

Developing an integrated surface/subsurface watershed model by coupling APEX and MODFLOW

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Problem Statement

Upper Colorado River Basin - Salinity



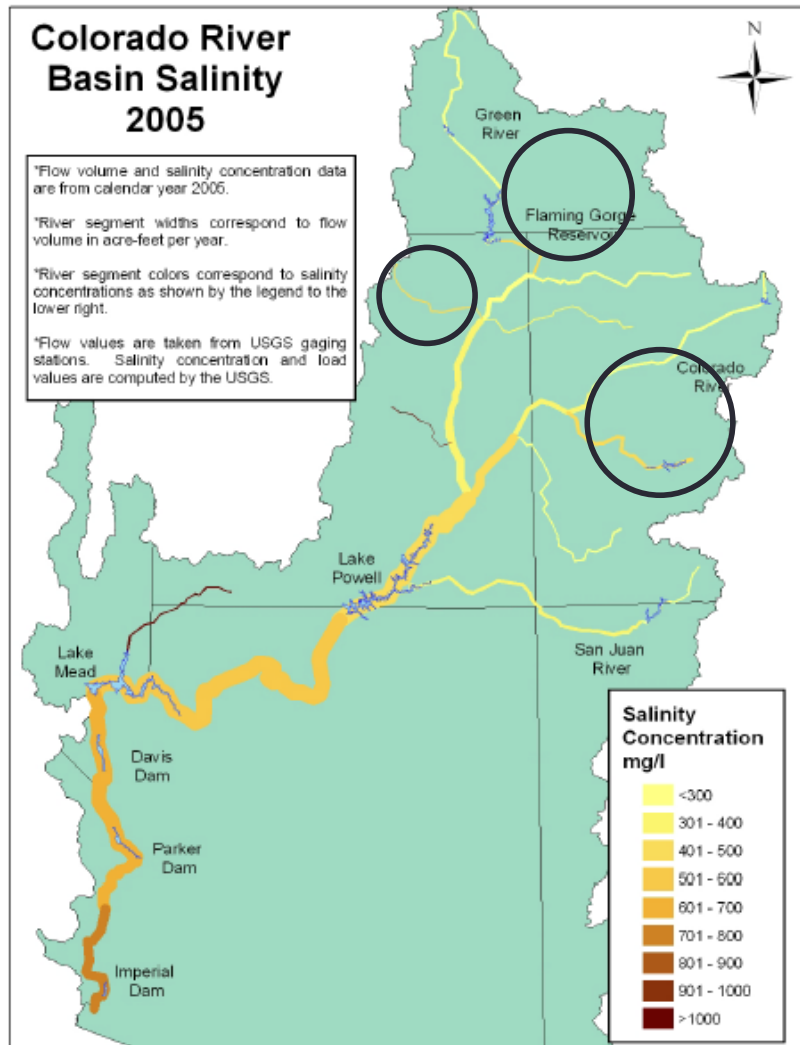
- 242,000 mi²
- Provides water to ~33 million people
- Irrigated agriculture, livestock grazing, mining, forestry, manufacturing, oil and gas production, recreation, and tourism

Salinity

- 50% natural, 50% from human activities
- Natural: saline springs, groundwater discharge, erosion and dissolution, evapo-concentration
- Human: irrigation runoff and irrigation return flows

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Problem Statement

Upper Colorado River Basin - Salinity

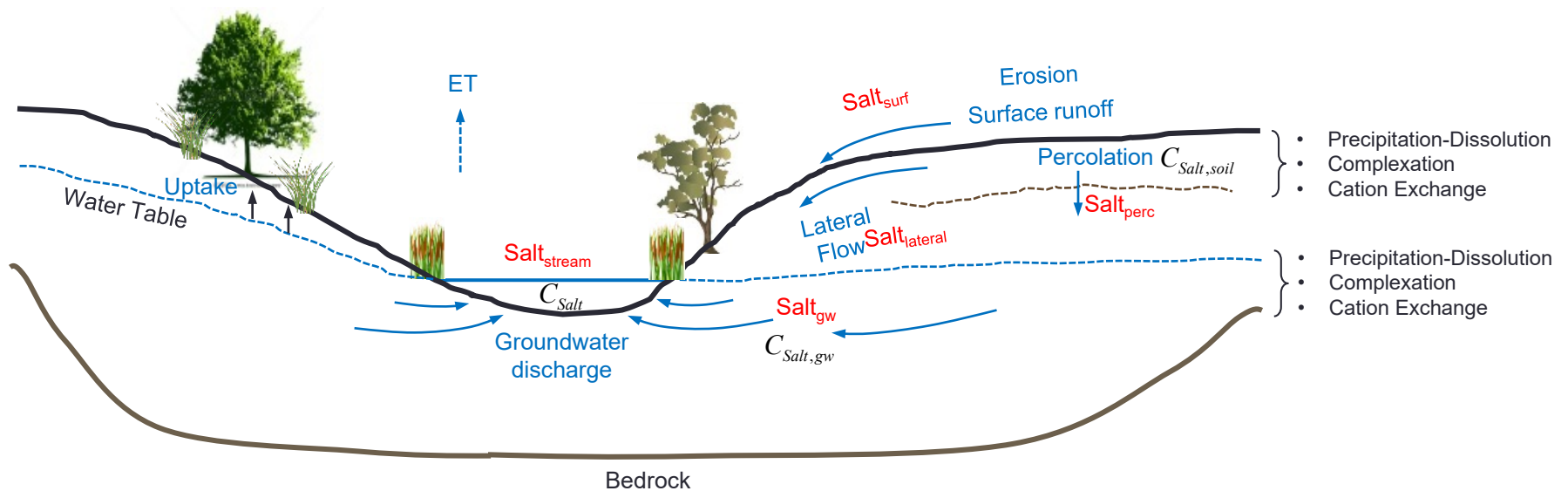


Problem Statement

Upper Colorado River Basin - Salinity

Rangeland Salt Transport

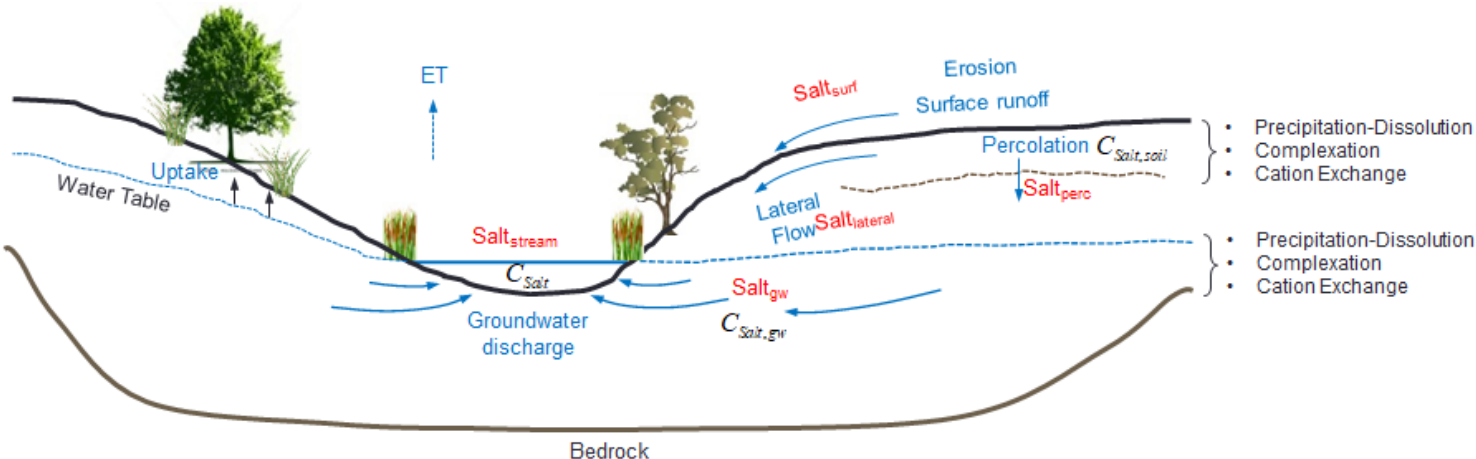
(Salt = SO_4 , Ca, Mg, Na, K, Cl, CO_3 , HCO_3)



Project Objectives

Upper Colorado River Basin - Salinity

- Develop physically-based model capable of simulating salt transport in rangeland watersheds (erosion, salt ion transport) **APEX-MODFLOW model**
- Test the model for several rangeland watersheds **Utah, Colorado**
- Determine effect of land use and climate on site vulnerability to soil erosion, salt transport, salt groundwater loading to streams **Scenarios**



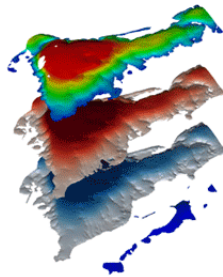
Model Development

Model Testing

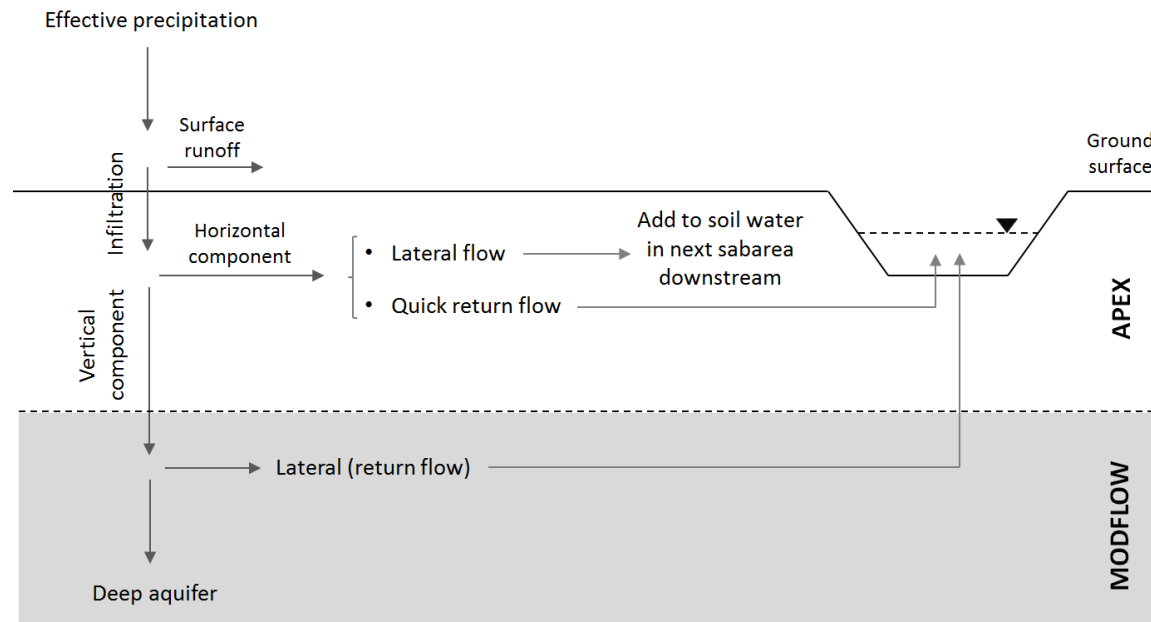
BMP Analysis

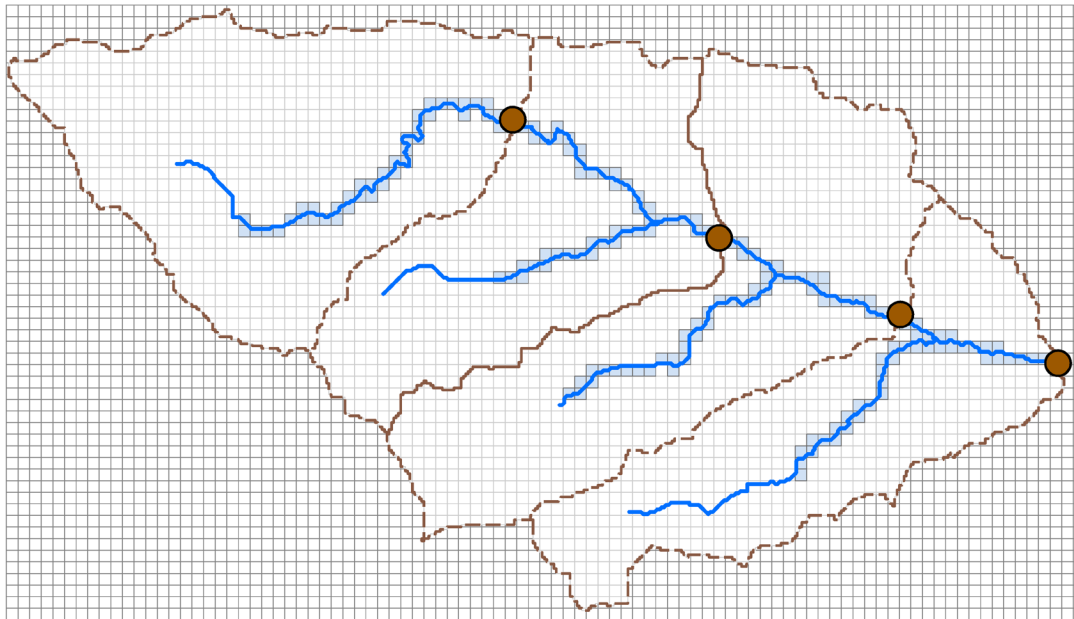


MODFLOW



- routes water, sediment, nutrients, and pesticides across landscapes and channel systems to the watershed outlet
- Divides the watershed into subareas
- Groundwater flow in heterogeneous 3D aquifer systems
- Accounts for all major inputs/output to groundwater (pumping, gw/sw interactions)





APEX subarea outlets



APEX streams



MODFLOW river grids



APEX subareas



MODFLOW grid



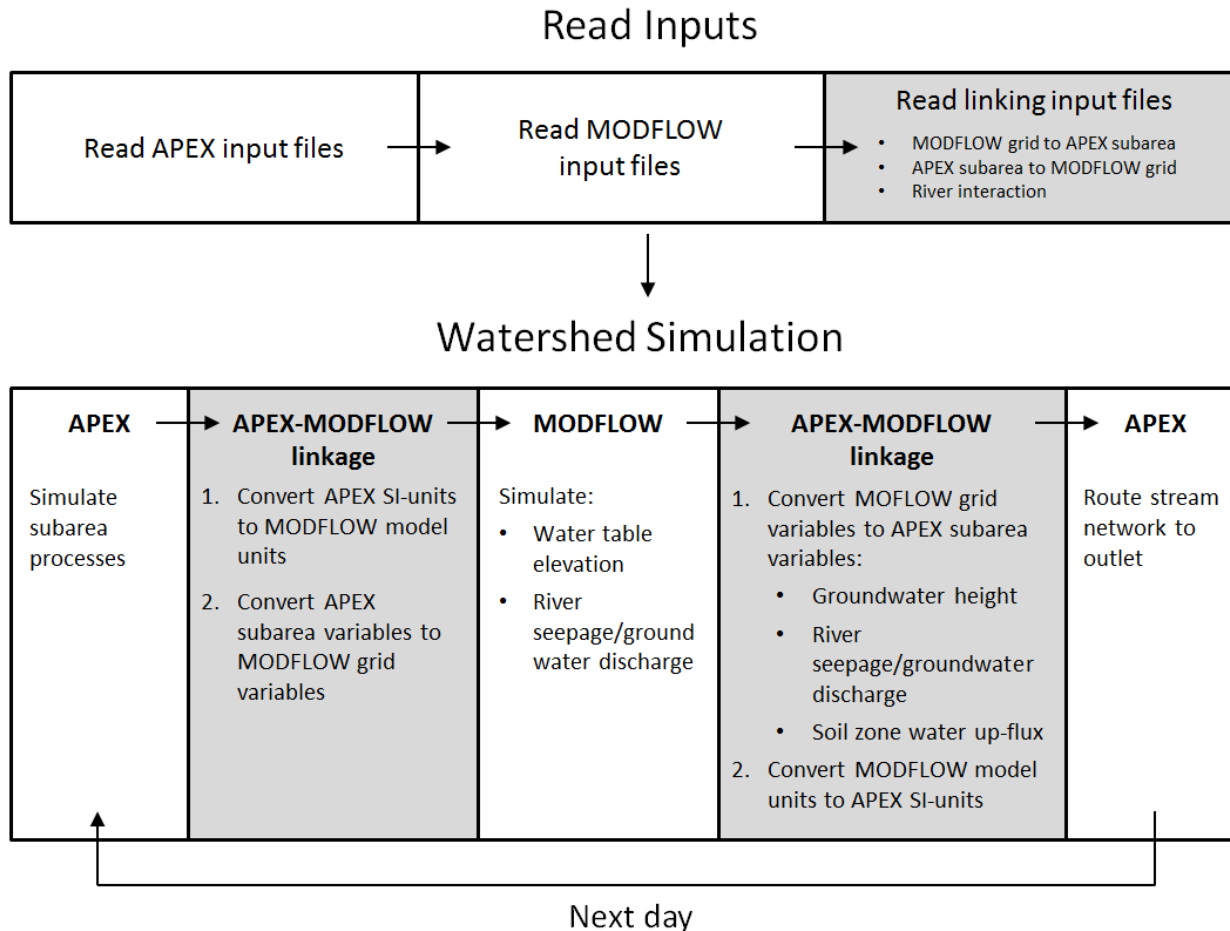
MODFLOW grids intersecting APEX subareas

- **Linkage:** Intersect the APEX subareas and MODFLOW grid cells, to be able to pass variables between the two models during the integrated model run.
- **Linkage files:** information on connection between APEX subareas and MODFLOW cells.

Model Development

Model Testing

BMP Analysis



amrt_main.f

**Read linkage
input files**

mapping APEX subareas to MODFLOW grids
mapping MODFLOW grids to APEX subareas
mapping APEX reaches to MODFLOW river cells

Call APEX (MAIN_APEX.f)

Run loop

Simulation loop (BSIM.f)

Annual loop

Daily loop

Command loop

Subarea loop (BSUB.f)

Compute daily infiltration (HPURK.f)

Convert to MODFLOW units

Pass the vertical component of infiltration to MODFLOW

End Subarea loop

MODFLOW performs water table calculations (water table)

MODFLOW simulates the return flow to APEX stream and deep percolation

Convert back to APEX units and pass to APEX

Route water through the stream network (ROUTE.f)

End command loop

Print outputs

End daily loop

End annual loop

End simulation loop

End run loop

End APEX

End amrt_main

The main code structure of APEX-MODFLOW

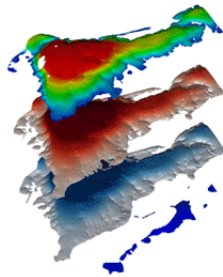
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Model Testing

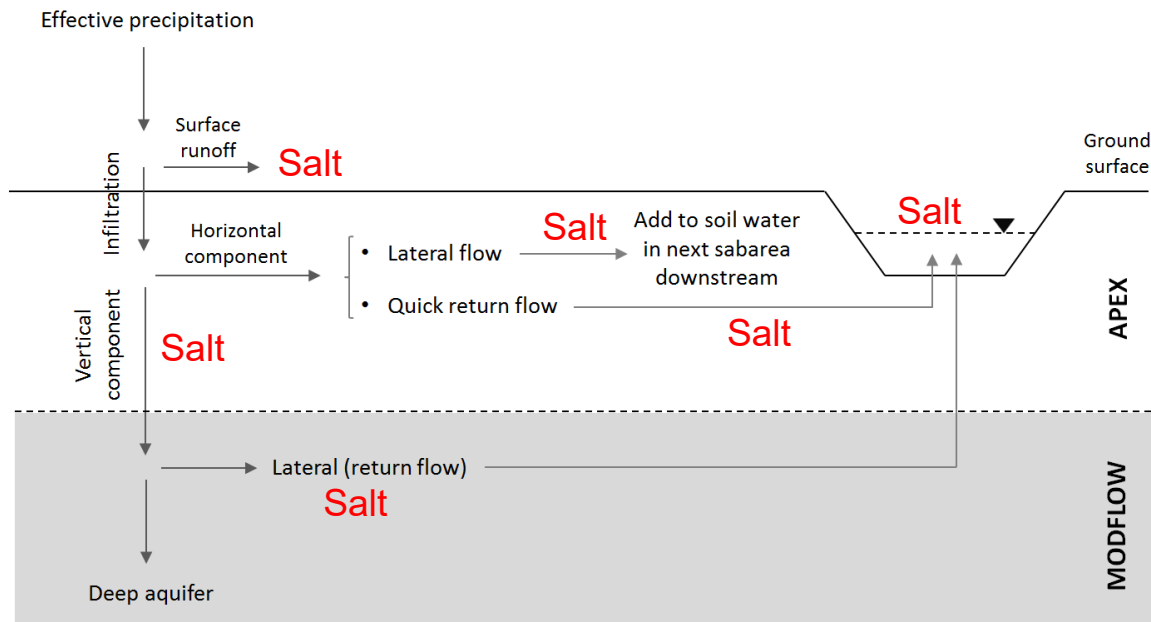
BMP Analysis



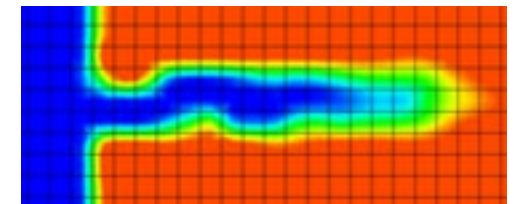
MODFLOW



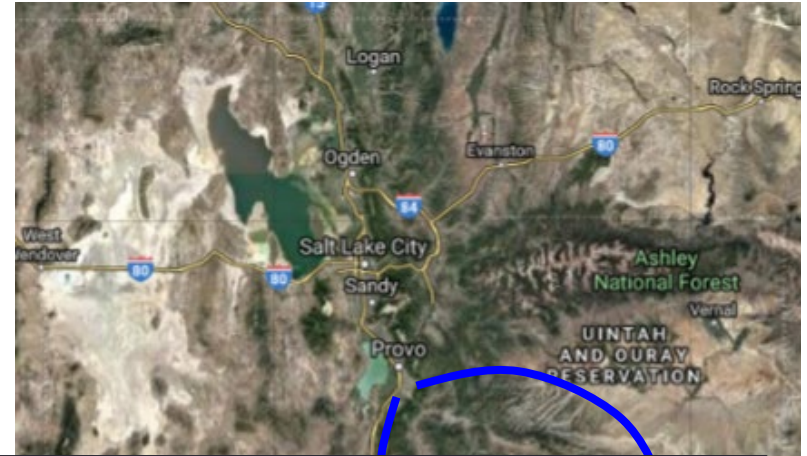
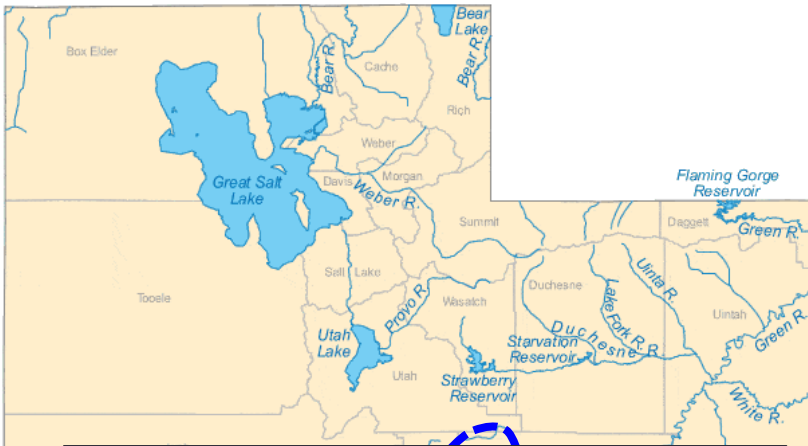
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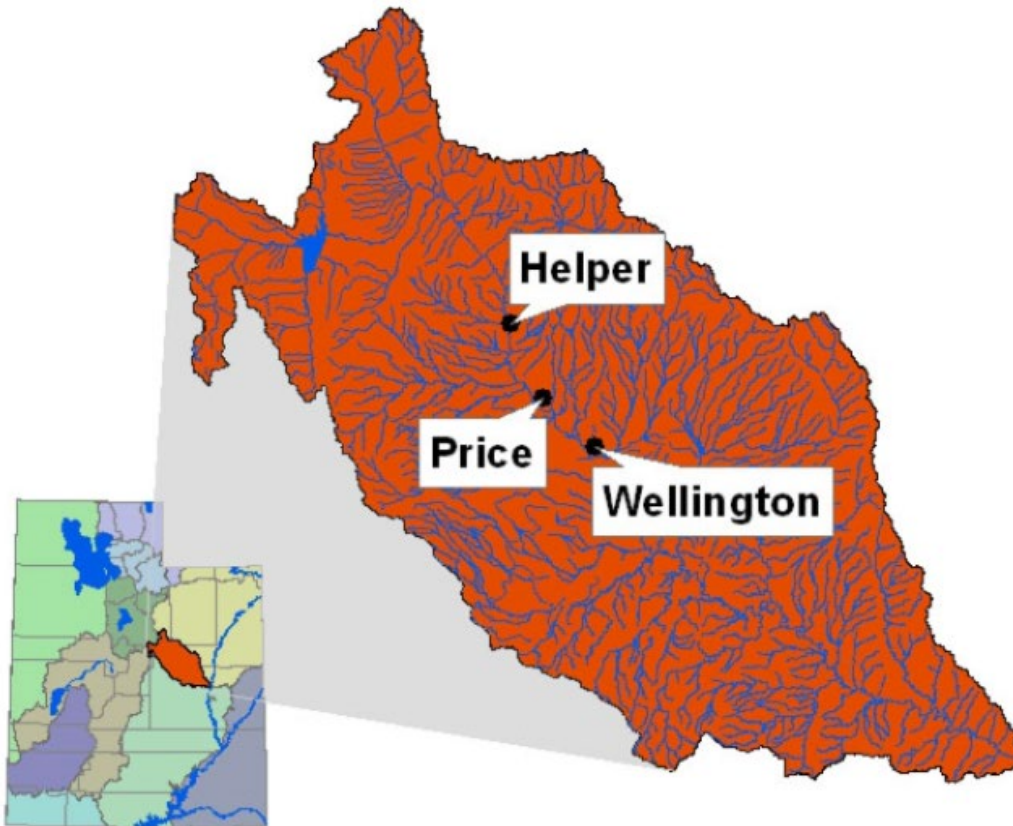
RT3D



Price River Watershed, Utah

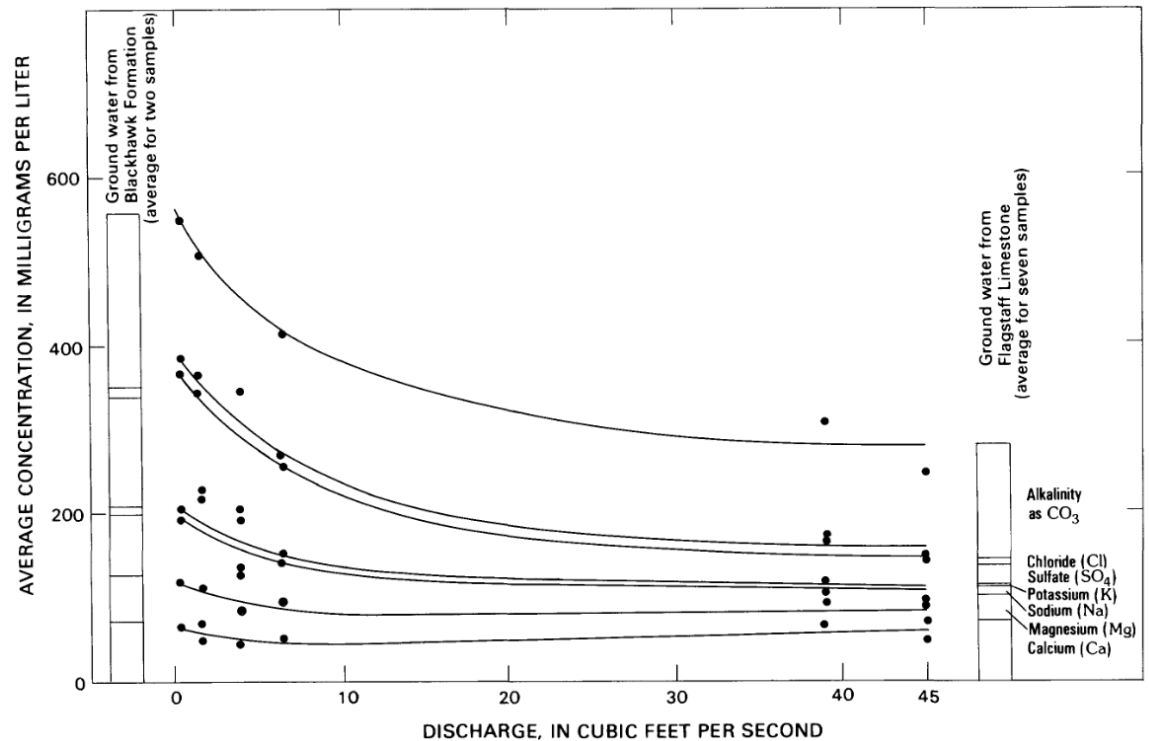
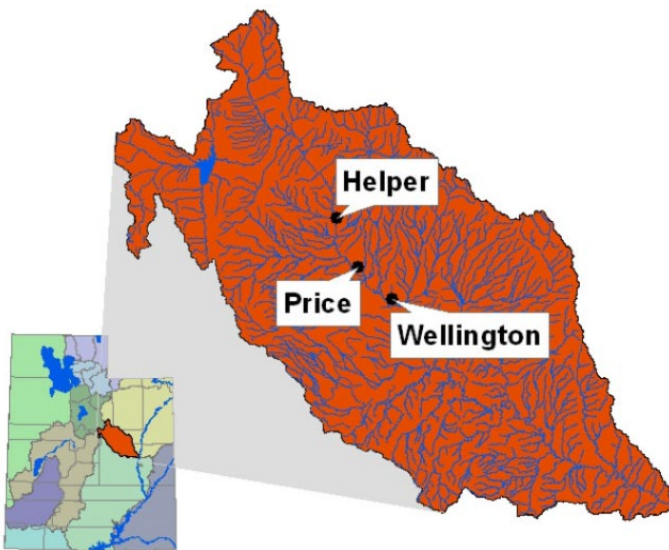


Price River Watershed, Utah

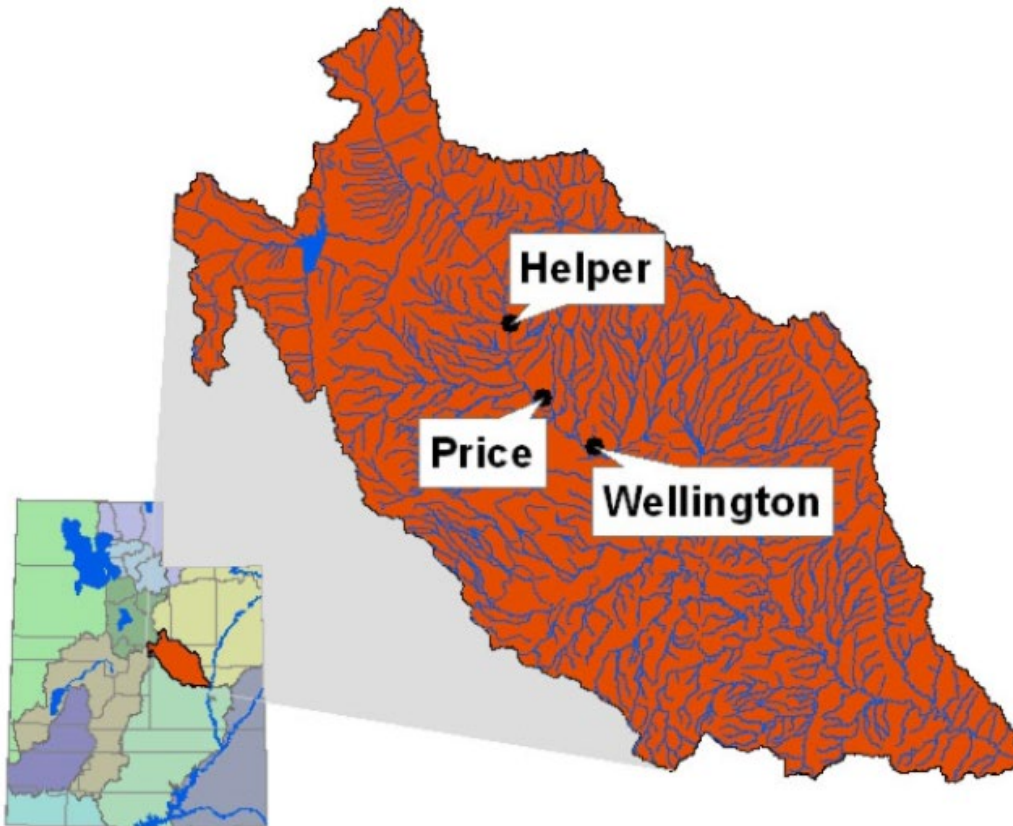


- 4,740 km² in east-central Utah.
- **Land use**
 - Shrubland (60%)
 - Forest (35%)
 - Others (5%)
- **Elevation** 1,409 - 3,182 m
- **Rainfall** 240-800 mm/yr
- Calcium (Ca), Magnesium (Mg), Sodium (Na), and bicarbonate (HCO₃) are principal salt ions contributing to salinity.

Price River Watershed, Utah



Price River Watershed, Utah



- Construct APEX model
- Construction MODFLOW model
- Create linked APEX-MODFLOW model
- Calibration and testing (hydrology, salt)
- Analyze vulnerability of sites within watershed to salt runoff, salt groundwater loading to [tributaries](#) and [Price River](#)

Thank you



Colorado
State
University



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