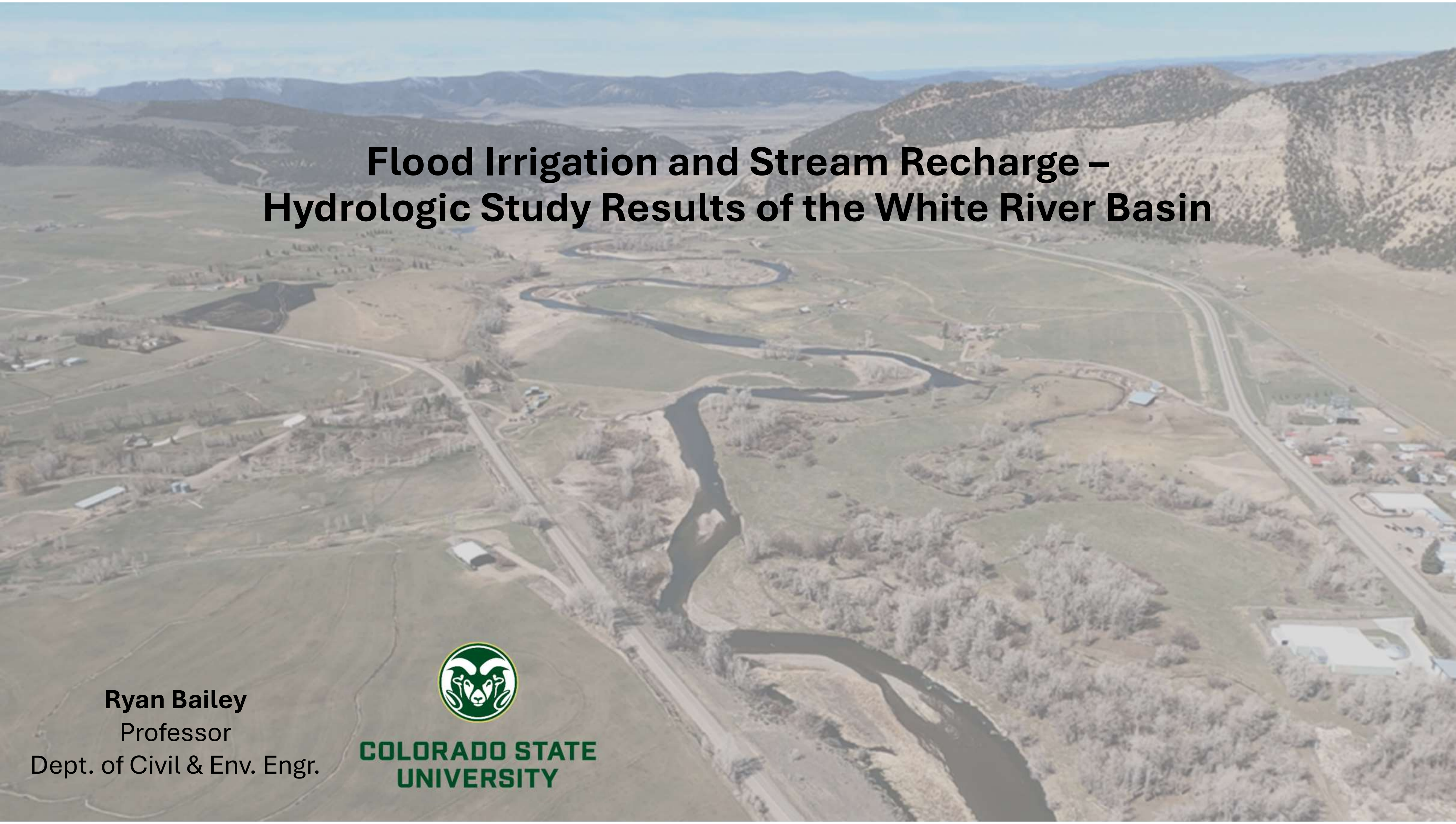

Flood Irrigation and Stream Recharge – Hydrologic Study Results of the White River Basin

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Acknowledgements

Liz Chandler
Watershed Coordinator
White River Integrated Water Initiative

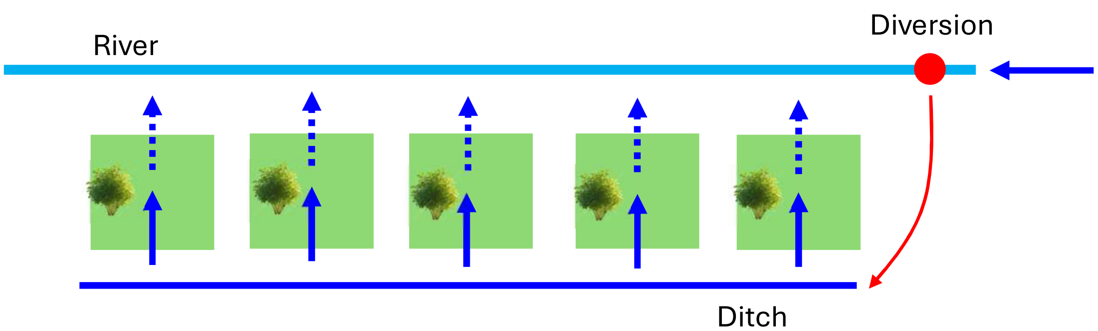
COLORADO
Colorado Water Conservation Board
Department of Natural Resources

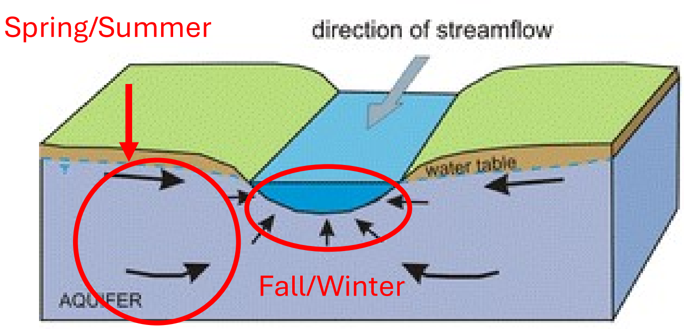
Outline of Presentation

1. Problem Statement
2. Insights from field data
3. Results from the hydrologic model
4. Scenarios

Problem Statement

Flood irrigation:

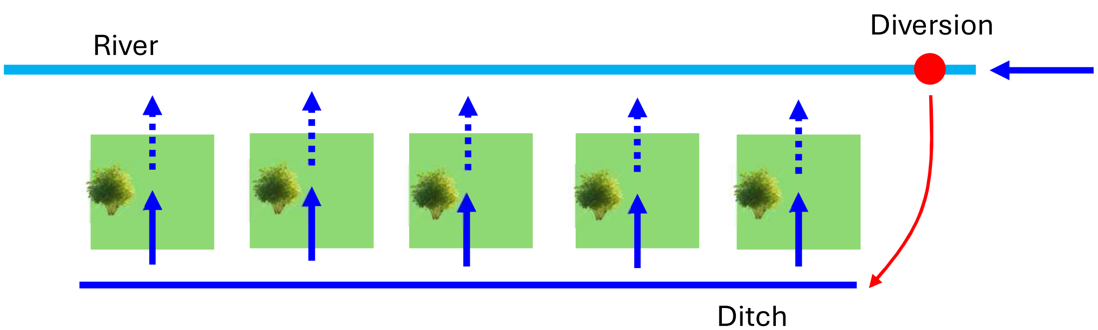


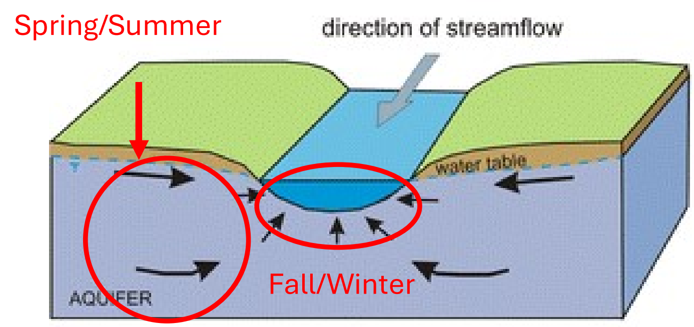


How much groundwater discharges to the White River? When and where does this happen? How do these discharge amounts **compare** to other components? (diversion, crop ET, ditch seepage, etc.)

Problem Statement

Flood irrigation:



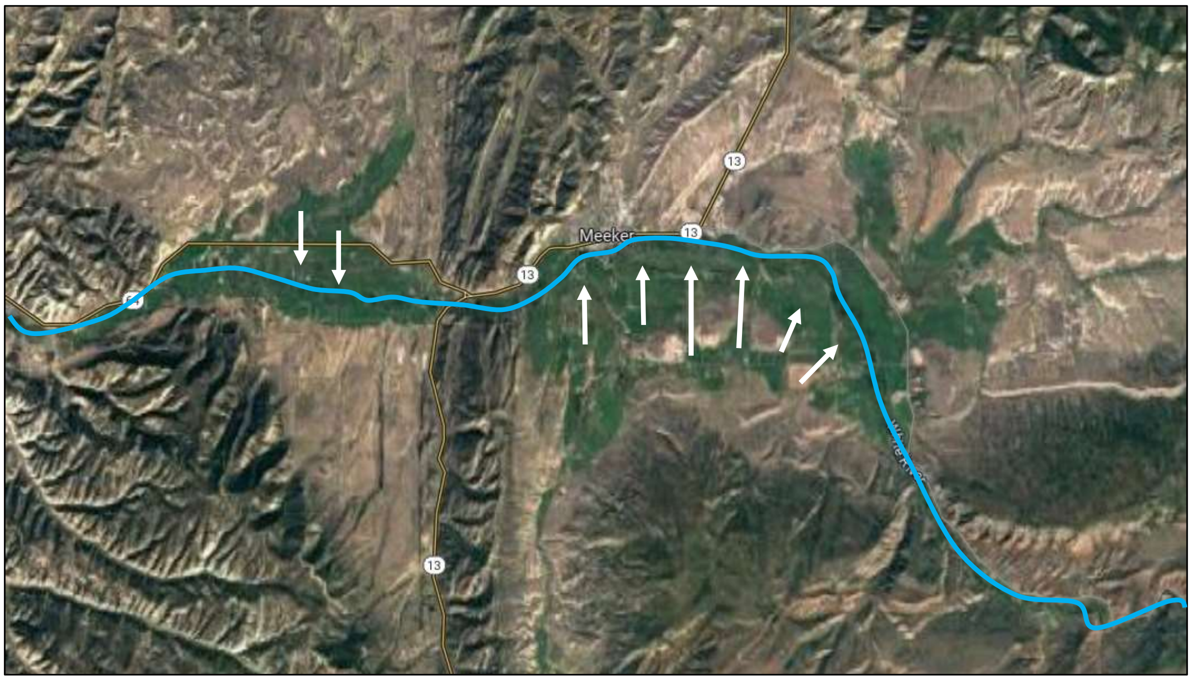


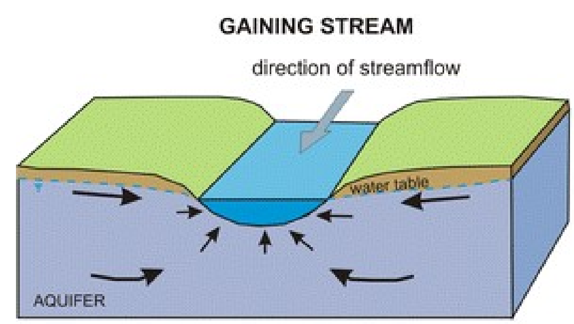
If **flood irrigation** is switched to **sprinkler irrigation**, what will happen to the magnitude and timing of groundwater return flows to the river? What will happen to river flow in the fall/winter months?

Project Objectives

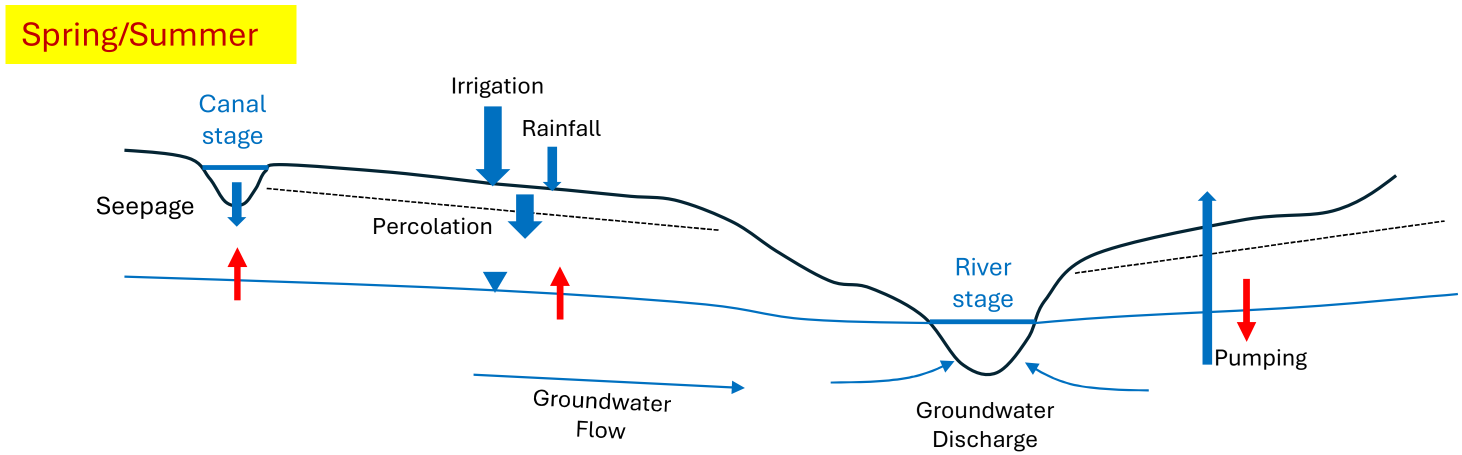
What we want to know

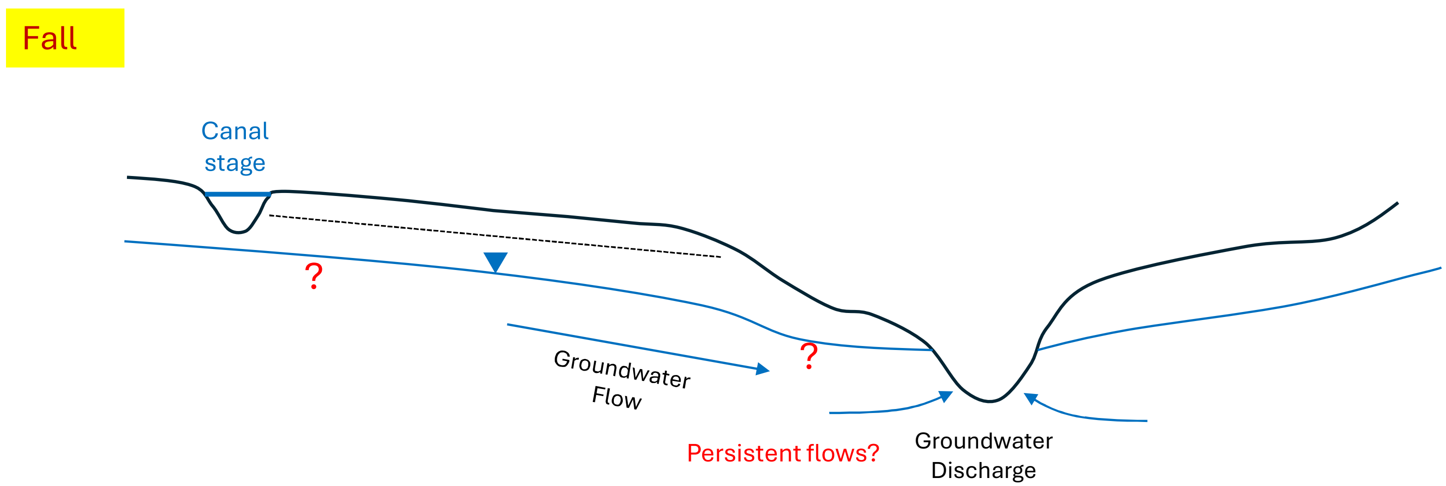
- How much groundwater enters the White River? Where and when does this occur?
- How do ditch diversions and groundwater return flows affect streamflow in the White River?
- What happens to groundwater return flows and the timing of streamflow, if **flood irrigation** is converted to **sprinkler irrigation**? What happens during **calls** on the river?

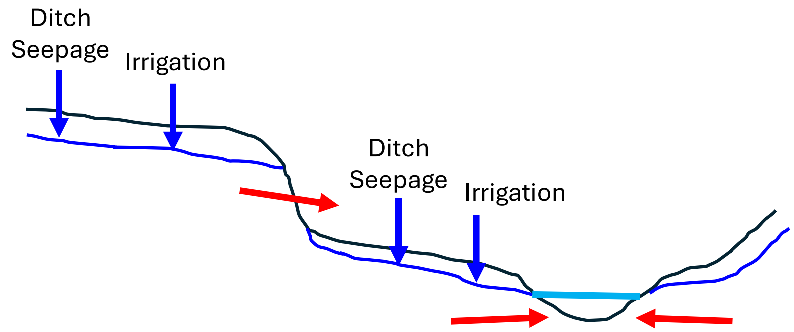


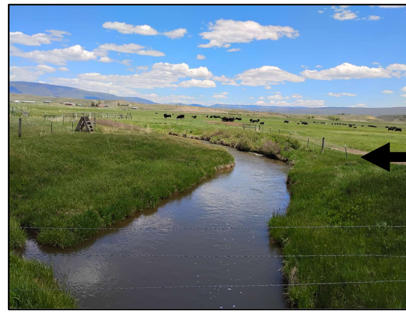


Project Objectives



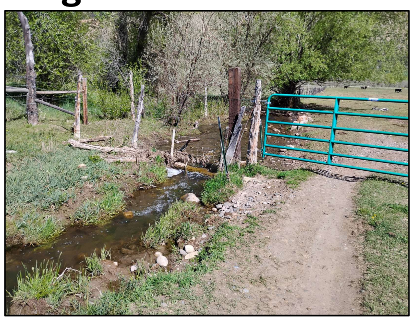






Coal Creek

Flag Creek



Groundwater Seepage

Outline of Presentation

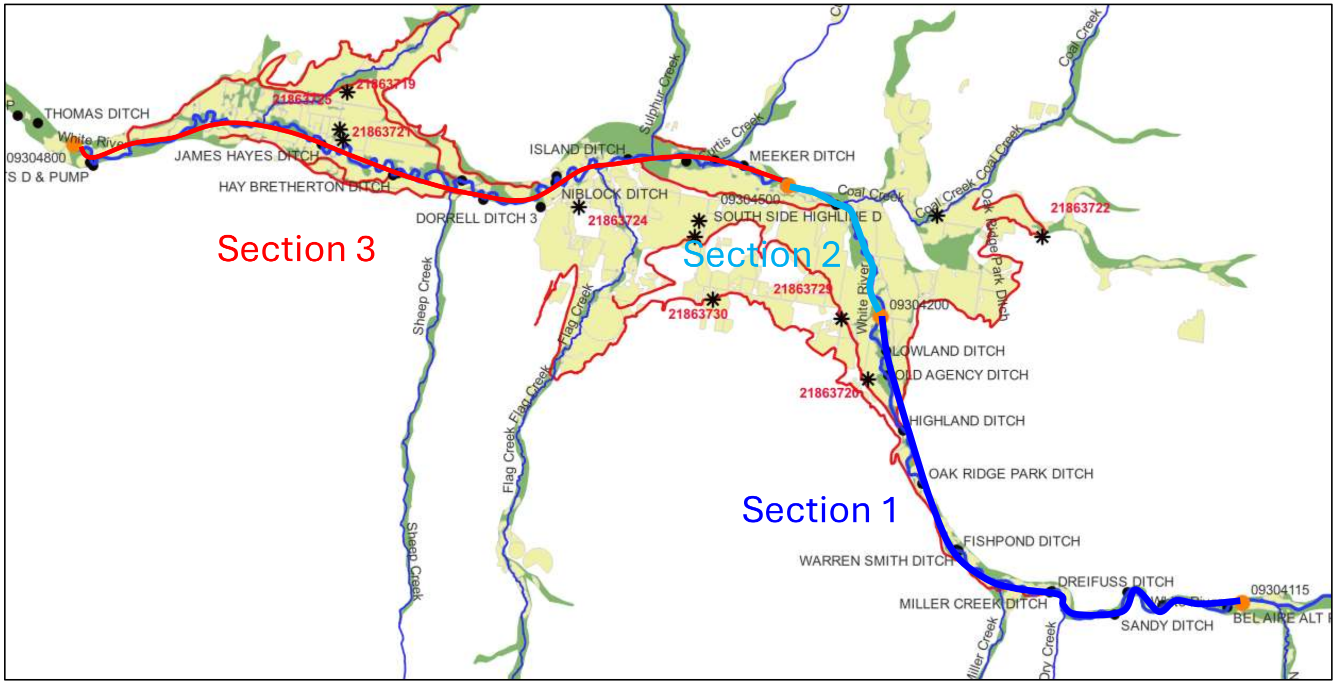
1. Problem Statement
2. Insights from field data
3. Results from the hydrologic model
4. Scenarios

Outline of Presentation

1. Problem Statement
2. Insights from field data: 1) river water balance; 2) groundwater monitoring
3. Results from the hydrologic model
4. Scenarios

Insights from Field Data

Using River Flow Data to Estimate Groundwater Discharge



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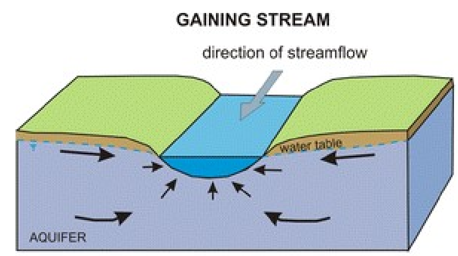
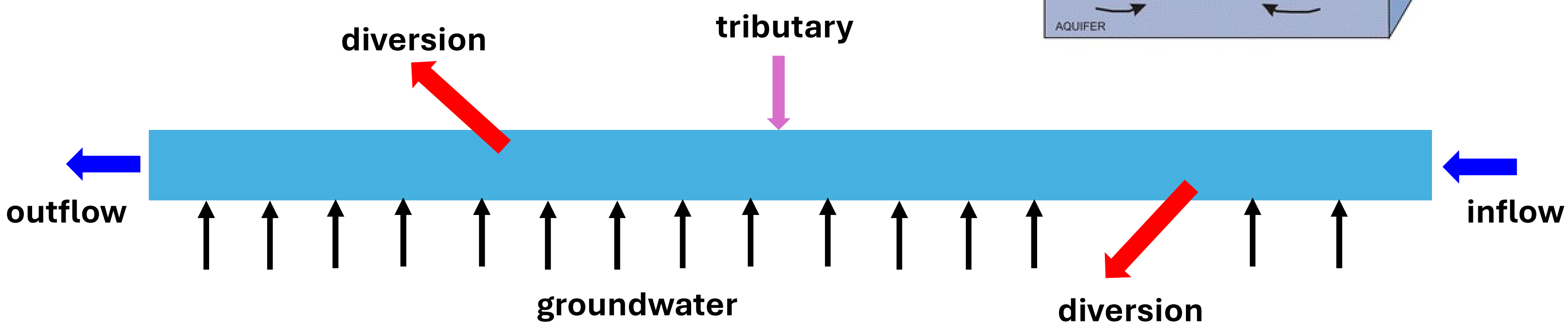


River water balance:

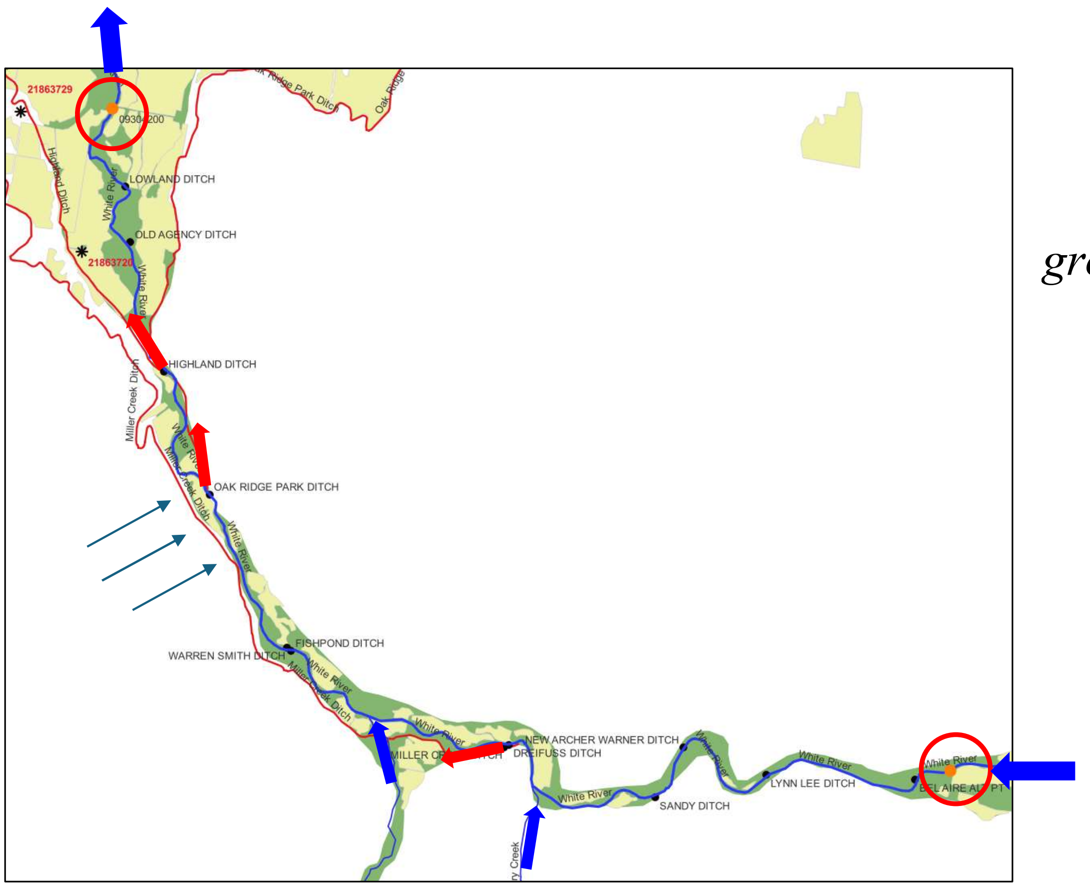


$$outflow = inflow + tribs - diversions + groundwater$$

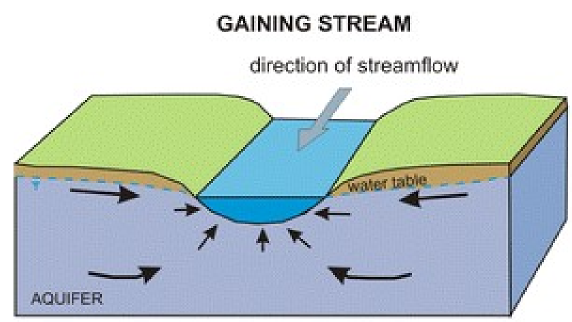
$$groundwater = outflow - inflow - tribs + diversions$$

Insights from Field Data

Using River Flow Data to Estimate Groundwater Discharge



$$groundwater = \overset{\text{USGS DWR}}{outflow} - \overset{\text{USGS DWR}}{inflow} - \overset{\textbf{Watershed model}}{tribs} + \overset{\text{DWR}}{diversions}$$



Insights from Field Data

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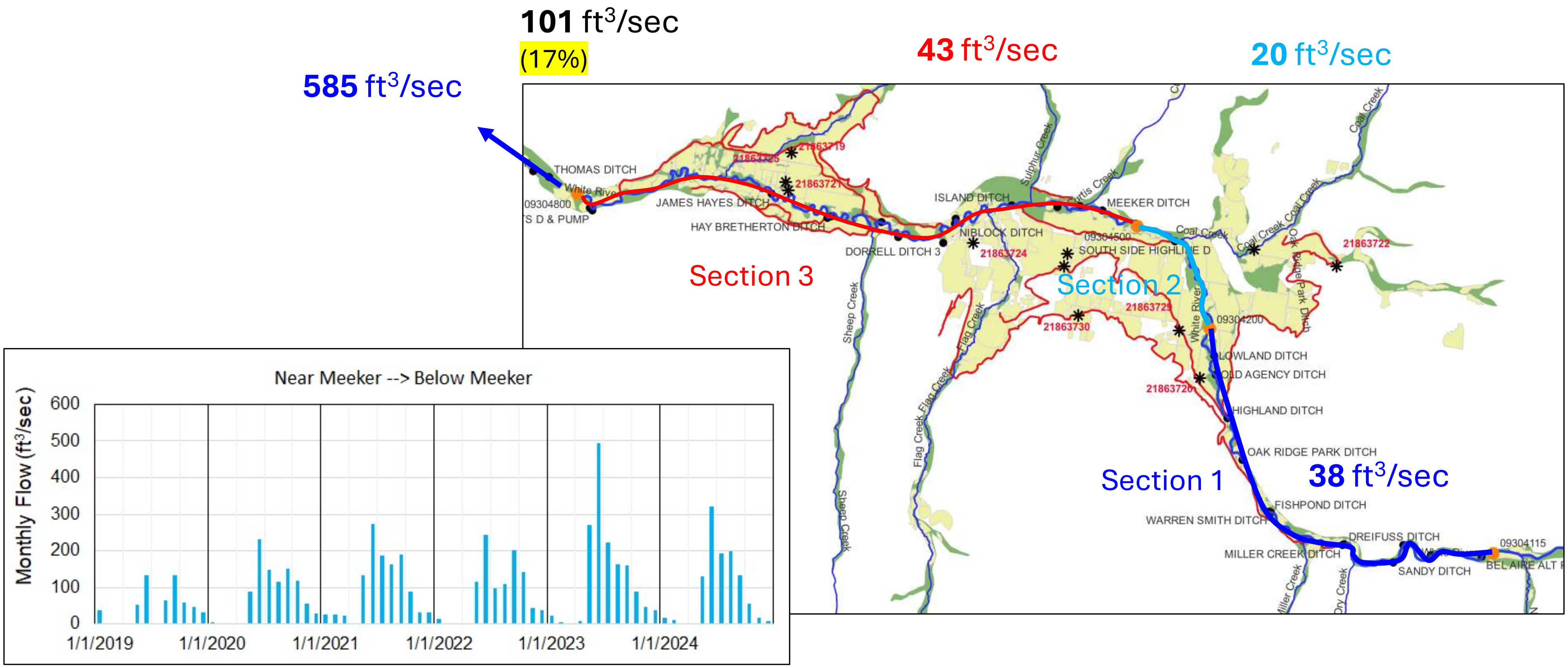
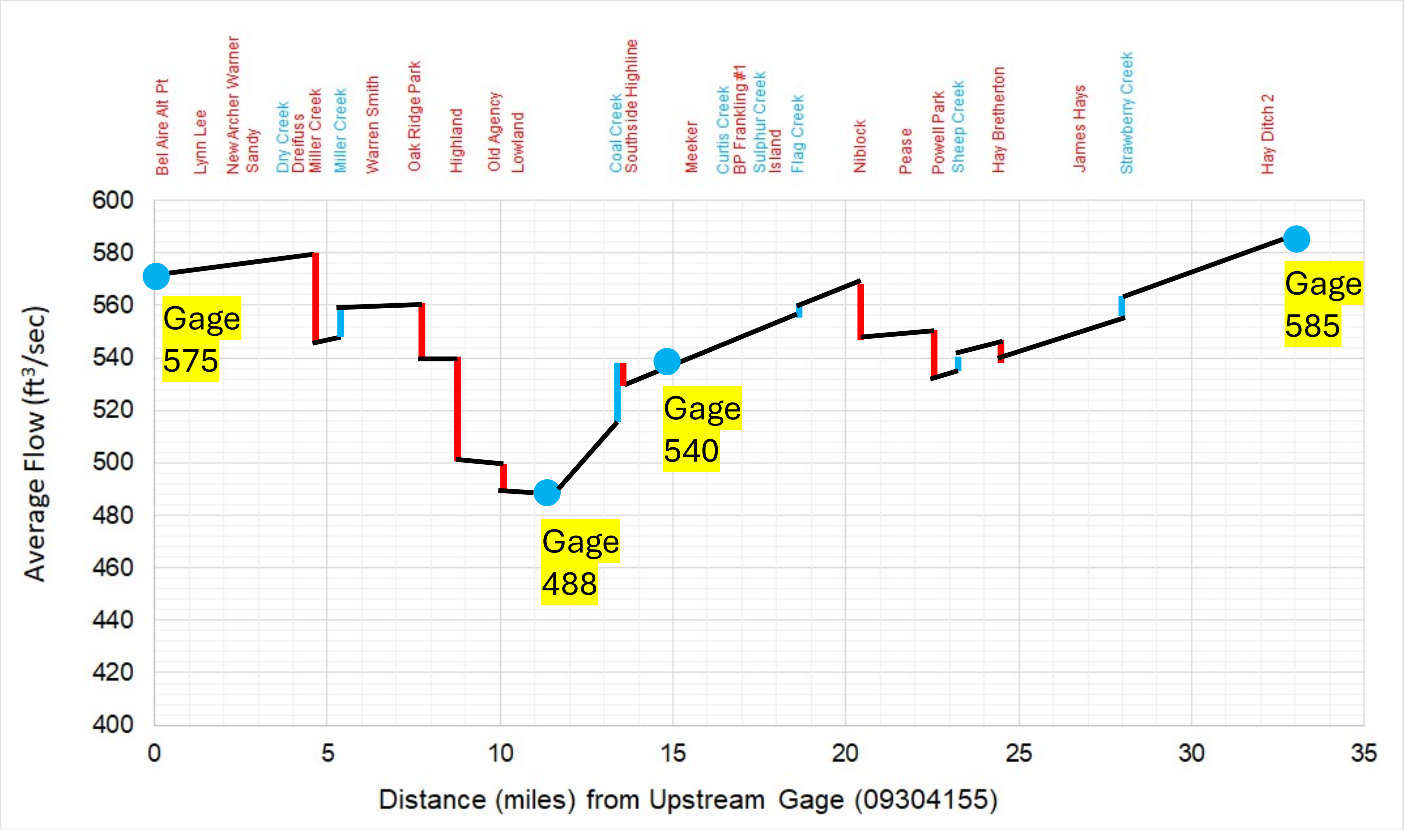
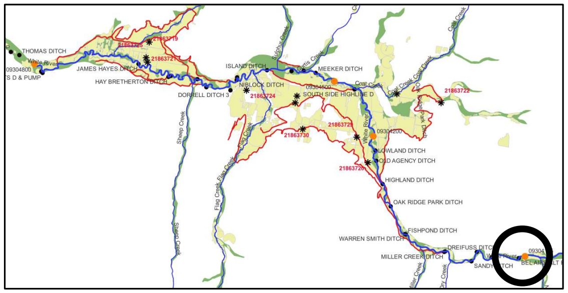


Insights from Field Data

Using River Flow Data to Estimate Groundwater Discharge

Track flow along White river (2019-2024; average)





Insights from Field Data

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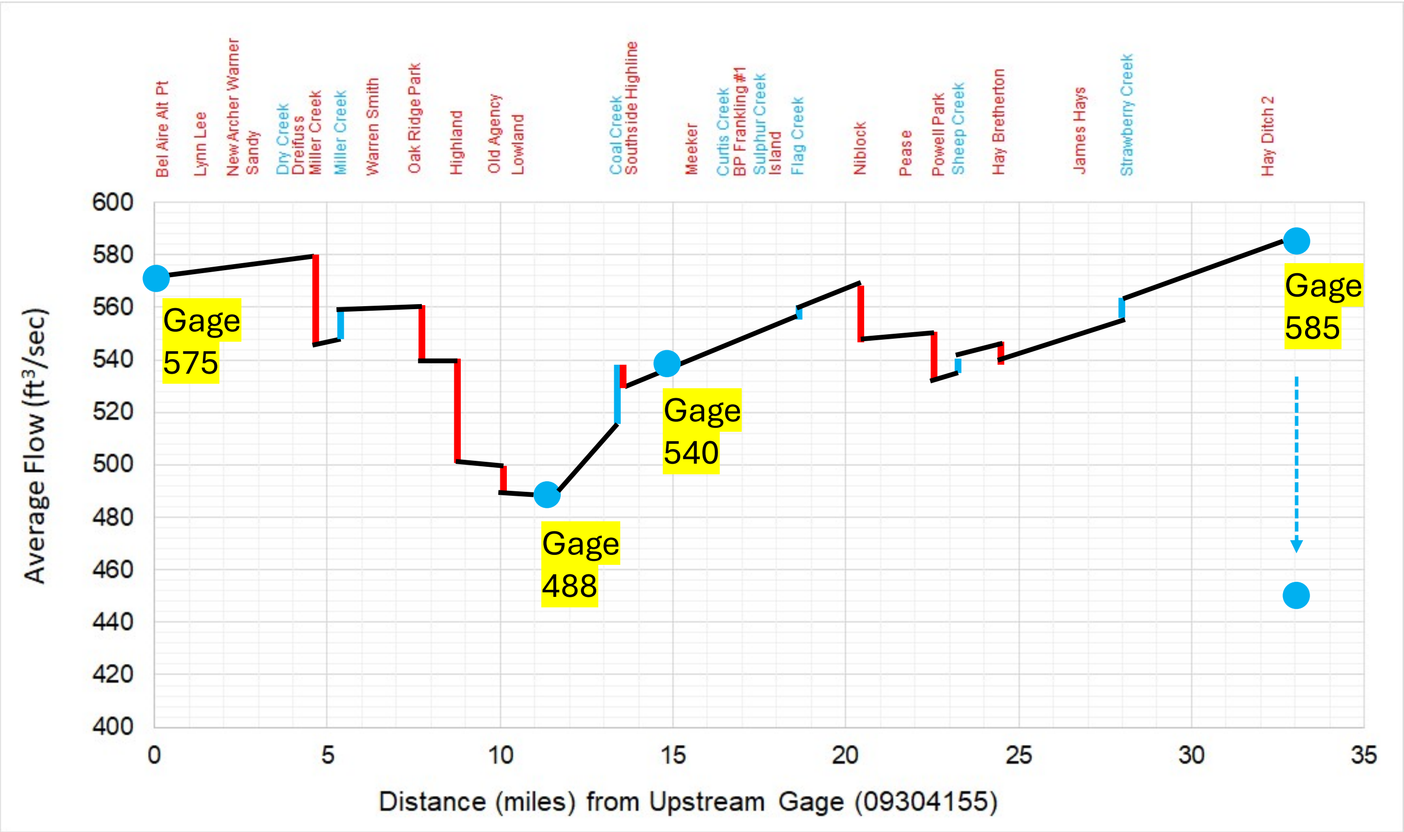
Track flow along White river (2019-2024; average)



Change in flow: +10 ft^3/sec

Tributary inflow: 60 ft^3/sec

Diversions: 182 ft^3/sec

Groundwater: 132 ft^3/sec

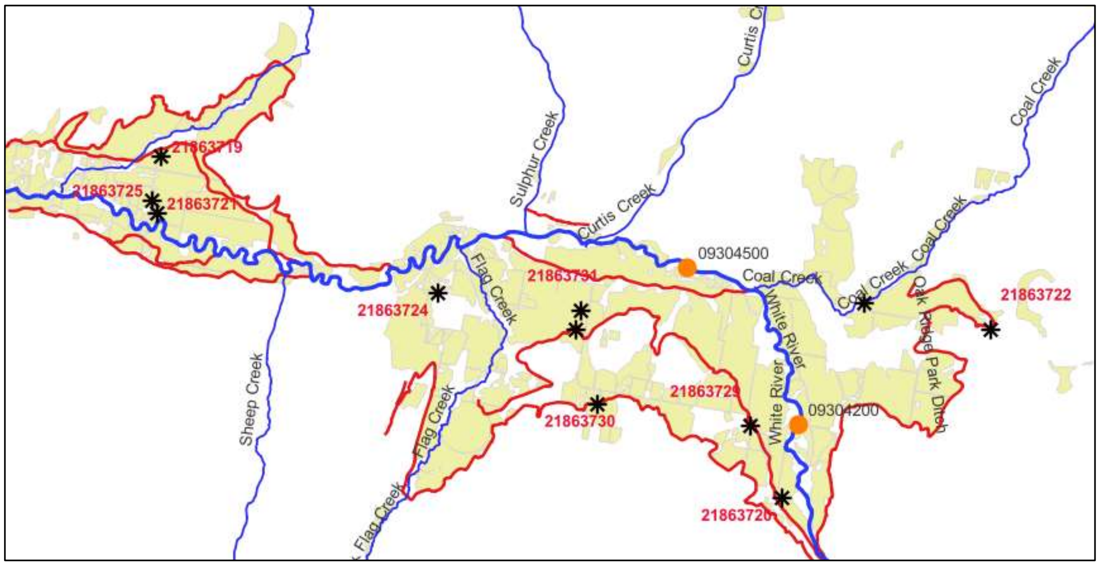
Groundwater is ~70% of diversions
(remaining water = crop consumption)

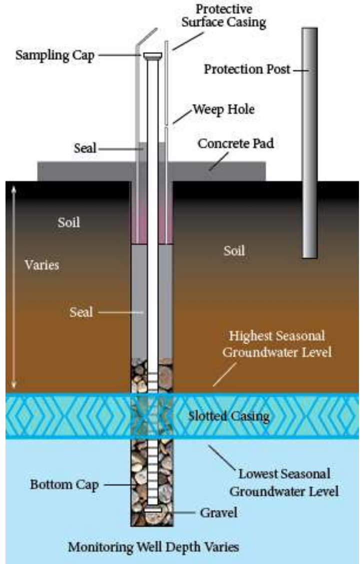
If no groundwater discharge:
River flow at downstream end ~ 450 ft^3/sec

Insights from Field Data

Groundwater Monitoring
(water table fluctuations)

11 Data loggers: measure water levels <u>every hour</u>





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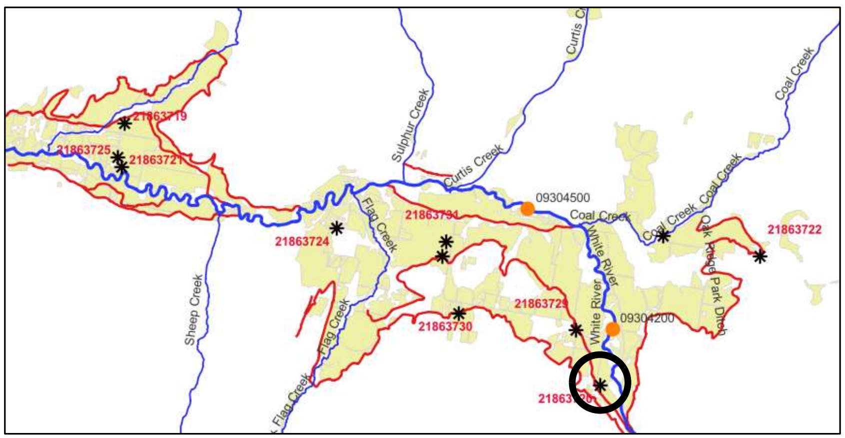

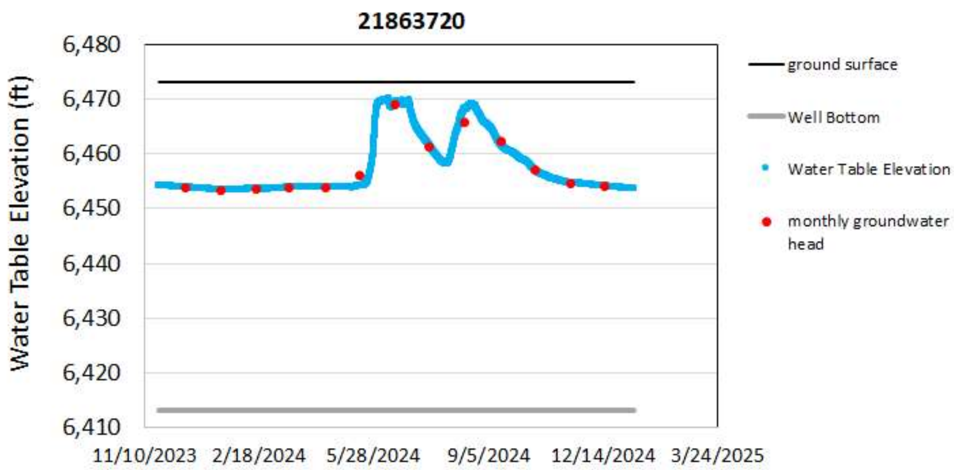

15 feet rise (late May)
10 feet rise (mid August)
(combination of **ditch seepage** & **irrigation recharge**)

Insights from Field Data

Groundwater Monitoring
(water table fluctuations)

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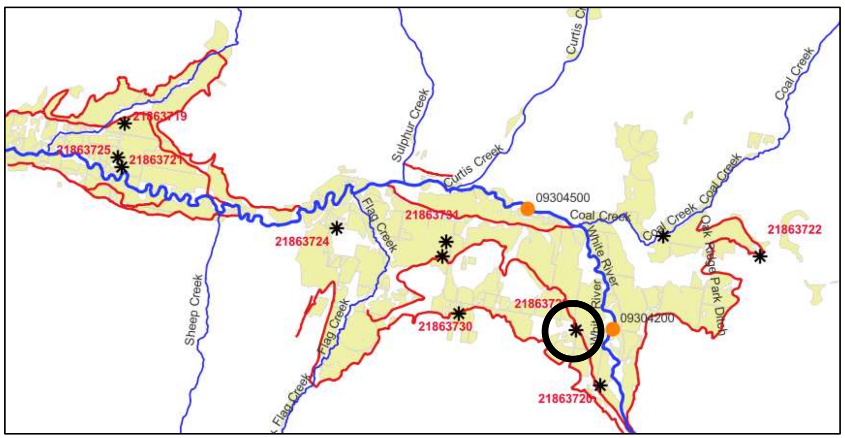

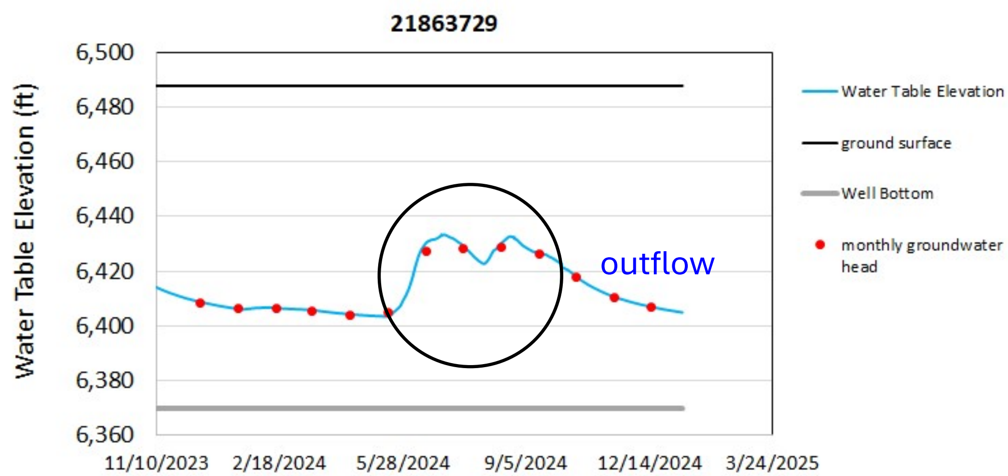

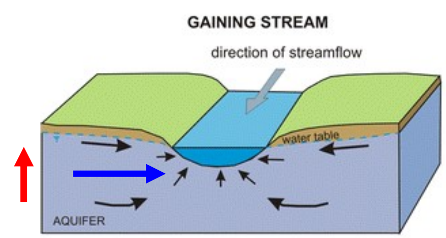

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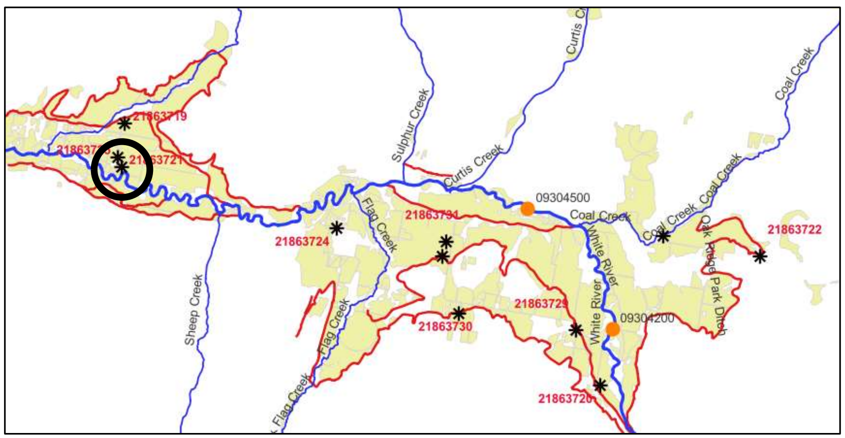

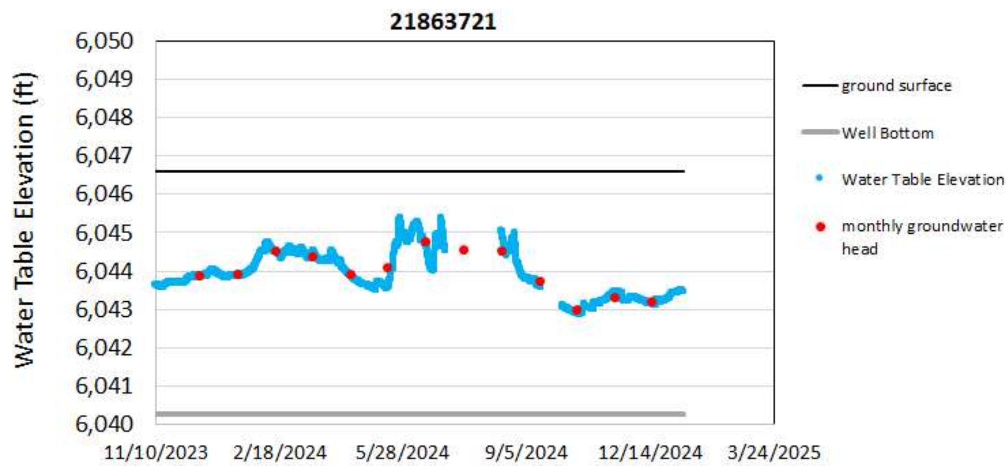

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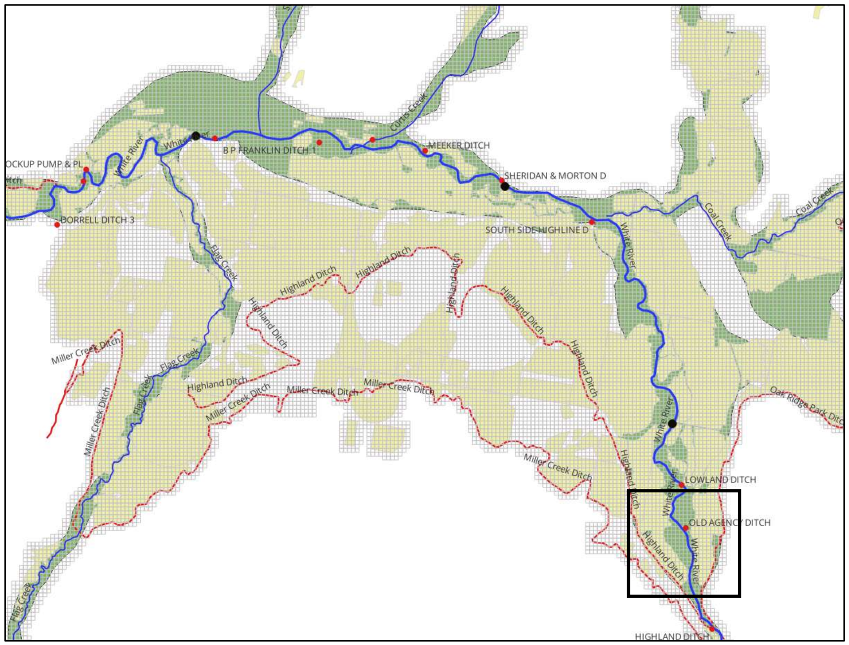
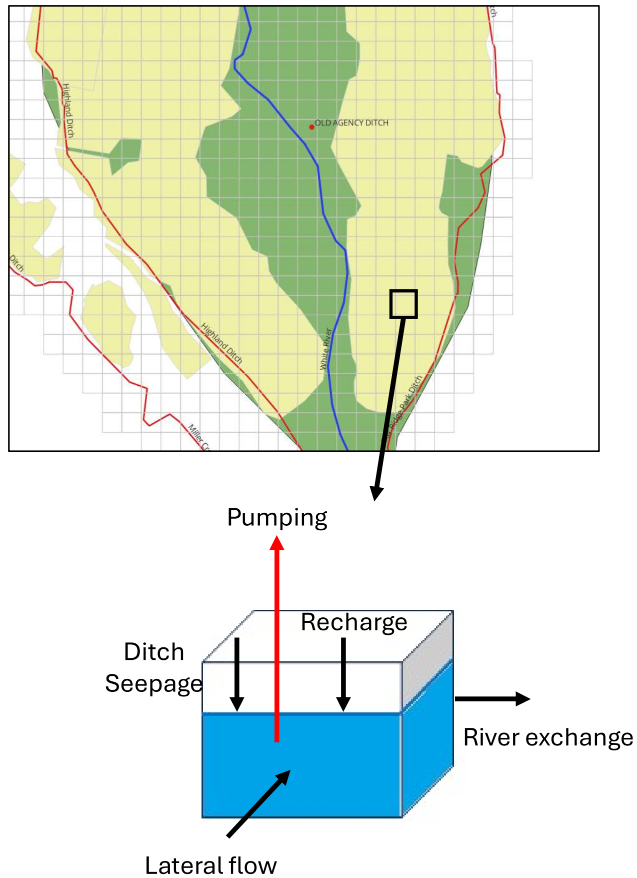
4. Scenarios

Modeling Results

What is a groundwater model?



Create a “grid” (collection of cells)



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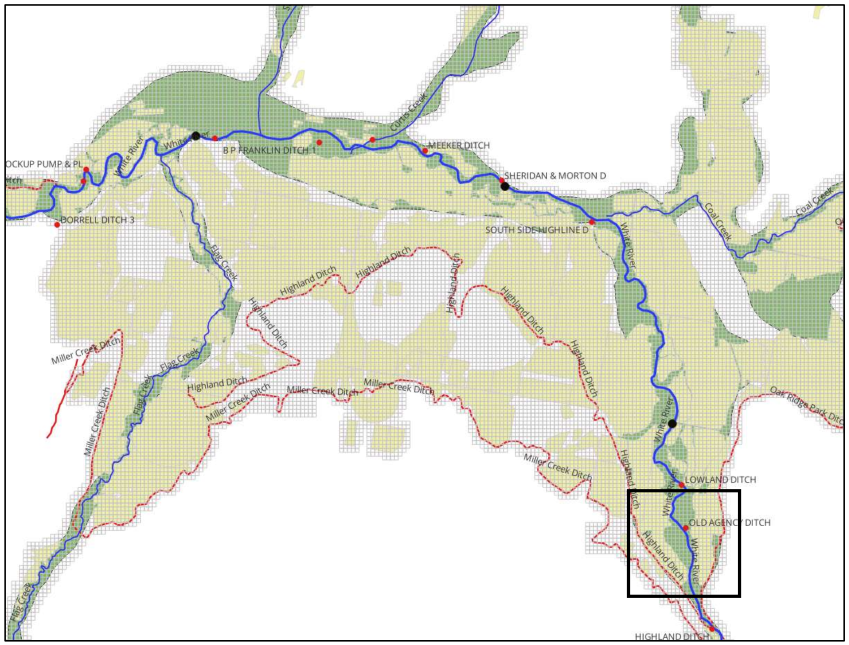

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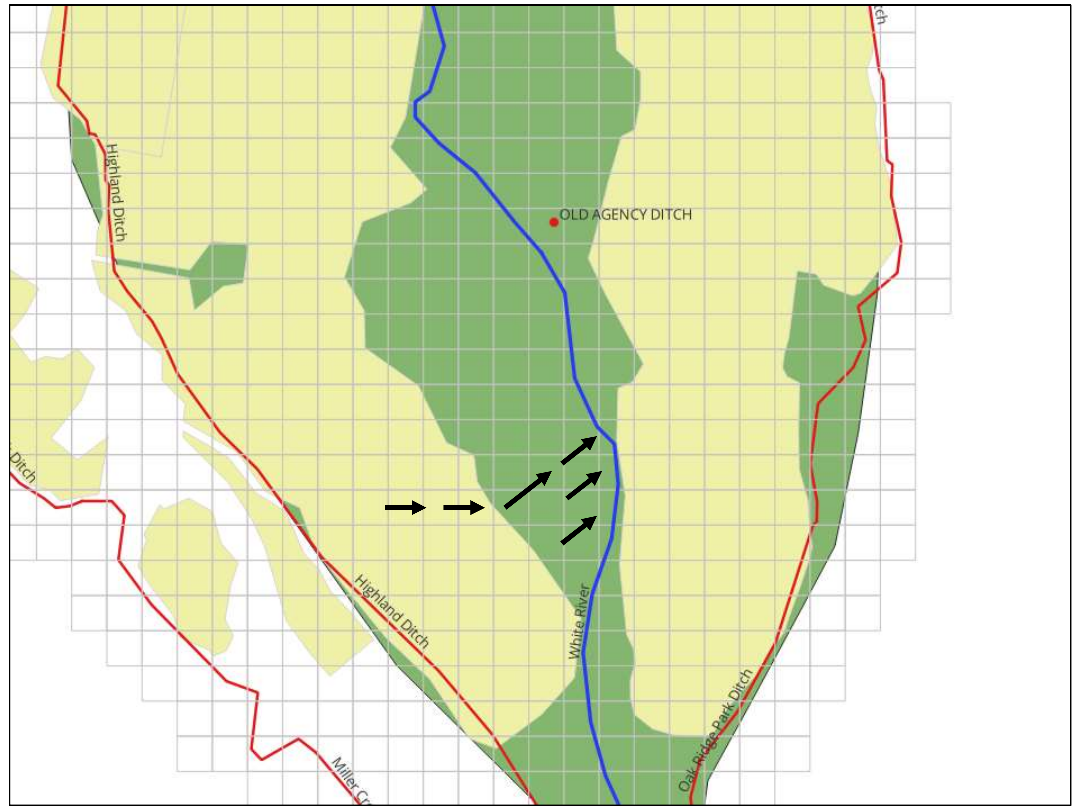
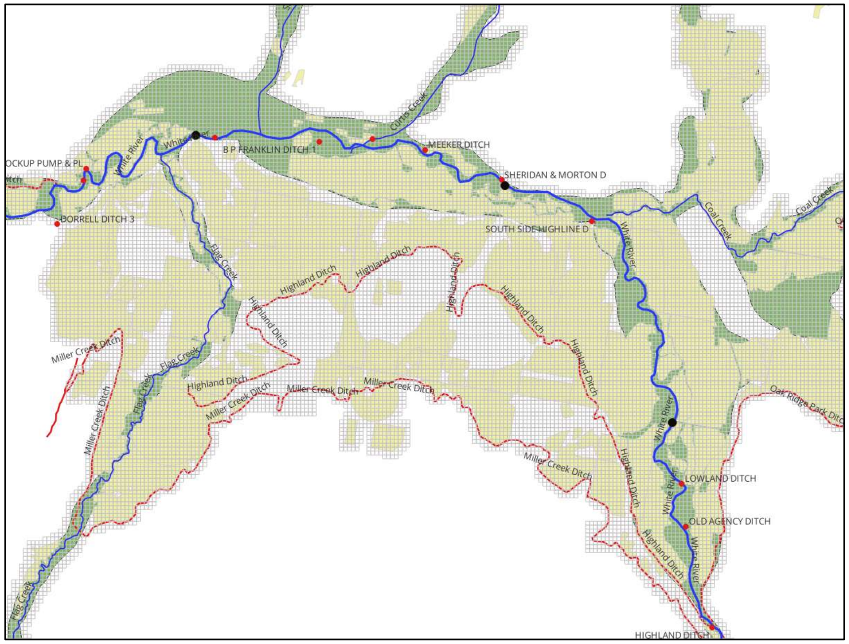


Modeling Results

Use a groundwater model (MODFLOW) to learn about hydrology



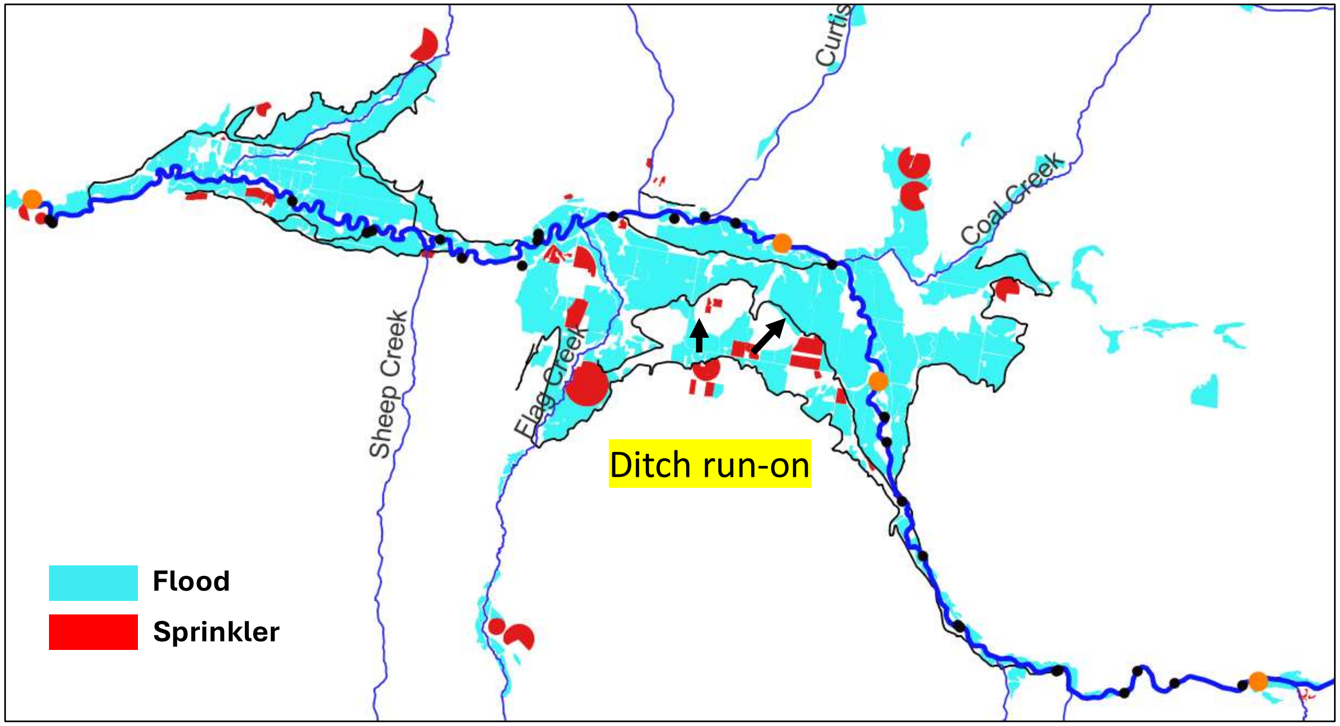
MODFLOW grid (200 ft x 200 ft)

- **Time Period**: 2019-2024 (daily time steps)
- **Features**:
  - Ditch seepage to aquifer
  - Recharge (rainfall, irrigation) to aquifer, using soil water balance
  - Pumping (Meeker wells)
  - Exchange between aquifer and tributaries (+ / -)
  - Exchange between aquifer and White River (+ / -)
  - Water table elevation for each grid cells
- **New Irrigation Package** (diversions, canal seepage, soil water balance)
- **Model testing**:
  - Groundwater exchange with White River (water balance)
  - Water table elevation (monitoring wells)
  - Canal seepage

Modeling Results

Use a groundwater model (MODFLOW) to learn about hydrology

Irrigated Fields

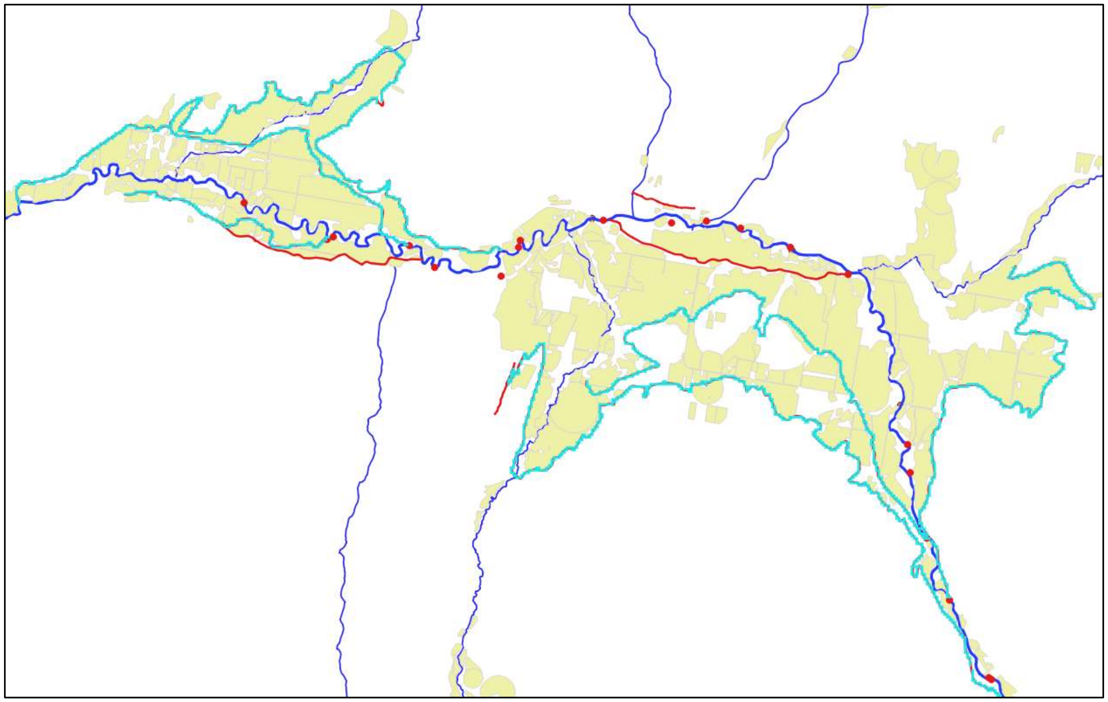


Modeling Results

Use a groundwater model (MODFLOW) to learn about hydrology

Groundwater-Ditch exchange

2,118 Ditch Cells



Modeling Results

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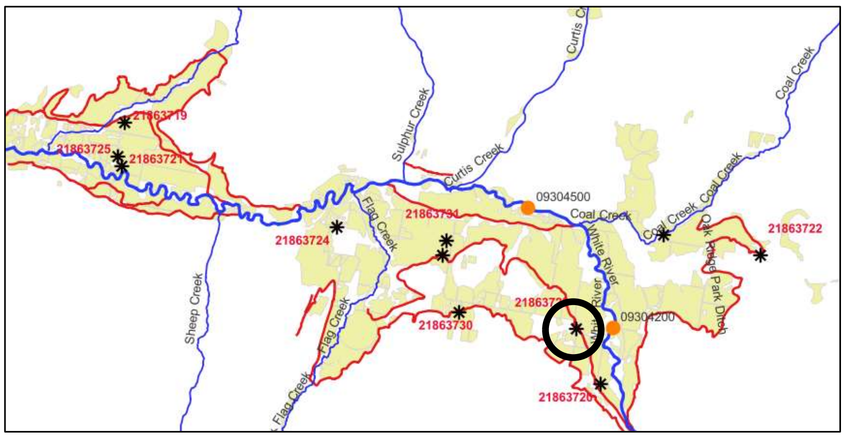
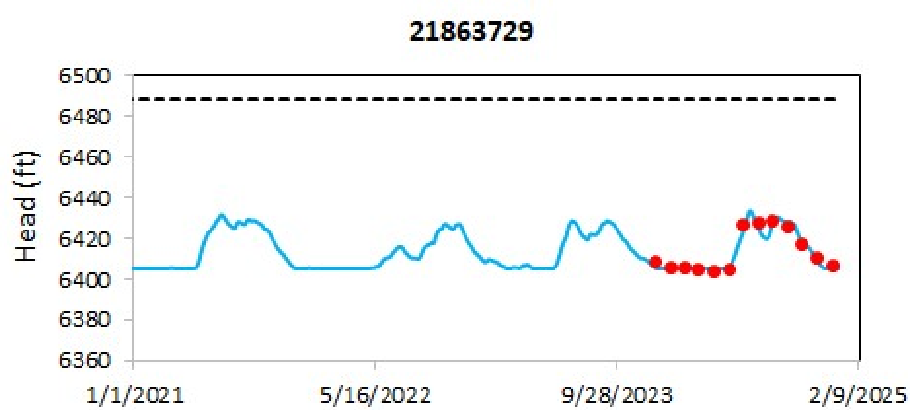
Model Testing

1. Water table elevation
2. Groundwater discharge to White River





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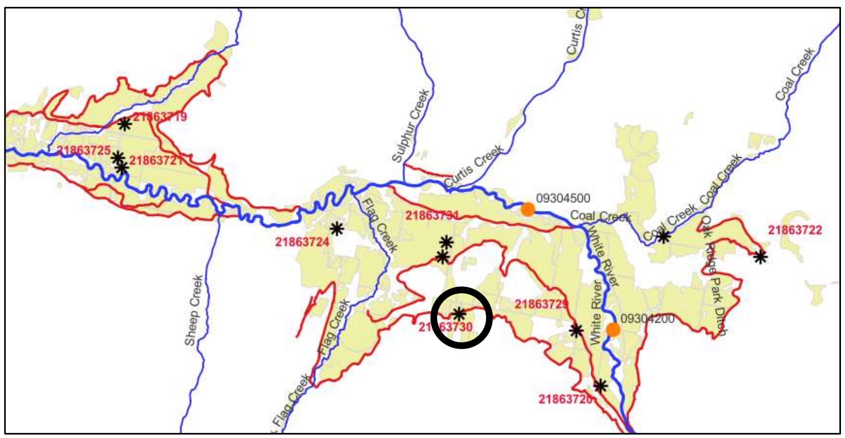

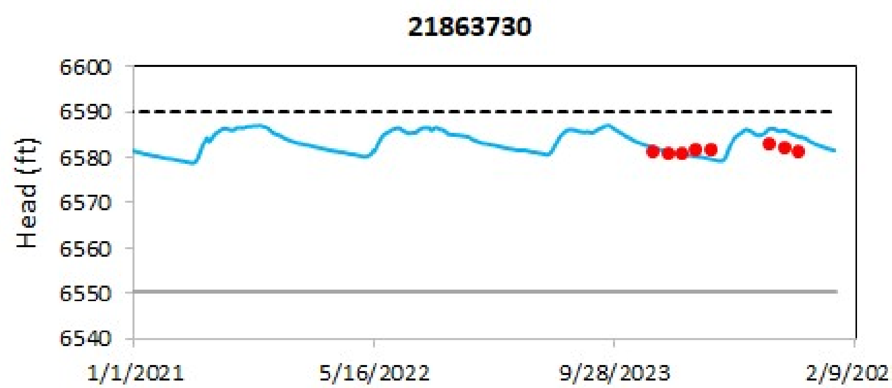

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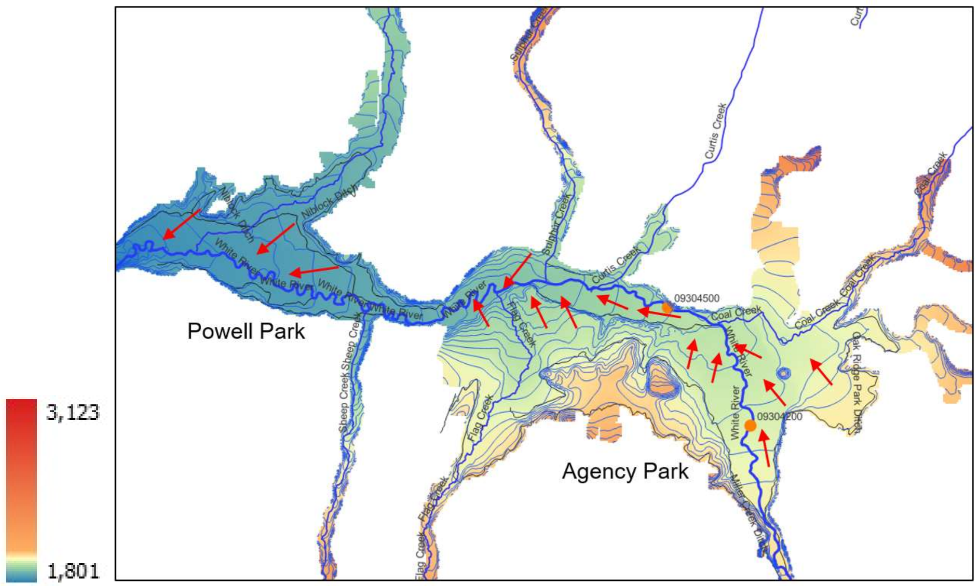

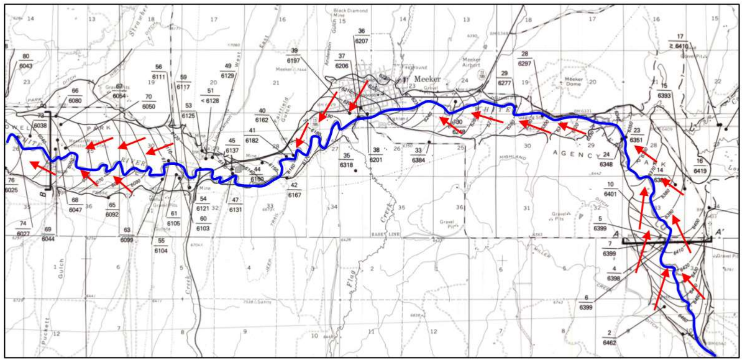

USGS Field study (Van Liew and Gesink, 1985)

Modeling Results

Use a groundwater model (MODFLOW) to learn about hydrology

Model Testing

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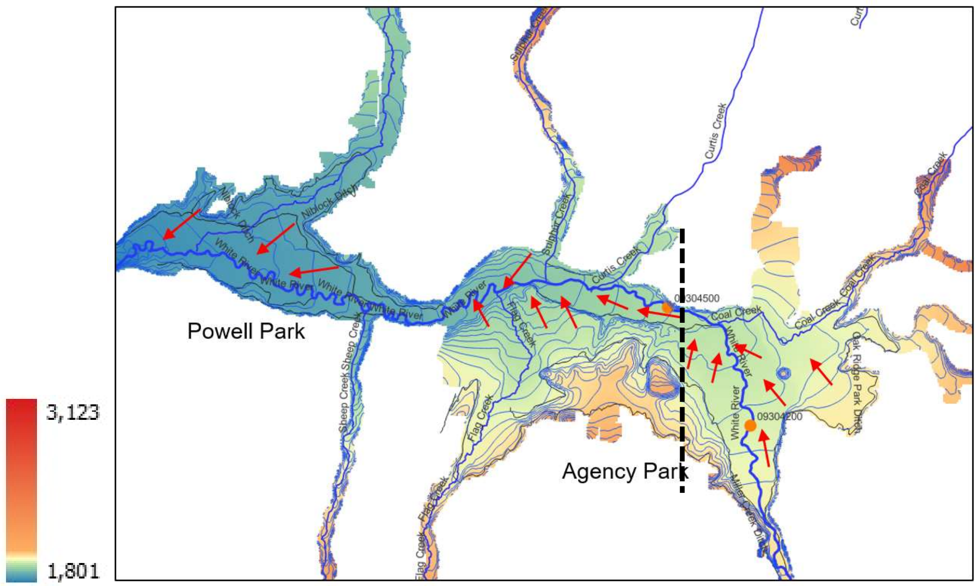

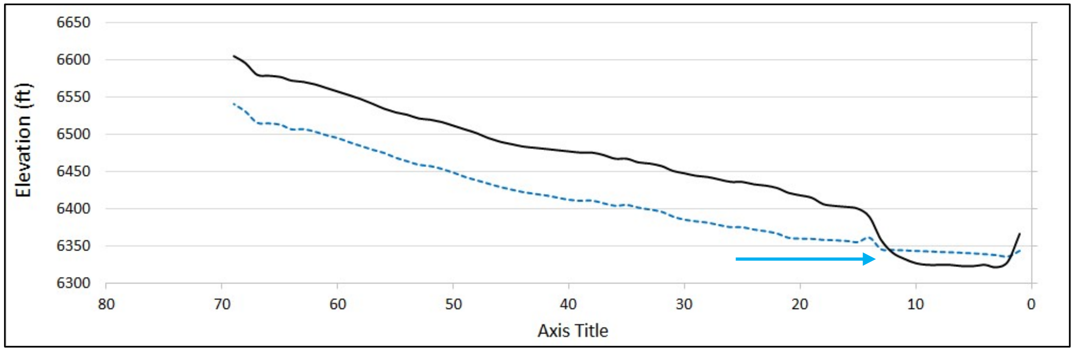

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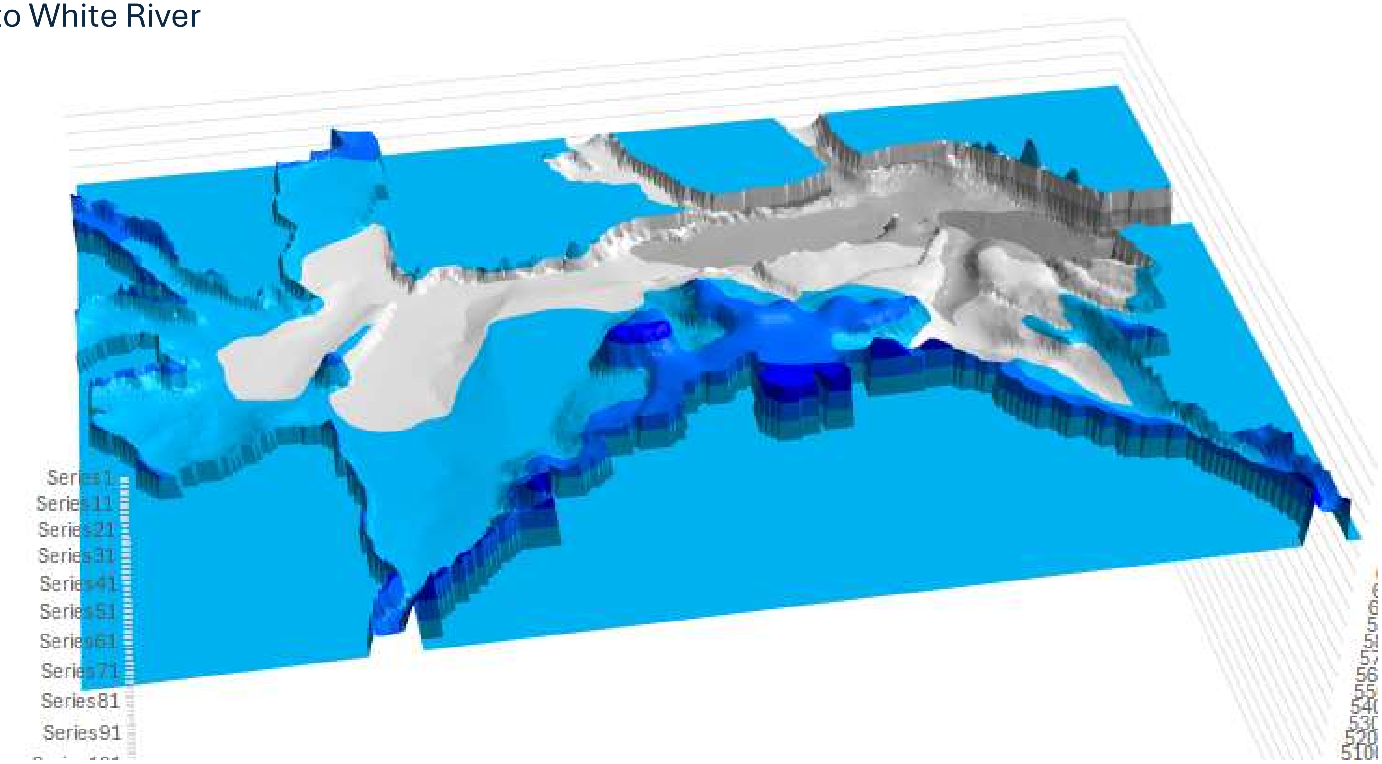

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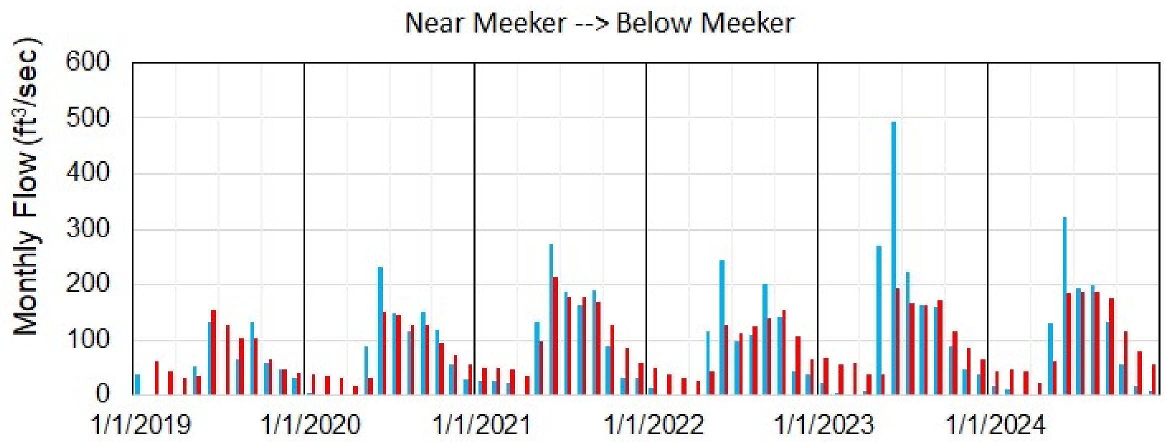
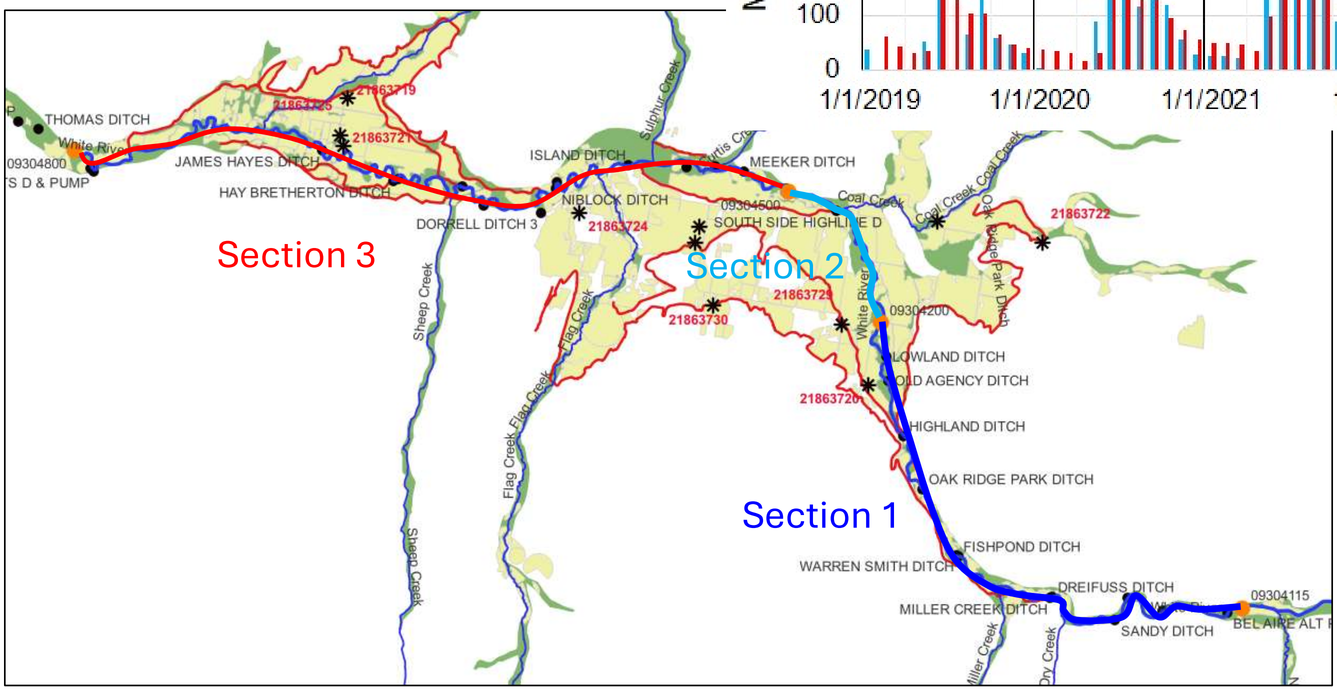


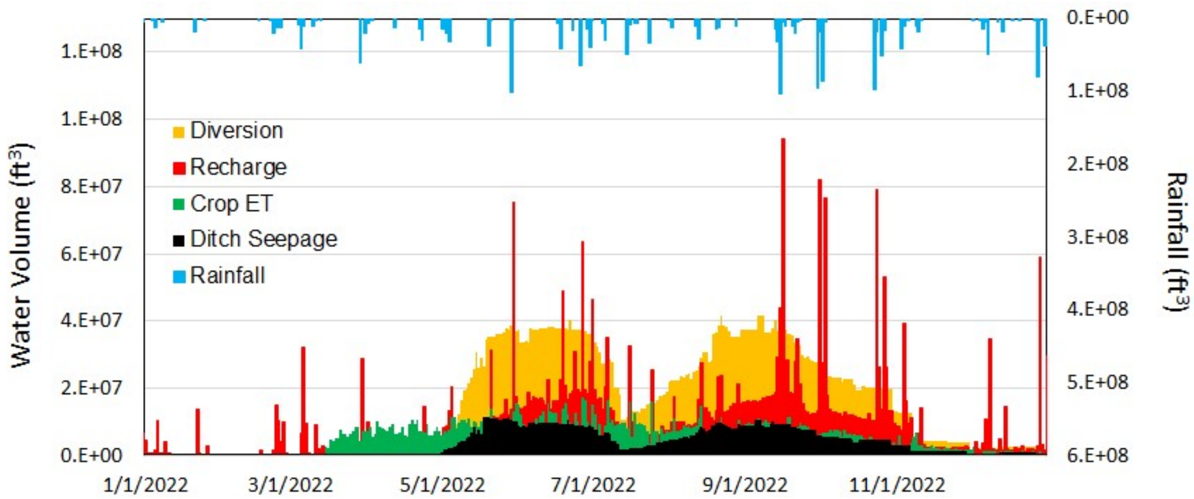


Modeling Results

Use a groundwater model (MODFLOW) to learn about hydrology

Major Results

1. Daily hydrologic volumes
2. Average water transfers
3. River water balance



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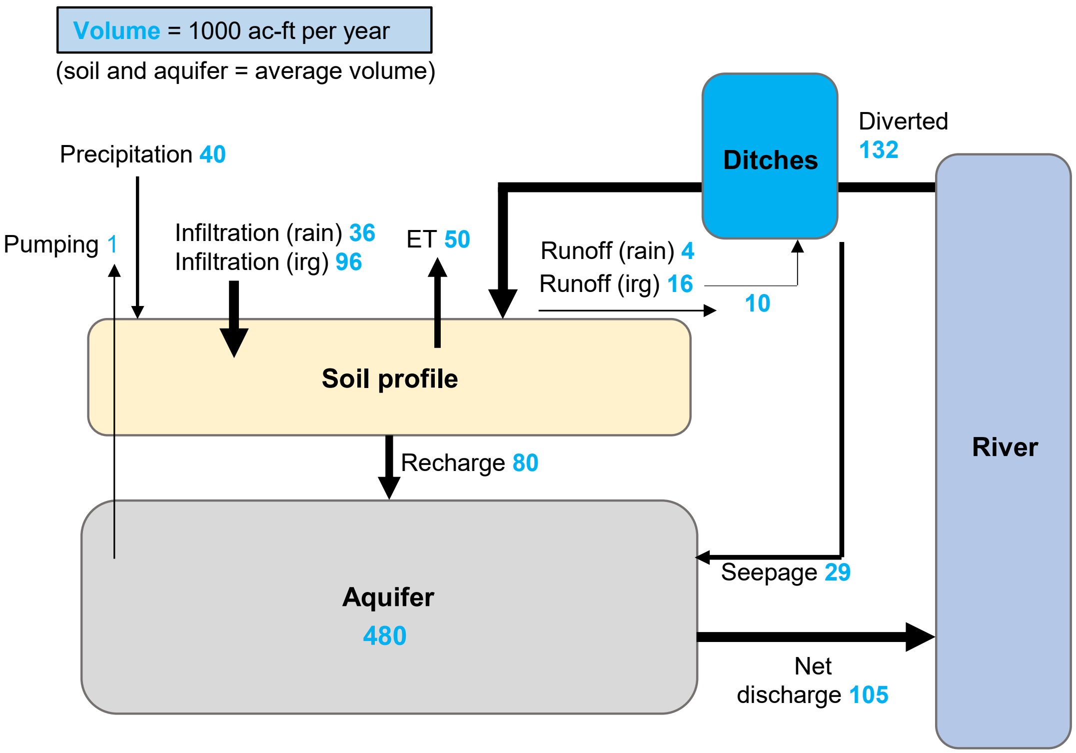
Use a groundwater model (MODFLOW) to learn about hydrology



- *Groundwater fraction*: The ratio of net groundwater discharge (**105**) to diverted water (**132**) is 80%.
- *Ditch seepage:* approximately 20% (**29**/**132**) of ditch water seeps to the aquifer.
- *Region-wide irrigation efficiency*: (**50**/(**132**-**29**)) = 50%. Although very low compared to other irrigated valleys, the majority of "lost" water recharges the aquifer, **returning to the river slowly** via groundwater return flows.
- For an average year, volumes of canal diversion, recharge, and groundwater discharge rates are equivalent to approximately 20% of aquifer groundwater storage. **The aquifer acts as a conveyor system** for unused river water that percolates through the soil profile, recharges the aquifer, returns to the river and its tributaries.

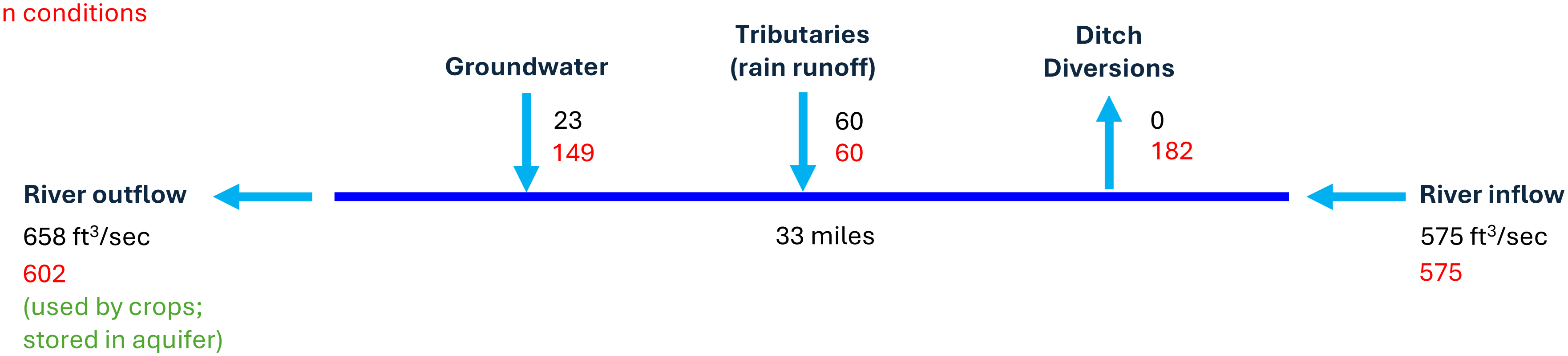
Modeling Results

Natural vs. Irrigated

Average for the year:

Natural conditions (no irrigation)

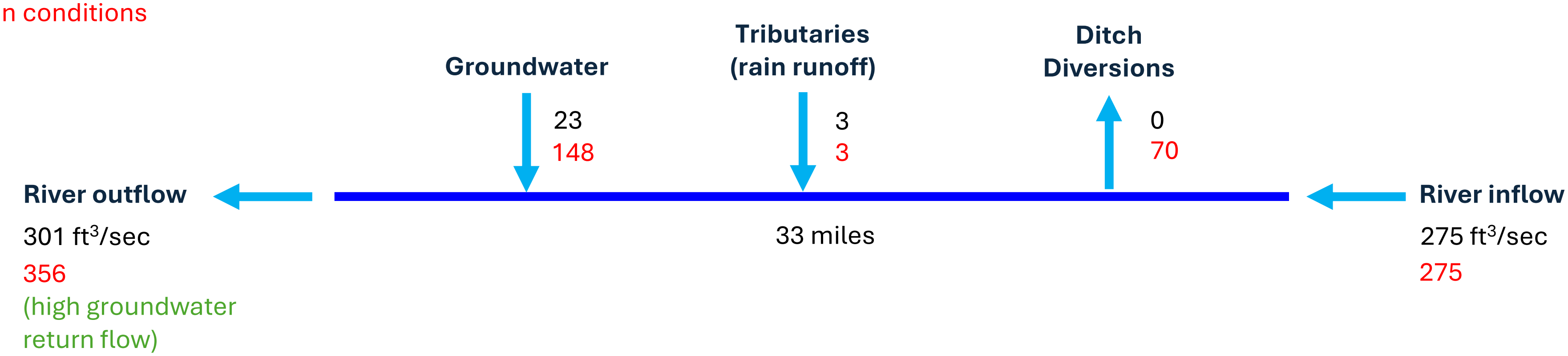
Flood irrigation conditions



Average for Oct-Dec:

Natural conditions (no irrigation)

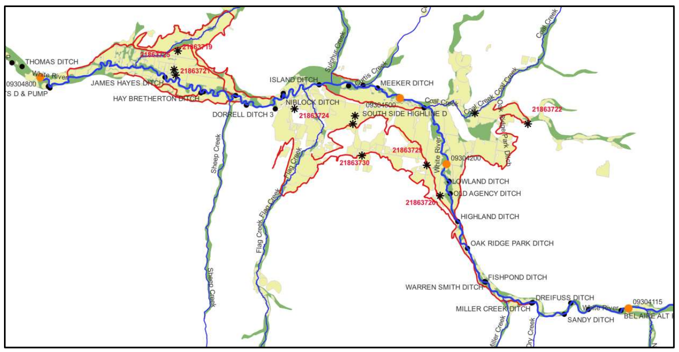
Flood irrigation conditions



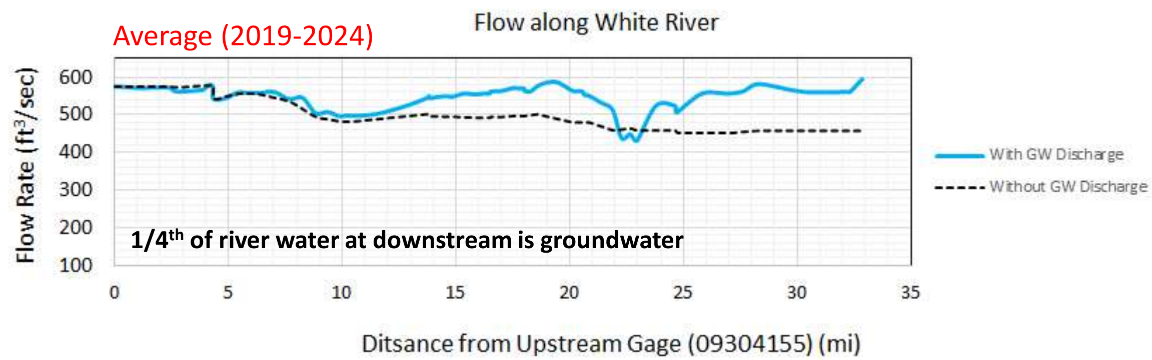
Modeling Results

What if Groundwater did not Discharge to the River?

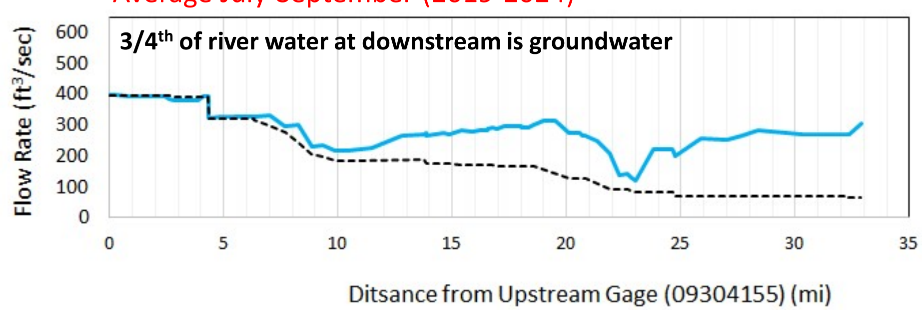
Track daily streamflow from upstream gage to downstream gage:
(ditch diversions, tributary inflows, groundwater-river exchange)



Average (2019-2024)



Average July-September (2019-2024)



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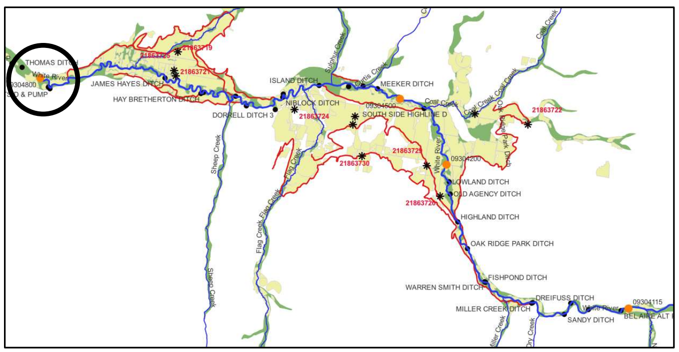
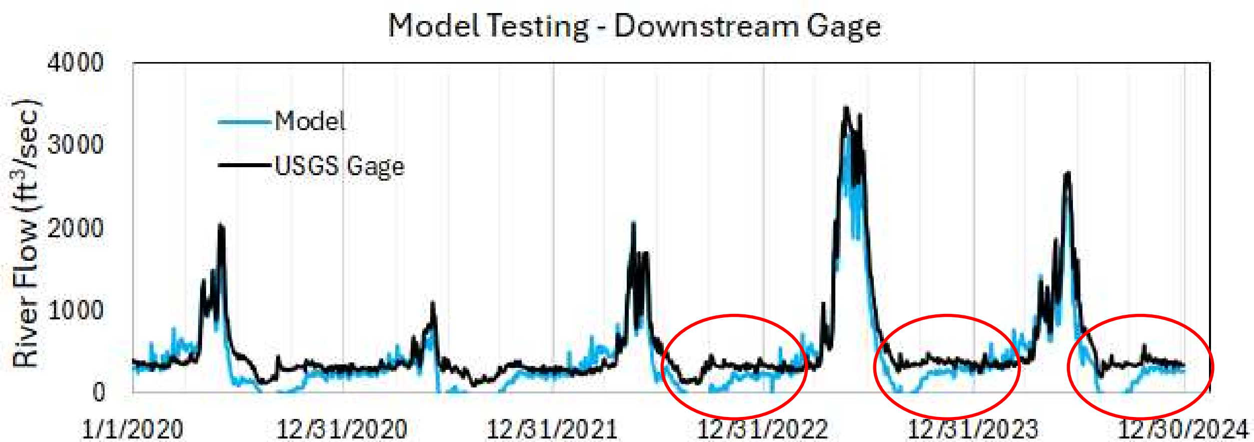
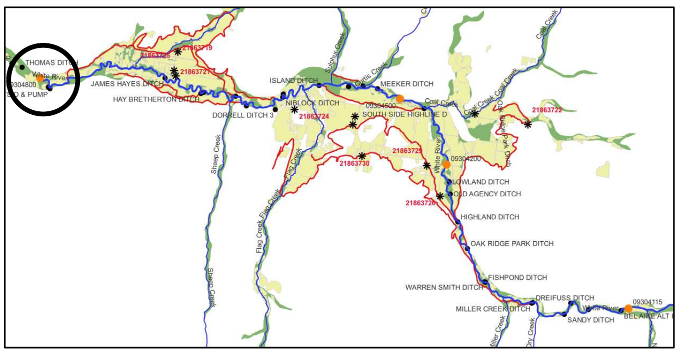


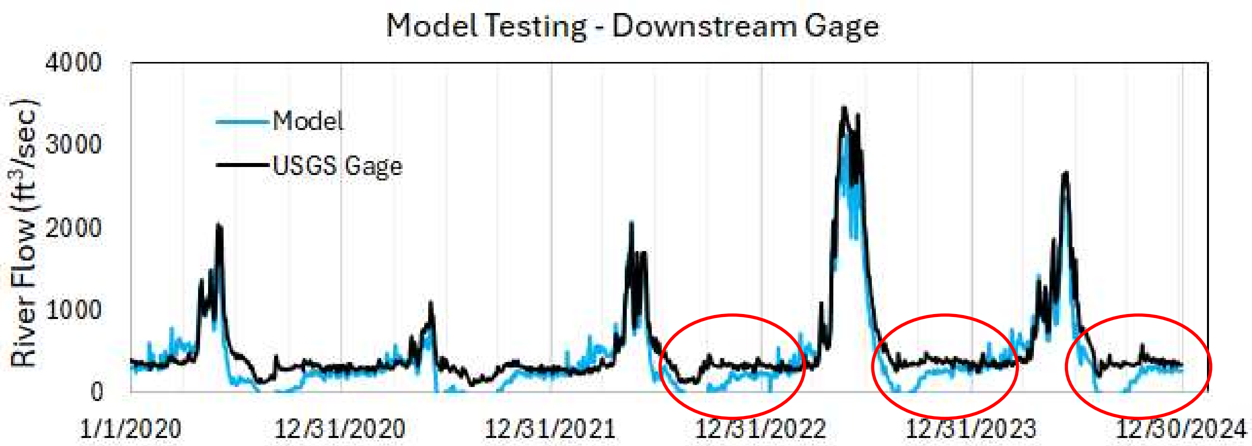


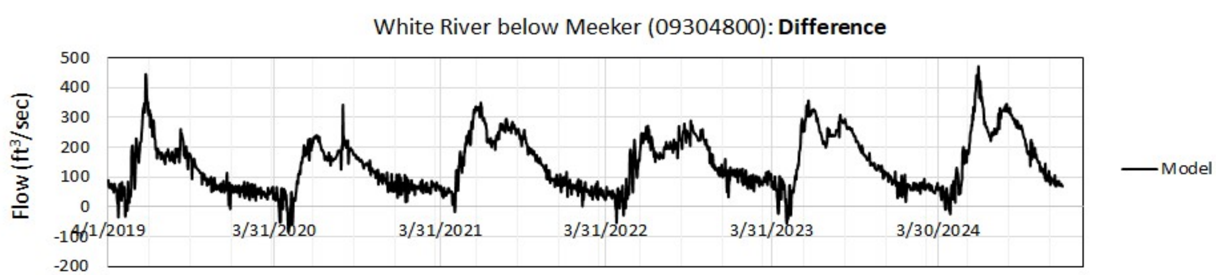
Without groundwater,
very low river flow in
September - November

Modeling Results

What if Groundwater did not Discharge to the River?







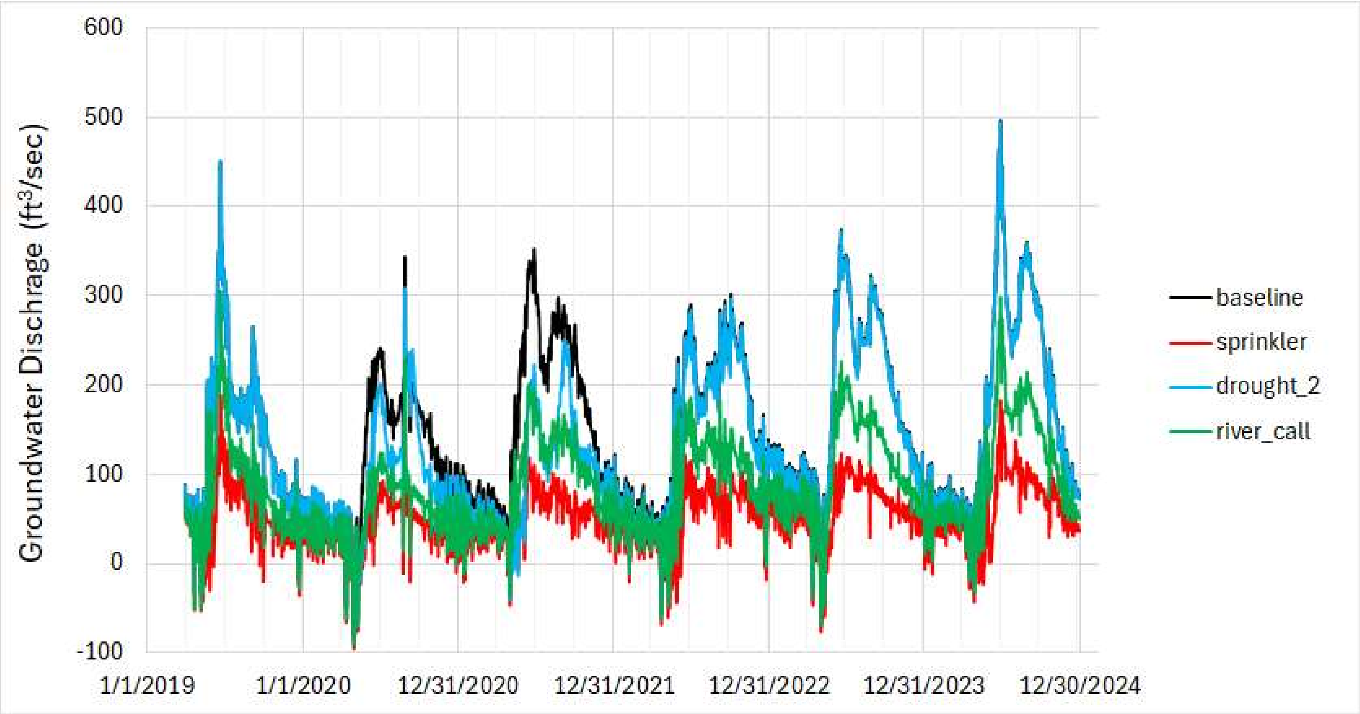
Outline of Presentation

1. Problem Statement
2. Insights from field data
3. Results from the hydrologic model
4. Scenarios: what happens if the system changes? Irrigation, weather, etc.

Scenarios

What happens if the system changes?

1. Change flood → sprinkler
2. Consecutive drought years
3. Administrative call on the river (1922)



105,000 ac-ft / yr

38,000 ac-ft / yr **36%**

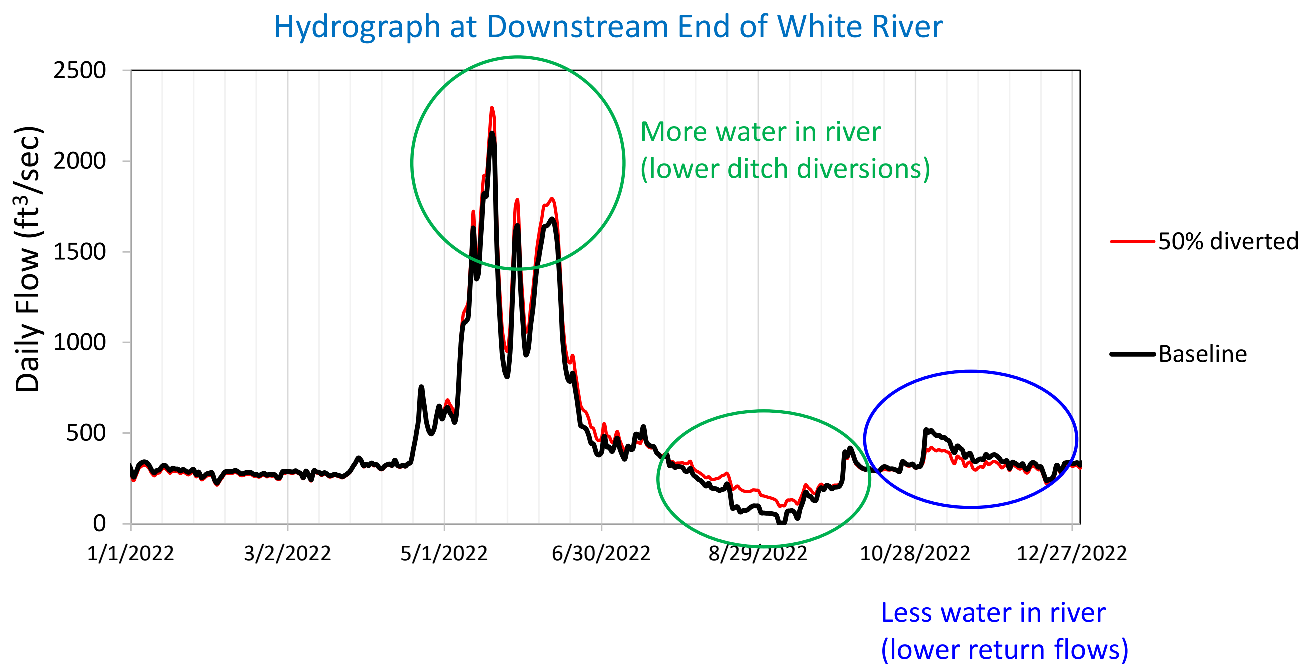
94,000 ac-ft / yr **90%**

62,000 ac-ft / yr **60%**

Scenarios

What happens if the flood irrigation is changed to sprinkler?

- With flood irrigation, most of the water applied to the fields (75%) becomes **deep percolation**
- If sprinkler irrigation is used with the aim of increasing irrigation efficiency (i.e., no runoff or deep percolation), then **<u>less water</u>** needs to be diverted from the White River.



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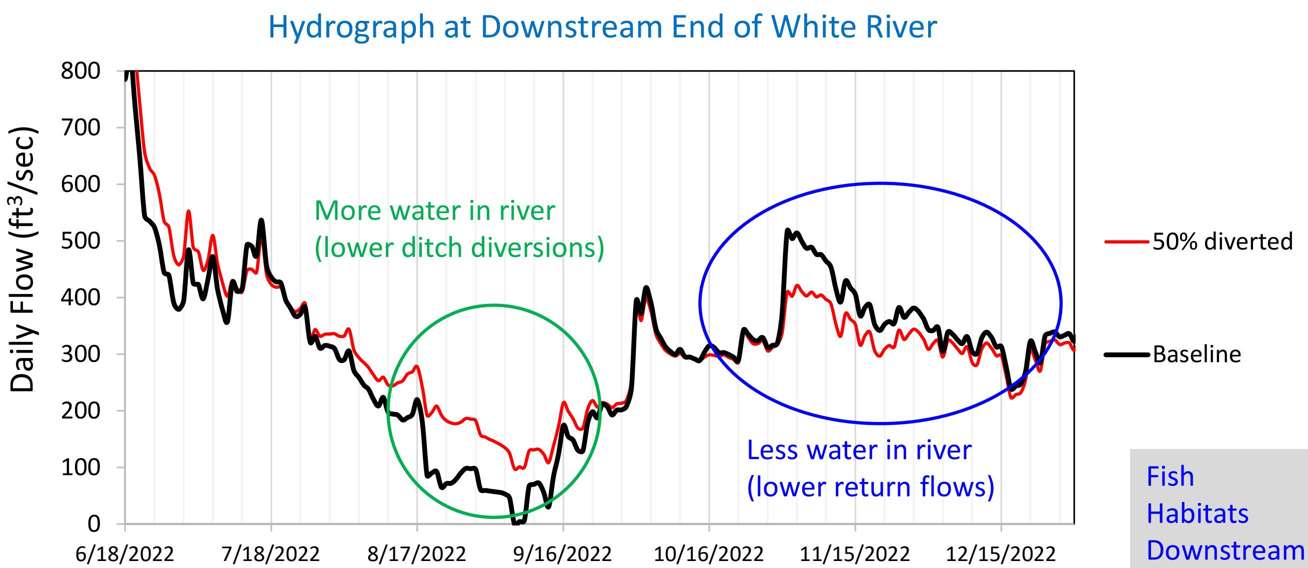
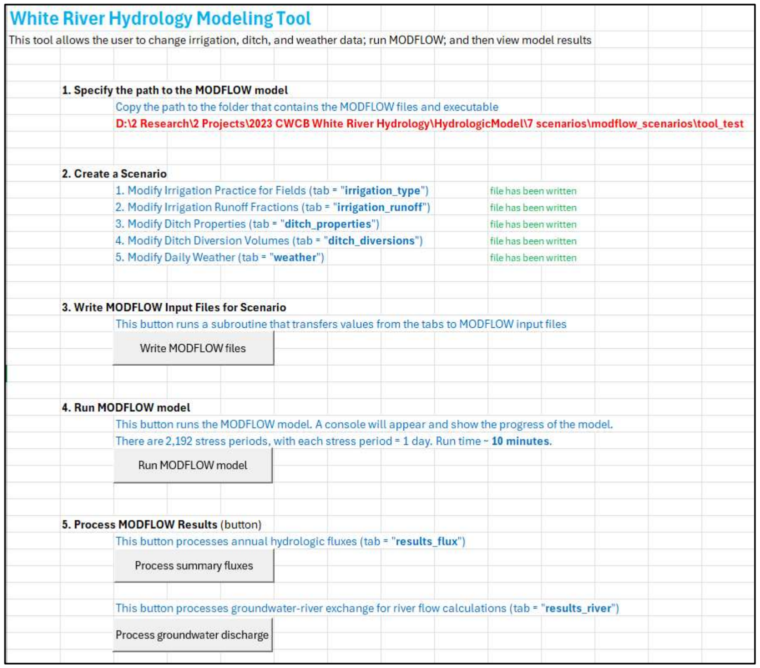


Fish
Habitats
Downstream hydropower

Summary of Findings

1. The ratio of groundwater discharge to the White River to diverted water is 80%
2. Region-wide irrigation efficiency = 50%; however, "lost" water recharges the aquifer, inducing groundwater discharge to the White River and its tributaries.
3. The aquifer acts as a conveyor system for diverted, unused river water that percolates through the soil profile, recharges the aquifer, and returns to the White River in the fall and winter months.
4. During the months of **July-September**, approximately 75% of water in the White River is due to groundwater discharge.
5. The aquifer has a short "memory"; because of its high conductivity, weather and diversion conditions from one year do not have an affect on groundwater patterns the following year.
6. **Scenarios**: diverting less water (sprinkler; administrative calls) will change the timing of river flow; there will be higher flow rates in the spring and summer months, but less in the fall and winter months. This may have negative effects on environmental flows, habitat/wetland maintenance, and river water temperature.

Decision Support Tool



Excel Spreadsheet:

- **Tabs**: change inputs (irrigation type for each field; daily diversion volumes for each ditch; daily weather)
- **Button**: write MODFLOW input files
- **Button**: run MODFLOW model
- **Button**: process MODFLOW output (annual fluxes, groundwater discharge, etc.); compare against baseline values