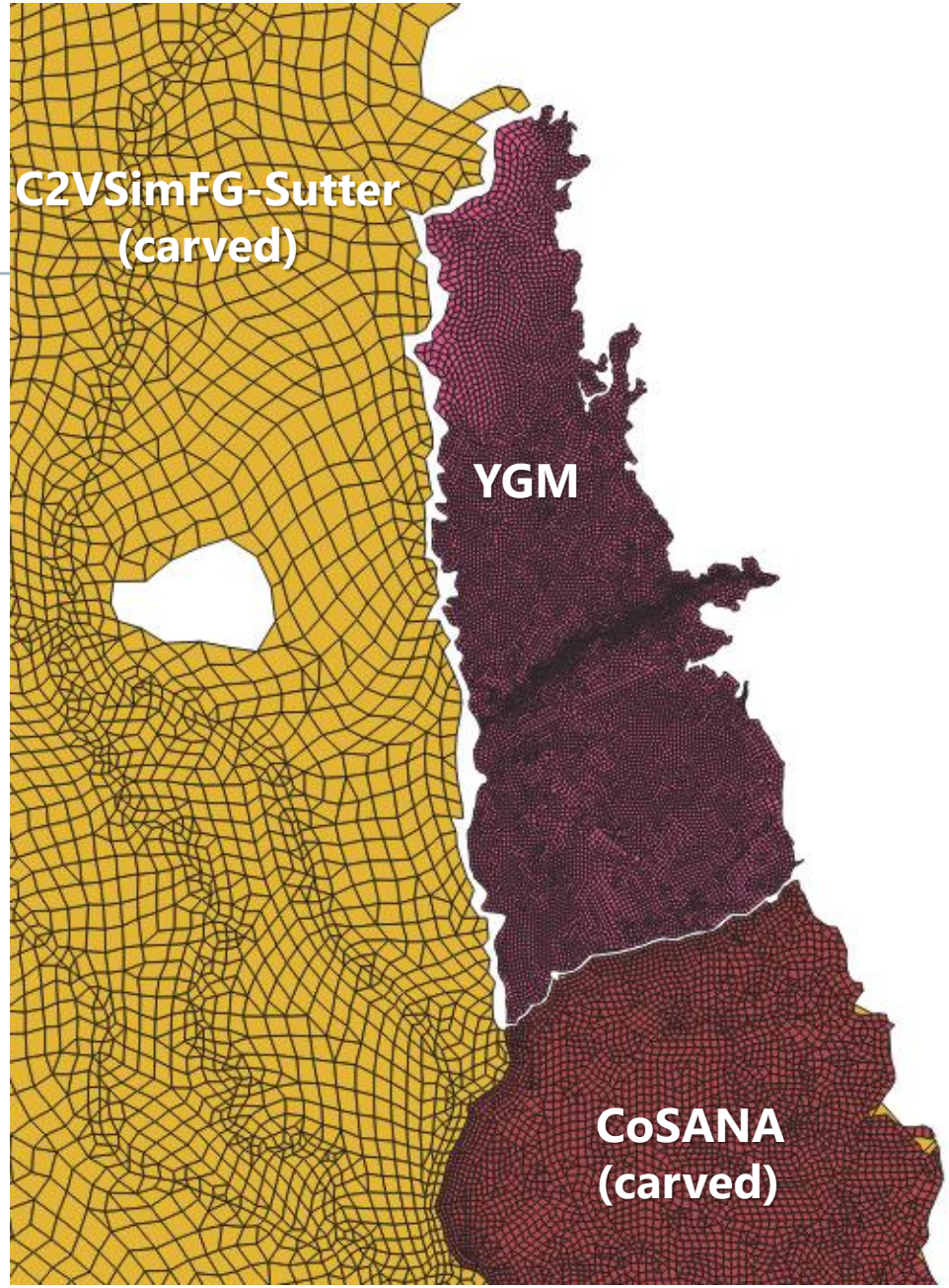
MultiModel Applications
Background

Model Name	Scale
YGM	Local
C2VSimFG-Sutter	Regional model, refined locally
CoSANA	Local
SVSim	Regional



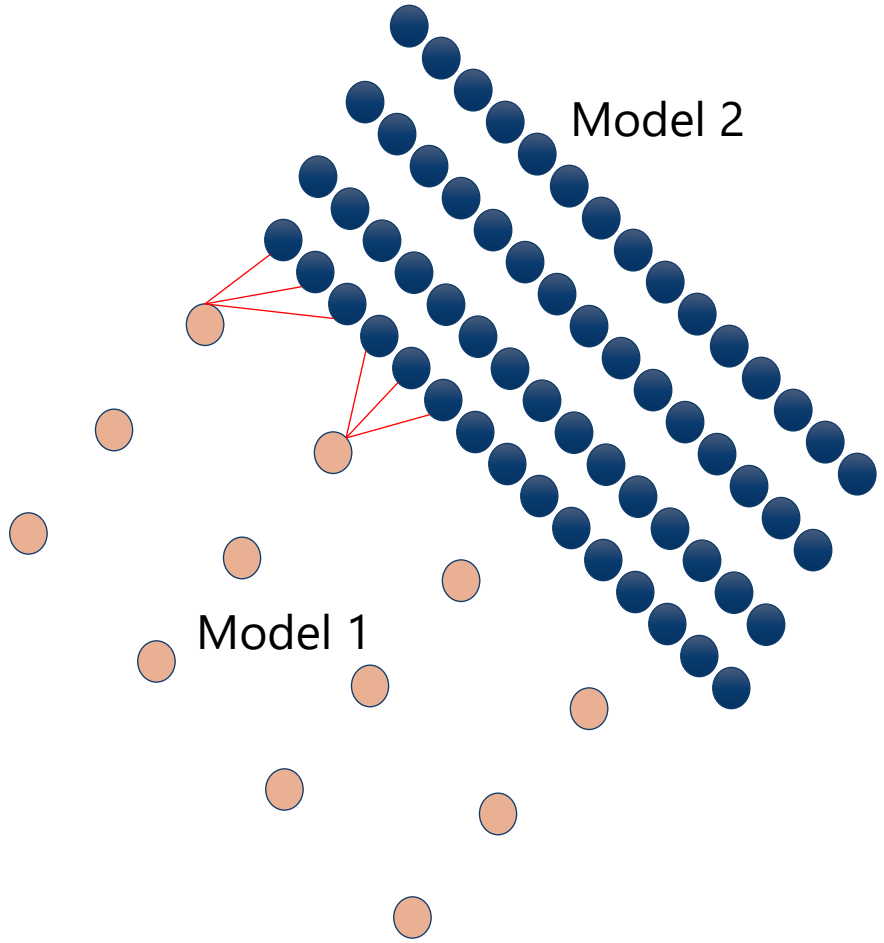
Linking the Models
Overlapping Domains

- Wherever linked models overlap, one must "carve out" the overlapping portion from the model(s) of lesser interest
- The "carved out" area should leave space between the overlapping models
- Streams shared between the models must be removed from all but one



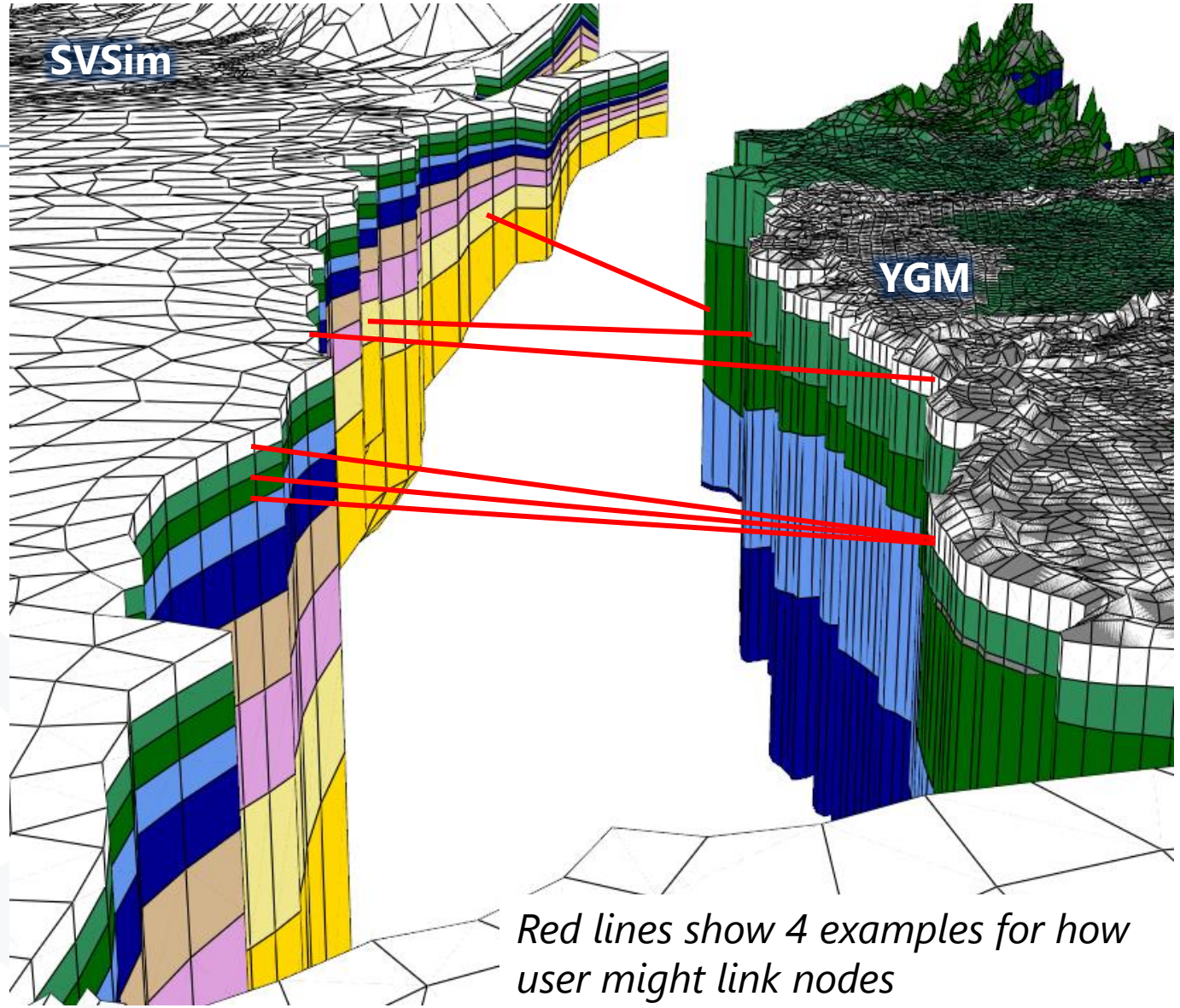
Linking the Models
Connecting Nodes

- Models linked by defining connections between boundary nodes
- MM can handle multiple nodes/layers linked to one node



Linking the Models
Stratigraphy

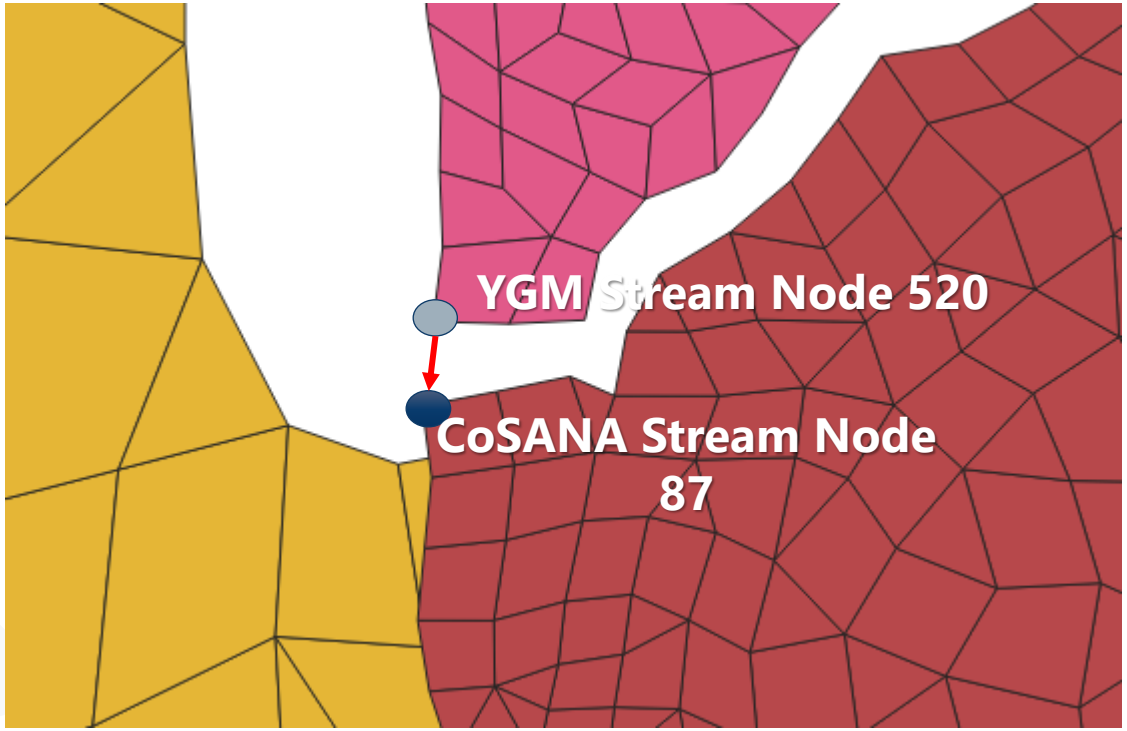
- Each model's stratigraphy, aquifer parameters, and simulated groundwater heads are used to calculate boundary conditions for the neighboring model(s)
  - Connections between layers are established manually by the user
  - Multiple nodes/layers from one model can be linked to a single node/layer from another model



Red lines show 4 examples for how user might link nodes

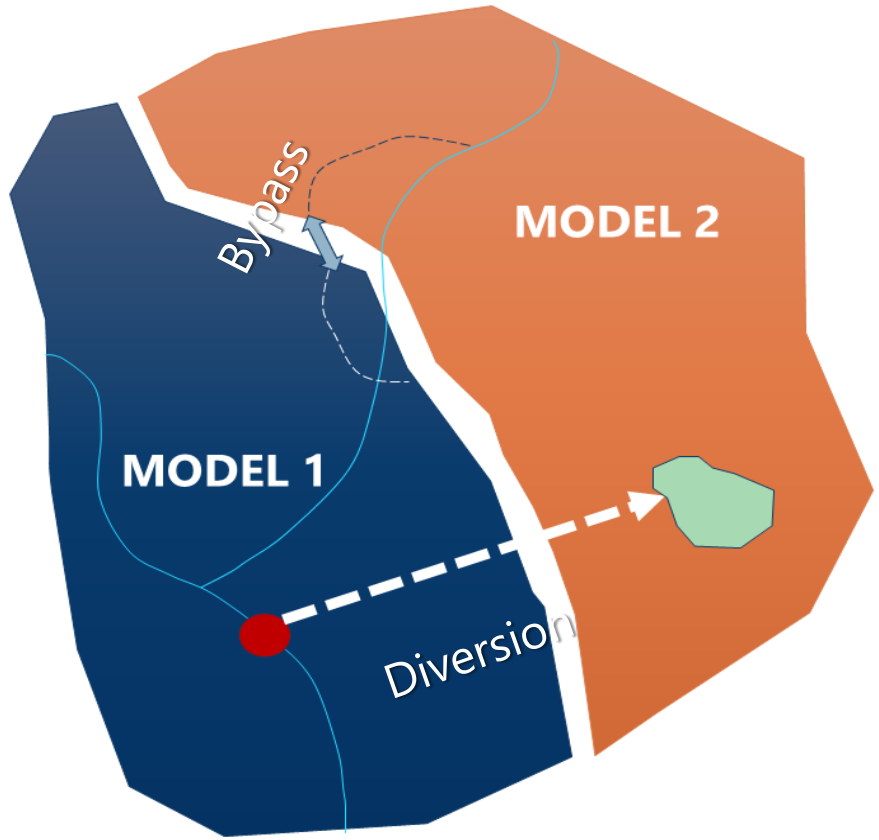
Linking the Models
Streams

- Stream outflows from one model can be used as stream inflows of another
- Must remove stream nodes that overlap (overlapping domains)
- Stream-aquifer interaction in the carved-out model is conceptually accounted for through boundary conditions



Linking the Models
Diversions and Bypasses

- Diversions from one model can be exported to another
- These diversions must exist in both models – one specified as import, one as export
- Bypasses from one model can be linked to another



Challenges

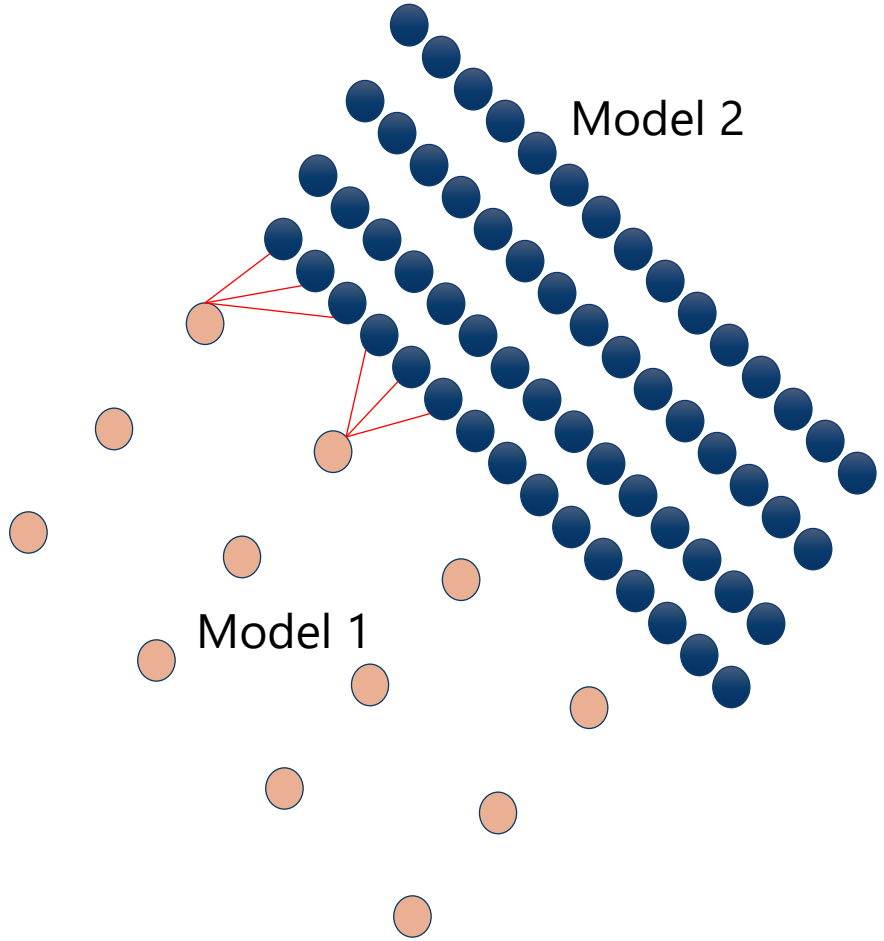
- The model carve-out procedure is labor intensive and not easily automated
- The MM executables may struggle with convergence
  - The maximum number of iterations (*mi*) can be set to a lower value to manage runtime
  - The MM executable will **not** crash if the model doesn't converge after *mi* iterations
  - The MM executable prints out the maximum error (and associated node/layer) that results from convergence issues to monitor convergence
- Runtime is slightly longer than the slowest running model

Runtime Comparison

Model	Runtime (h:mm)	Executable Version
YGM	0:24 (0:13 w/ PLL)	v2015.1.1443
SVSim	3:58	v2015.0.1422
CoSANA	0:52	v2015.0.1129
Sutter	2:17	v2015.0.1129
YGM + CoSANA + Sutter (MM1)	8:58	v2023.0.1495
YGM + SVSim (MM2)	4:38	v2023.0.1495

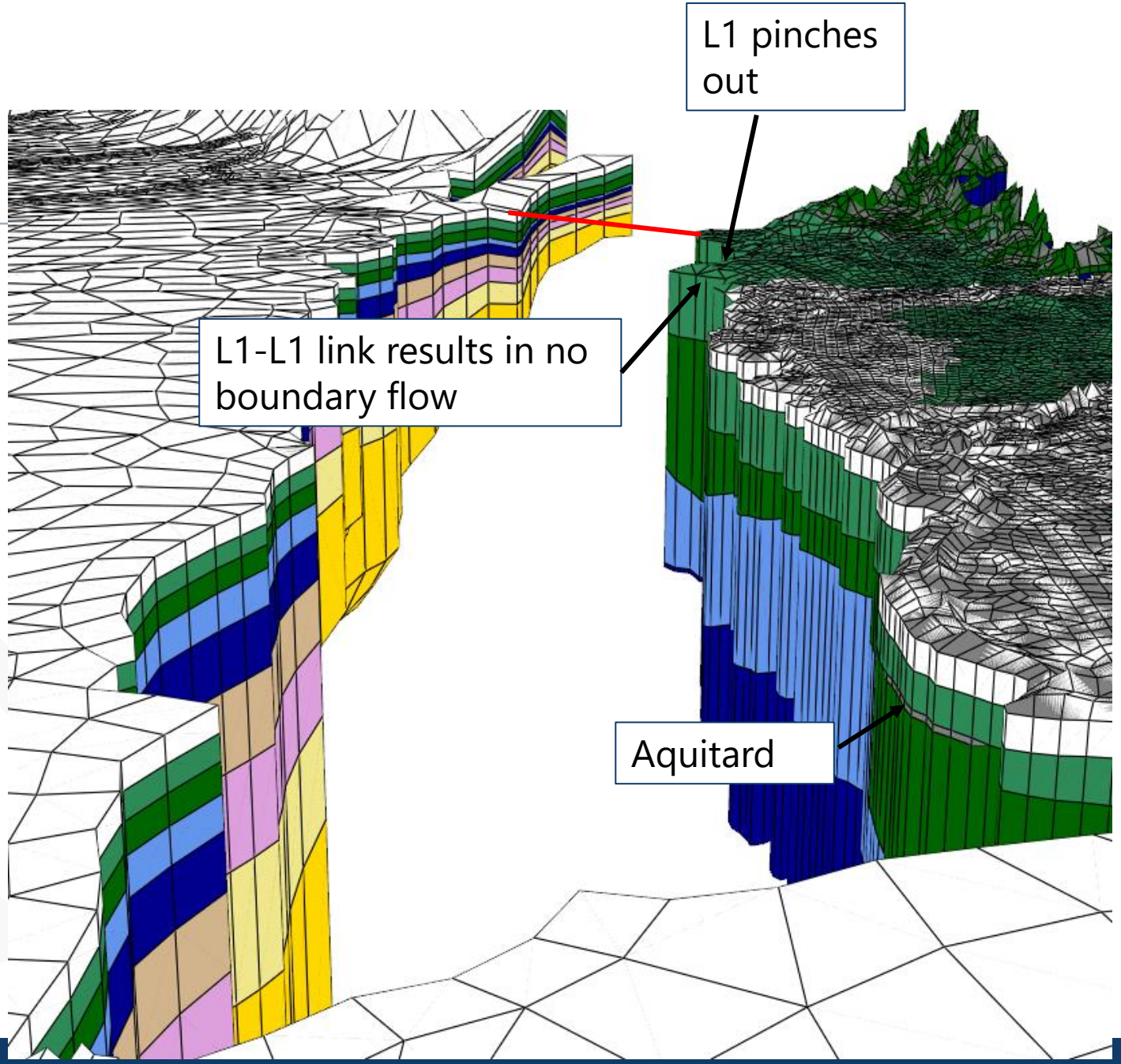
Insights Gained

- Must ensure all boundary nodes are linked between models
- Otherwise, boundary flow between models will be incomplete



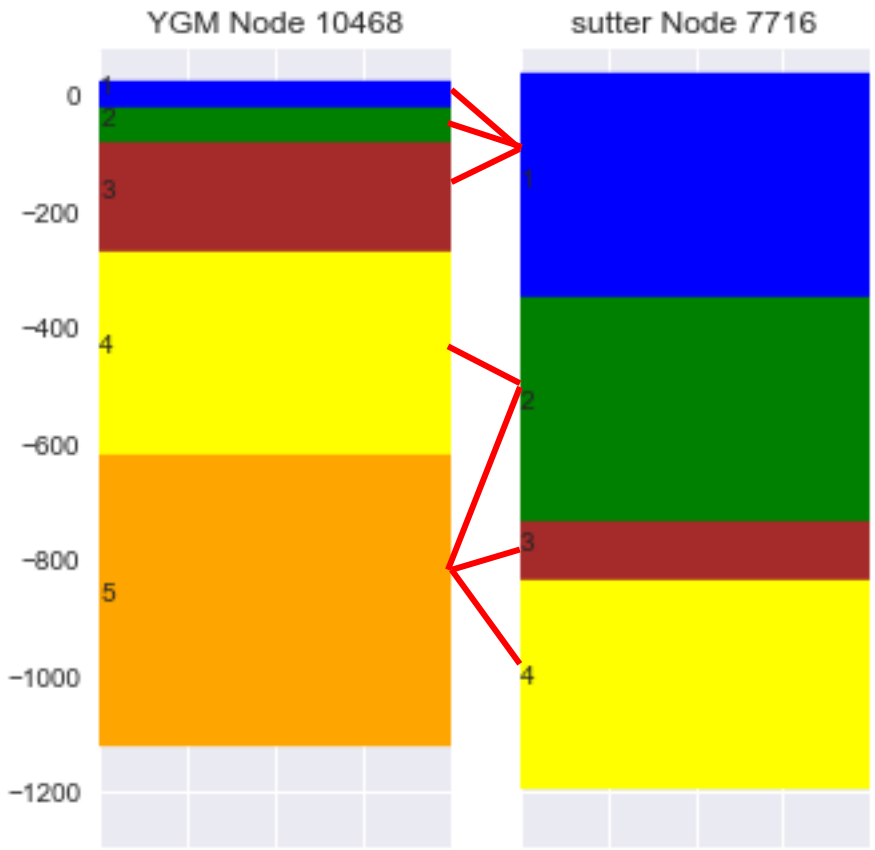
Insights Gained

- Stratigraphic pinch-outs complicate linking of layer-node pairs
  - Links including pinched-out layers will return a warning ("*Zero effective conductance*")
  - Running the model with such links will likely result in incorrect boundary flows
- Aquitards assume vertical flow only, no need to link



Insights Gained

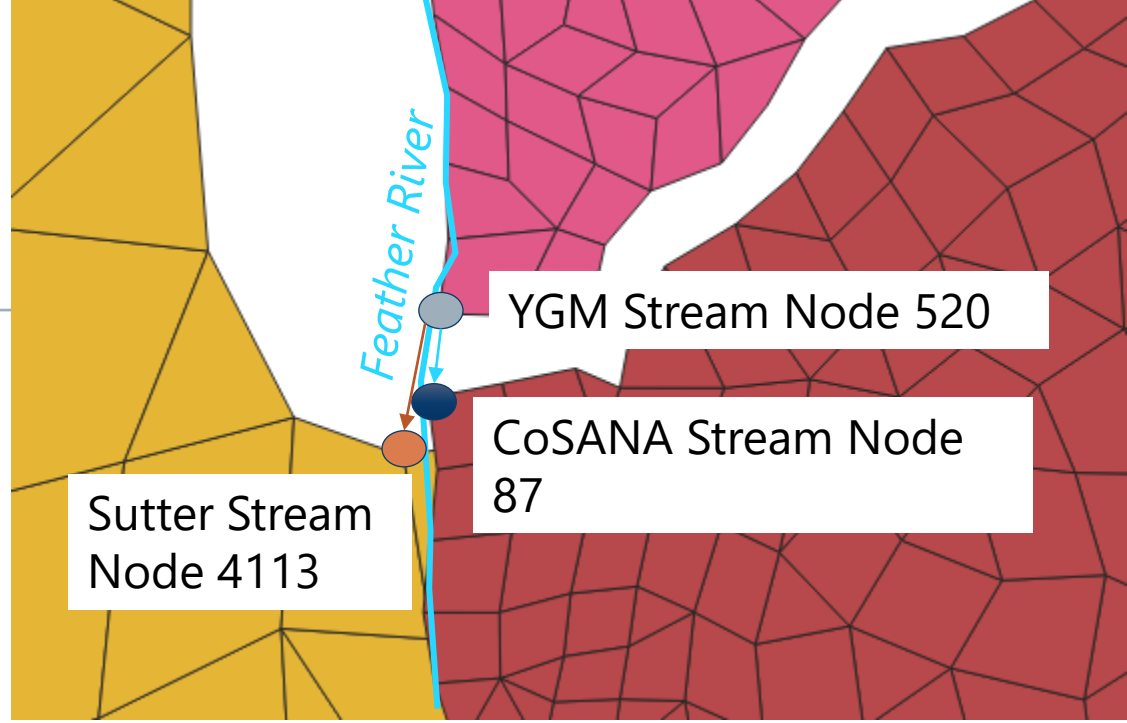
- Stratigraphy can be linked effectively with a relatively simple algorithm that links stratigraphy at each node based on a minimum percent overlap
- In the event of many-to-one joins, the strata of the "many" are averaged

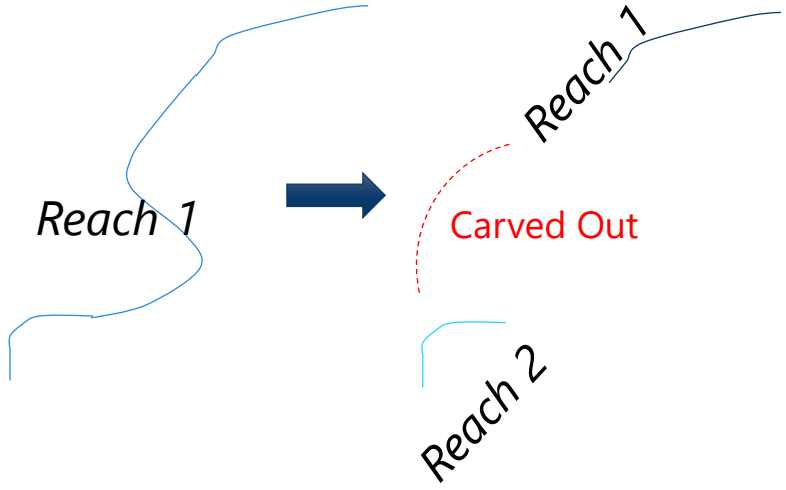


YGM	sutter
1	1
2	1
3	1
4	2
5	2
5	3
5	4

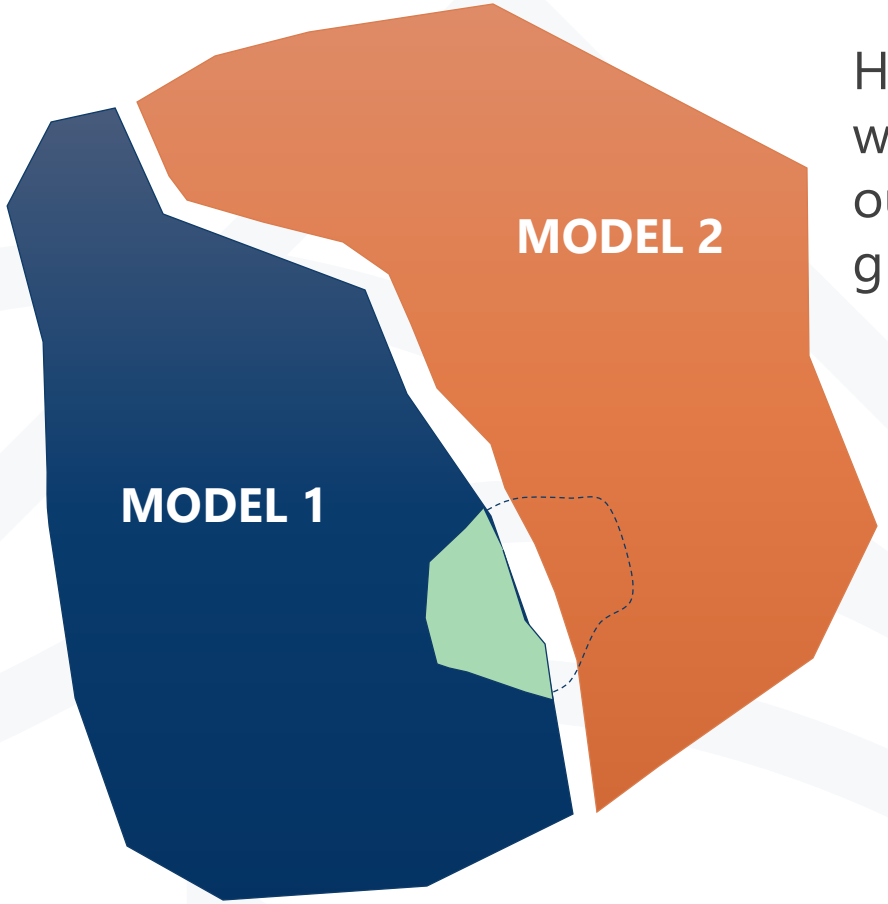
Insights Gained

- If streamflows from one model are routed to multiple downstream models:
  - Flows aren't divided, but will cause discrepancy in budgets *(will be fixed in IWFM)*
- If two separate streamflows from one model are routed to the same node on the downstream model:
  - One will overwrite the other – can stagger nodes to which they are routed *(will be fixed in IWFM)*
- If a stream reach is divided during "carve out", must split into two reaches
  - Model will run if you do not do this now that non-sequential node numbering is allowed, but the representation will not be correct



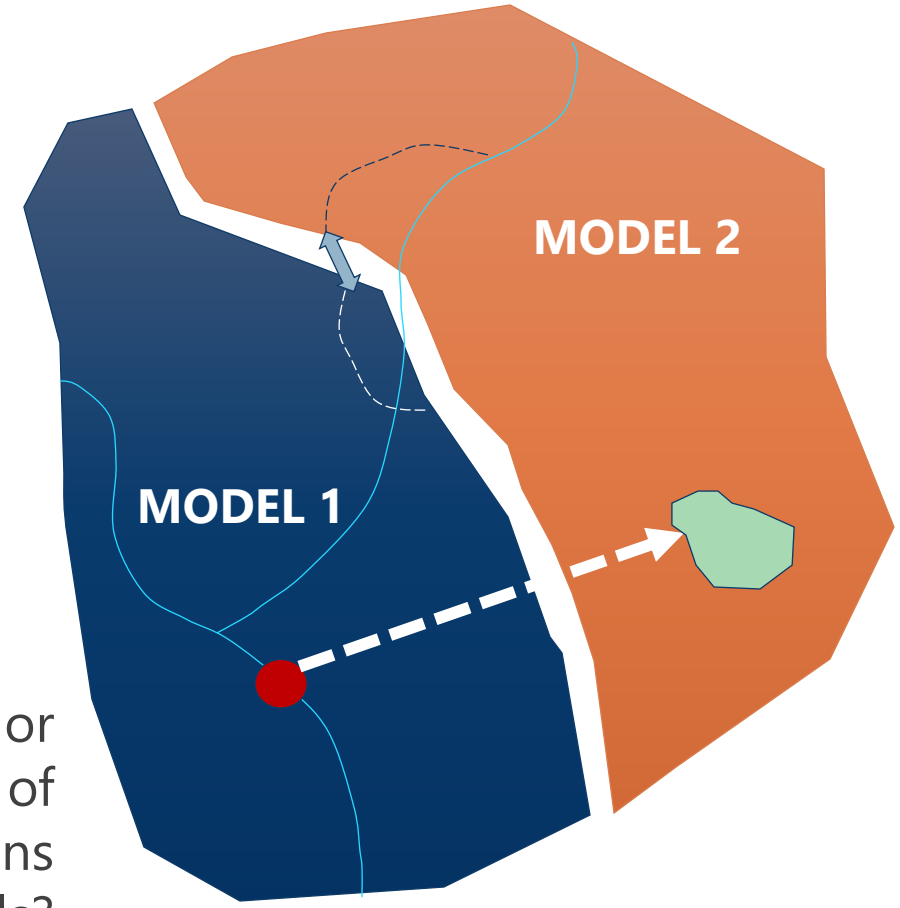


Remaining Conceptual Challenges



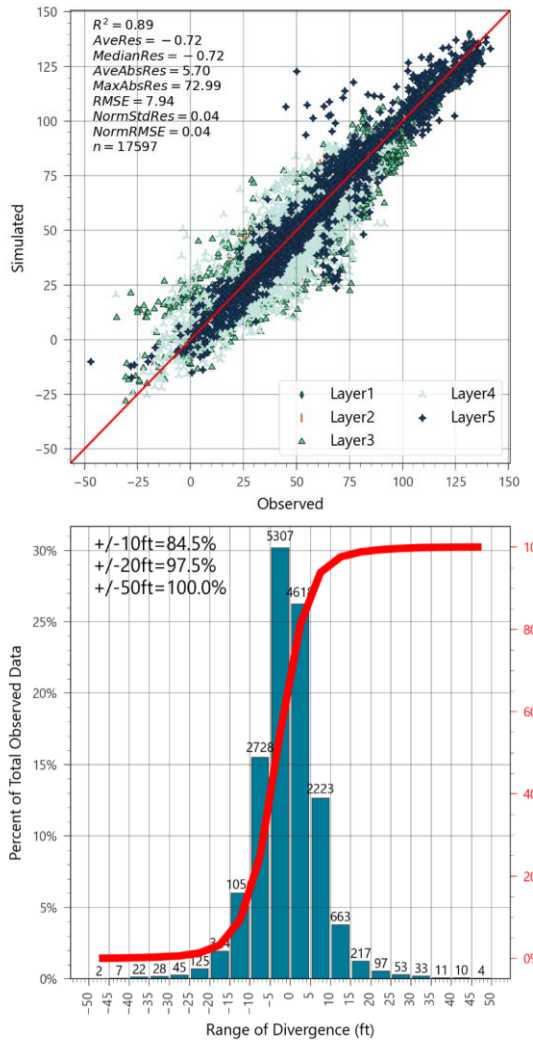
How do we redistribute water from partially "carved out" element delivery groups/recharge zones?

How do we effectively link or automate the linking of bypasses and diversions between models?

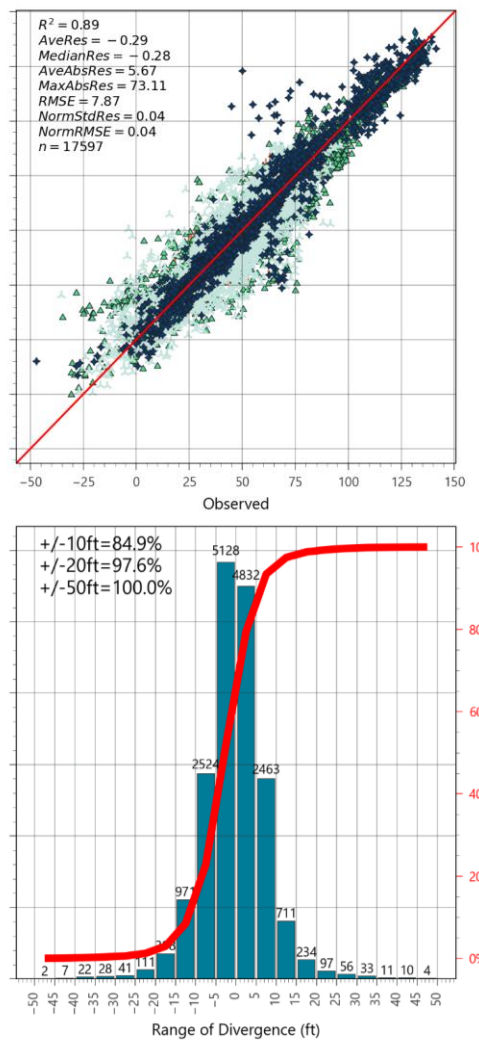


Comparison of Results
Groundwater Levels (ft amsl)

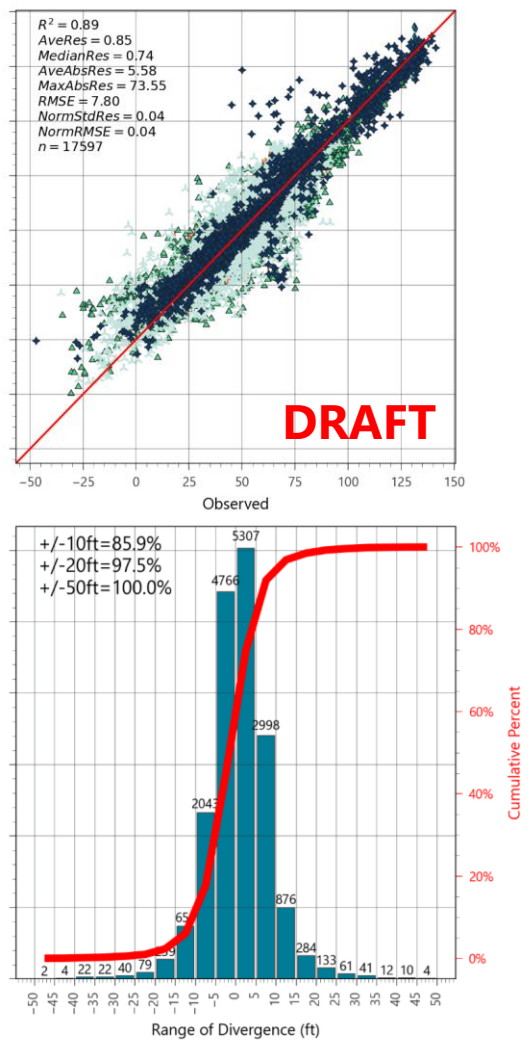
YGM + CoSANA + C2VSimFG-Sutter



YGM + SVSim



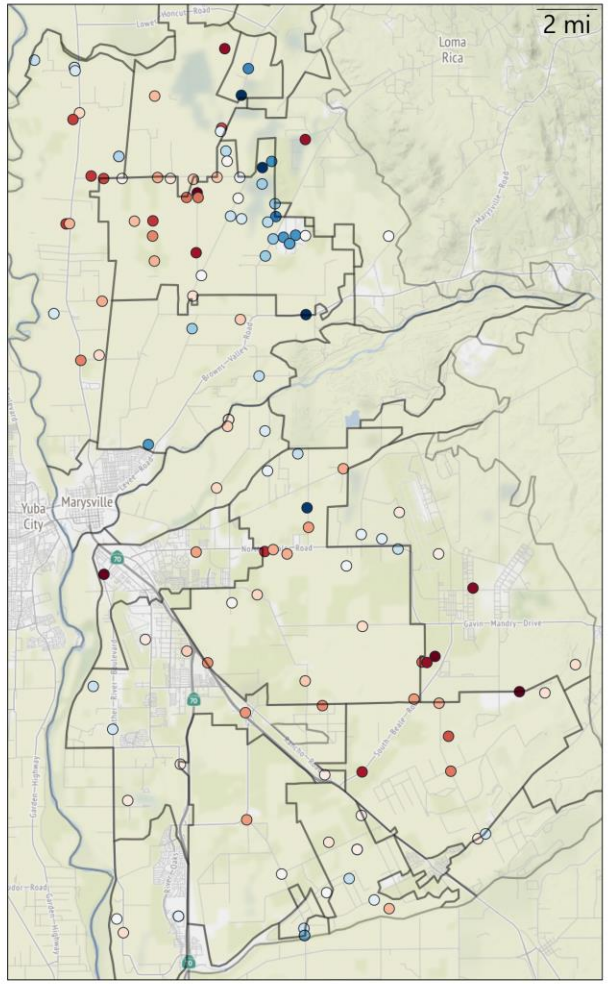
YGM



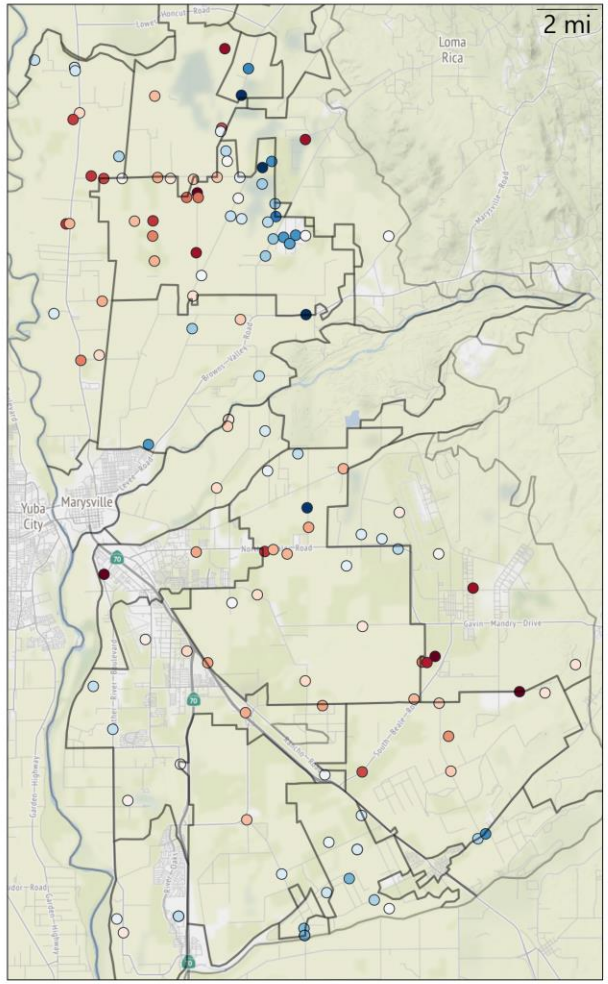
Note: No calibration was done on MultiModels

Comparison of Results
Groundwater Levels

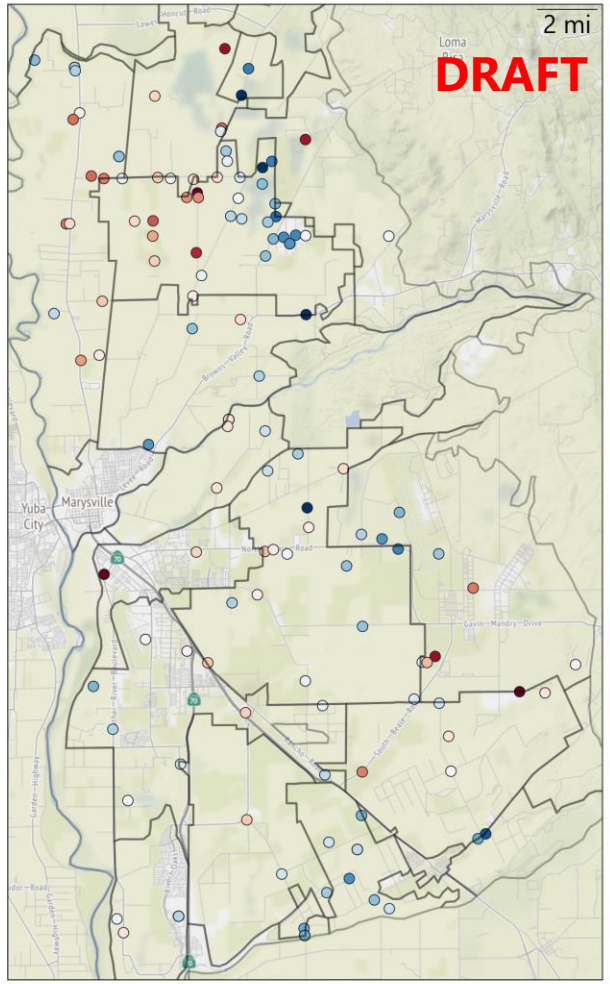
YGM + CoSANA + C2VSimFG-Sutter

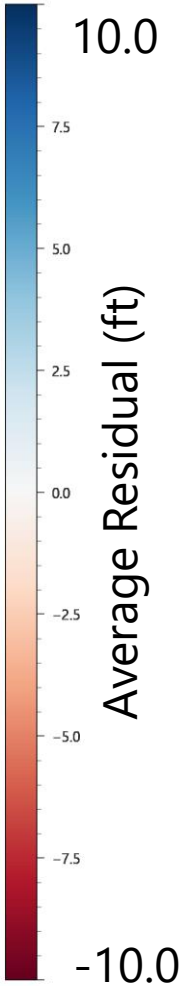


YGM + SVSim



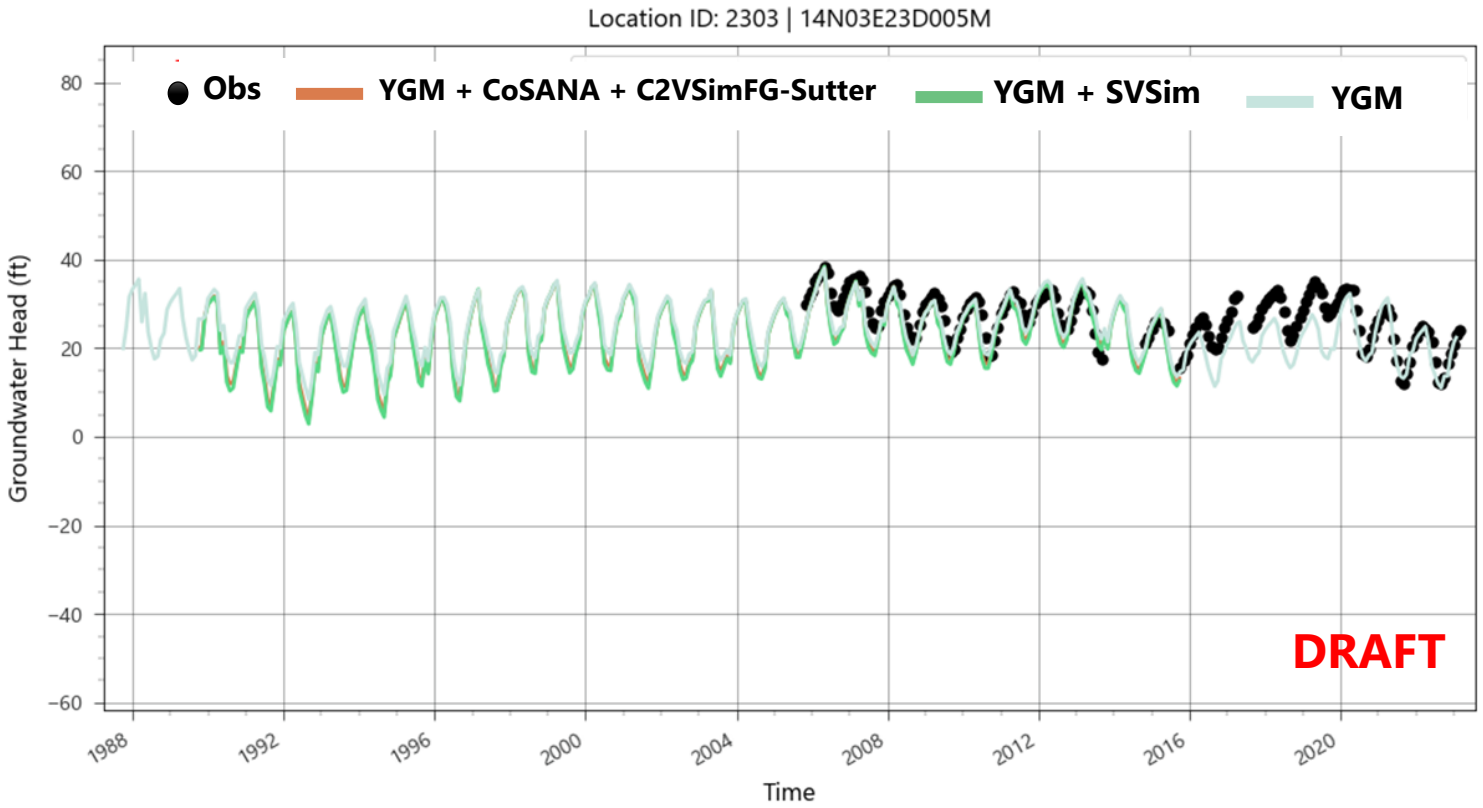
YGM



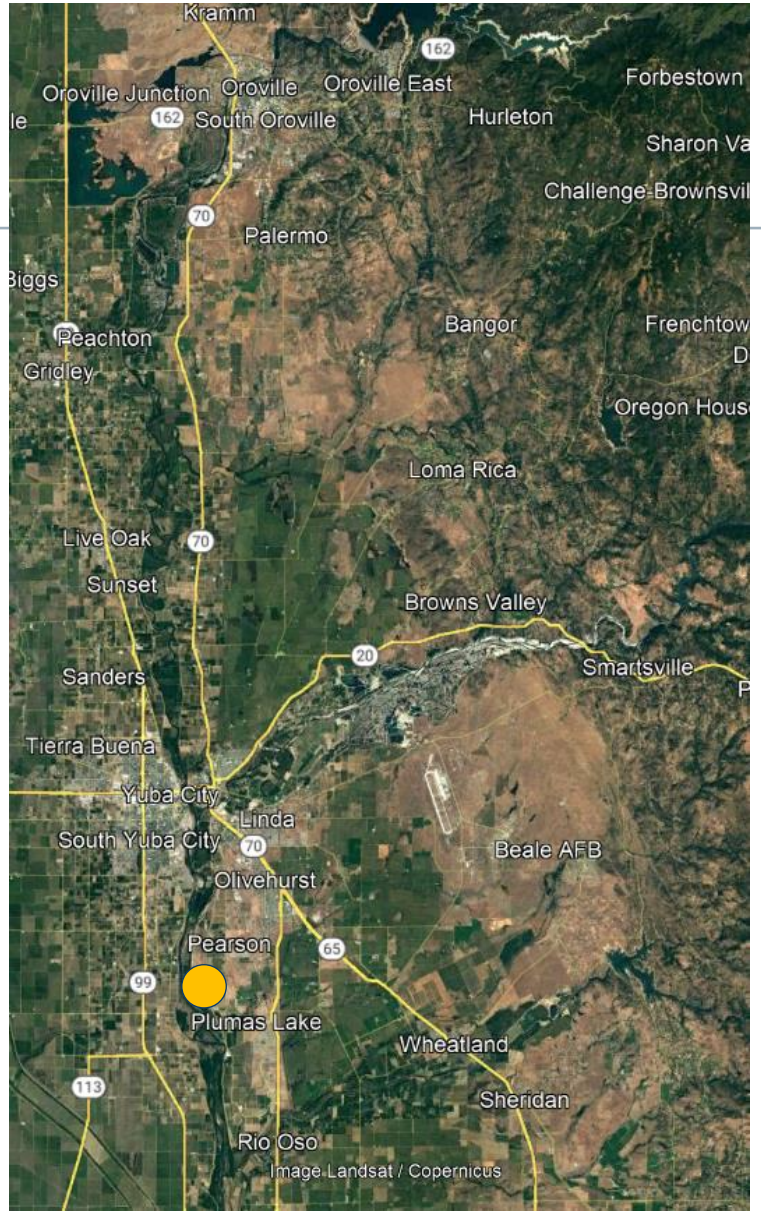


Note: No additional calibration performed on MultiModels

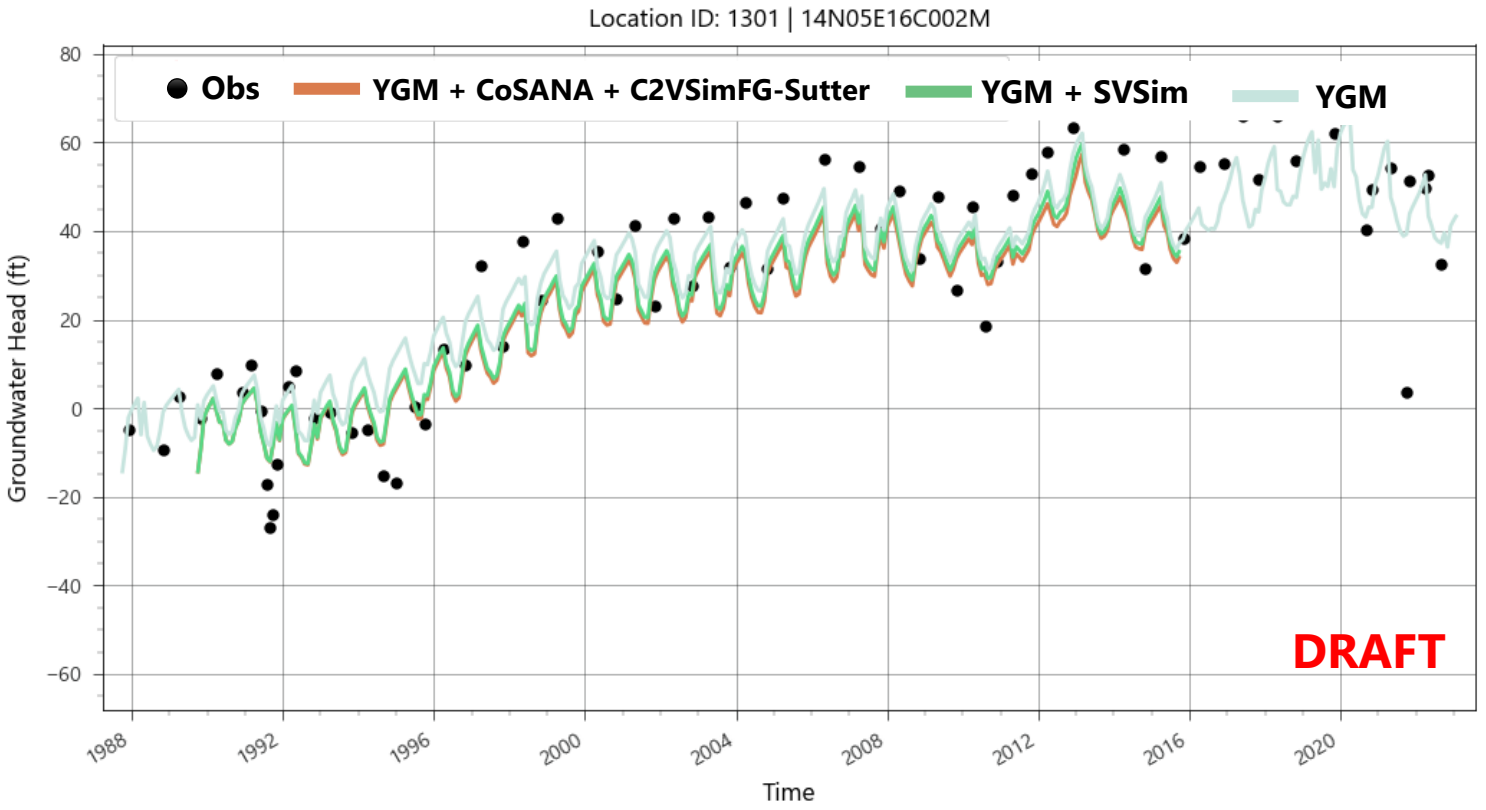
Hydrograph Comparison
South Yuba



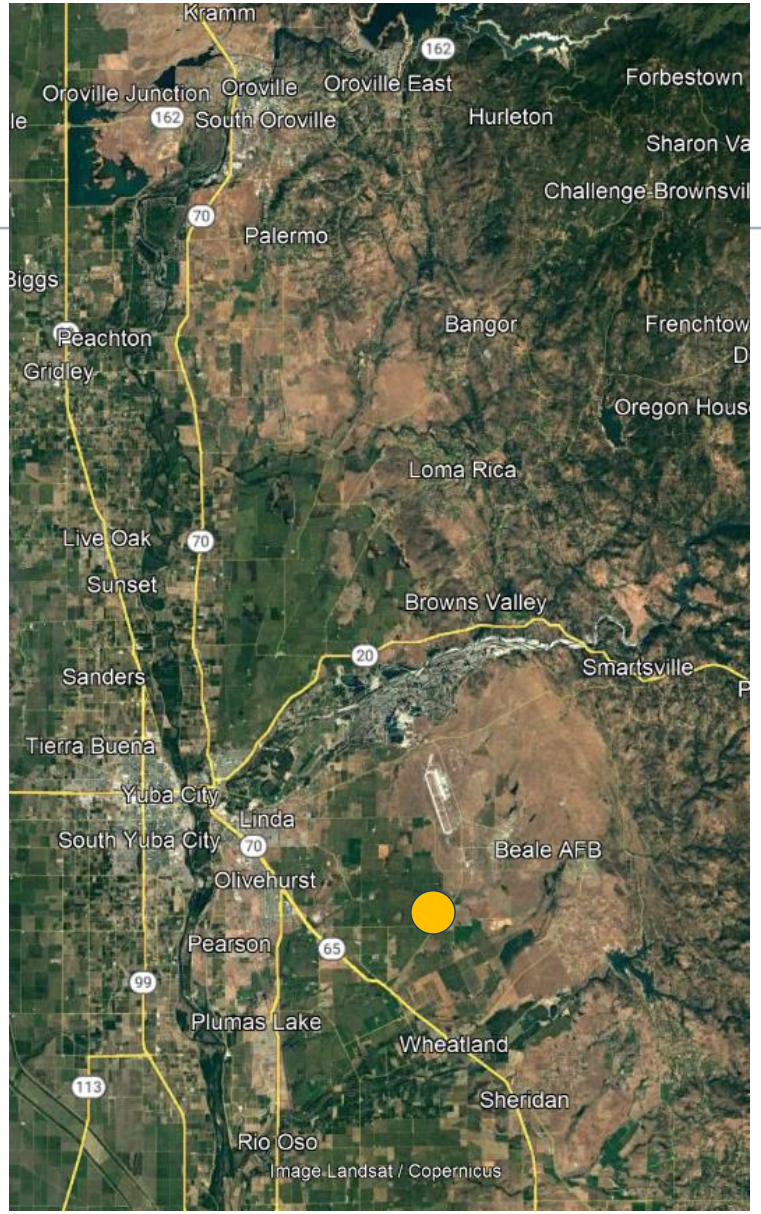
Perforation Top Depth: 664 ft.
Perforation Bottom Depth: 684 ft.



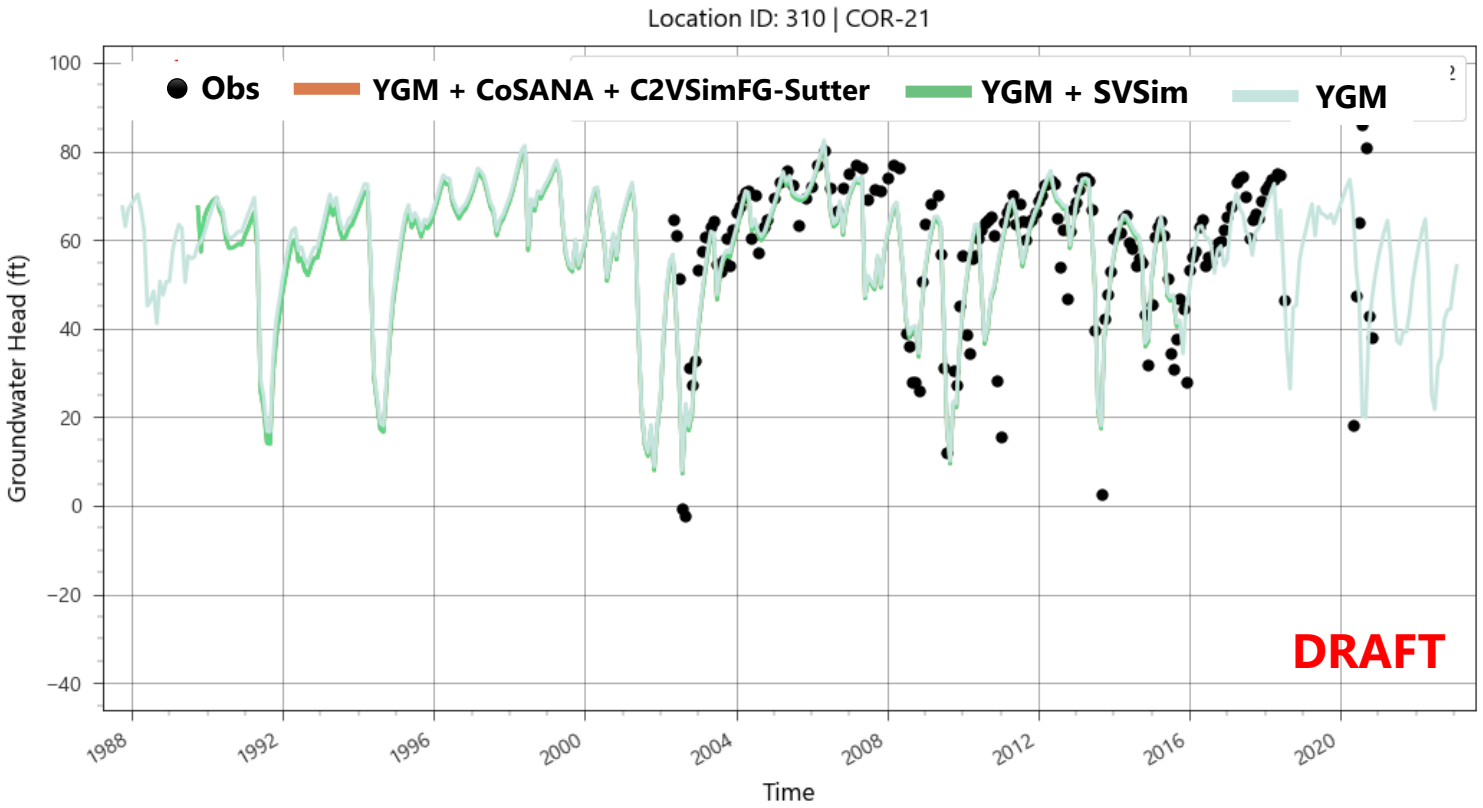
Hydrograph Comparison
South Yuba



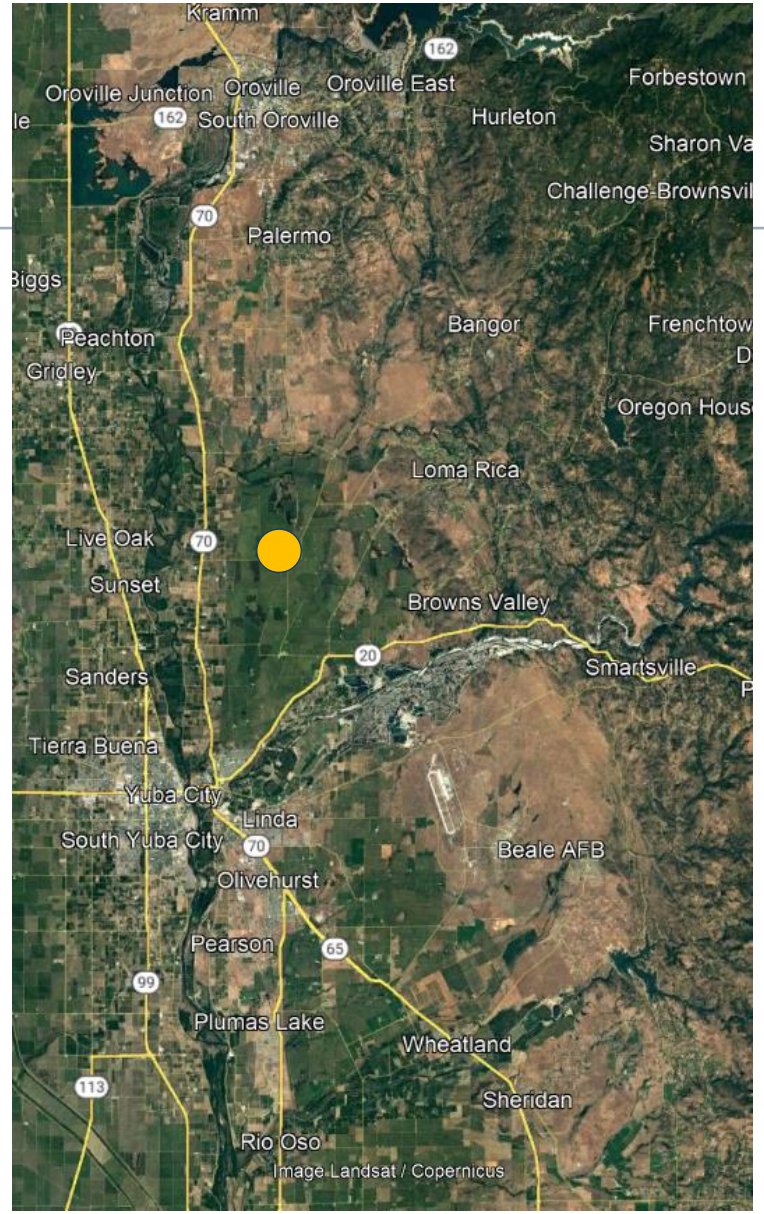
Perforation Top Depth: 177 ft.
Perforation Bottom Depth: 361 ft.



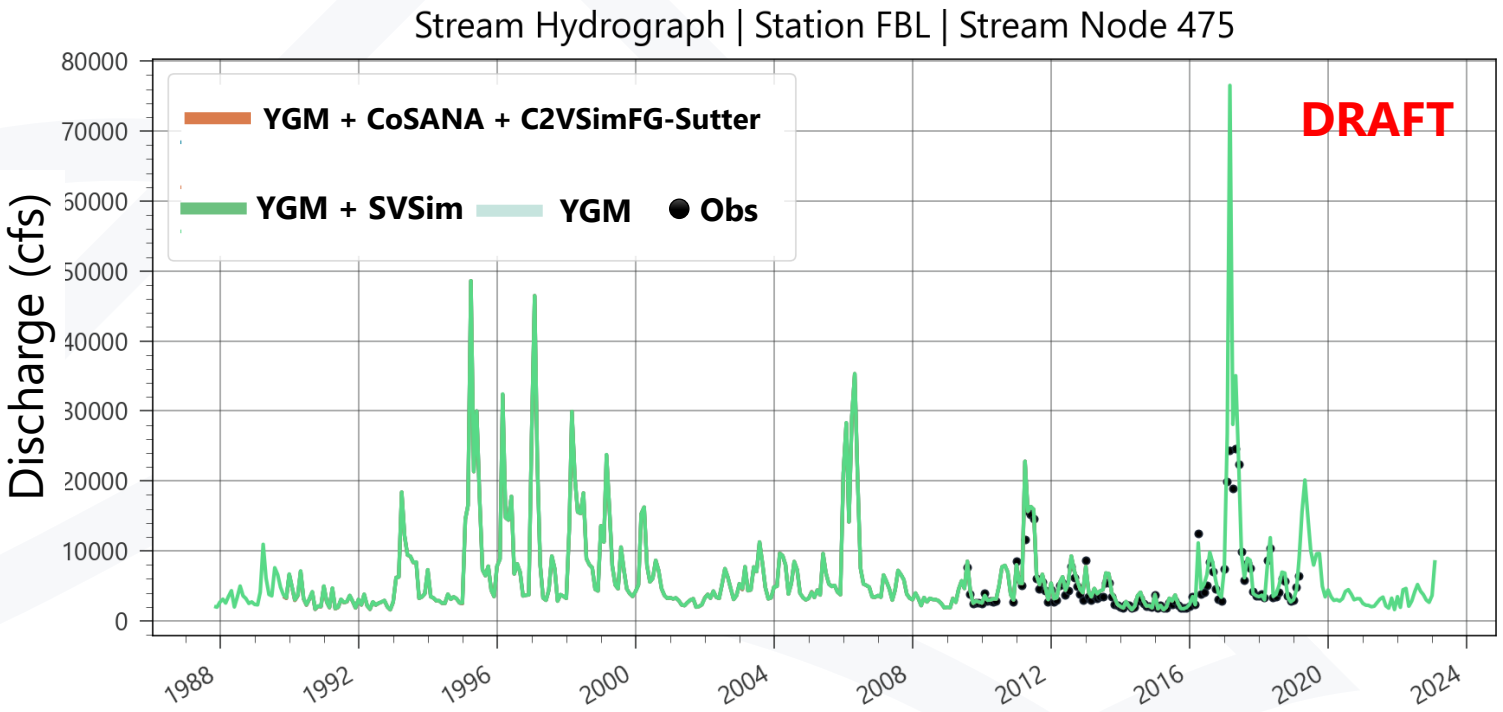
Hydrograph Comparison
North Yuba

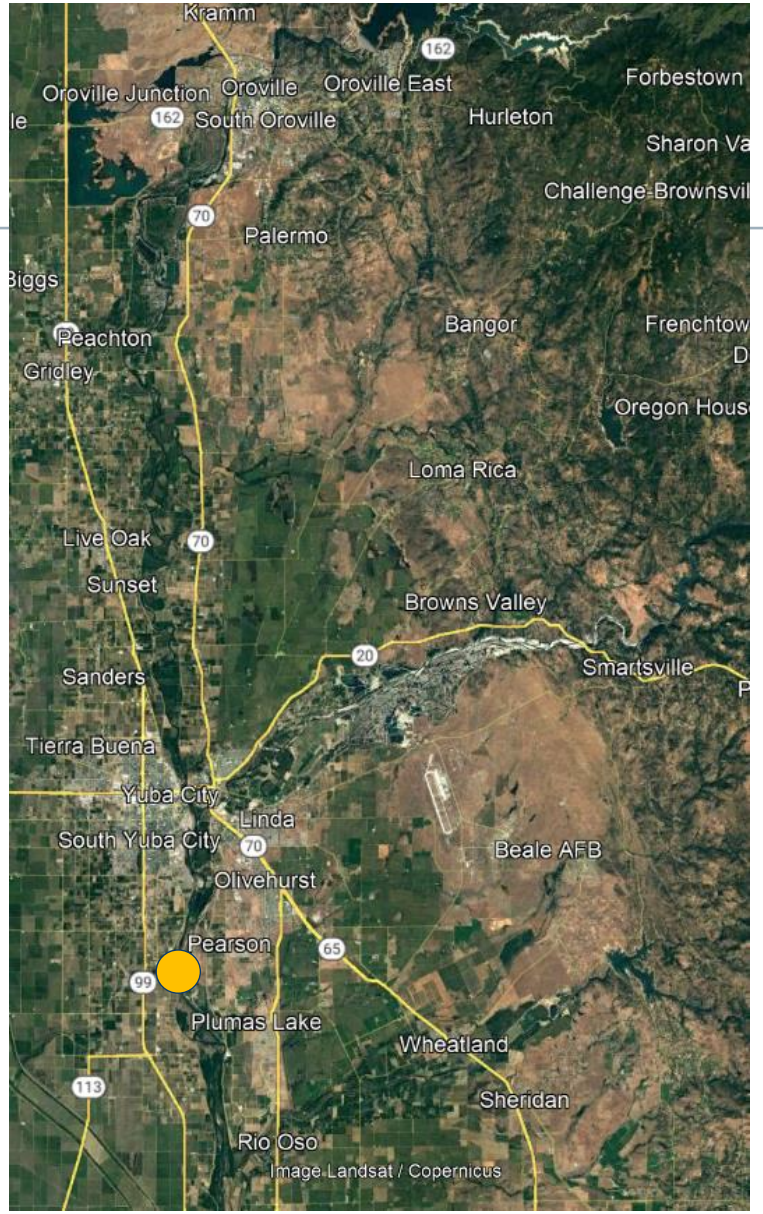


Perforation Top Depth: 99 ft.
Perforation Bottom Depth: 330 ft.

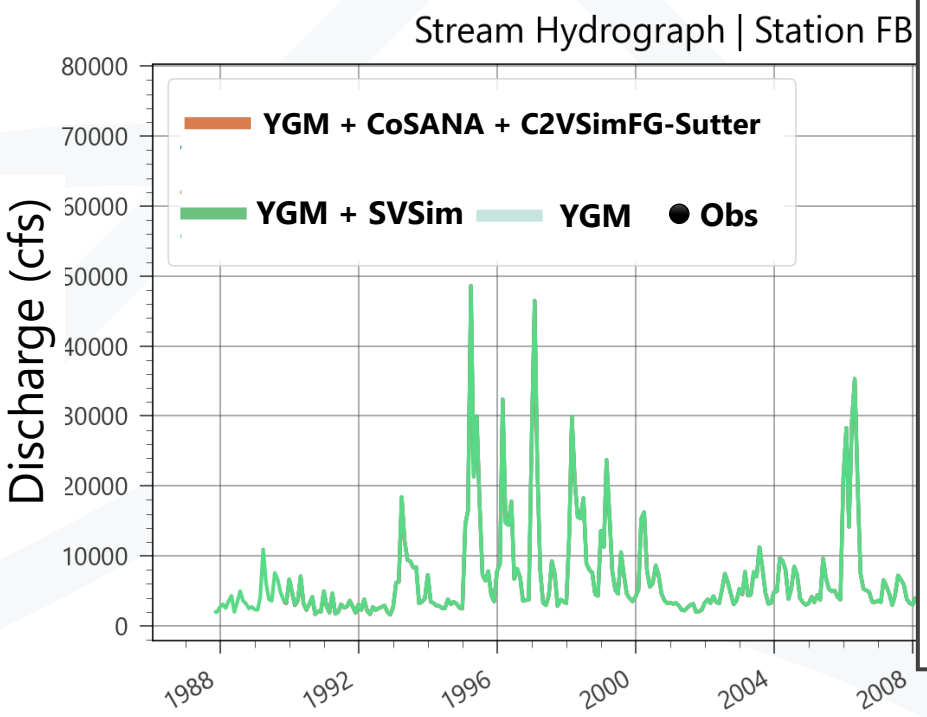


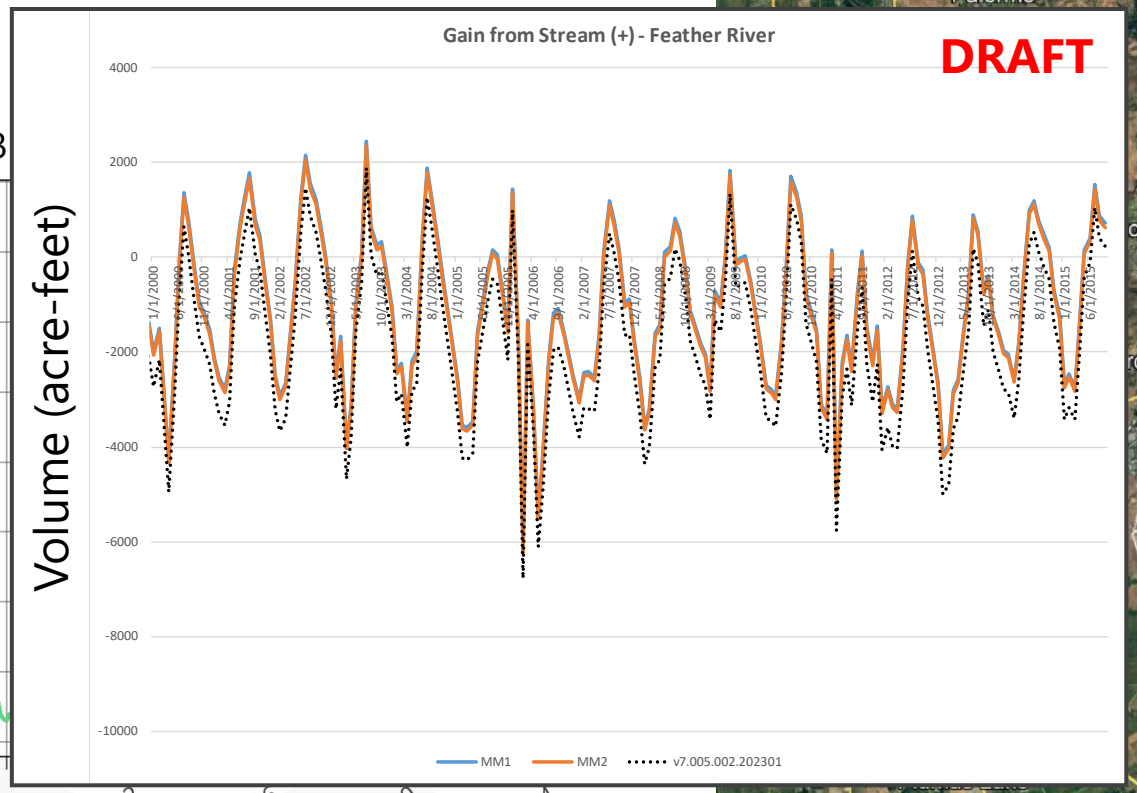
Stream Hydrograph Comparison
Feather River

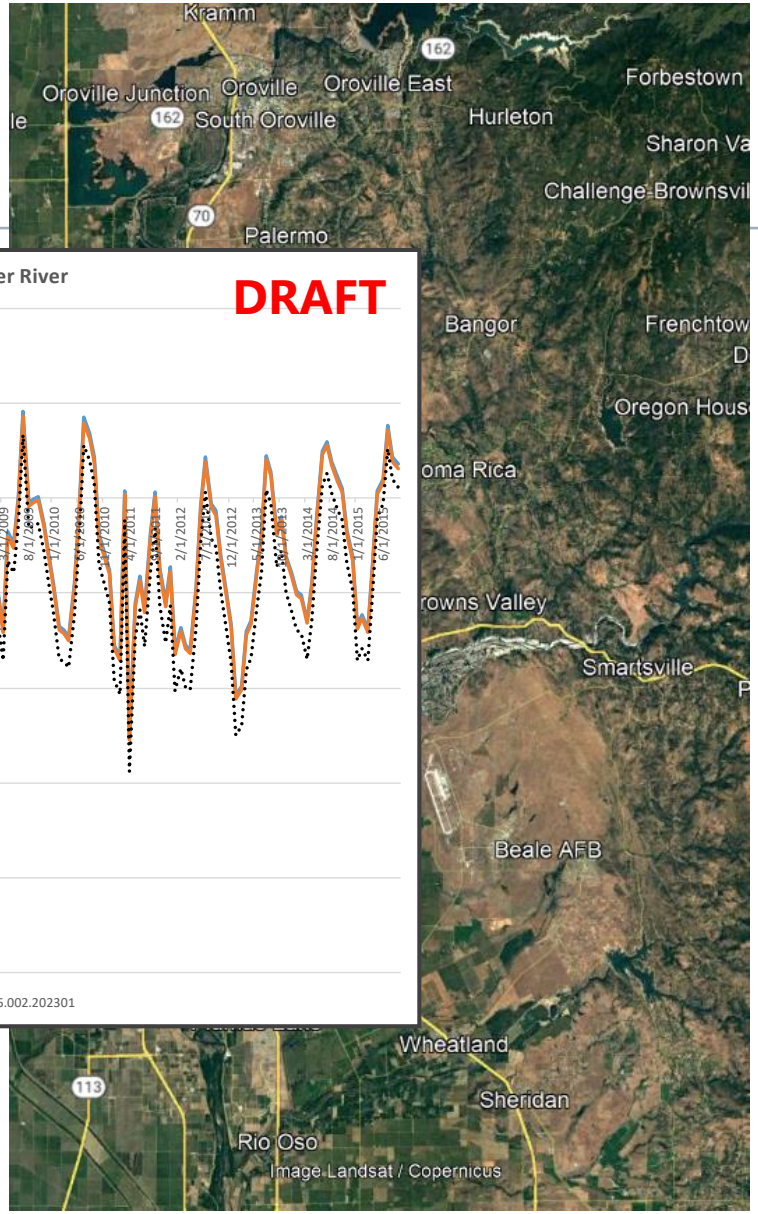




Stream Hydrograph Comparison
Feather River







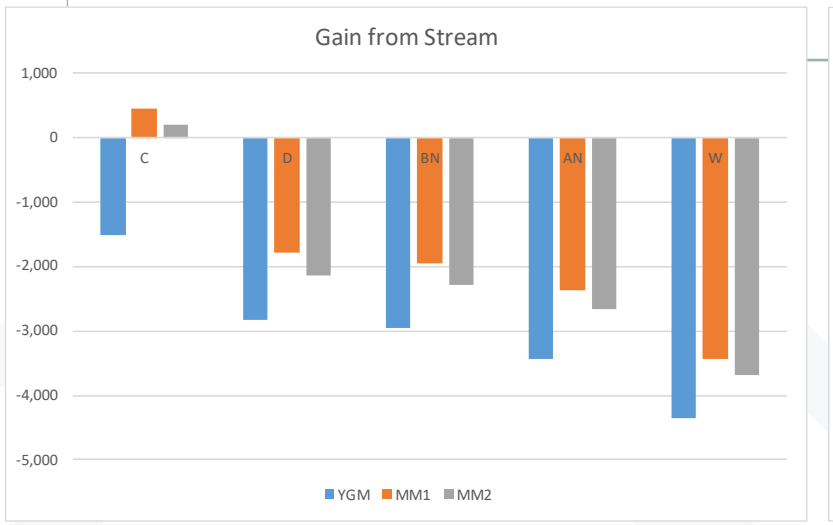
Preliminary Results

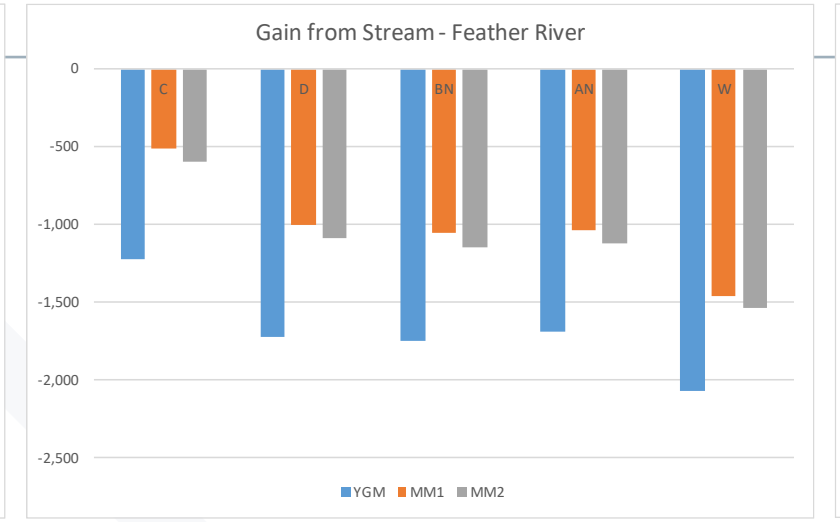
Gain from Stream and Boundary Inflow by WY Type

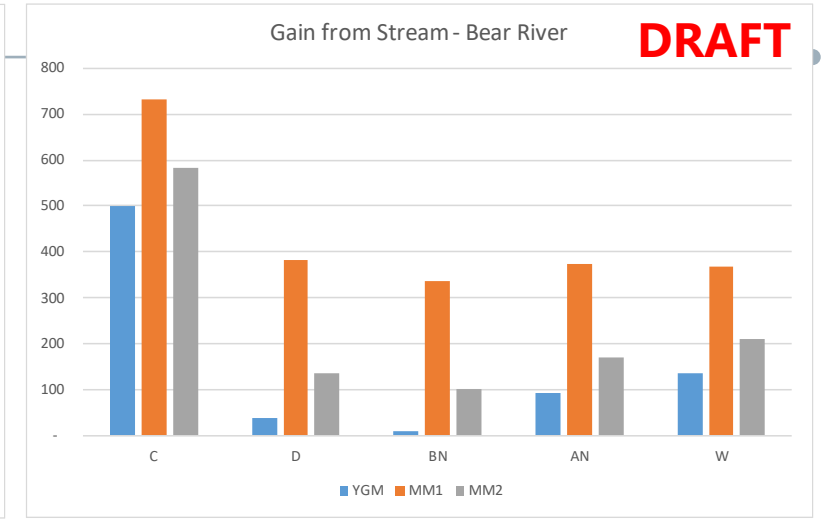
YGM + CoSANA + C2VSimFG-Sutter

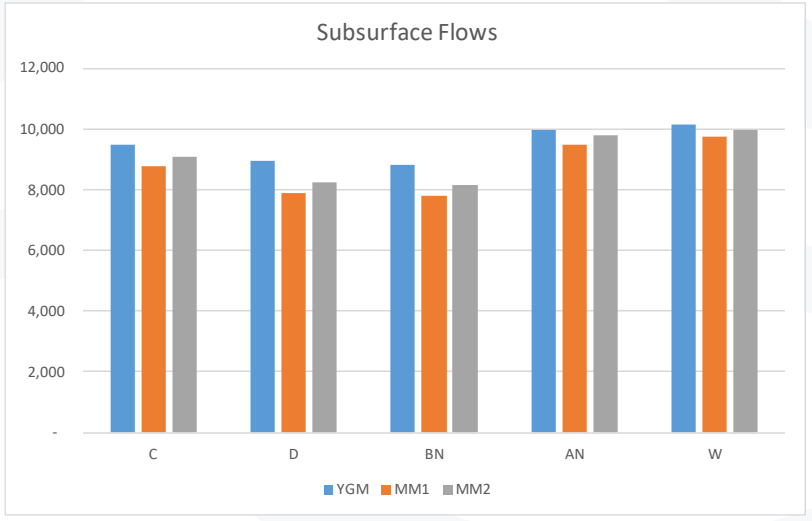
YGM + SVSim

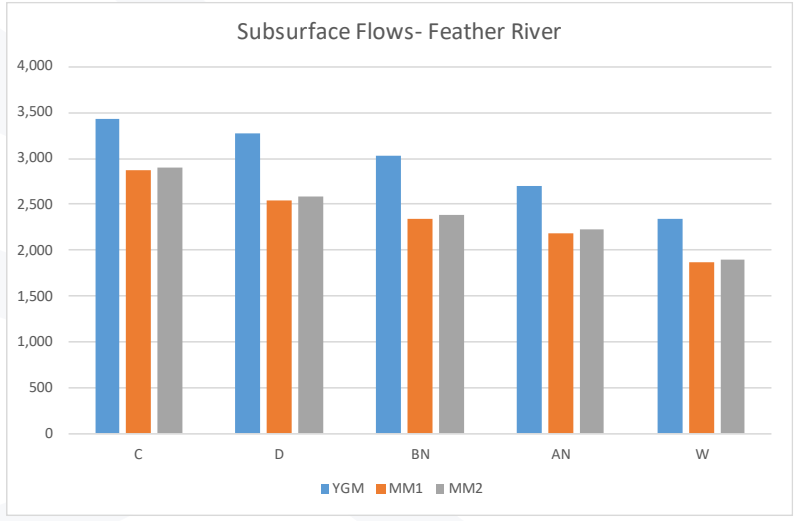
YGM

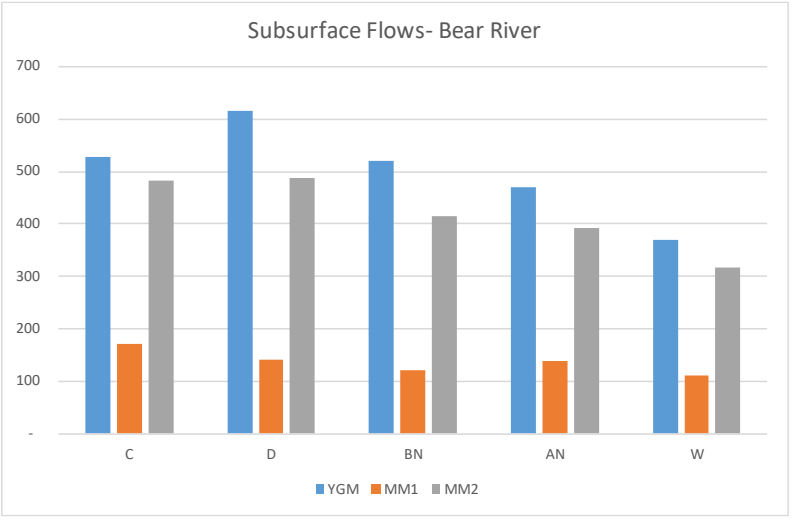












Note: All units in acre-feet

Conclusions

- IWFM MultiModel is a powerful and flexible tool for integrating regional and local models
- MultiModels allow modelers and water managers to cooperate and assess impacts beyond their basin
- MultiModels can be challenging and time-consuming to build

Next Steps

- Incorporate and test bypass and diversion linking features
- Experiment with delivery zones across model boundaries
- Work with DWR to devise methods/tools to simplify the carve-out process