Recent advancements in the SWAT+ gwflow module for coupled surface/subsurface hydrologic modeling

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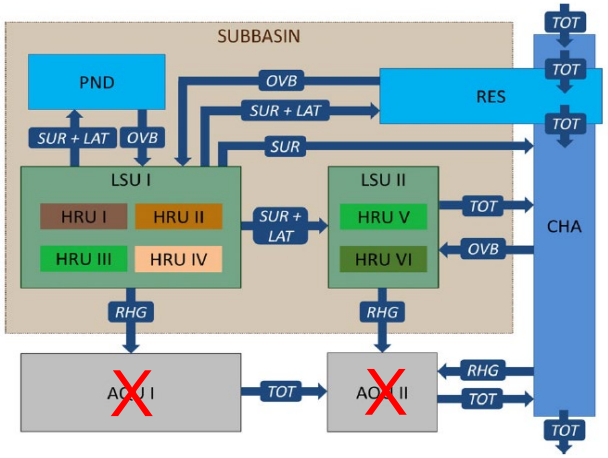
COLORADO STATE UNIVERSITY

Outline of Presentation

1. Overview: watershed modeling with SWAT+ and the new groundwater module (*gwflow*)
2. Recent developments
    a) Groundwater pumping for irrigation
    b) Using an unstructured grid
    c) Salt transport (surface/subsurface)
    d) Selenium transport (surface/subsurface)

Groundwater Module for SWAT+

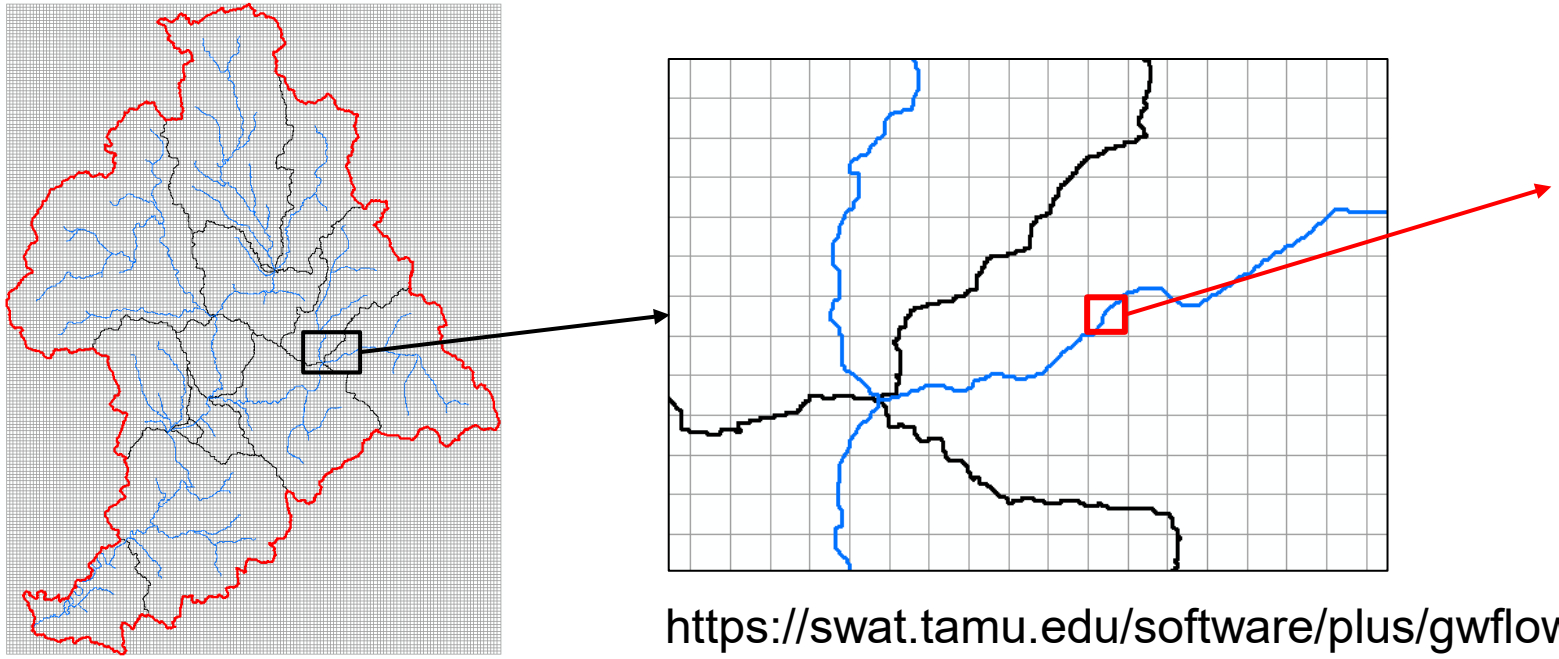


gwflow : new module that replaces original groundwater routine

- Physically based spatially distributed (PBSD) approach
- Spatio-temporal groundwater storage, head, fluxes

$$\frac{\Delta V}{\Delta t} = \sum Q_{in} - \sum Q_{out}$$

Recharge	Groundwater ET
Lateral flow	Lateral flow
Stream seepage	Pumping
Lake seepage	Discharge to streams
Floodplain seepage	Discharge to lakes
Canal seepage	Discharge to tile drains
	Transfer to soil profile



https://swat.tamu.edu/software/plus/gwflow/

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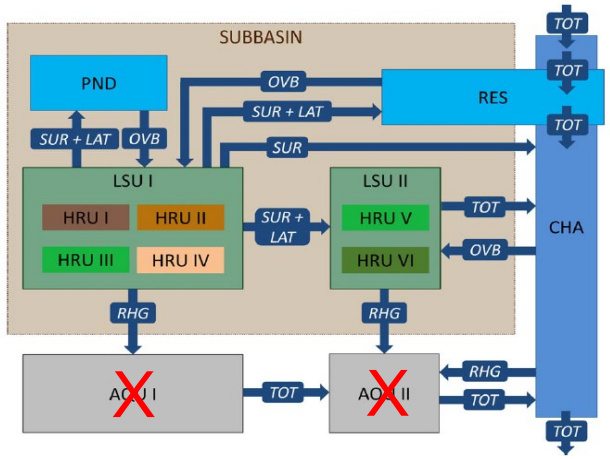
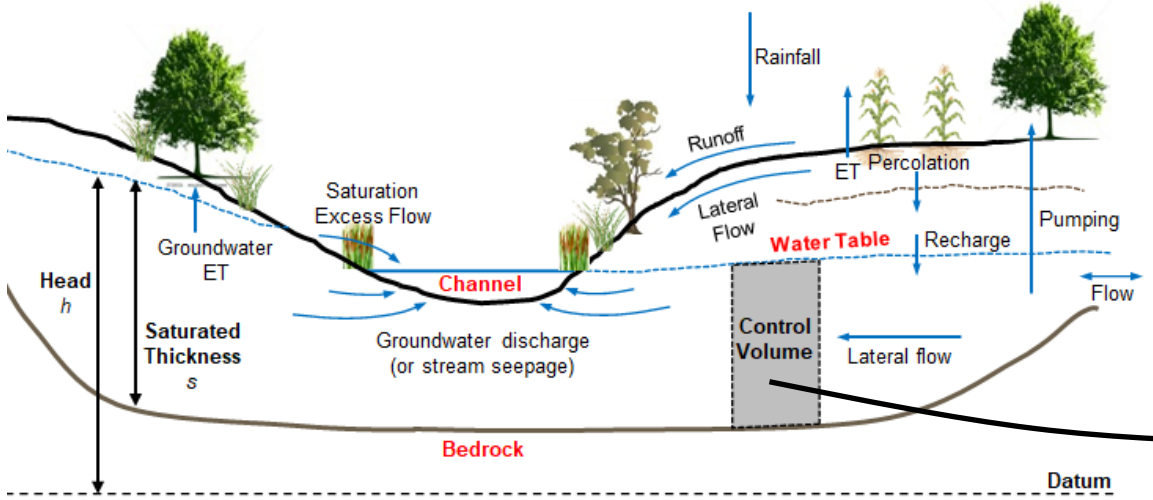
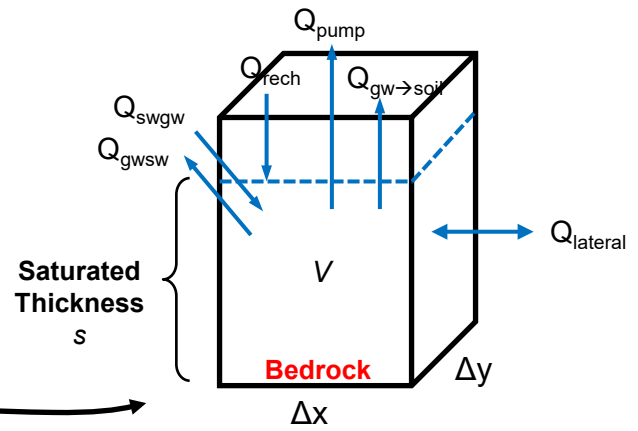


gwflow : new module that replaces original groundwater routine

- Physically based spatially distributed (PBSD) approach
- Spatio-temporal groundwater storage, head, fluxes
- **Datasets on aquifer thickness, aquifer permeability**





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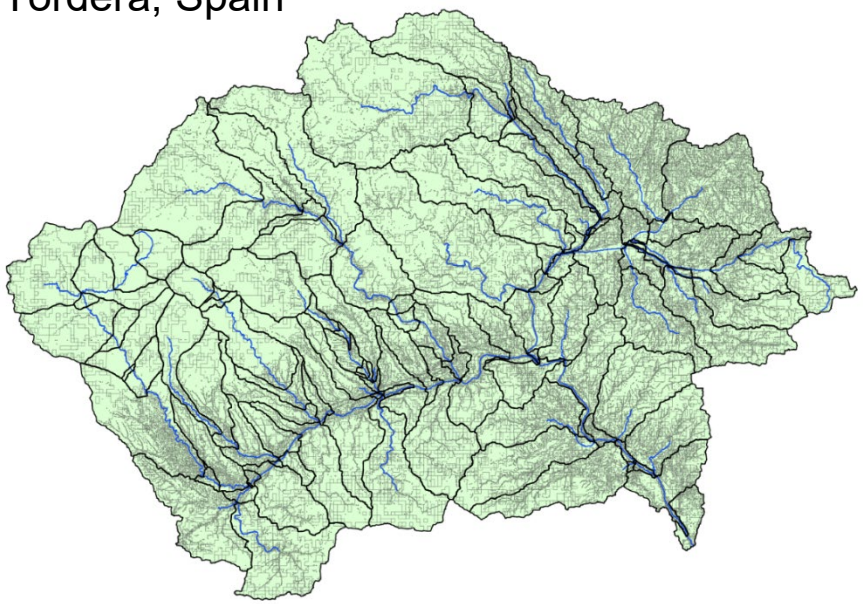
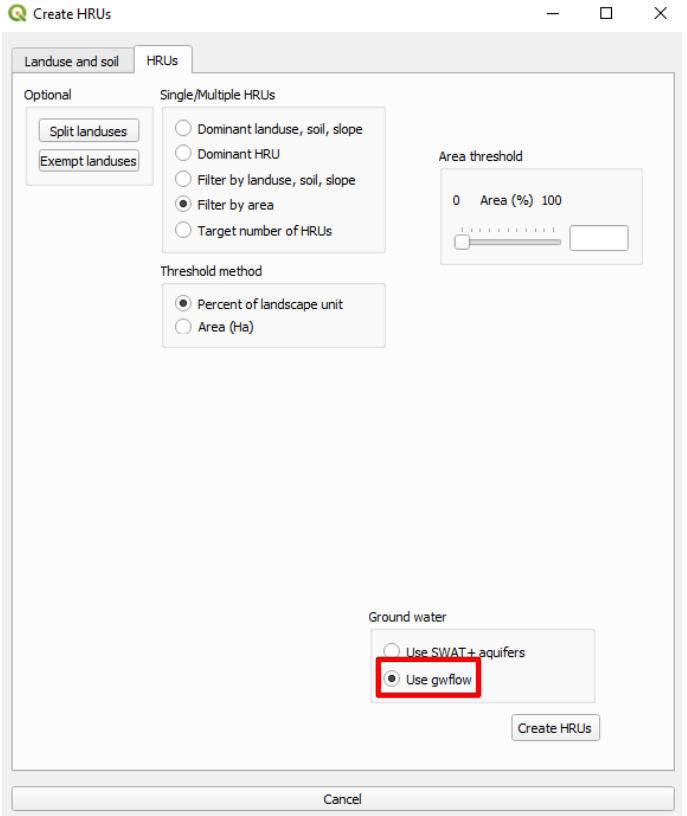
Creating *gwflow* inputs using QSWAT+

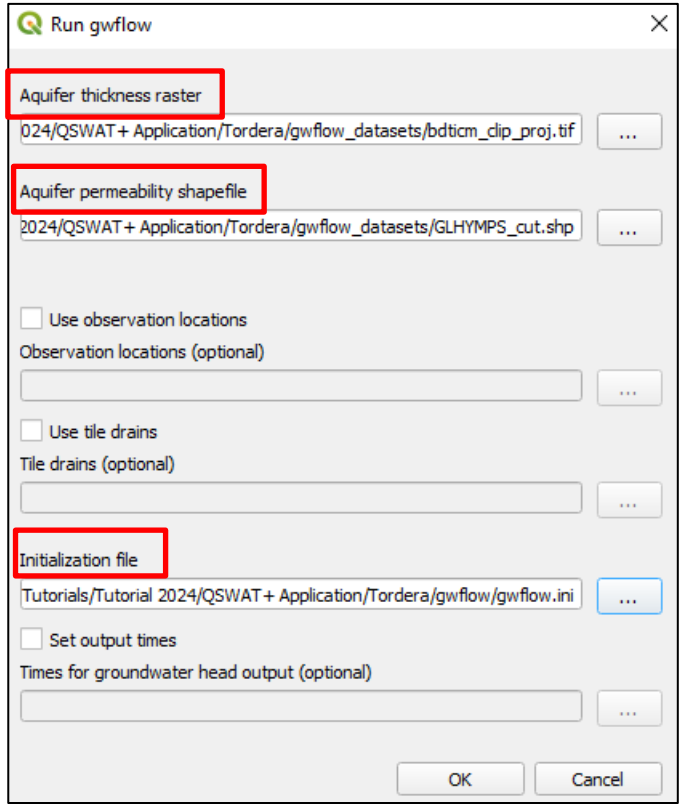
Previously: create connection between cells and HRUs, channels, reservoirs manually using QGIS, spreadsheets, and text files.

Now: use QSWAT+ and SWAT+Editor (thank you, Chris George and Jaclyn!!)

Tordera, Spain







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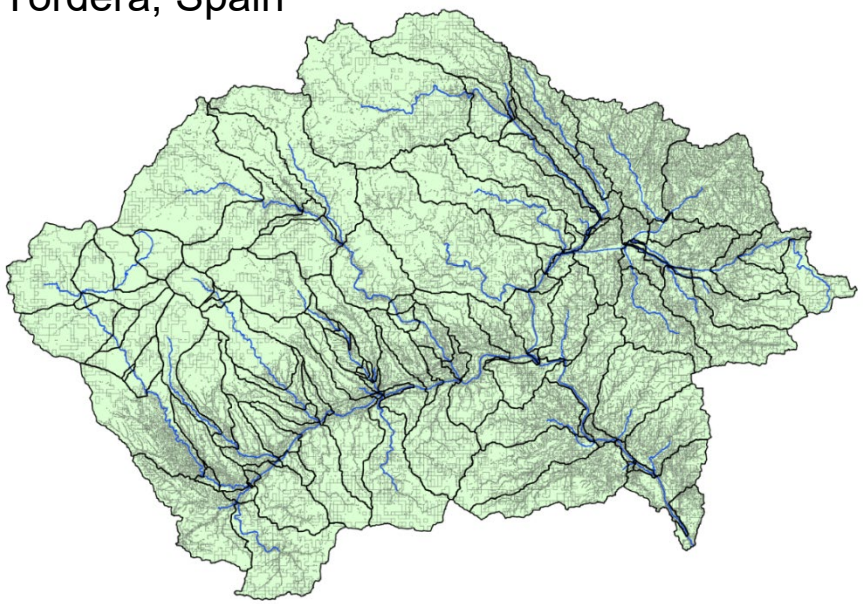

ion › Tordera › Scenarios › Default › TxtInOut

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fire.ops	6/27/2024 4:54 PM	OPS File
fort.1253	6/27/2024 4:55 PM	1253 File
grassedww.str	6/27/2024 4:54 PM	STR File
graze.ops	6/27/2024 4:54 PM	OPS File
gwflow.cellhru	6/27/2024 4:54 PM	CELLHRU File
gwflow.chancells	6/27/2024 4:54 PM	CHANCELLS File
gwflow.con	6/27/2024 4:54 PM	CON File
gwflow.hrucell	6/27/2024 4:54 PM	HRUCELL File
gwflow.input	6/27/2024 4:54 PM	INPUT File

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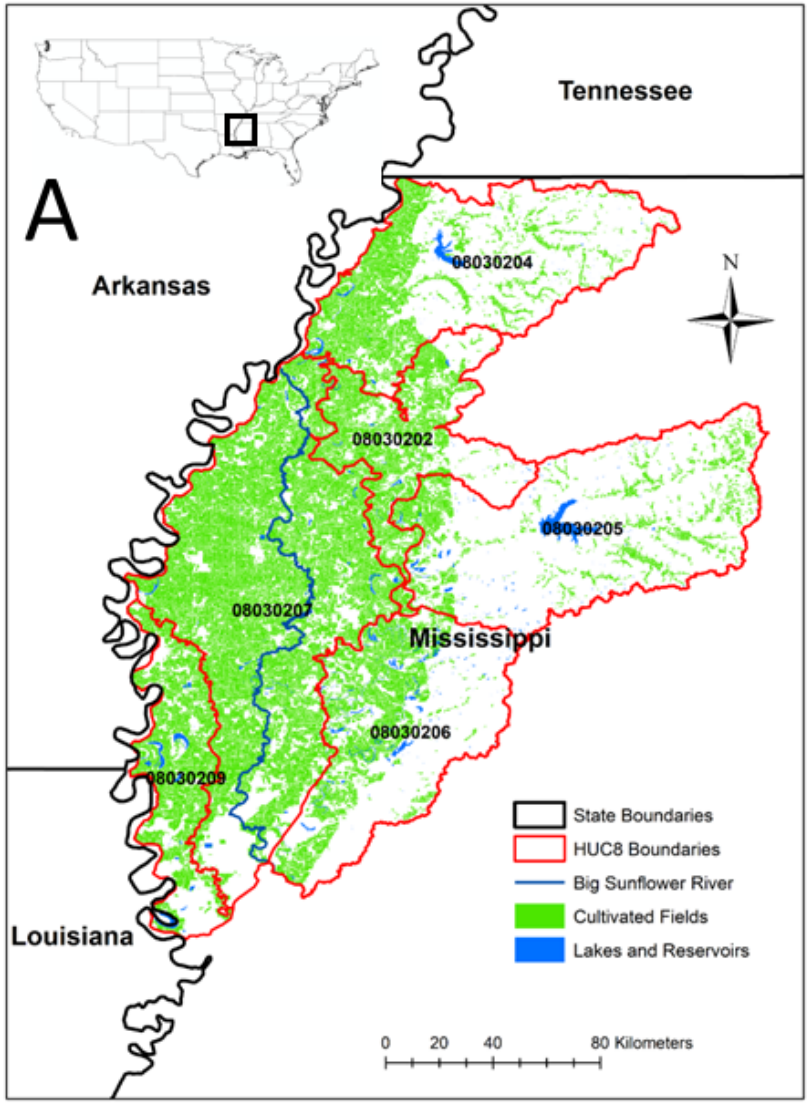
Groundwater Pumping for Irrigation

Mississippi Alluvial Plain (NW Mississippi)



soybean, corn, cotton, and rice

Daily loop during simulation period:
(water allocation in SWAT+)

Daily Crop Growth
(weather, crop type, mgt)

↓ *If water stress*

Daily Irrigation Demand

↓

Check Irrigation Source
(source: channel, reservoir, **aquifer**)
(check against available water)

↓

Apply irrigation water
(include irrigation efficiency)
(remove water from source → add to field surface)

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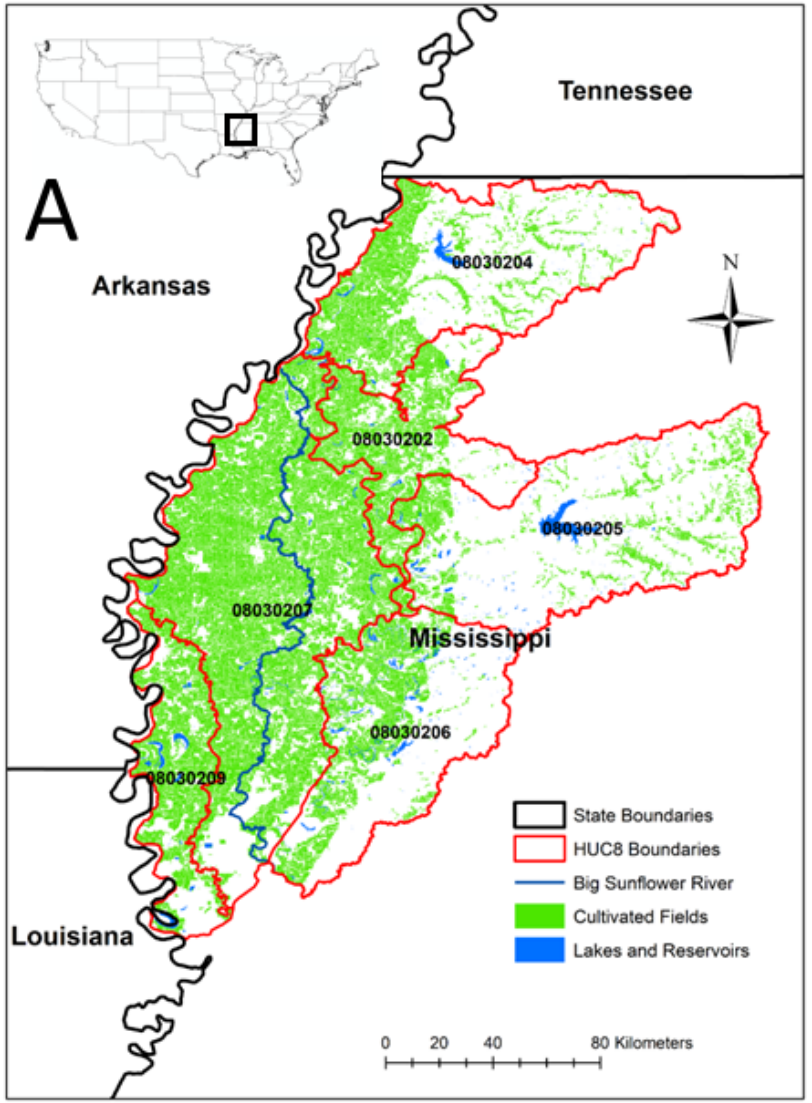

soybean, corn, cotton, and rice

wallo_dat (modified for Arkansas River Basin)

1															
NAME		RULE_TYP			SRC_OBS	DMD_OBS	CHA_DB								
11020009		high_right_first_serve			2	3920	n								
SRC_NUM	OB_TYP	OB_NUM	JAN_MIN	FEB_MIN	MAR_MIN	APR_MIN	MAY_MIN	JUN_MIN	JUL_MIN	AUG_MIN	SEP_MIN	OCT_MIN	NOV_MIN	DEC_MIN	DESCRIPTION
1	unl	0	0	0	0	0	0	0	0	0	0	0	0	0	unlimited source
2	aqu	0	0	0	0	0	0	0	0	0	0	0	0	0	gwflow source
NUMB	OB_TYP	OB_NUM	WITHDR		AMOUNT	W_RT	TR_TYP	TREAT	RCV_OB	RCV_NUM	RCV_DTL	SRCS	SCRC1	FRAC1	COMP1
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2	hru	1183	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
3	hru	1184	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
4	hru	1185	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
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6	hru	1187	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
7	hru	1188	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
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9	hru	1190	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	2	1	n
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11	hru	1192	irr_strs8_fld		25.00	jr	null	null	null	0	null	1	1	1	n
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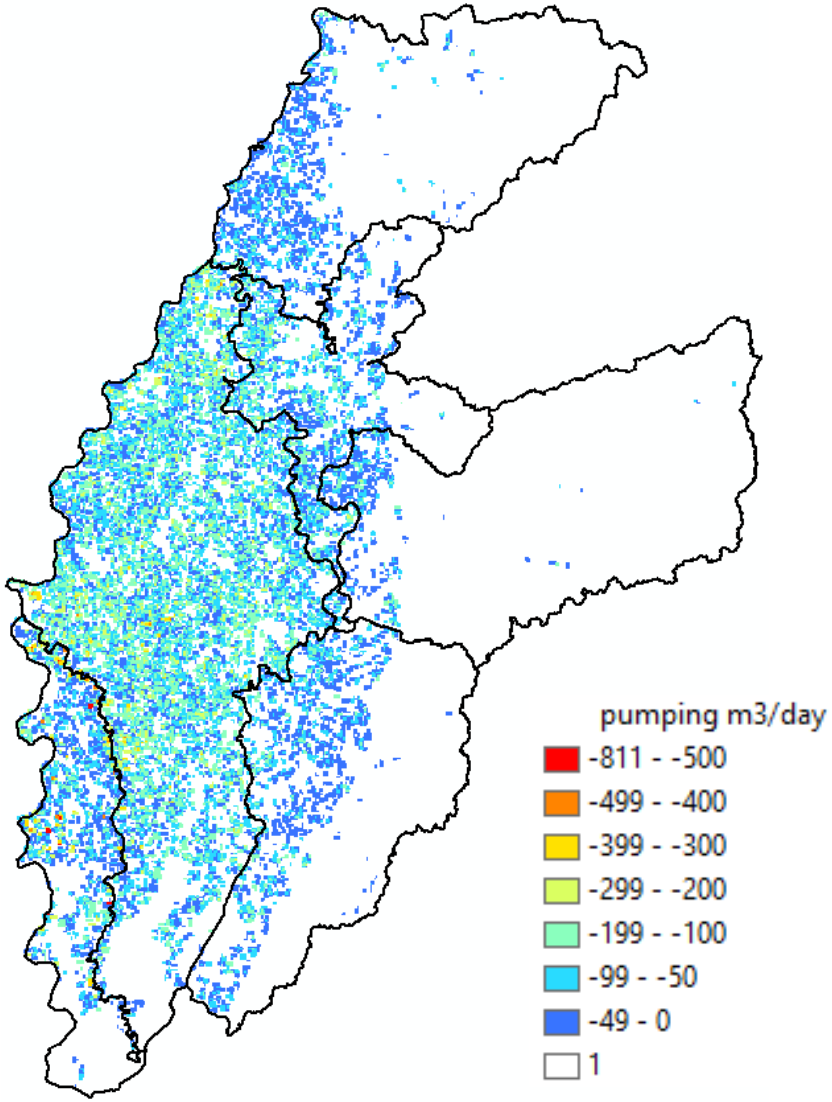
Groundwater Pumping for Irrigation

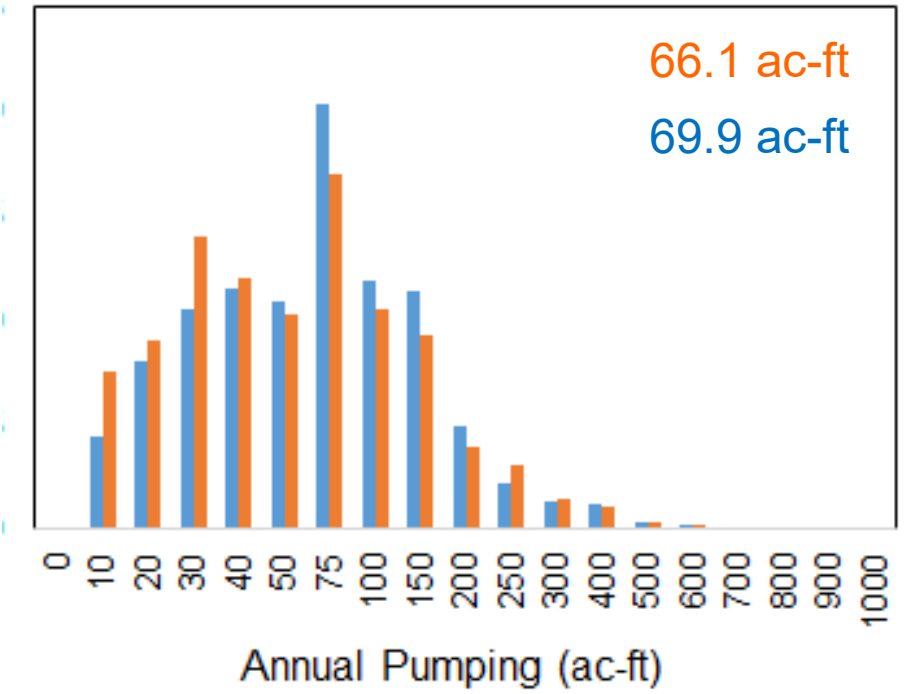


2017

Mississippi Department of Environmental Quality

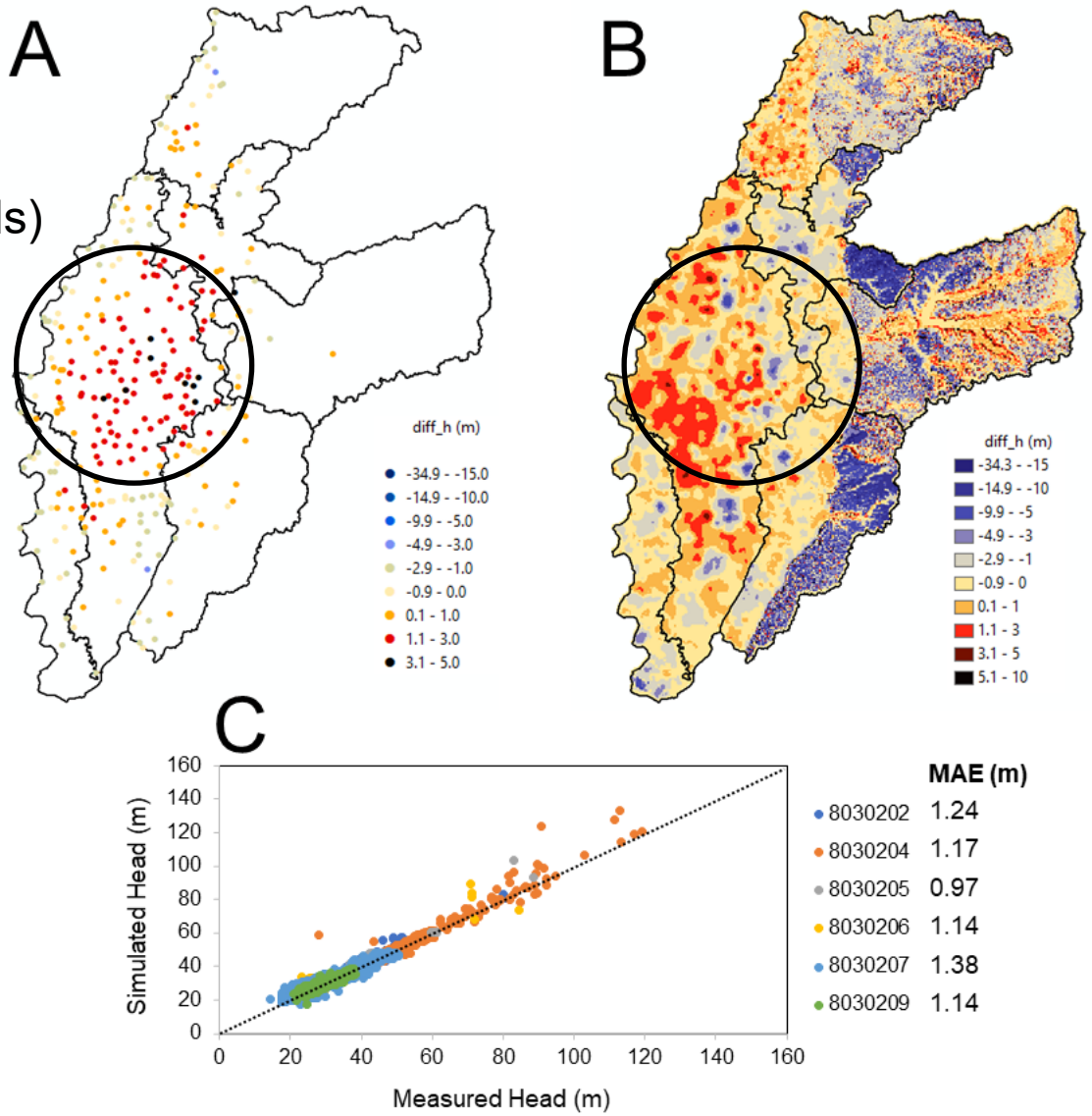
66.1 ac-ft

69.9 ac-ft



Groundwater Pumping for Irrigation

USGS
(2000-2015 levels)

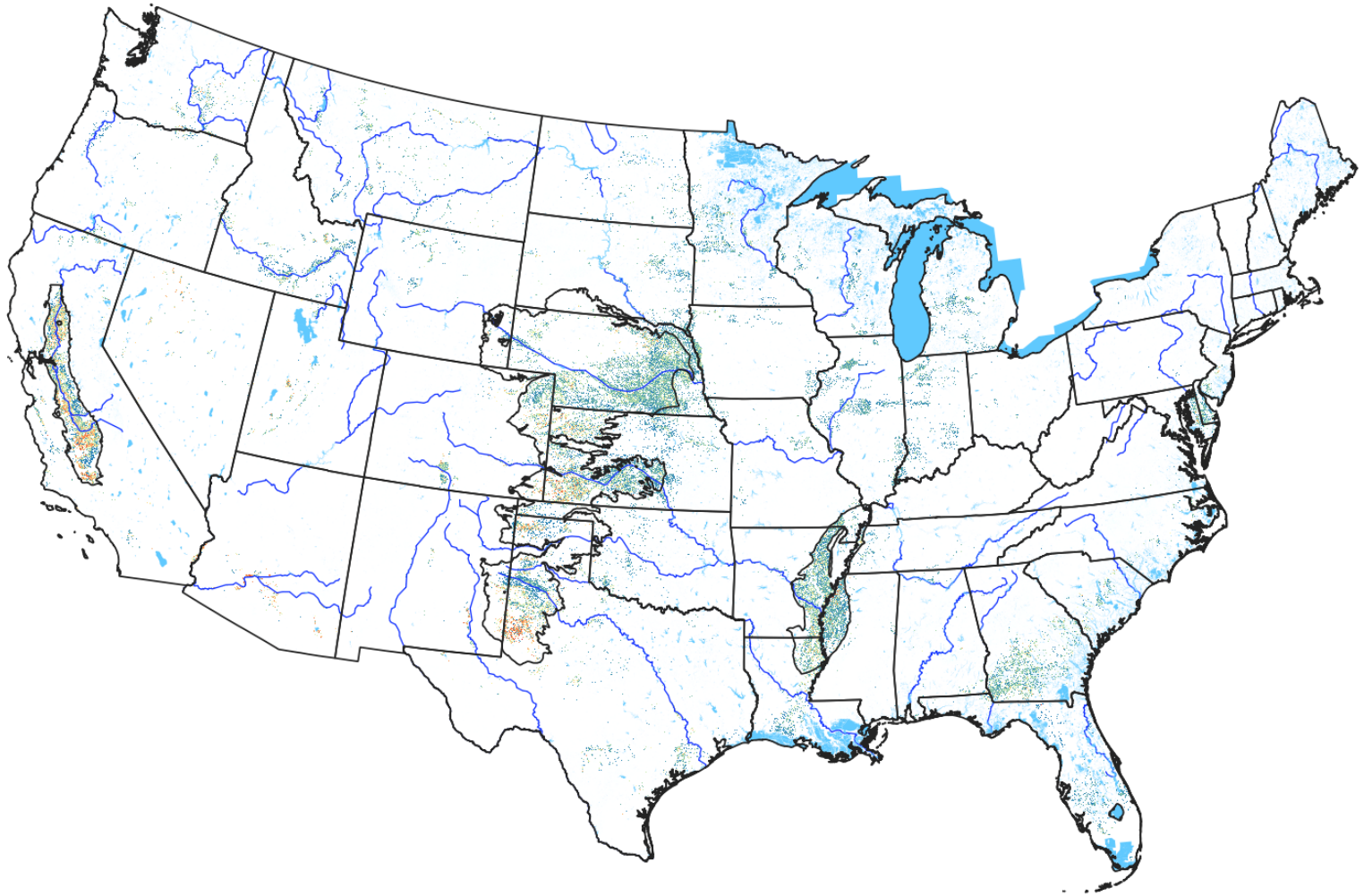


SWAT+ simulated
(2000-2015 levels)

<u>Other points of model corroboration</u>:

- Streamflow (USGS gages)
- OpenET
- Average annual fluxes (ET, runoff, baseflow)

Groundwater Pumping for Irrigation

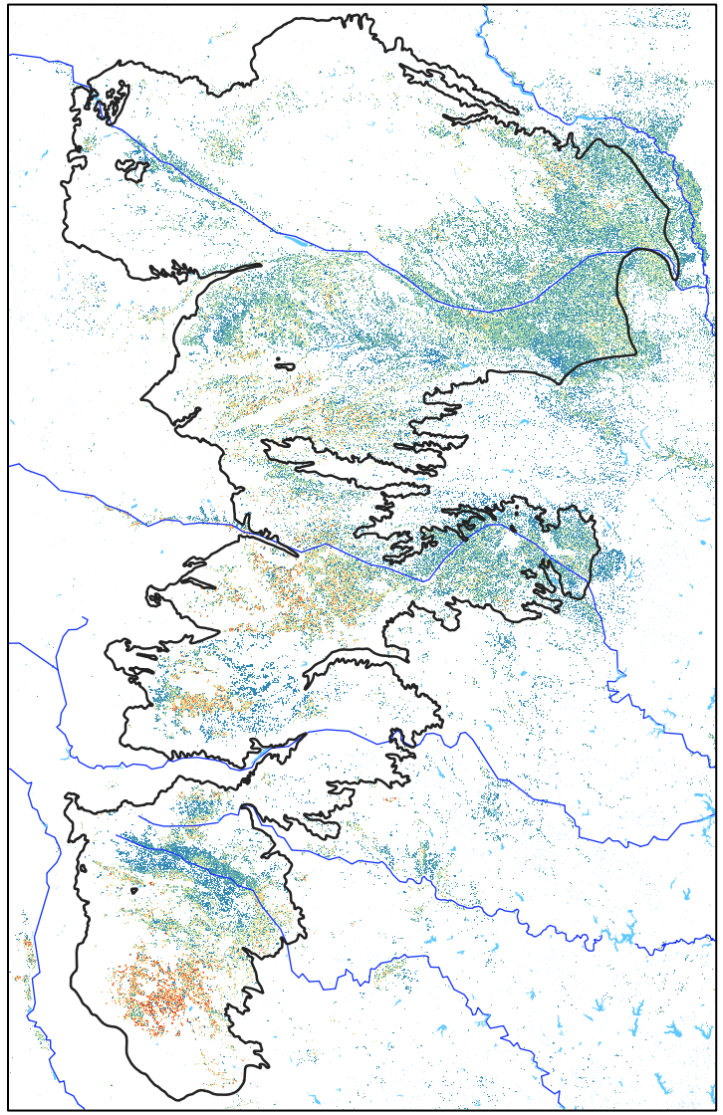


Irrigation Pumping (m^3/day)

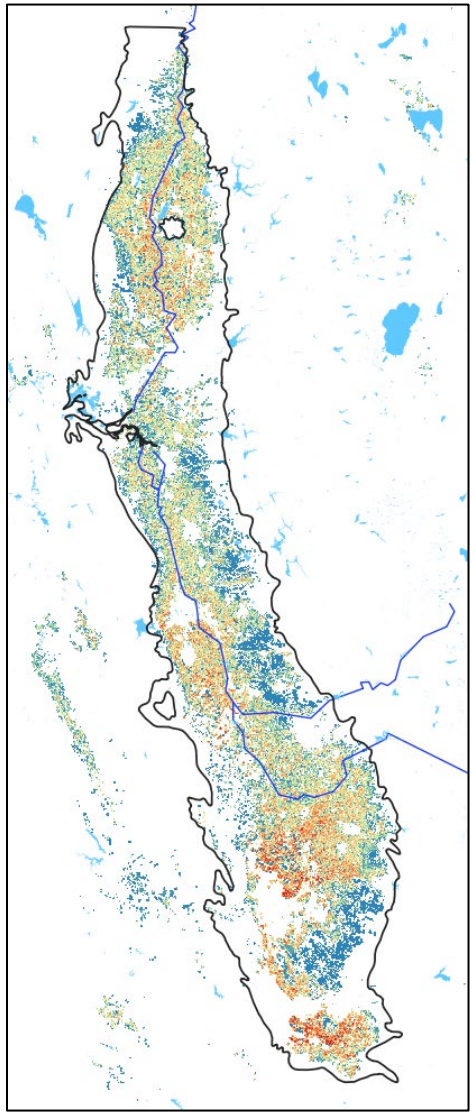
- -703
- -400
- -200
- -150
- -100
- -50
- -0

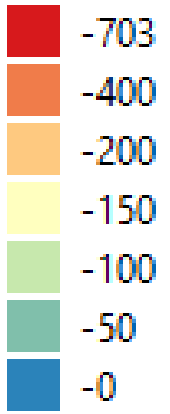
Groundwater Pumping for Irrigation

High Plains Aquifer

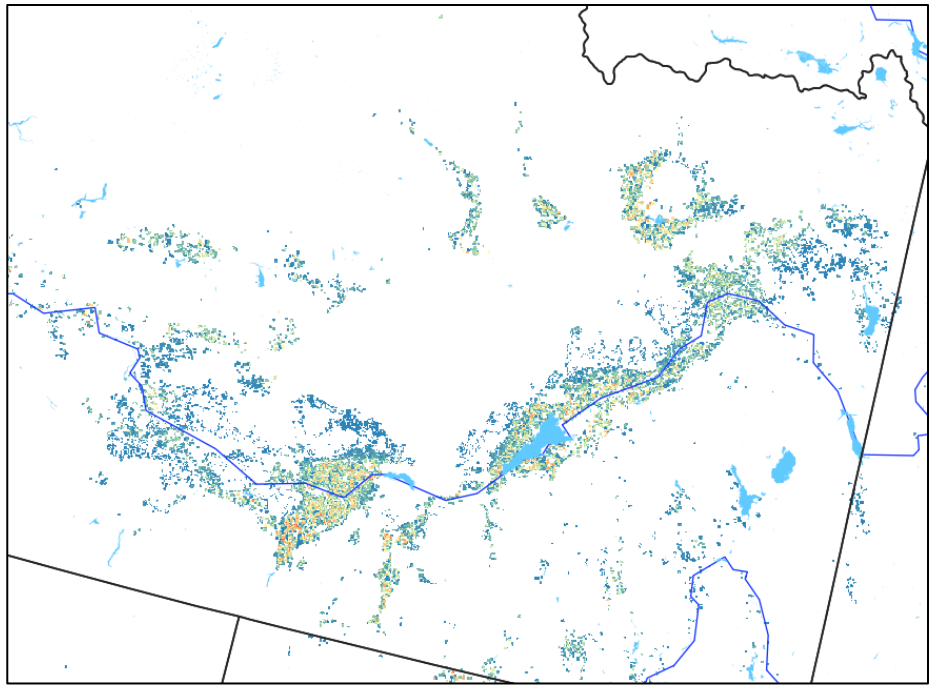


Central Valley





Snake River Valley (Idaho)



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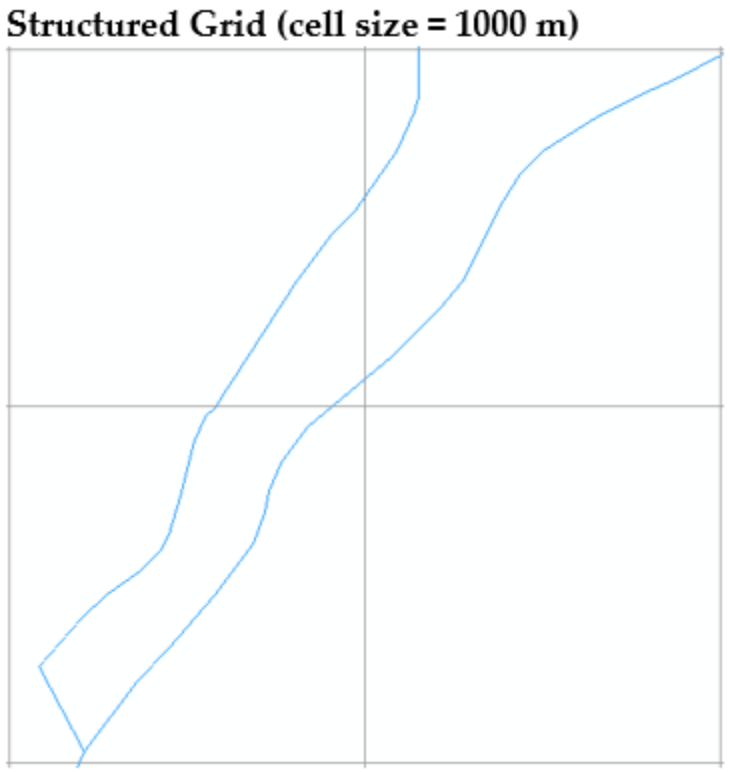
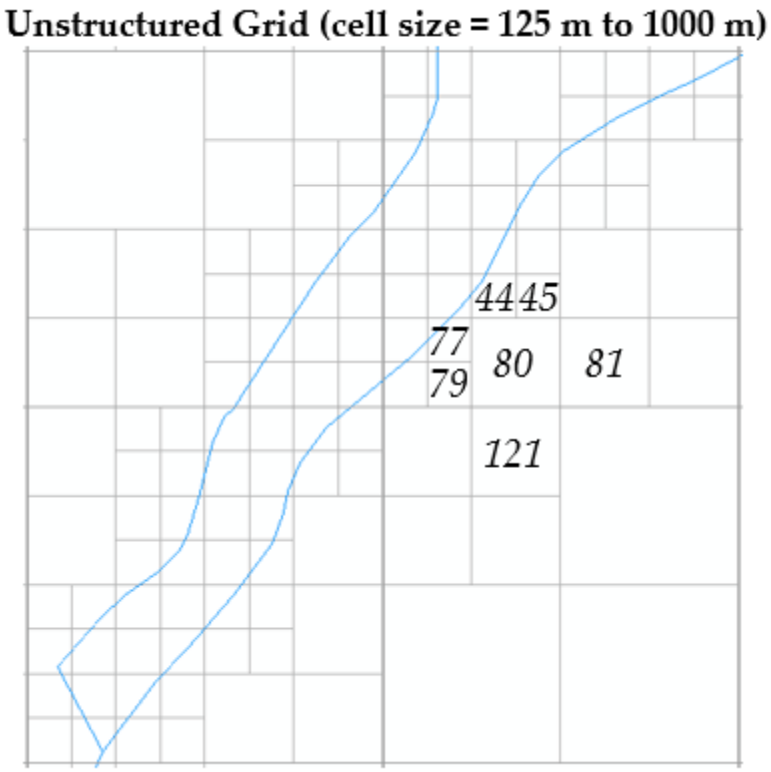
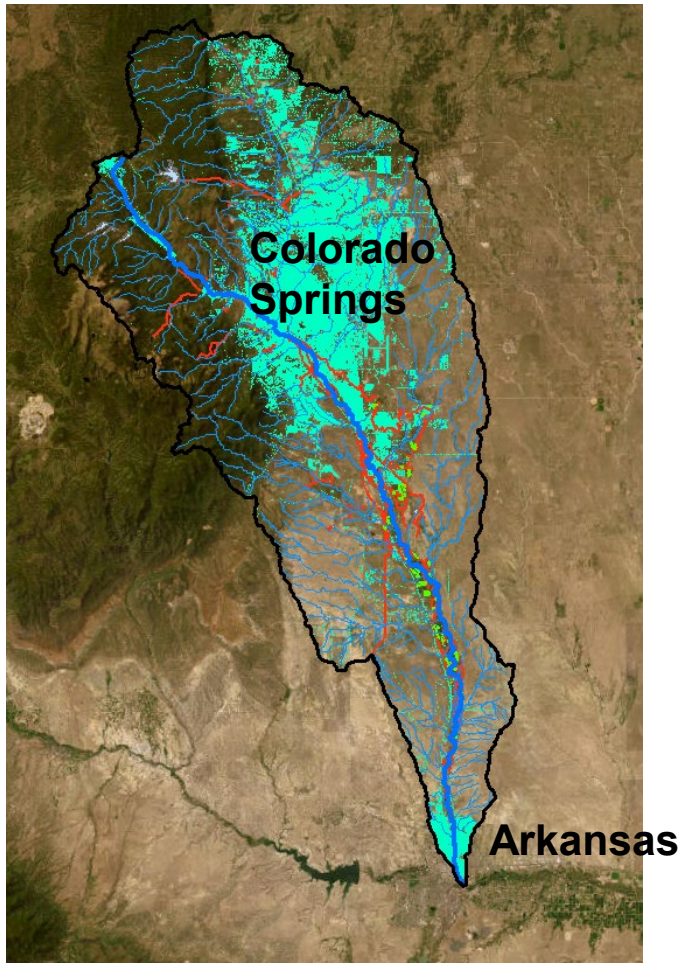
Using an Unstructured Grid

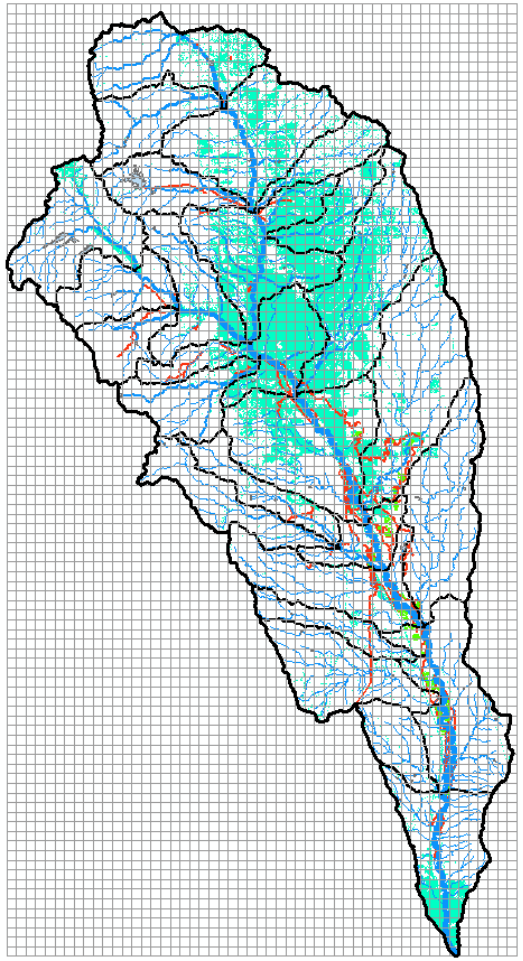


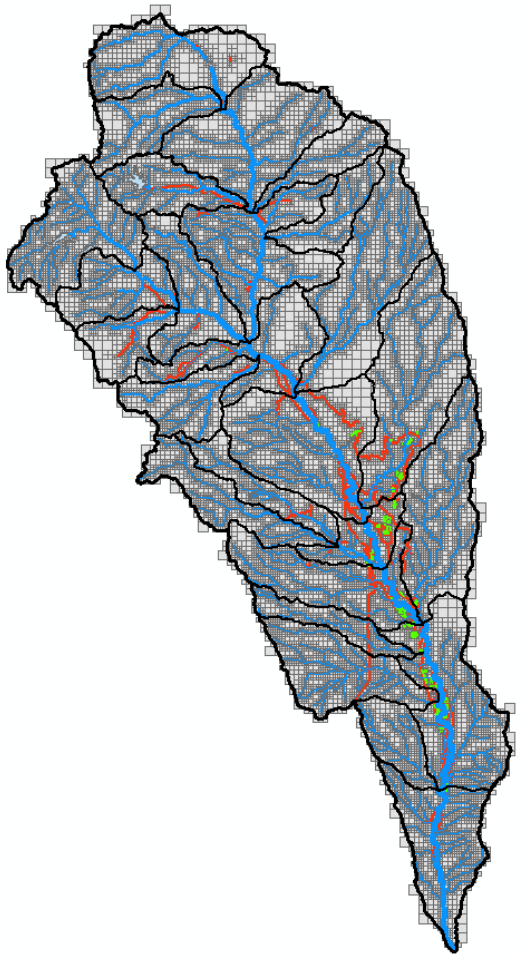


Using an Unstructured Grid

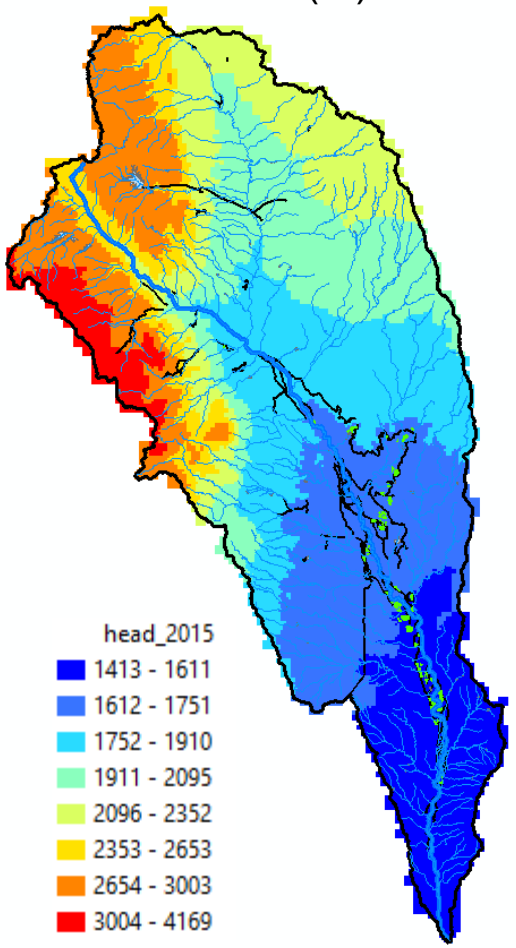
Fountain Creek Watershed (Colorado, USA)







Simulated Head (m)



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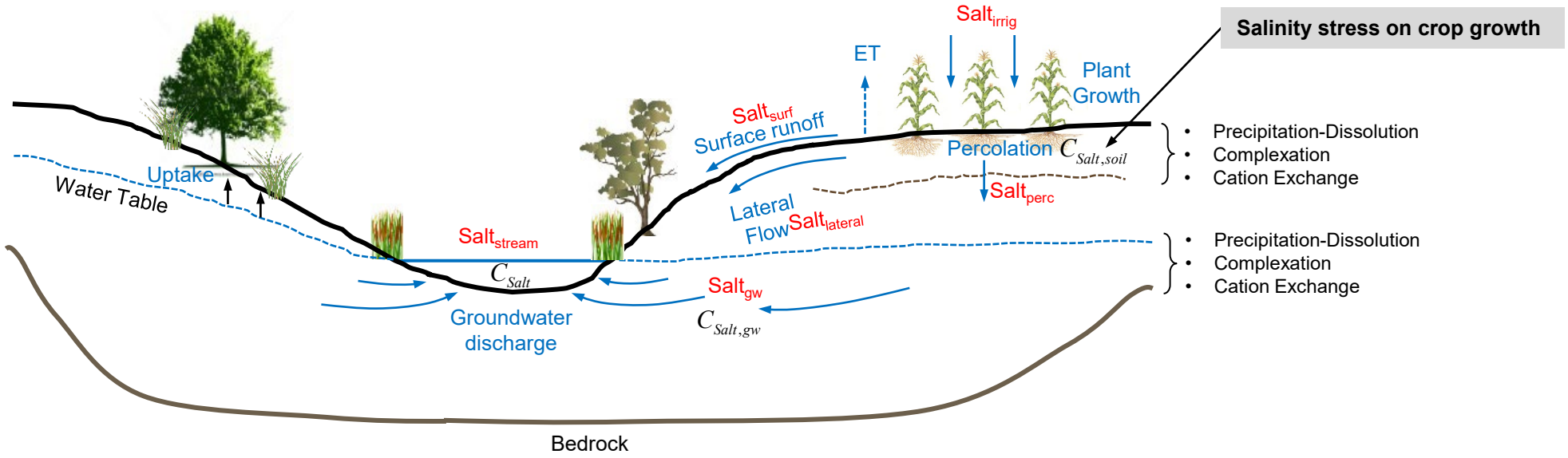
Salt Transport (surface-subsurface)

Salinity module for SWAT+

(Salt = SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3)



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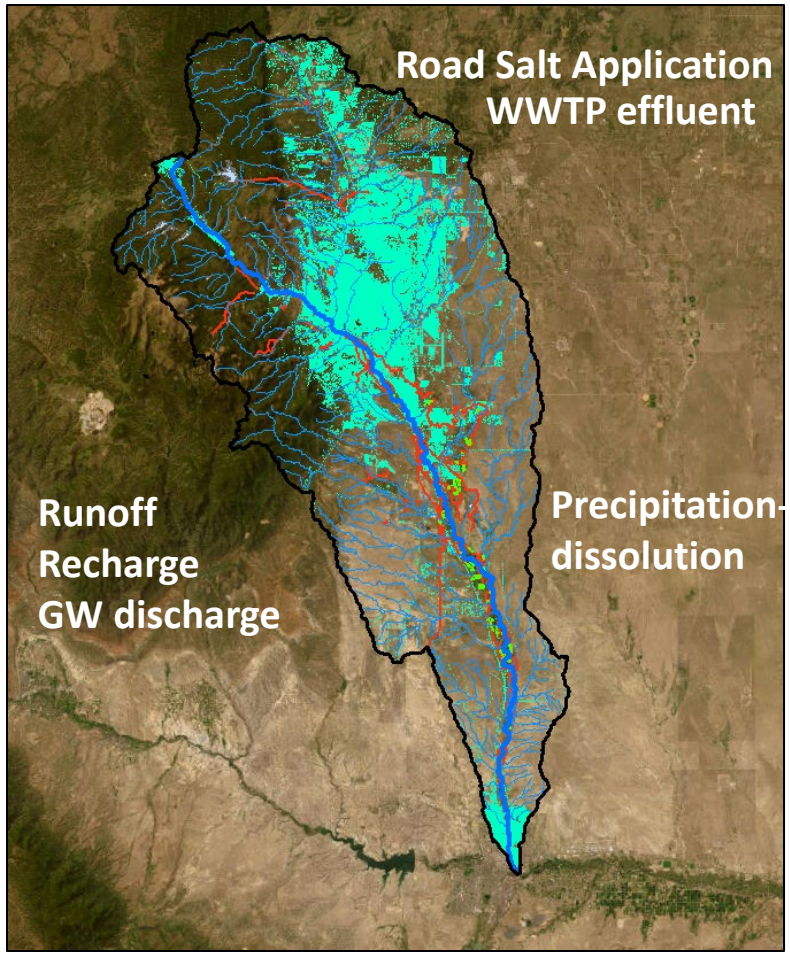

SWAT+ model:

Simulate streamflow

- ET from crops and vegetation
- Runoff from rainfall
- Runoff from irrigation
- Groundwater discharge to streams

Simulate salt mass transport in water

(Salt = SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3)

Test the model against measured streamflow and salt loadings (kg/day) in Fountain Creek; groundwater salt ion concentrations.

Use the model to determine where salt is being transported, and build-up of salt in the soil profile.

(Arkansas River Basin; South Platte River Basin; Central Valley of California)

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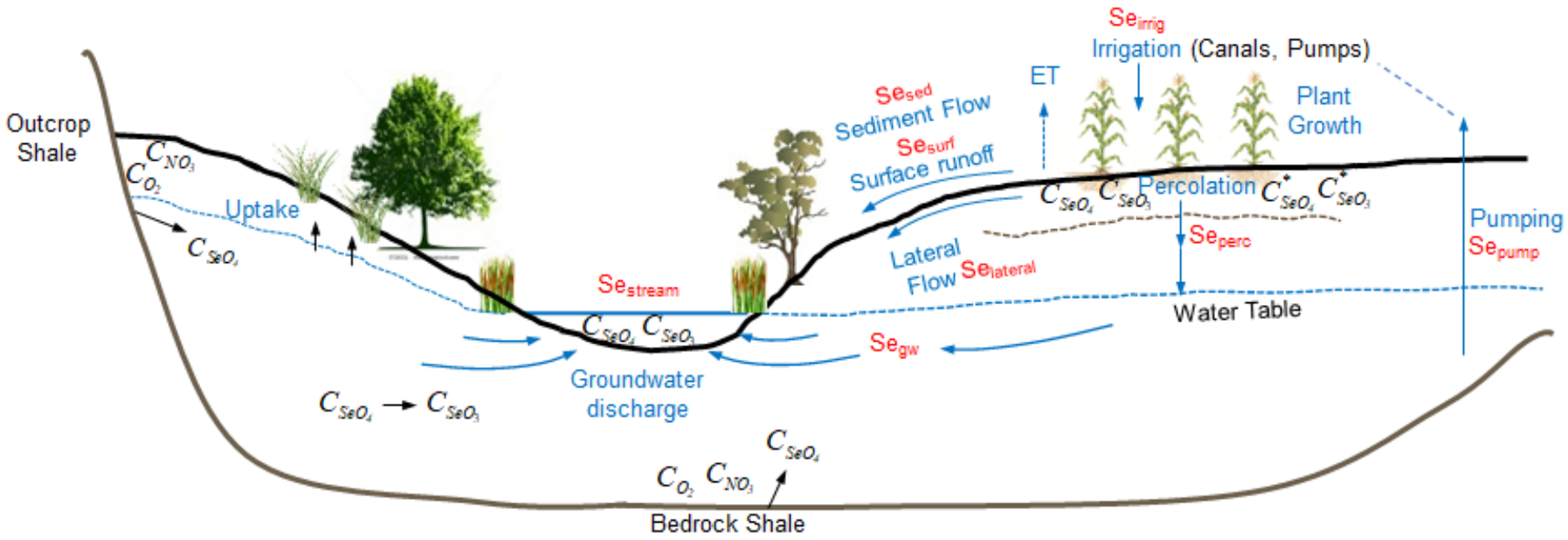
Selenium Transport (surface-subsurface)

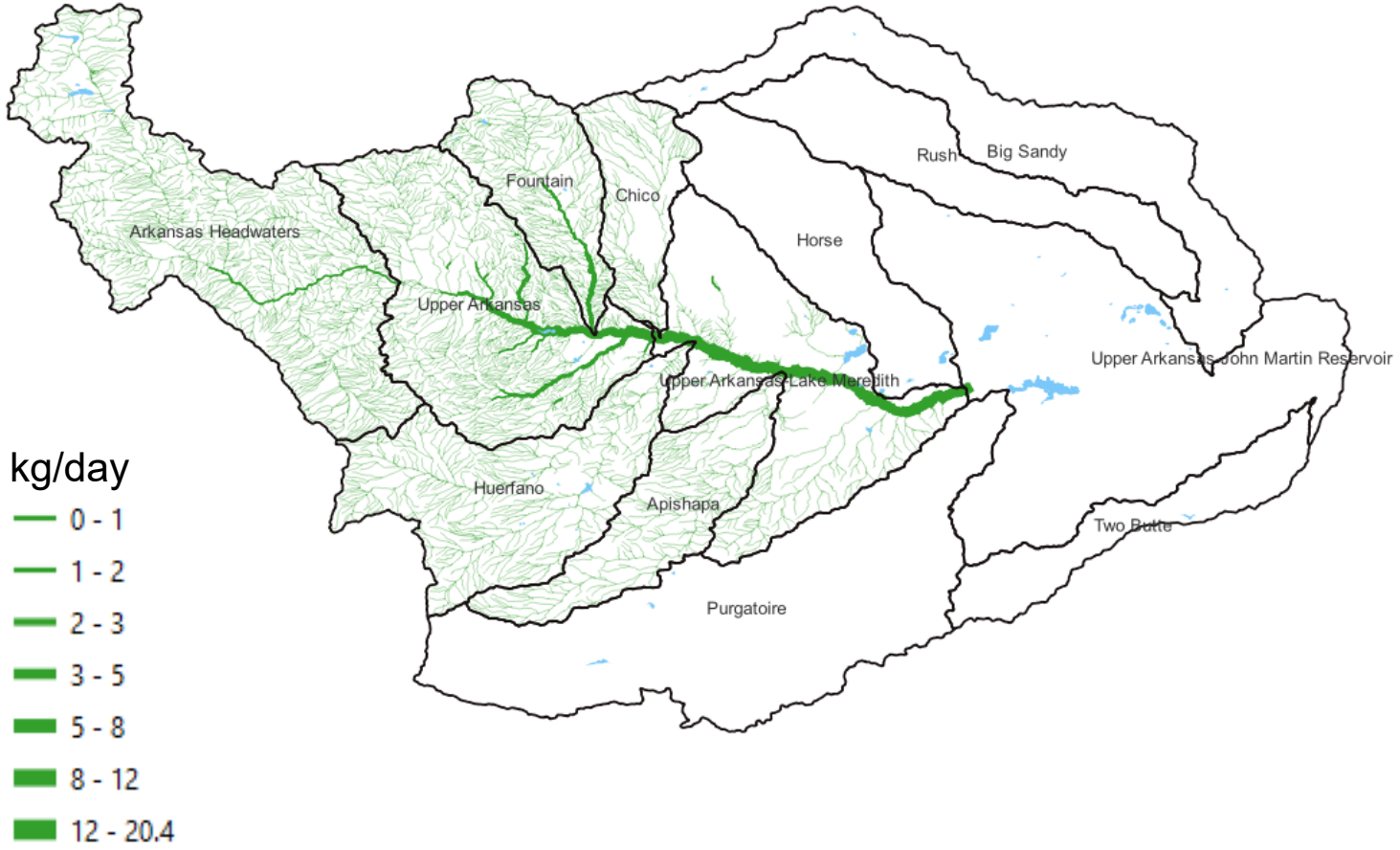
Selenium module for SWAT+



Selenium Transport (surface-subsurface)

Selenium module for SWAT+

Upper Arkansas River Basin (Colorado, USA)



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Thank you!

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