

Smoky Hill Ground-Water Model

Kansas Water Office Contract 07-136

**Lower Smoky Hill Water Resources
Informational Meeting
October 1, 2008**



**Brownie Wilson, Gaisheng Liu,
Don Whitemore, and Jim Butler**

**Geohydrology Section
Kansas Geological Survey**

What is a “Water” Model?

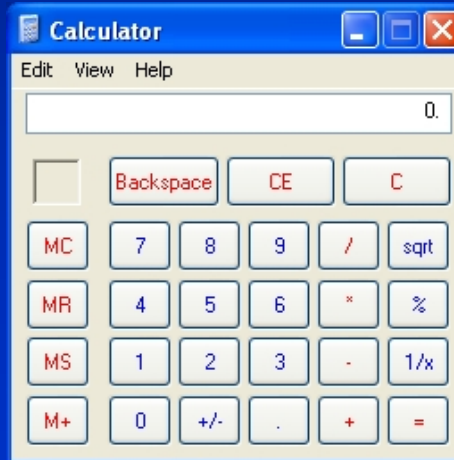
A group of water rules (e.g., water flows downhill) in the form of mathematical equations that portrays the natural environment.

In short - a water calculator.

Traditional Math

$$(2 \times 3) - 1$$

$$= 5$$



Water Model

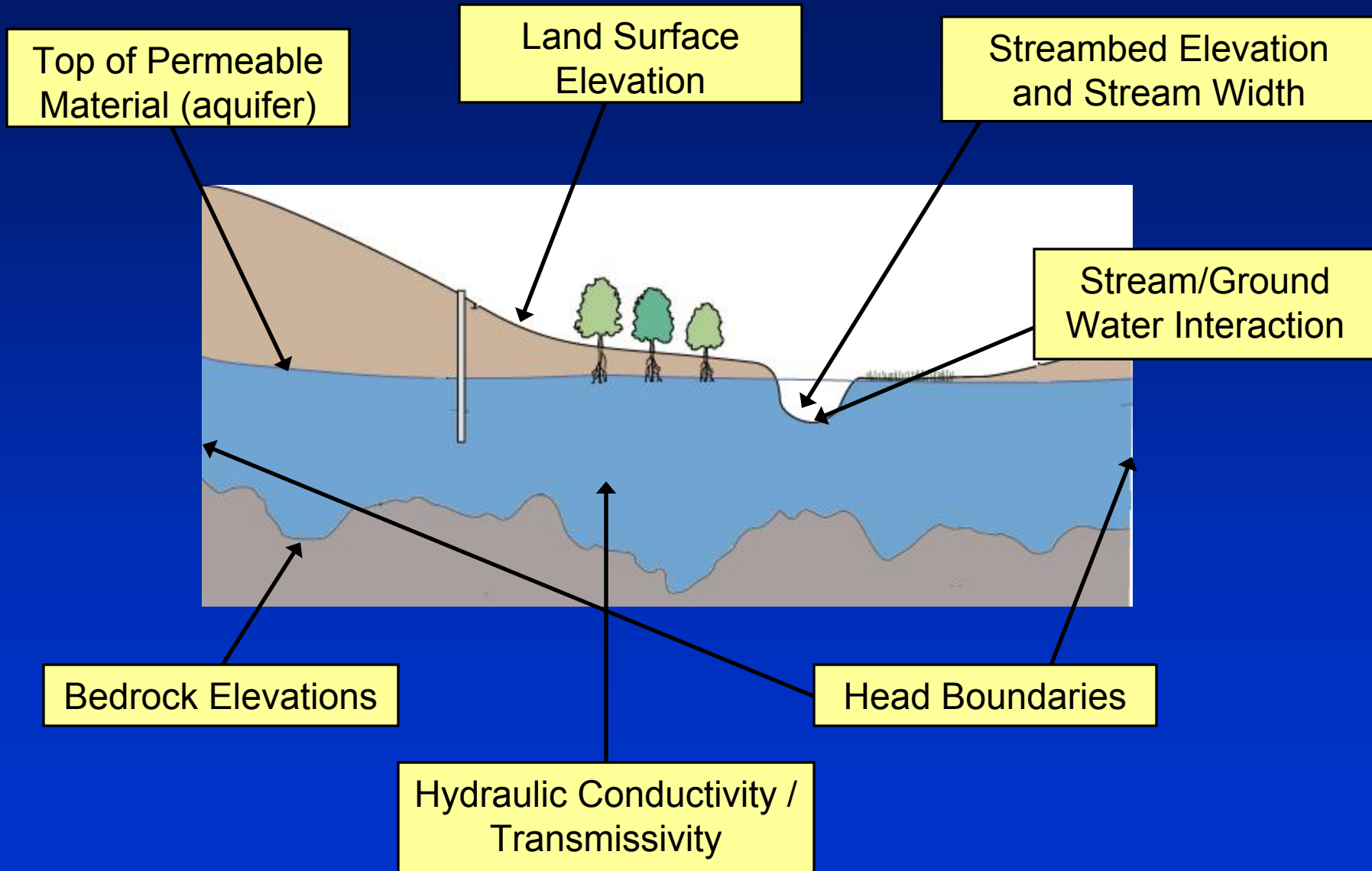
**Inflow (recharge) –
Outflow (pumping)**

**= Water-Level
Elevation**

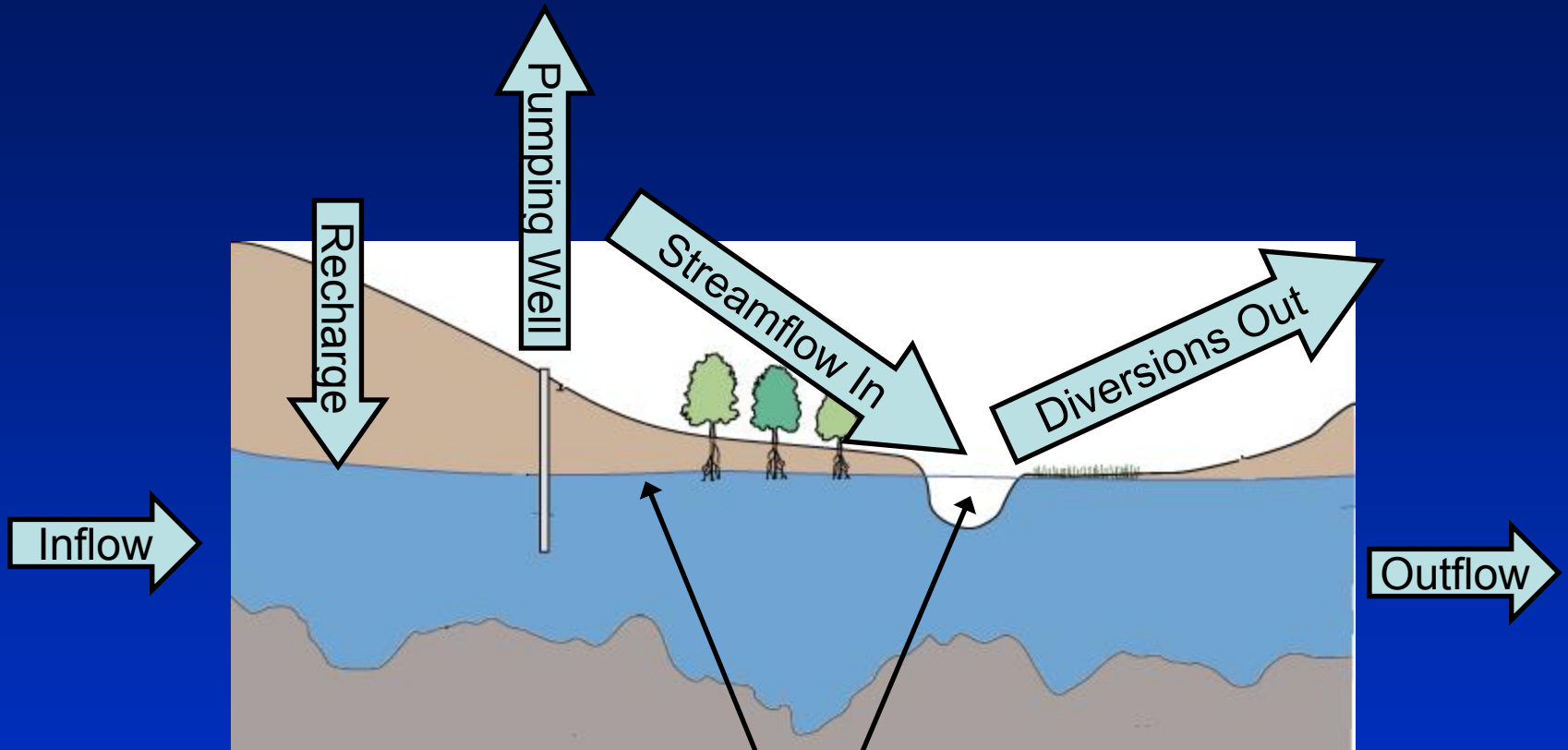
Creating a Water Model

- Establish unique rules and conditions that apply specifically to the study area
- Developed to answer specific questions/issues
- Study area is generally subdivided into cells
 - Focus of computations
 - Data intensive
- Required information can be very complex and detailed
- Some parameters can be gross assumptions with inherent levels of uncertainty = “Calibration”
- What goes in is what comes out

Creating a Water Model- An Example



Running a Water Model- An Example



Model Computations

- Water Table Elevations
- Streamflow

Final general thoughts on models

- **Water models are powerful tools for management and planning activities**
- **Expensive and time consuming to create**
- **Models are a representation of reality**
- **Kansas is very data rich in terms of hydrologic information**
- **Smoky Hill River Model**
 - **Simulates streamflow and water-level conditions**
 - **Will be used to run “What If...” scenarios**

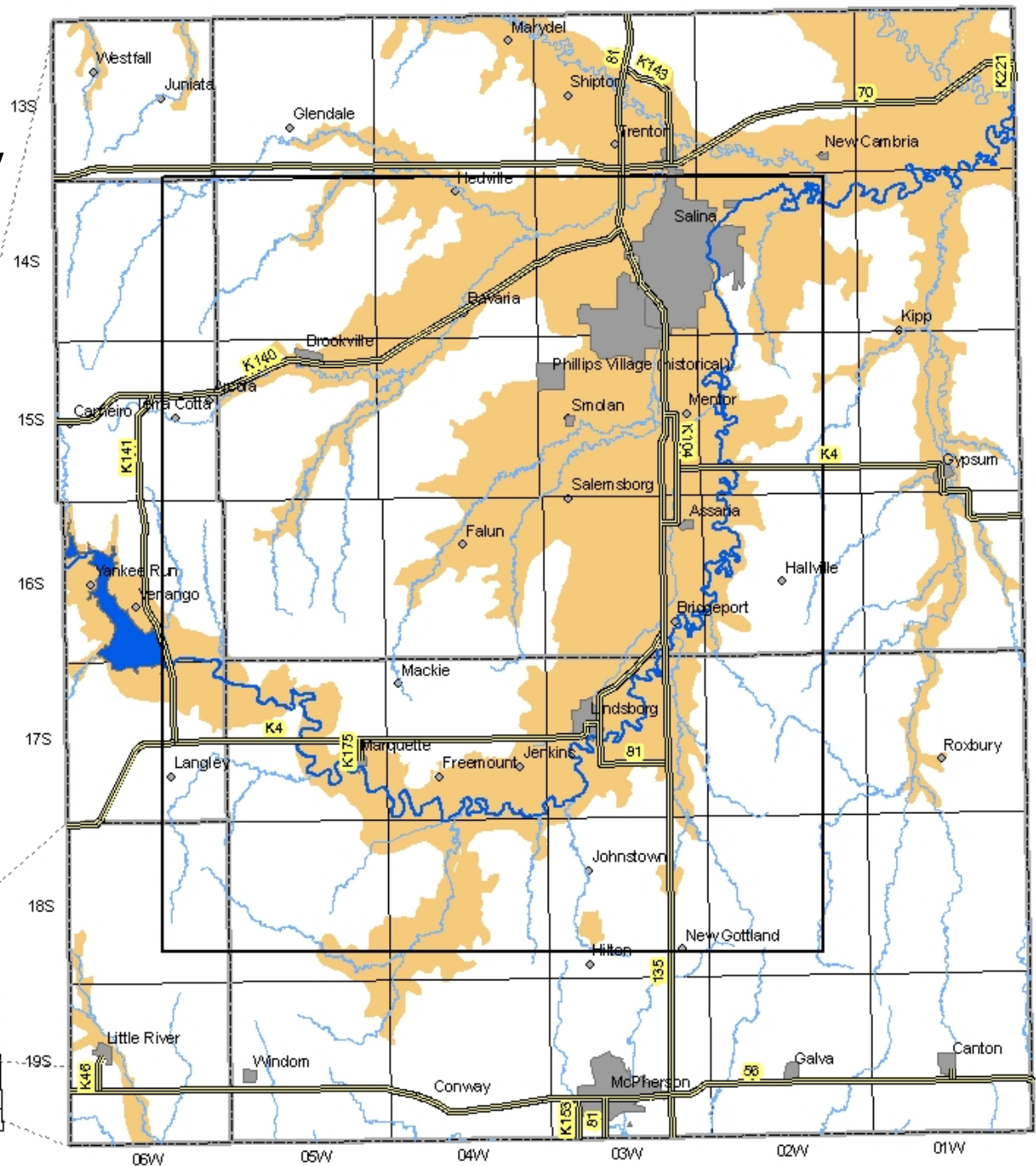
Smoky Hill Ground-Water Model

Model Purpose and Design

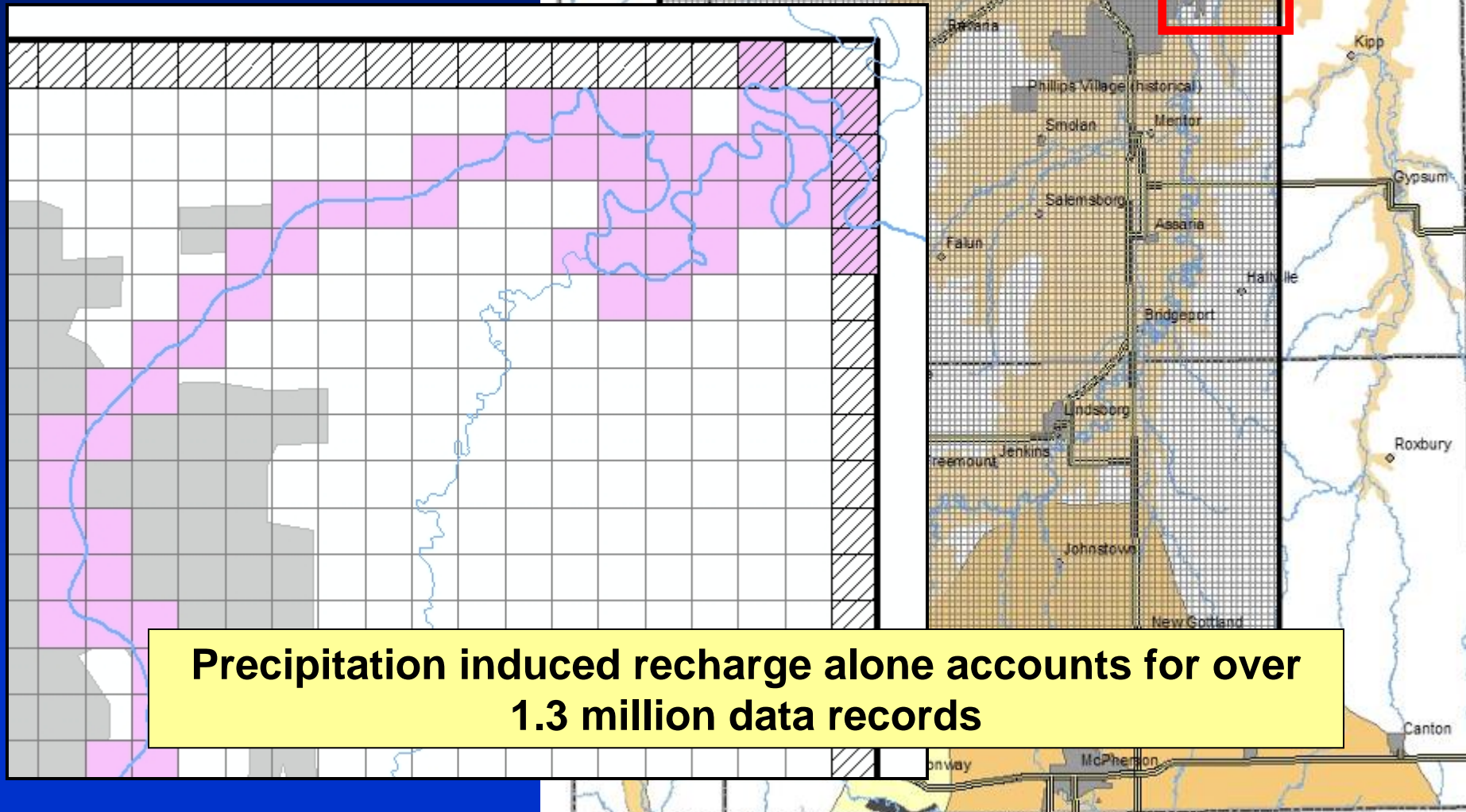
Smoky Hill Ground-Water Model

- **Funded by the Kansas Water Office**
- **Component of larger, regional water supply study**
- **Objective is to understand stream-aquifer interactions by simulating:**
 - **Streamflow in the Smoky Hill River**
 - **Ground-water levels in the alluvial aquifer**
- **Adaptation of MODFLOW**
 - **Kanopolis Reservoir to confluence of Smoky Hill and Saline Rivers (east of Salina)**
 - **Predevelopment (1944-1947) to 2006**
 - **Six month time steps**
 - **Growing Season (apr to sep)**
 - **Winter (oct to mar)**

Smoky Hill River Valley



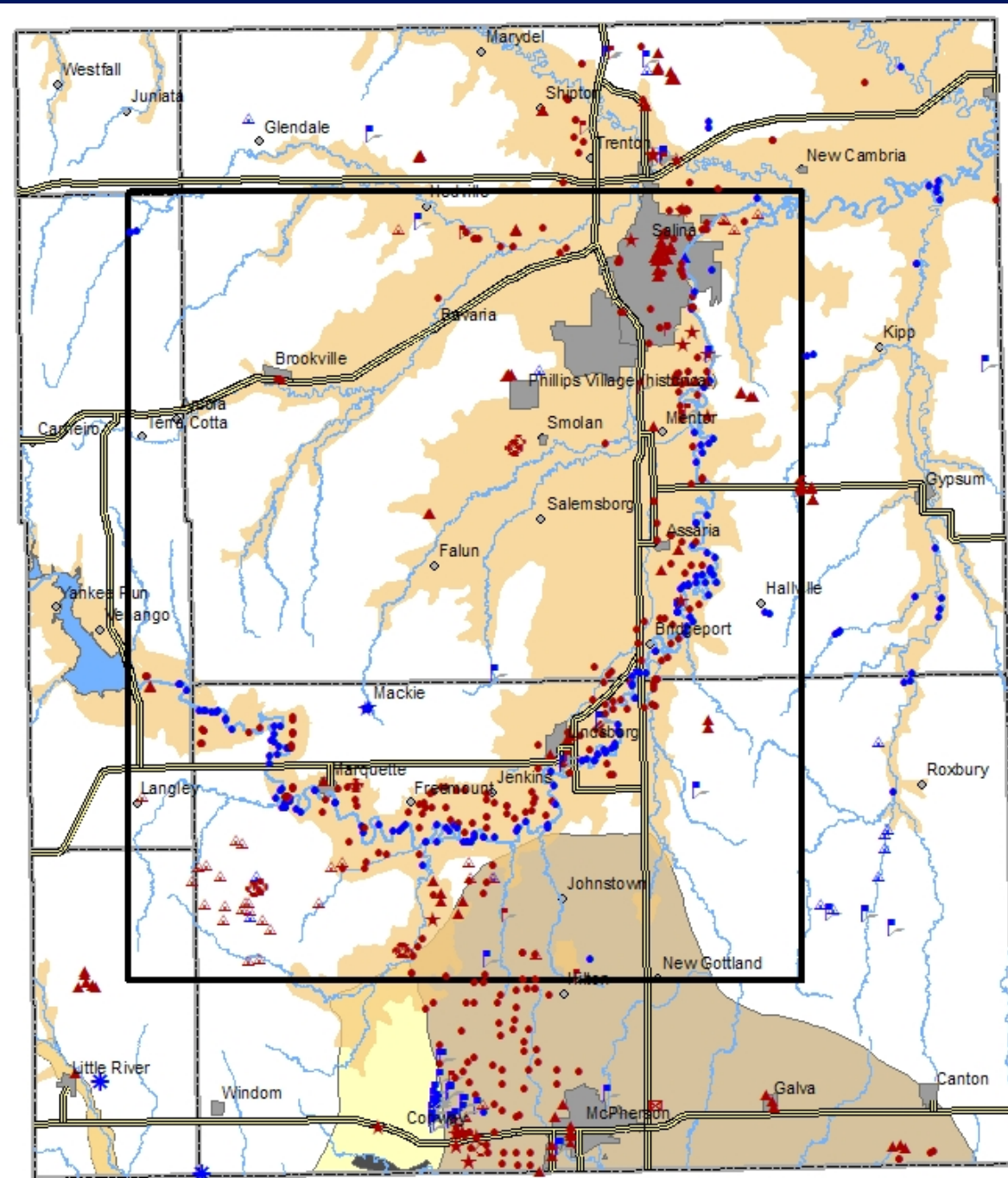
Smoky Hill River Valley Model Area



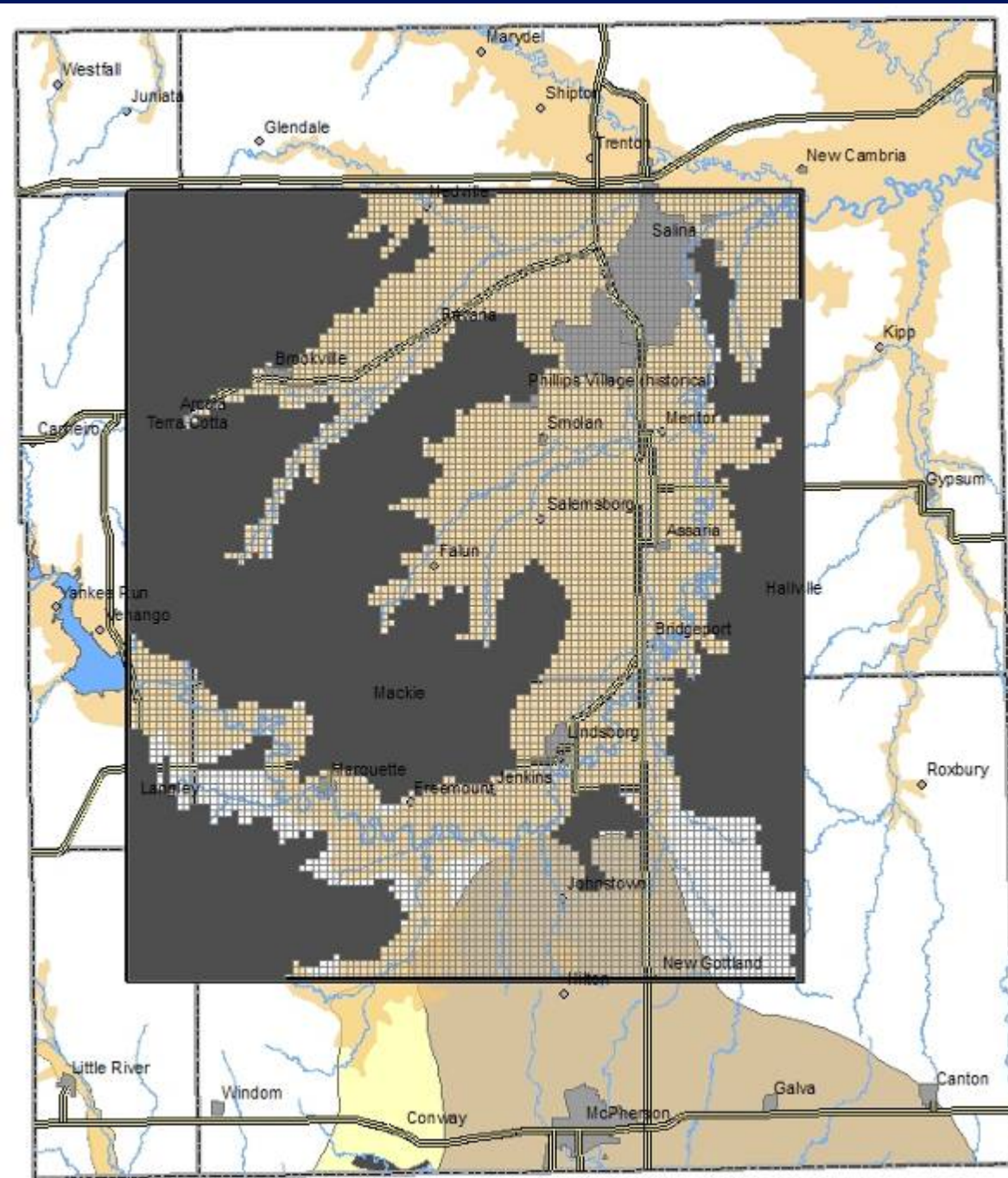
Precipitation induced recharge alone accounts for over 1.3 million data records

Smoky Hill Valley Water Rights and Aquifer Resources

☒	G_DEW
△	G_DOM
★	G_IND
●	G_IRR
▲	G_MUN
▤	G_REC
⊙	G_STK
⚡	G_THX
△	S_DOM
★	S_IND
●	S_IRR
▲	S_MUN
▤	S_REC
✳	S_SED

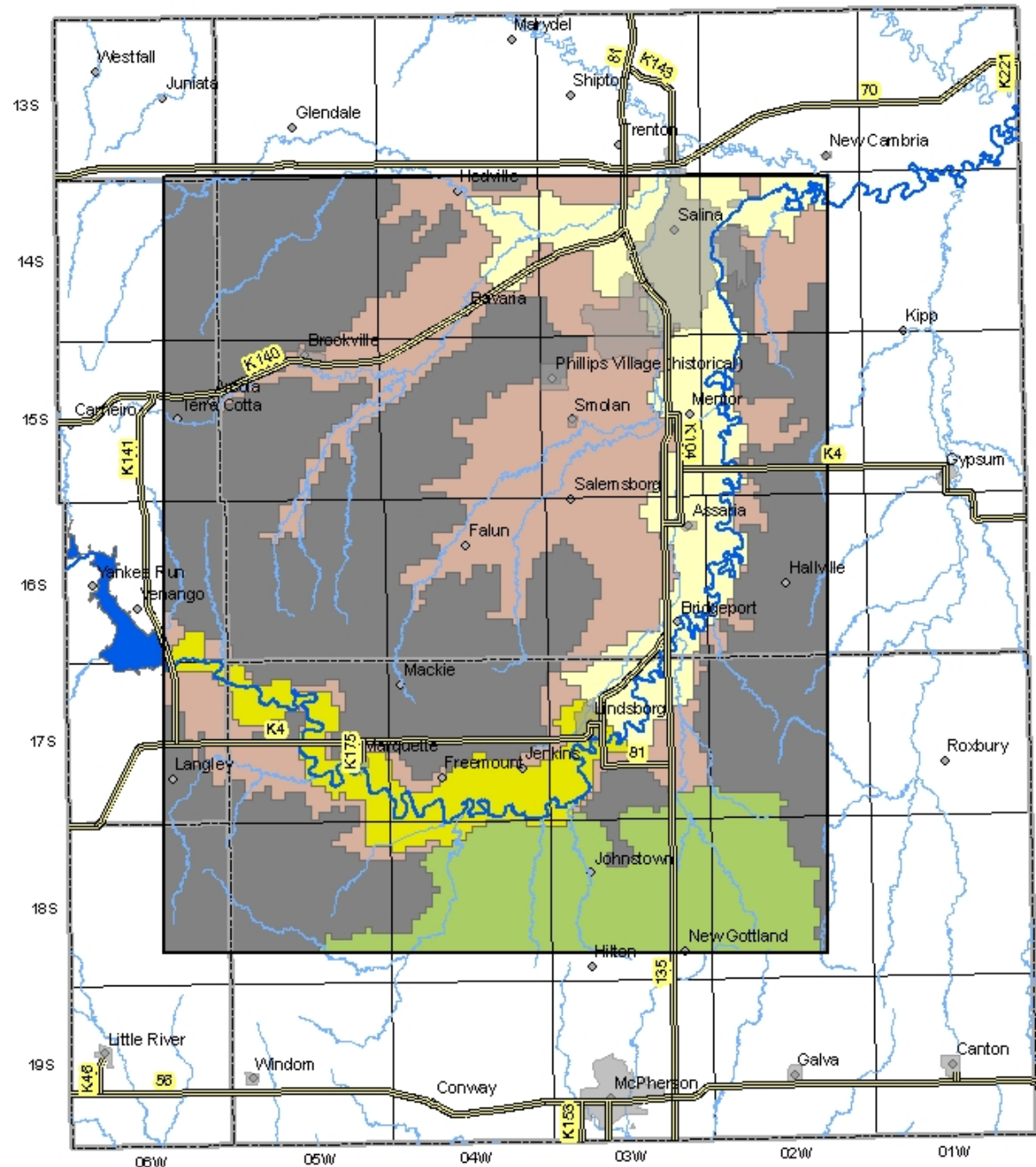


Smoky Hill Valley Active Area



Smoky Hill Valley Model Zones

- 4 Zones
- Assists in calibration

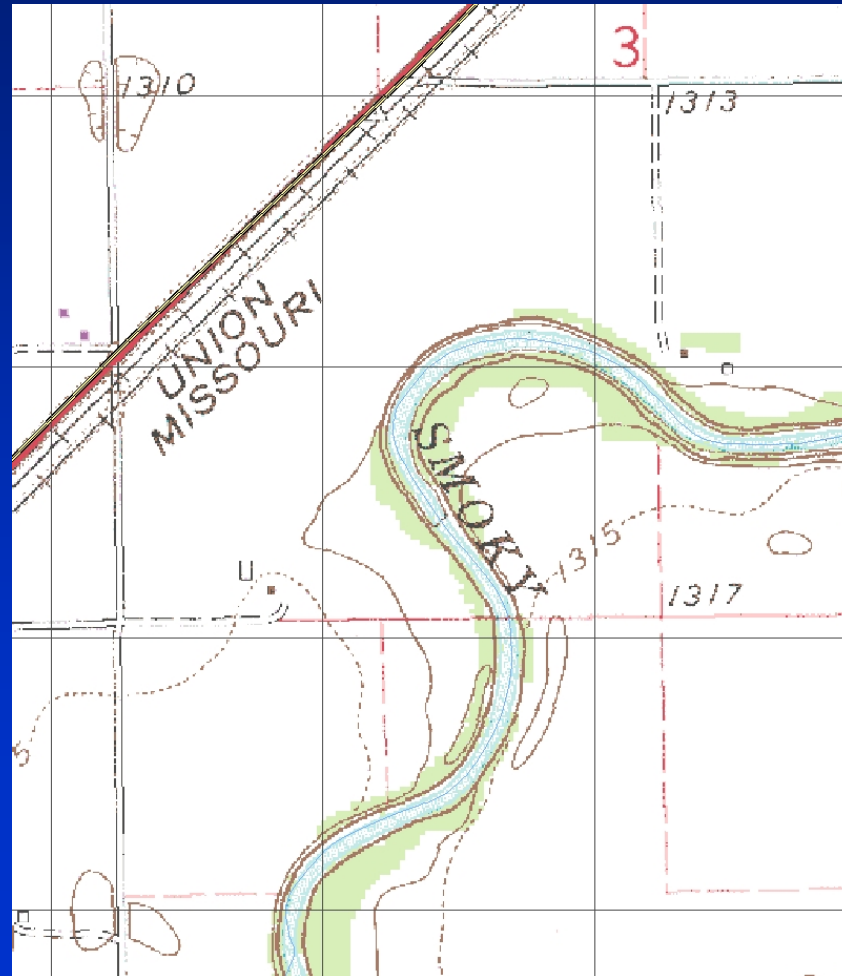


Smoky Hill Ground-Water Model

Stream Properties

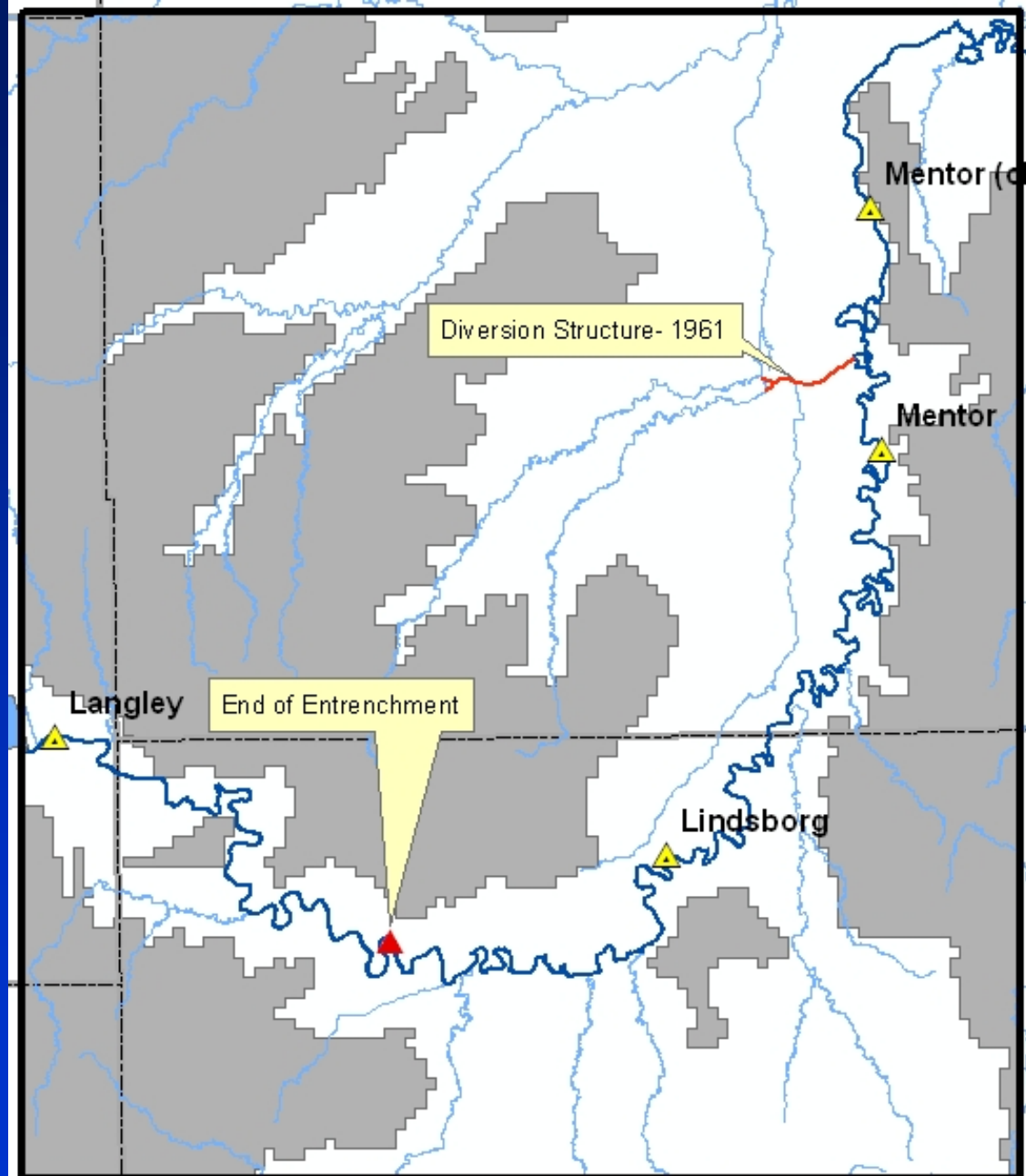
Streambed Elevations

- Streambed elevations from 1:24000 scale topographic maps
- Assigned to overlying model cells for the Smoky Hill River



Entrenchment of Smoky Hill River and Diversion Structure

Period	Adjustment	Notes
1943-1947	+3.6	Predevelopment
1948-1952	+2.0	
1953-1965	0	Period covering topographic maps
1965-2006	-1.7	
2007+	-2.7	Future scenarios



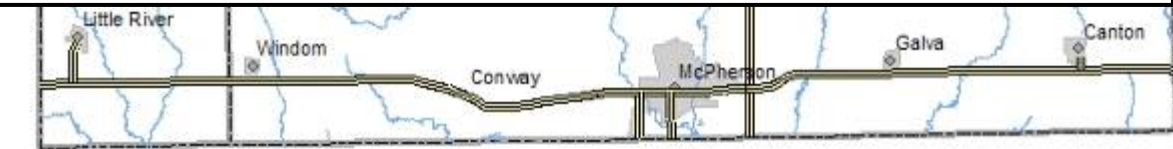
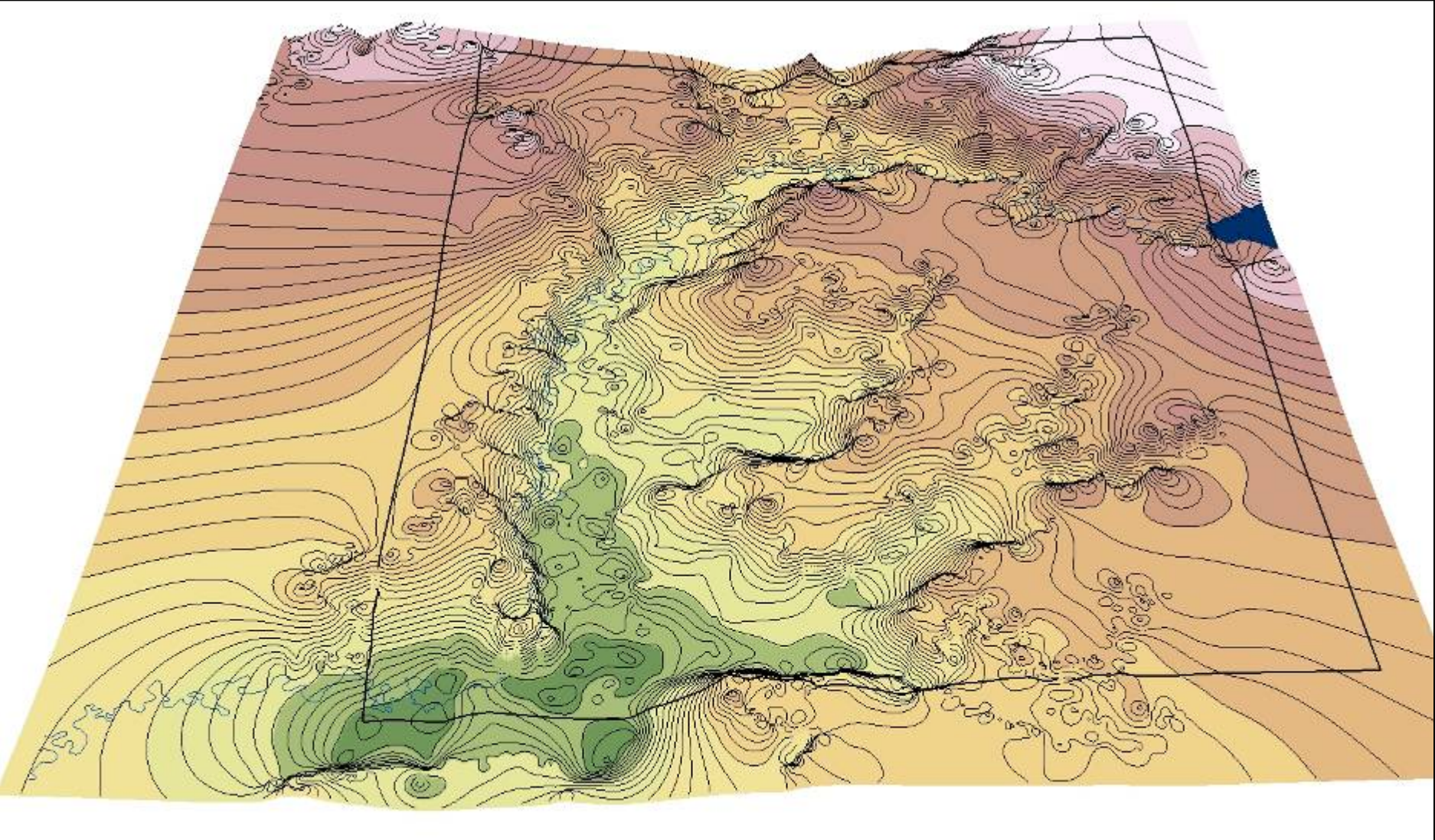
Smoky Hill Ground-Water Model

Aquifer Properties

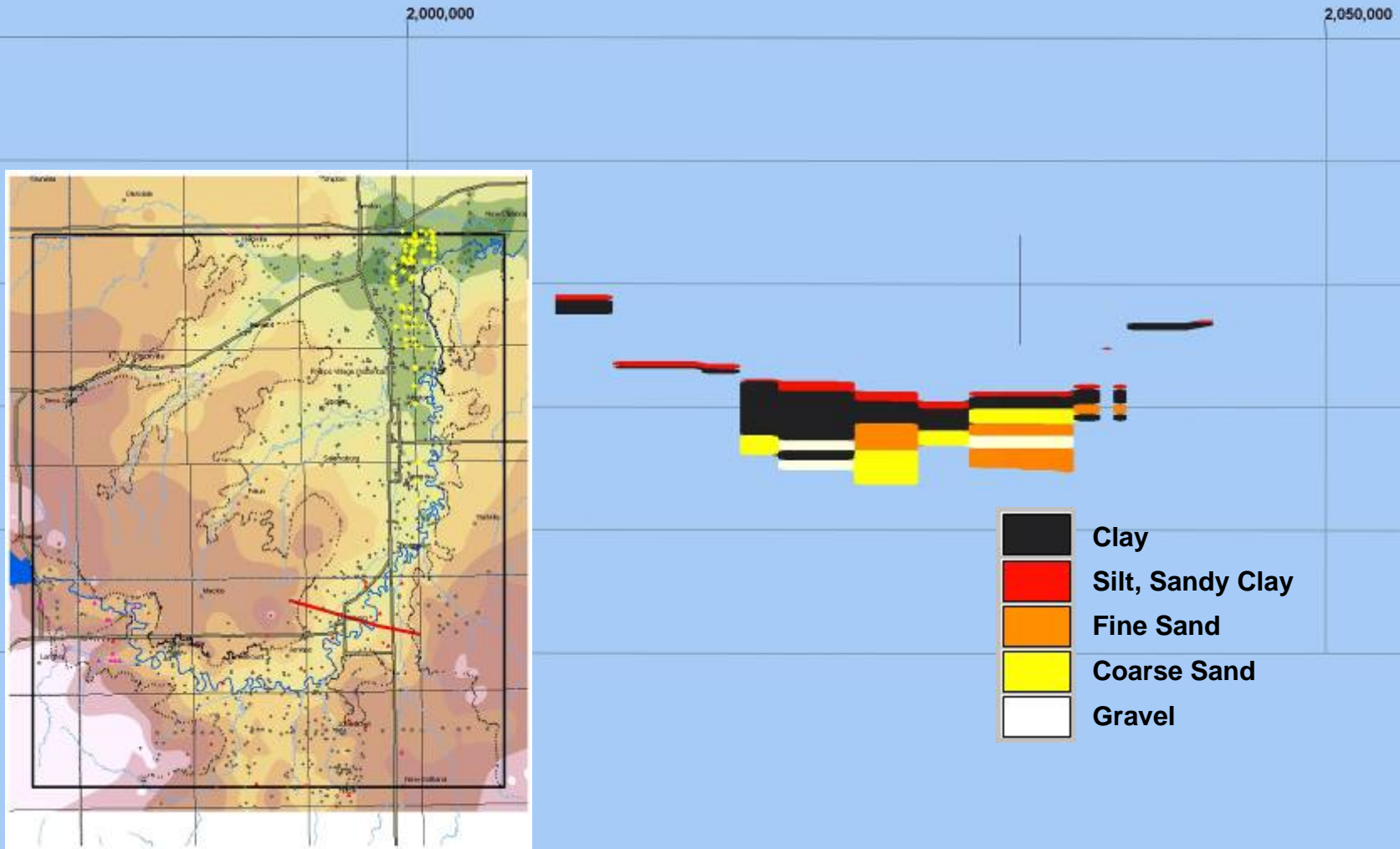
Smoky Hill Valley WWC5 Form

1 LOCATION OF WATER WELL:		WATER WELL RECORD	Form WWC-5	KSA 82a-1212	ID No.
County: <u>Saline</u>	near <u>1/4 center</u> <u>SW</u> <u>1/4</u>	Section Number	16	Township Number	T 13 S R 3 W
Distance and direction from nearest town or city street address of well if located within city? <u>3 miles West & 3 miles North of Salina KS</u>					
2 WATER WELL OWNER: <u>Allan Smith</u>		Board of Agriculture, Division of Water Resources			
RR#, St. Address, Box #: <u>750 Fairdale Rd.</u>		Application Number: <u>44,666</u>			
City, State, ZIP Code: <u>Salina, KS</u>					
3 LOCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX:		4 DEPTH OF COMPLETED WELL: <u>72</u> ft. ELEVATION:			
		Depth(s) Groundwater Encountered 1. _____ ft. 2. _____ ft. 3. _____ ft. WELL'S STATIC WATER LEVEL <u>21</u> ft. below land surface measured on <u>3/29/02</u> Pump test data: Well water was <u>47</u> ft. after <u>1</u> hours pumping <u>700</u> gpm Est. Yield <u>850</u> gpm: Well water was <u>54</u> ft. after _____ hours pumping <u>825</u> gpm Bore Hole Diameter: <u>30</u> in. to <u>72</u> ft., and _____ in. to _____ ft.			
WELL WATER TO BE USED AS:		5 Public water supply 8 Air conditioning 11 Injection well 1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below) <input checked="" type="checkbox"/> Irrigation 4 Industrial 7 Domestic (lawn & garden) 10 Monitoring well			
5 TYPE OF BLANK CASING USED:		Was a chemical/bacteriological sample submitted to Department? Yes _____ No <input checked="" type="checkbox"/> If yes, mo/day/yr sample was submitted _____			
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) <input checked="" type="checkbox"/> PVC 4 ABS 7 Fiberglass		5 Wrought iron 8 Concrete tile CASING JOINTS: Glued <input checked="" type="checkbox"/> Clamped _____ Welded _____ Threaded _____			
Blank casing diameter: <u>16</u> in. to <u>32</u> in. Dia.		Casing height above land surface: <u>12</u> in. weight: <u>16, 15</u> lbs./ft. Wall thickness or gauge No. <u>500</u>			
TYPE OF SCREEN OR PERFORATION MATERIAL:		1 Steel 3 Stainless steel 5 Fiberglass <input checked="" type="checkbox"/> PVC 10 Asbestos-cement 2 Brass 4 Galvanized steel 6 Concrete tile 8 RMP (SR) 11 Other (specify) _____ 9 ABS 12 None used (open hole)			
SCREEN OR PERFORATION OPENINGS ARE:		1 Continuous slot <input checked="" type="checkbox"/> <u>3/8" slot</u> 5 Gauzed wrapped 8 Saw cut 11 None (open hole) 2 Louvered shutter 4 Key punched 6 Wire wrapped 9 Drilled holes 7 Torch cut 10 Other (specify) _____			
SCREEN-PERFORATED INTERVALS:		From: <u>32</u> ft. to <u>72</u> ft. From _____ ft. to _____ ft. From _____ ft. to _____ ft. From _____ ft. to _____ ft.			
GRAVEL PACK INTERVALS:		From: <u>20</u> ft. to <u>72</u> ft. From _____ ft. to _____ ft. From _____ ft. to _____ ft. From _____ ft. to _____ ft.			
6 GROUT MATERIAL:		1 Neat cement <input checked="" type="checkbox"/> Cement grout 3 Bentonite 4 Other _____ Grout intervals: From: <u>0</u> ft. to <u>20</u> ft. From _____ ft. to _____ ft. From _____ ft. to _____ ft.			
What is the nearest source of possible contamination: <u>None within 1/4 mile</u>		10 Livestock pens 14 Abandoned water well 1 Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well 2 Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage 16 Other (specify below) _____ 3 Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage			
Direction from well? _____		How many feet? _____			
FROM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	4	Topsoil			
4	10	Clay, brown			
10	32	Clay, silty, brown			
32	46	Clay, gray			
46	69	Sand, medium to coarse with gravel			
69	72	Shale, gray			
7 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was <u>00</u> constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (mo/day/year) <u>3/29/02</u> and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. <u>138</u> . This Water Well Record was completed on (mo/day/yr) <u>4/1/02</u> under the business name of <u>Peterson Irrigation, Inc.</u> by (signature) <u>Mike Peterson</u>					
INSTRUCTIONS: Use typewriter or ball point pen. PLEASE PRINT NAME and PRINT clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone 785-296-5524. Send one to WATER WELL OWNER and retain one for your records. Fee of \$5.00 for each <u>02132009</u> well.					

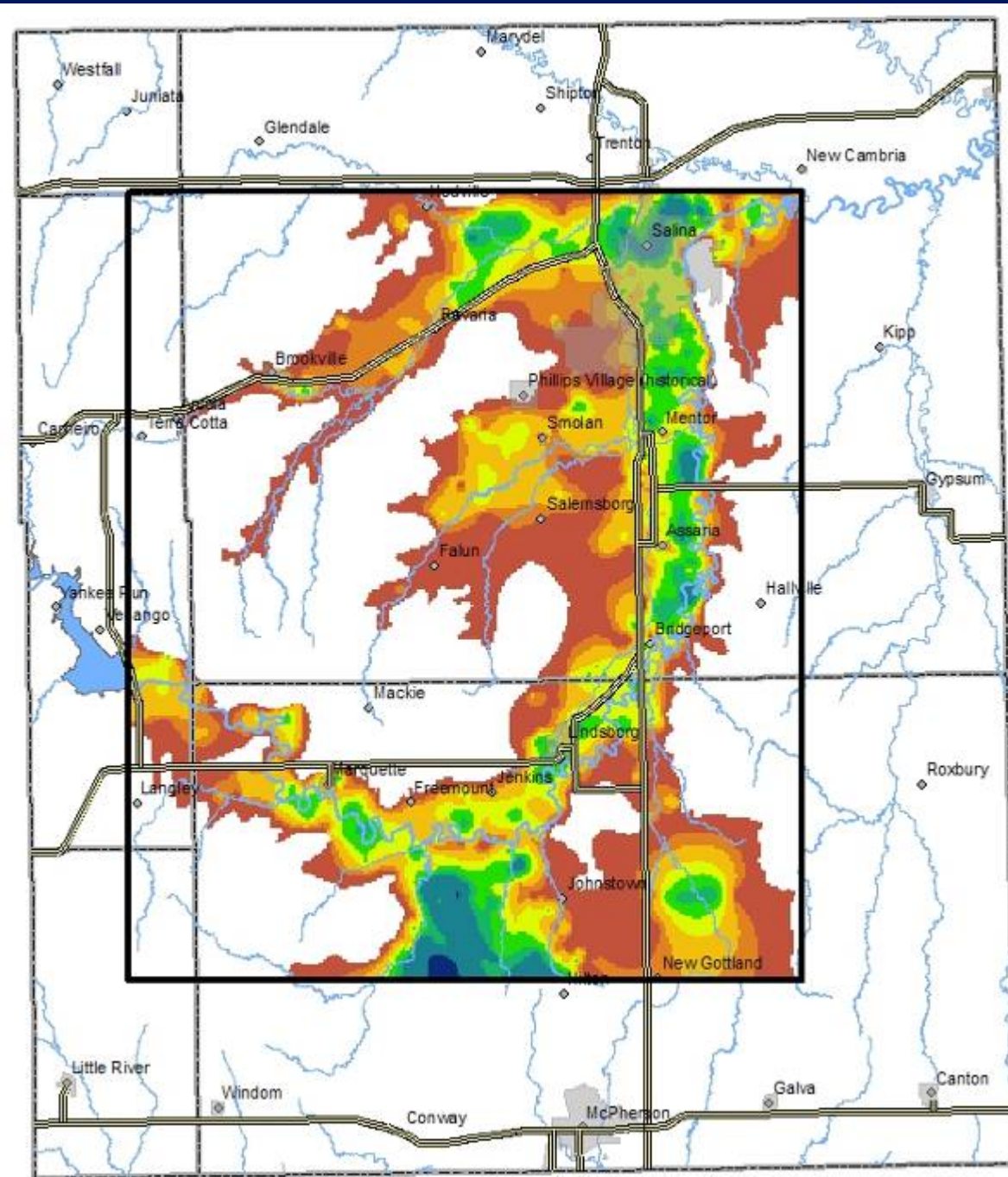
Smoky Hill



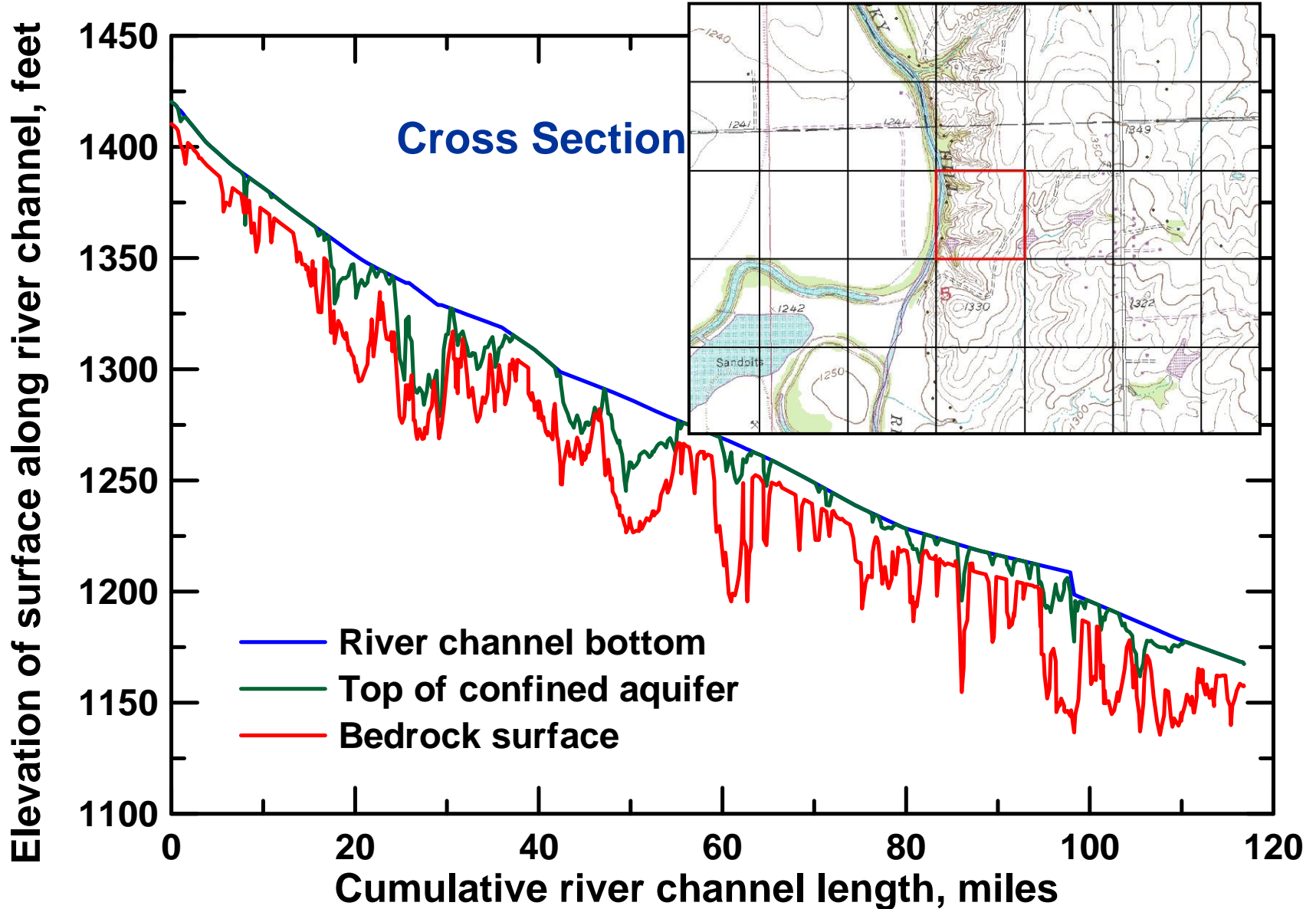
Smoky Hill Valley Lithologic Cross-section



Smoky Hill Valley Permeable Thickness



Smoky Hill River Cross Section Adjustments

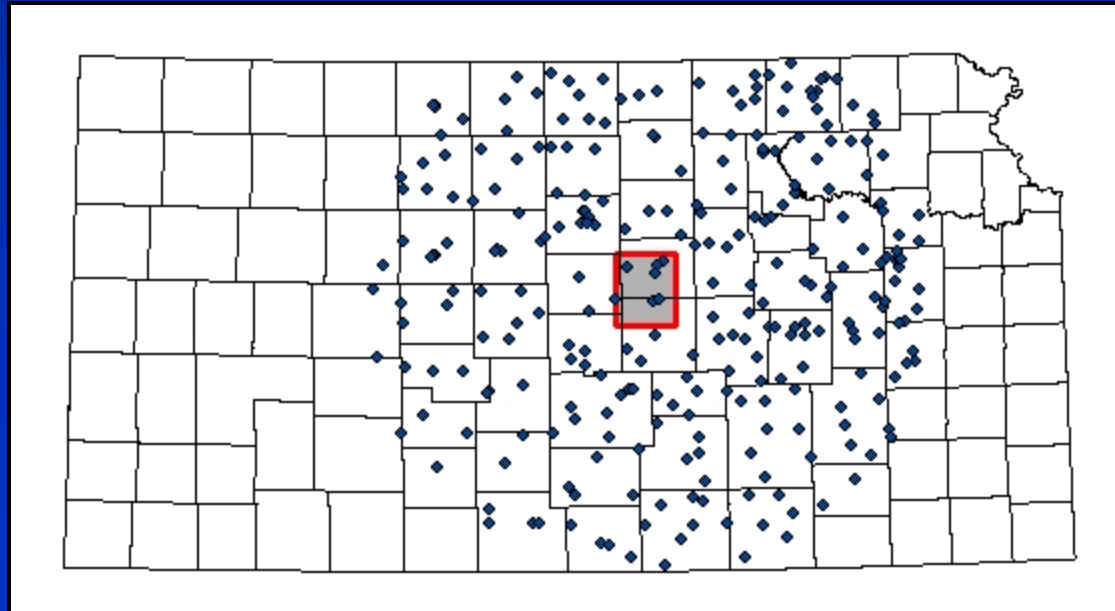


Smoky Hill Ground-Water Model

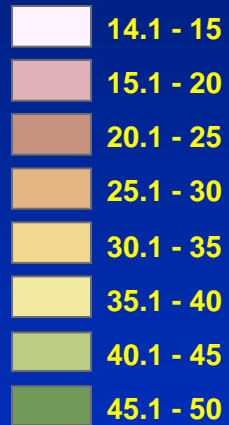
Dynamic Variables

Precipitation

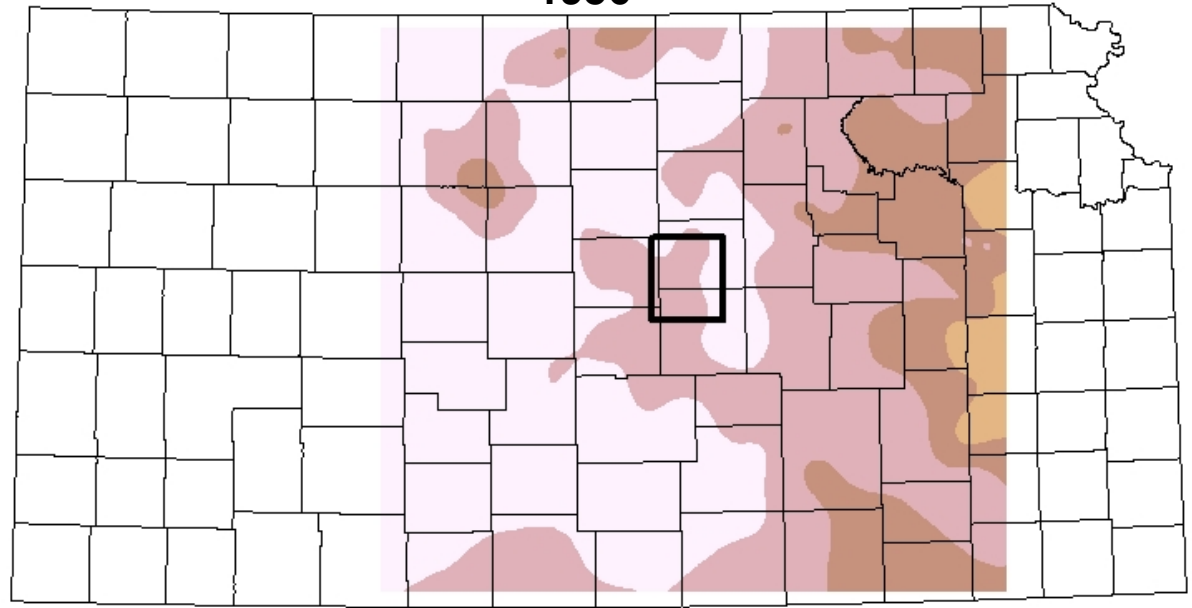
- Monthly precipitation data from 1944 to 2006
- Obtained from the National Climatic Data Center (NCDC)
- Data processed and totaled to Seasonal (Apr to Sep) and Annual values
- Interpolated across model area and assigned to model cells by year and season



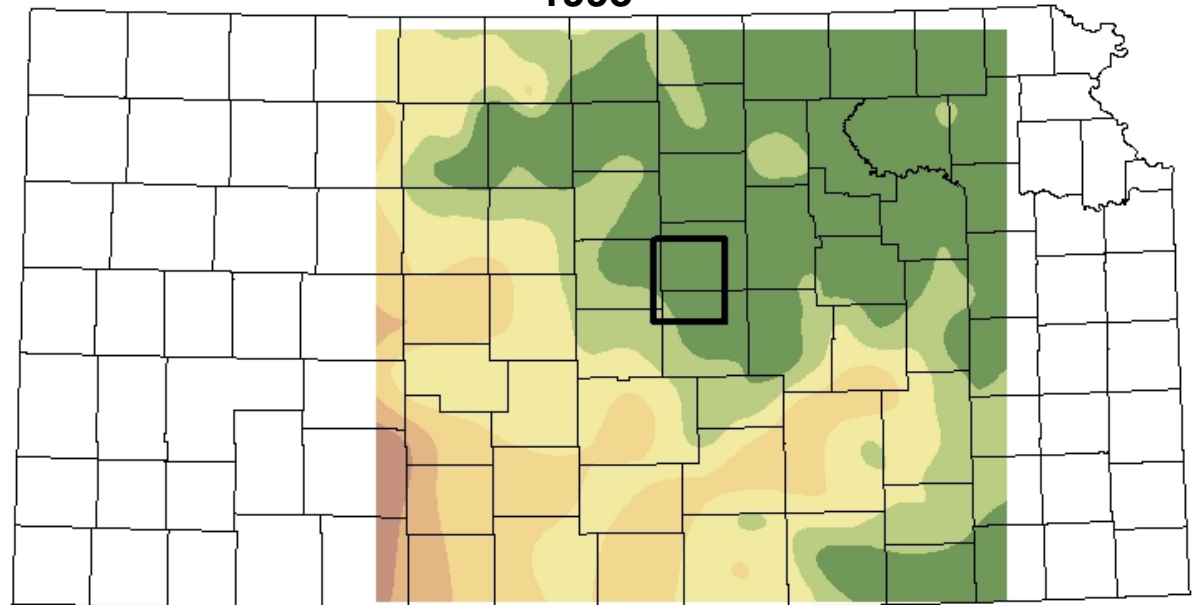
Interpolated Precipitation



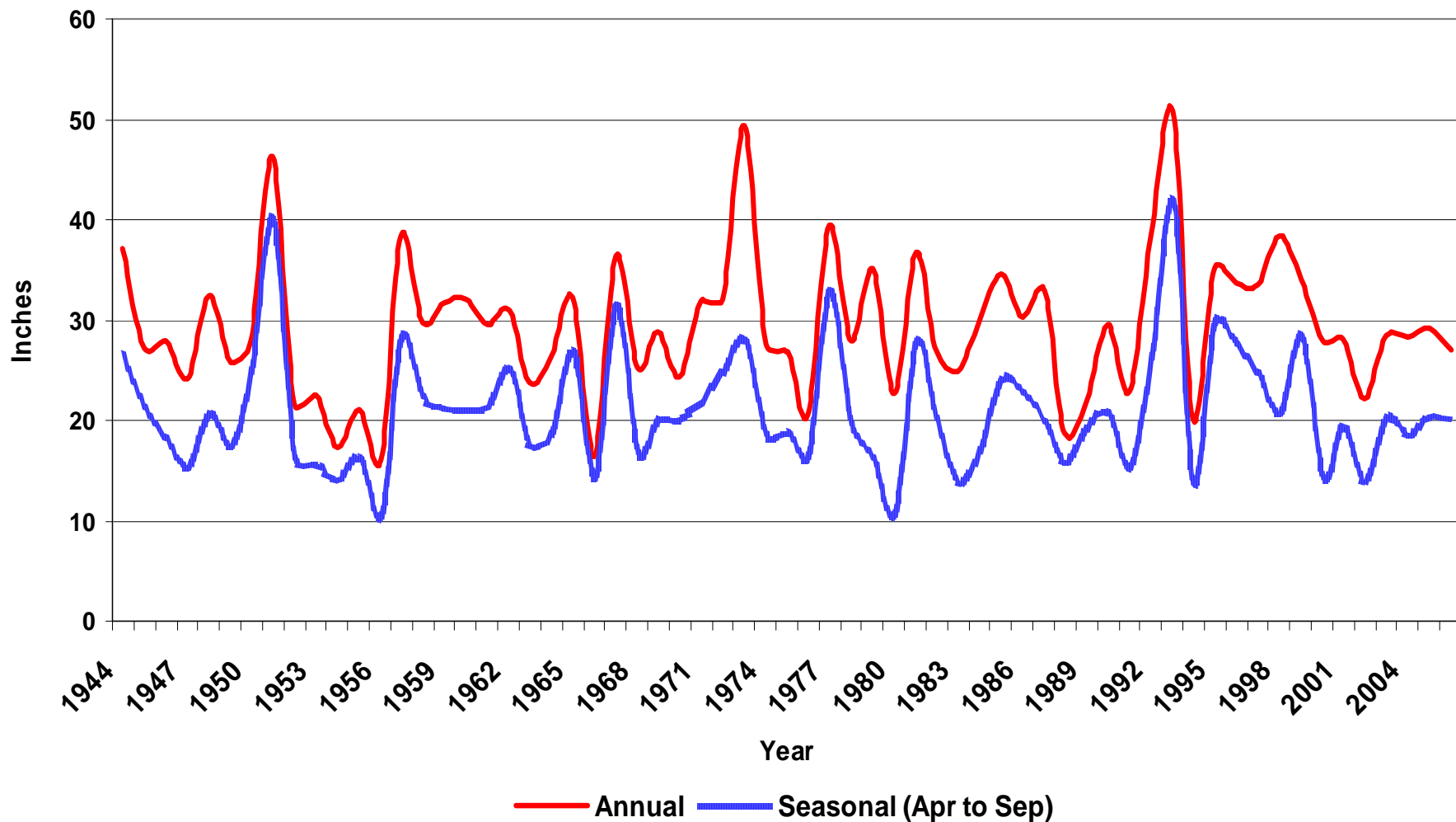
1956



1993

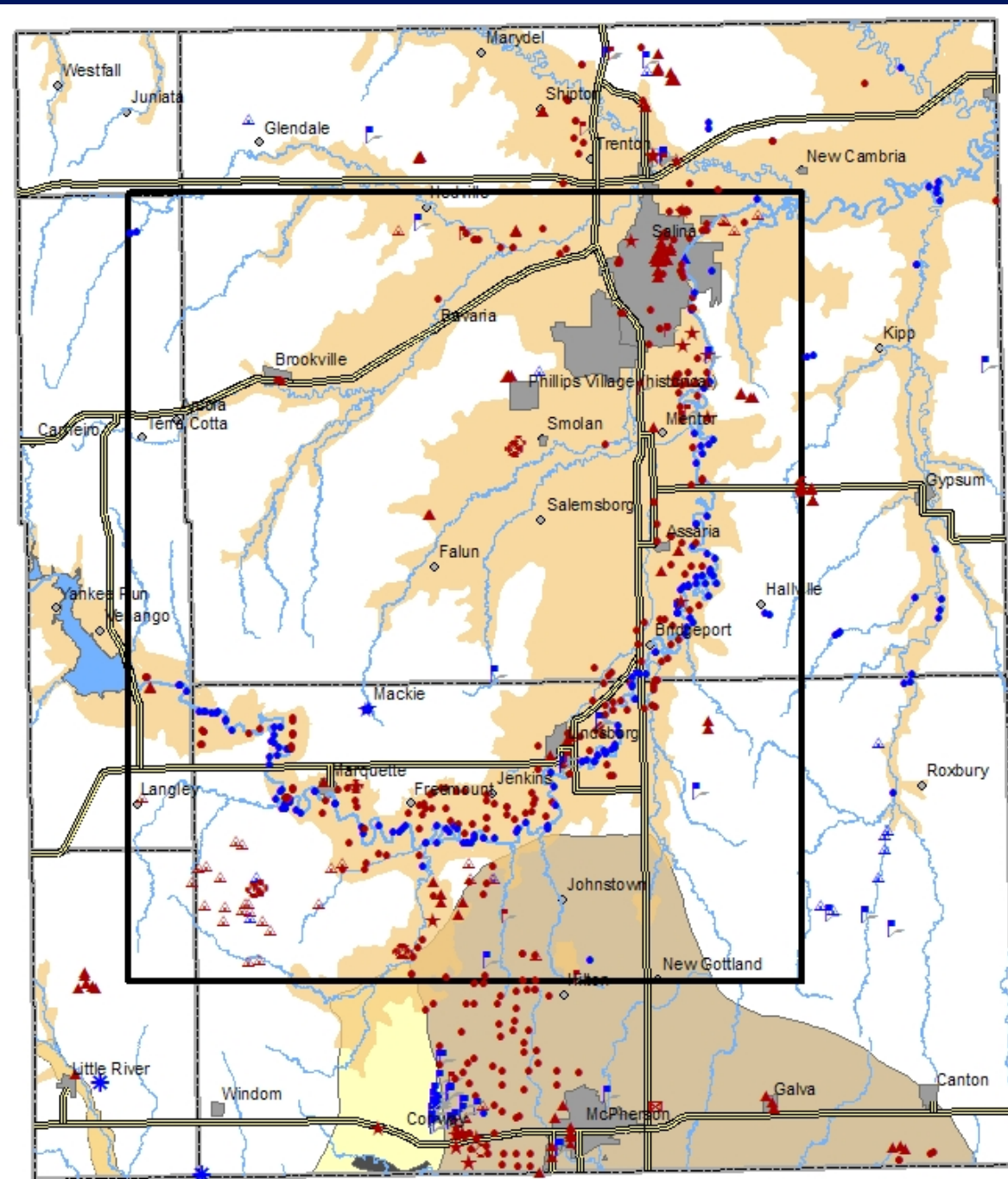


Average Total Precipitation Smoky Hill Model Grid

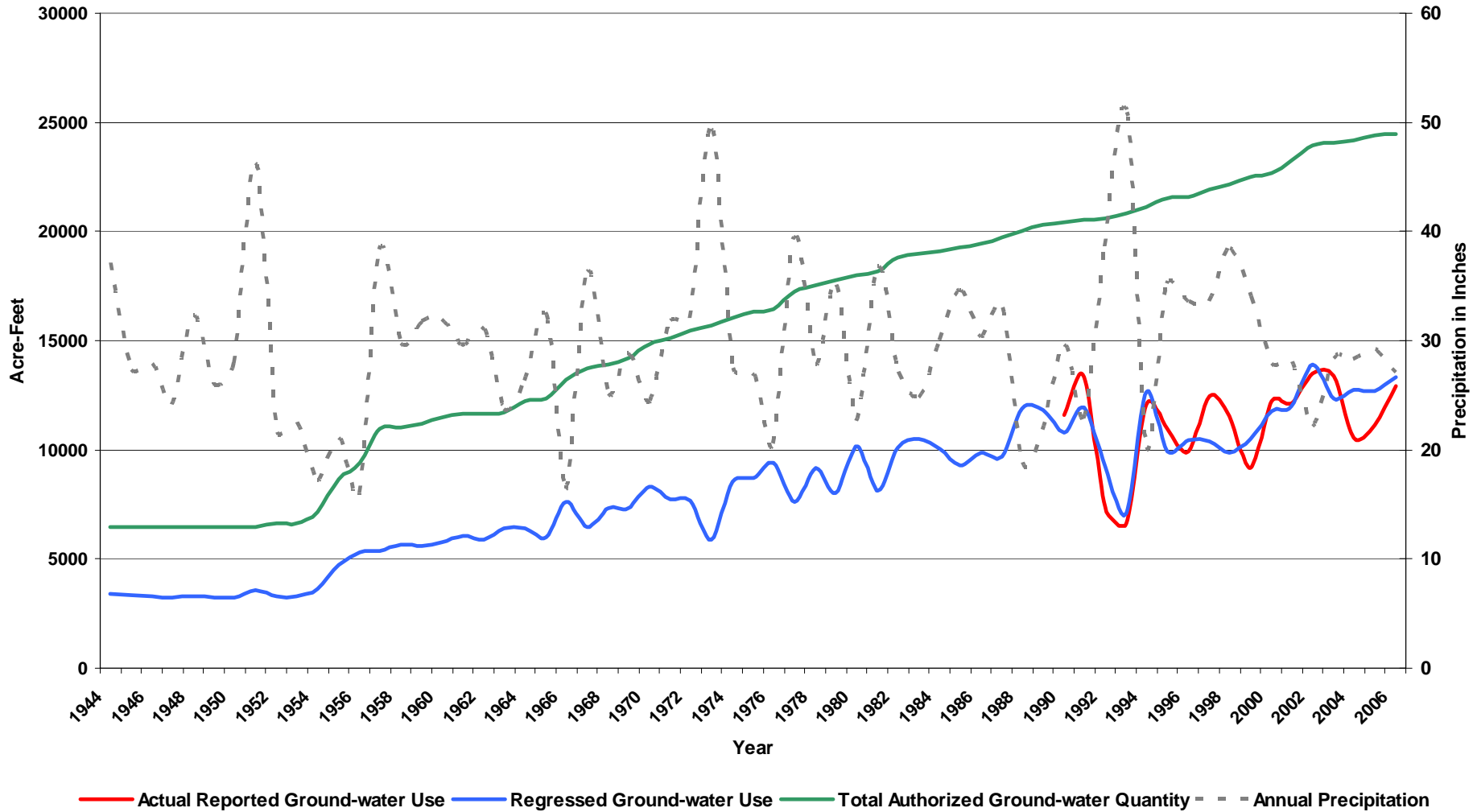


Smoky Hill Valley Water Rights

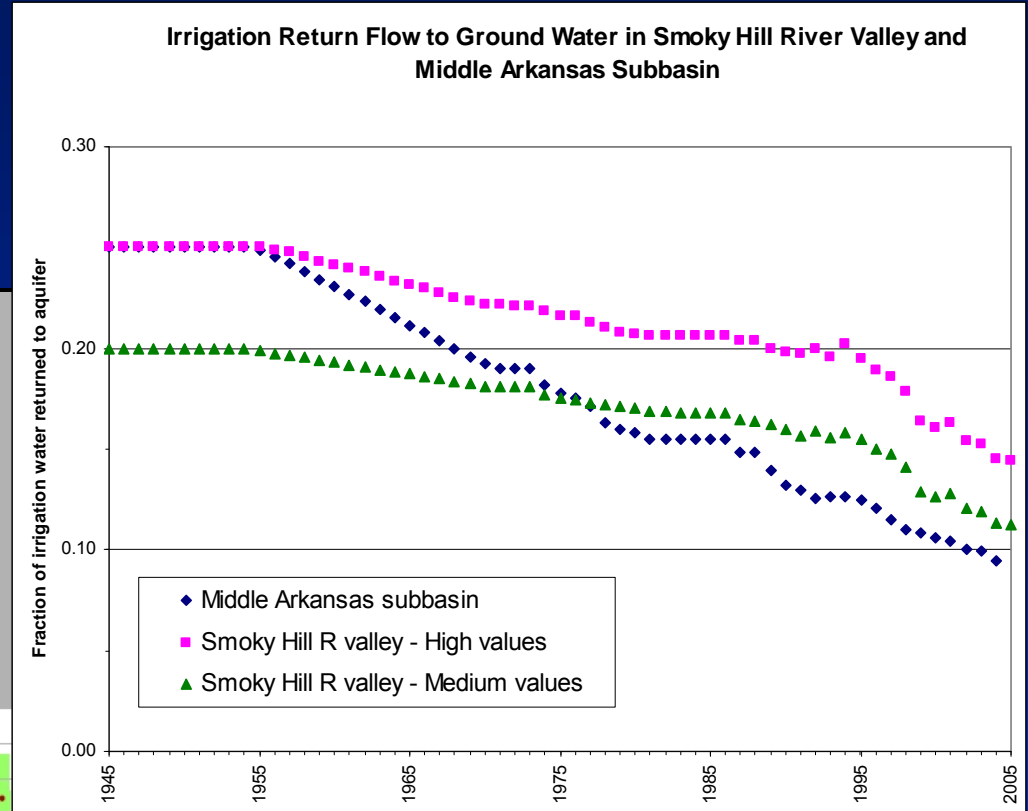
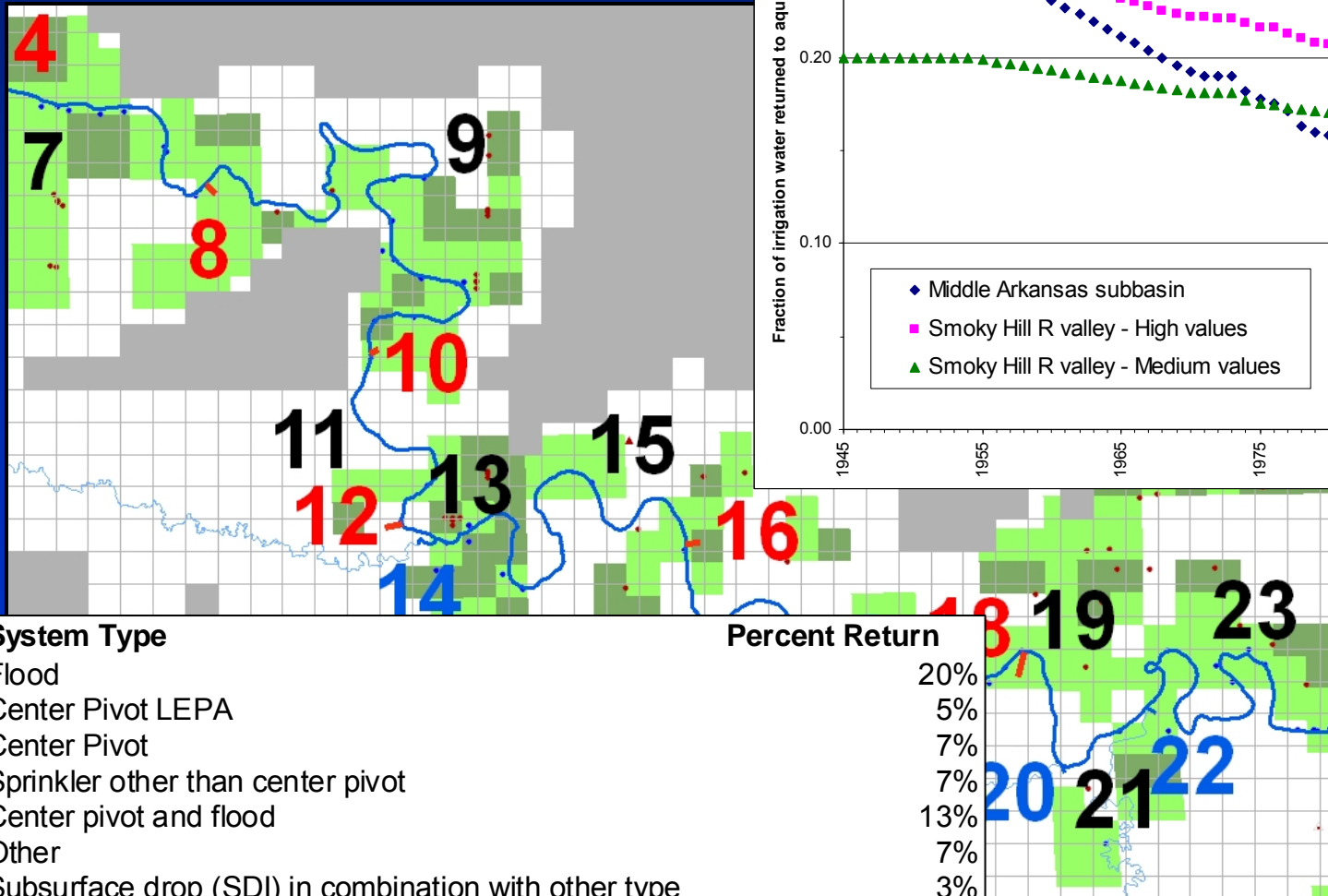
⊠	G_DEW
△	G_DOM
★	G_IND
●	G_IRR
▲	G_MUN
▤	G_REC
⊙	G_STK
⚡	G_THX
△	S_DOM
★	S_IND
●	S_IRR
▲	S_MUN
▤	S_REC
✳	S_SED



Pumping Estimates- Ground-Water Uses



Net Pumping and Return Flows



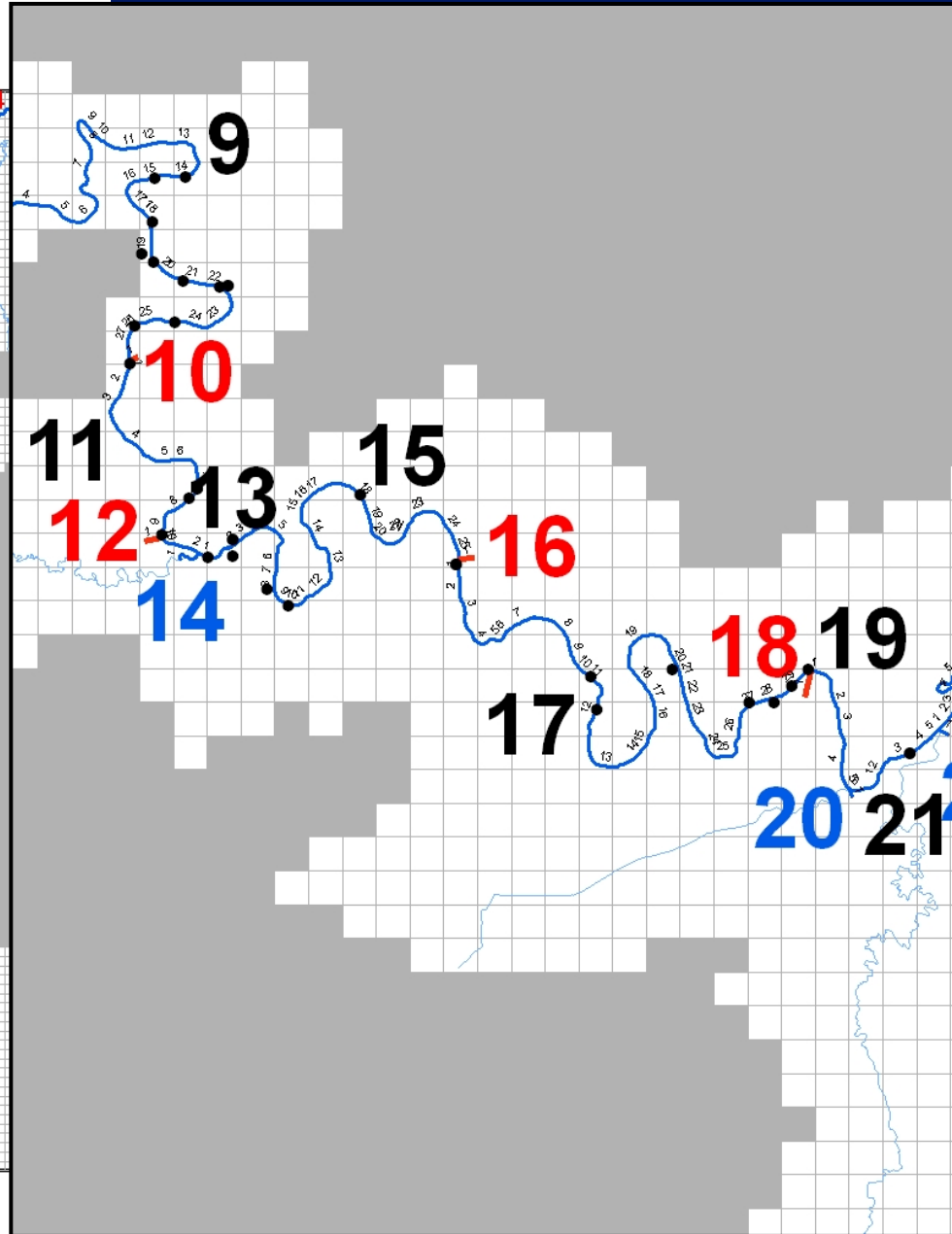
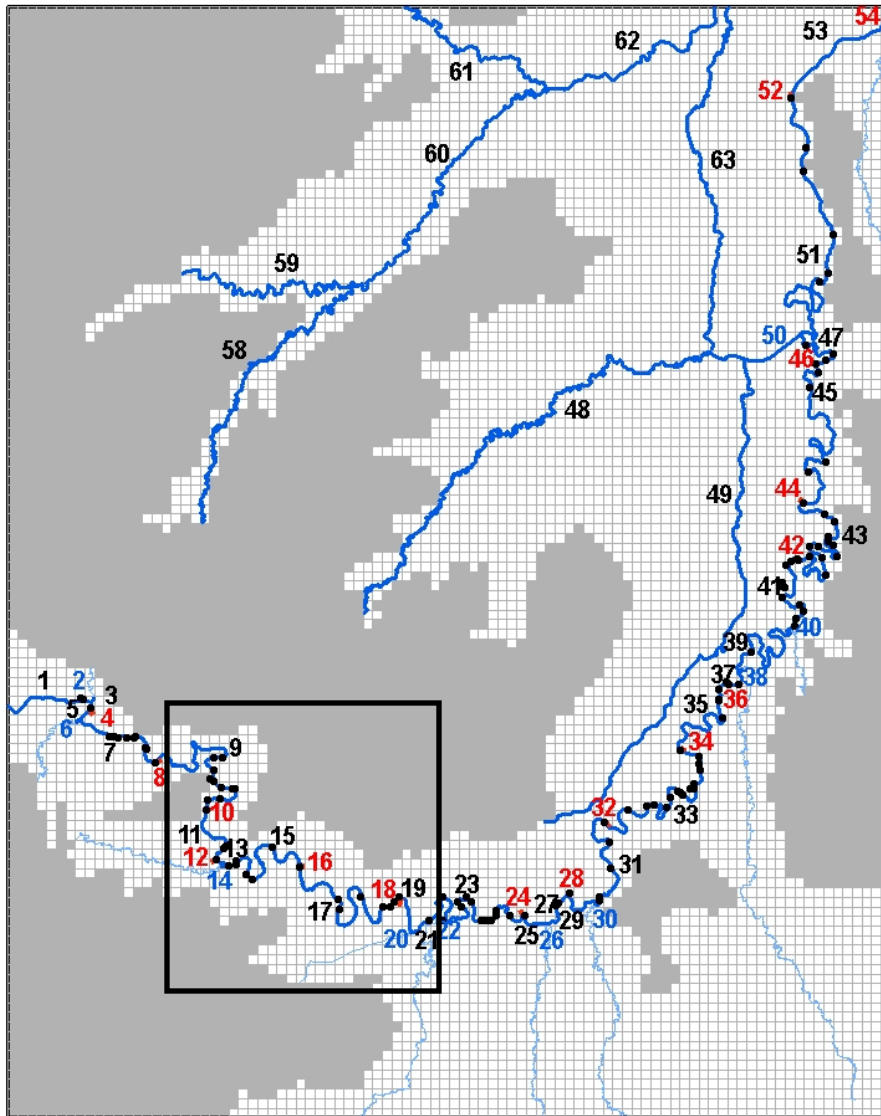
System Type

- Flood
- Center Pivot LEPA
- Center Pivot
- Sprinkler other than center pivot
- Center pivot and flood
- Other
- Subsurface drop (SDI) in combination with other type
- Trickle-drip

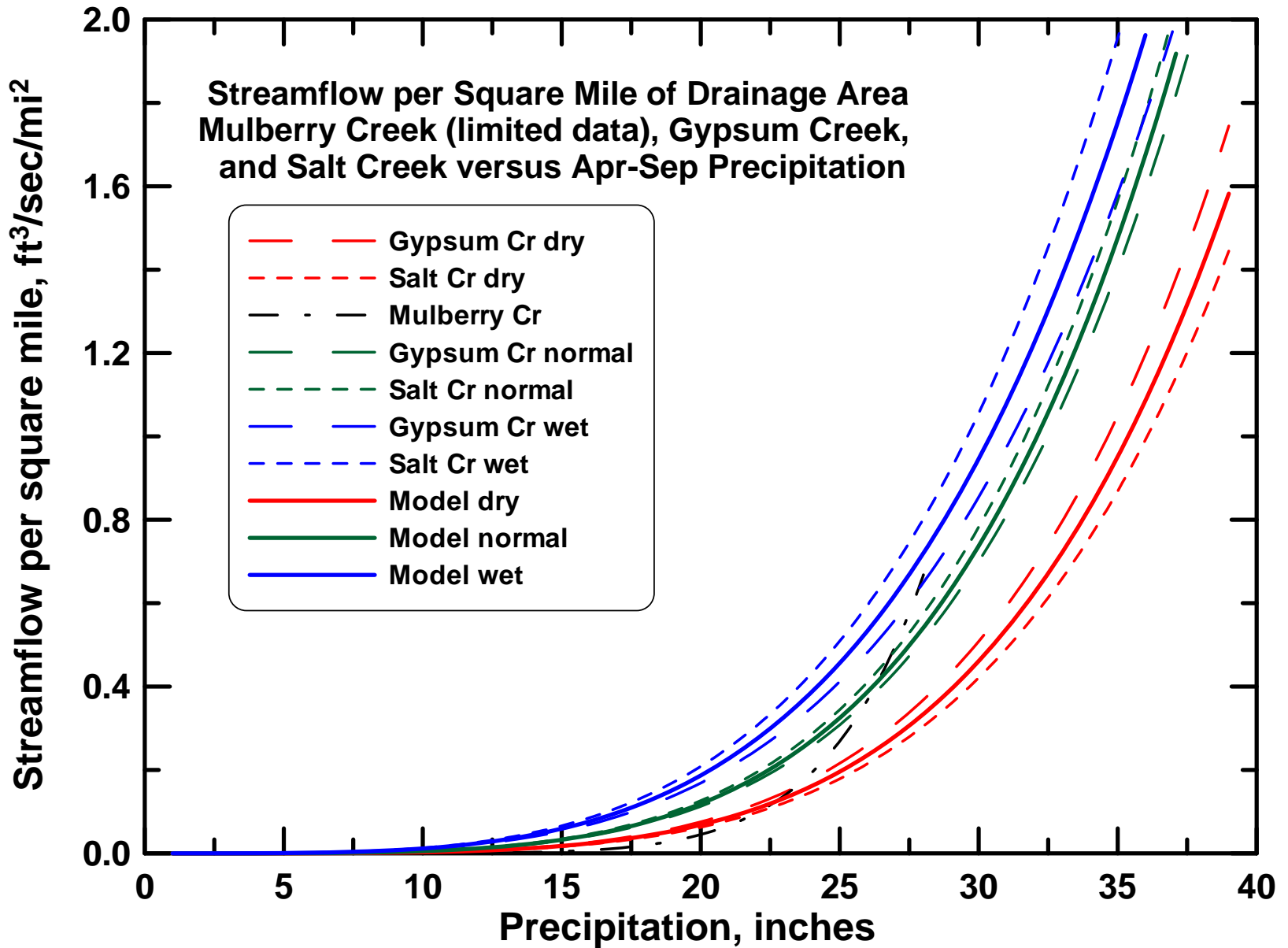
Percent Return

- 20%
- 5%
- 7%
- 7%
- 13%
- 7%
- 3%
- 2%

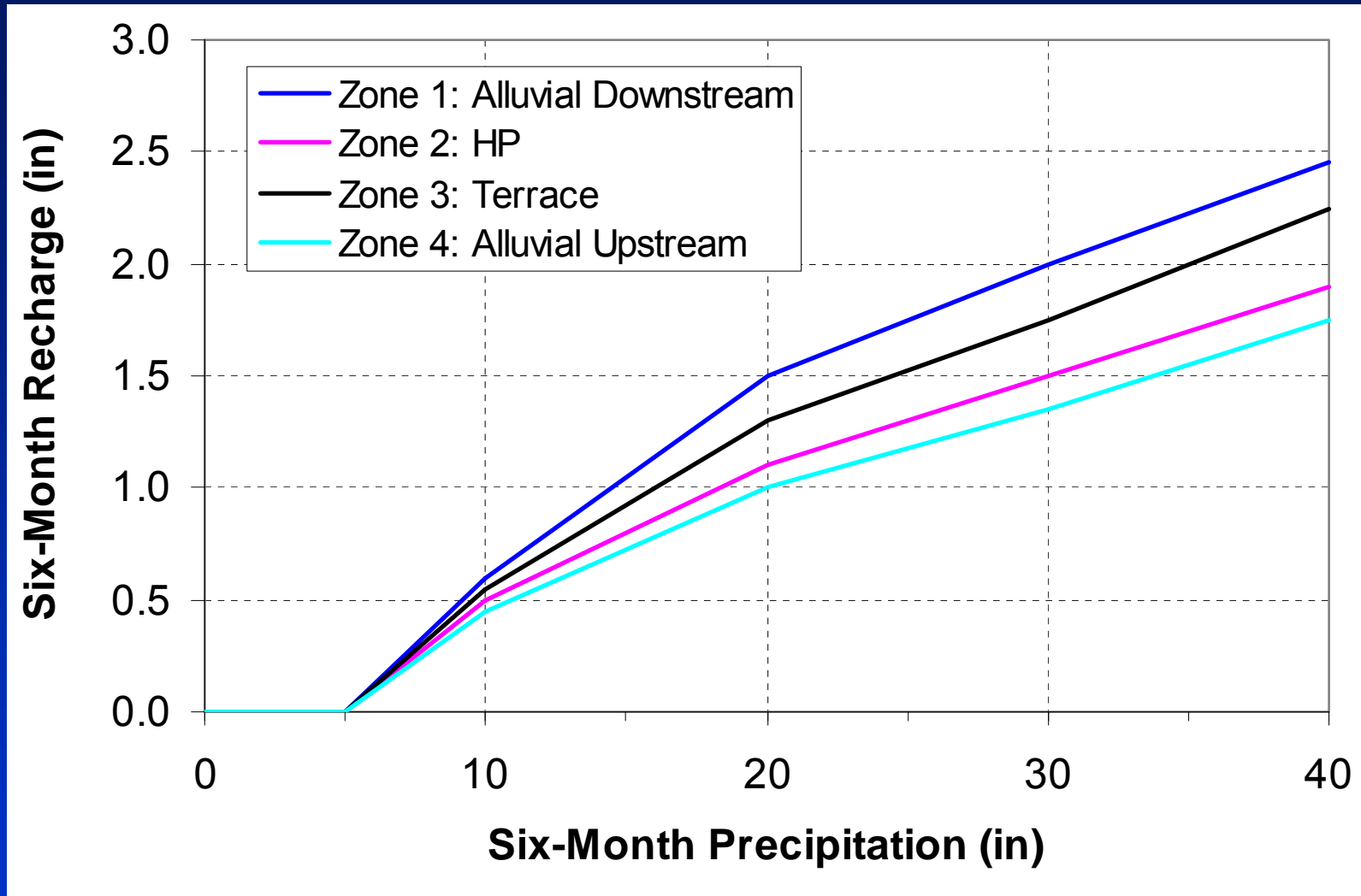
Surface Inflows/Outflows



Tributary Inflow – Antecedent Conditions



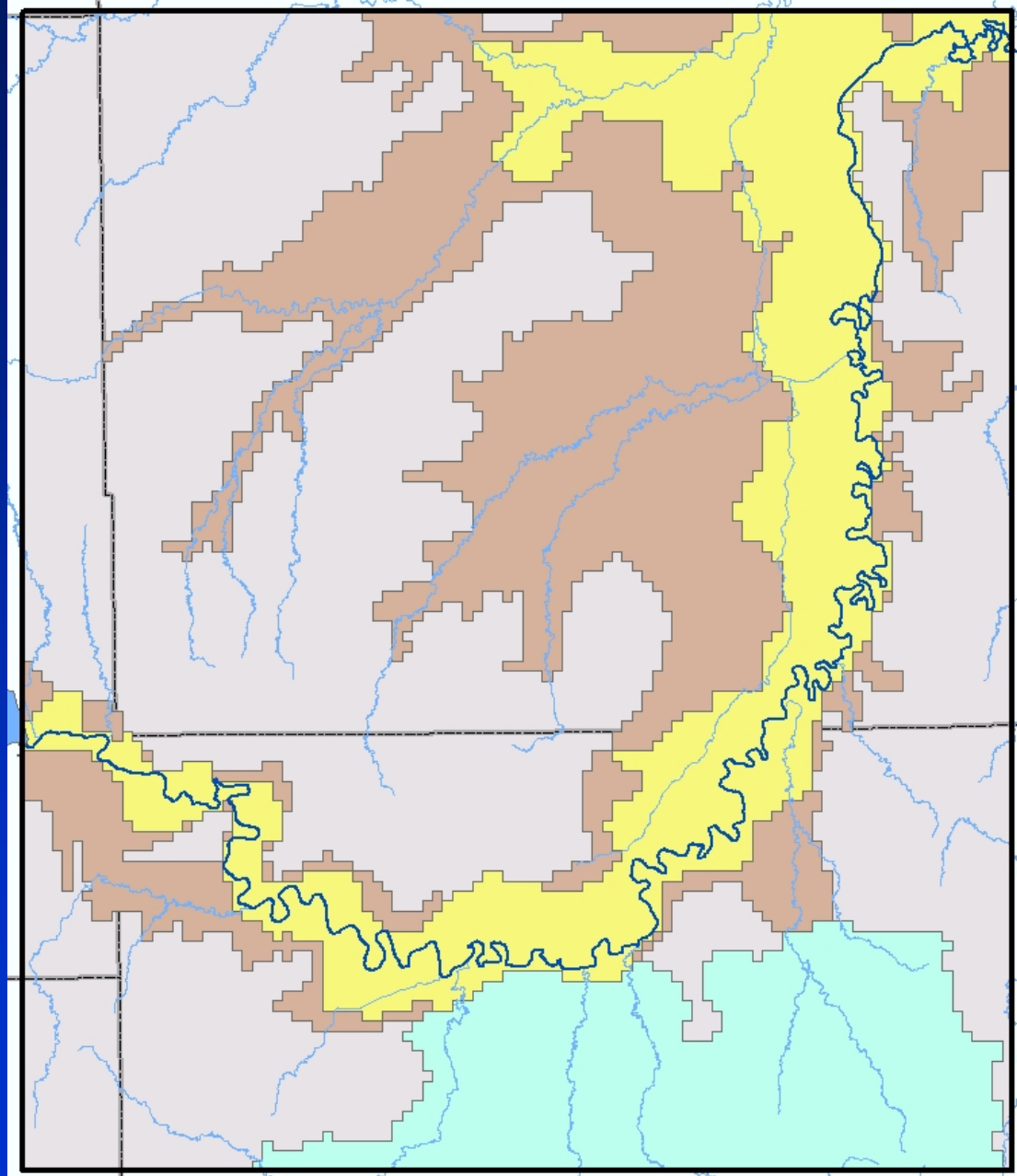
Calibrated Winter Recharge Curves



- Summer recharge curves similar to winter curves, but with an offset of 15 inches.

Evapotranspiration- Alluvial Zone

- ET only considered in the main alluvial zone.
- Maximum ET rate at the surface, 15.55 in/yr.
- Extinction depth 5.0 ft.
- ET rate linearly interpolated between the land surface and extinction depth.

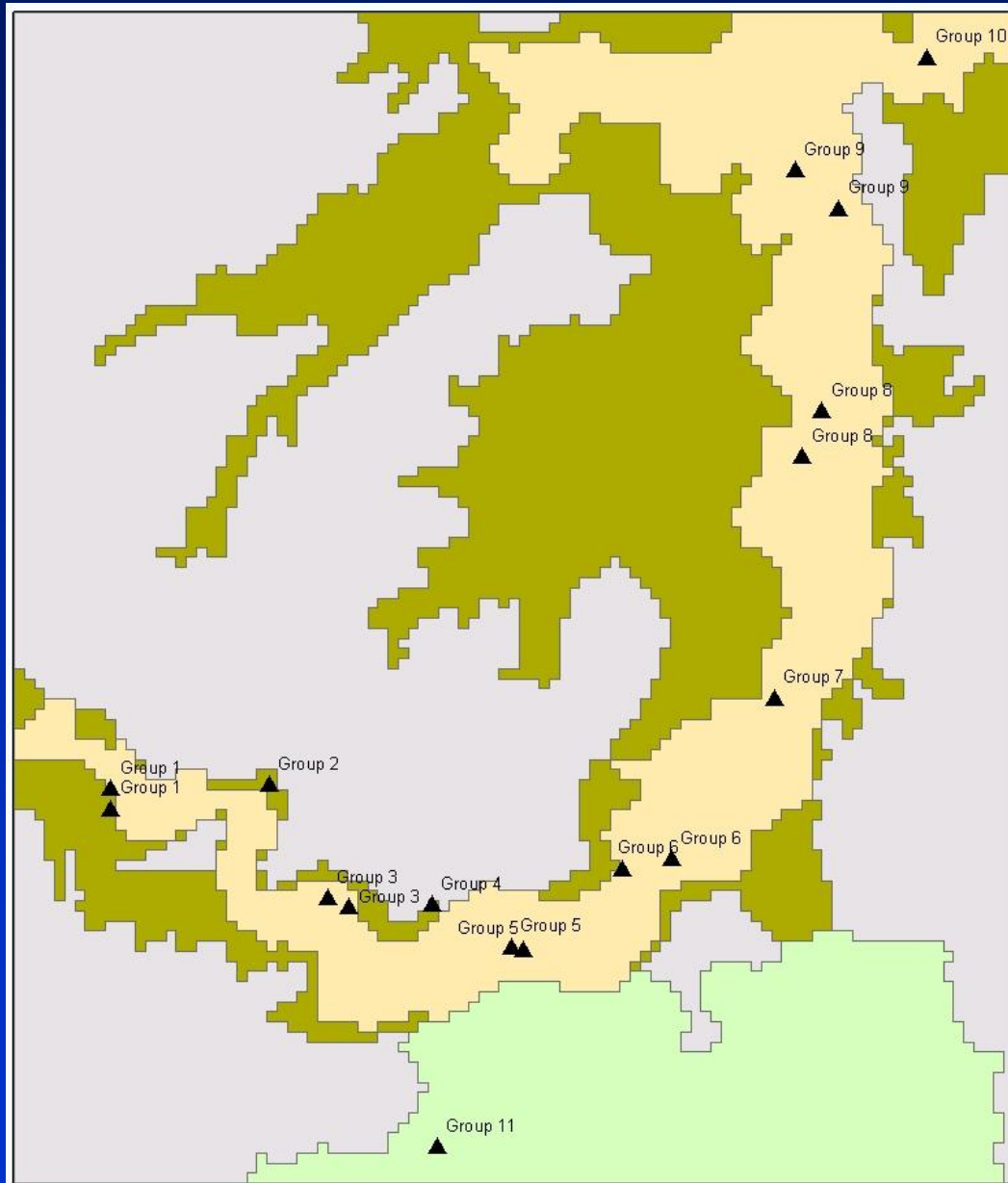


Smoky Hill Ground-Water Model

Model Results- Water Levels

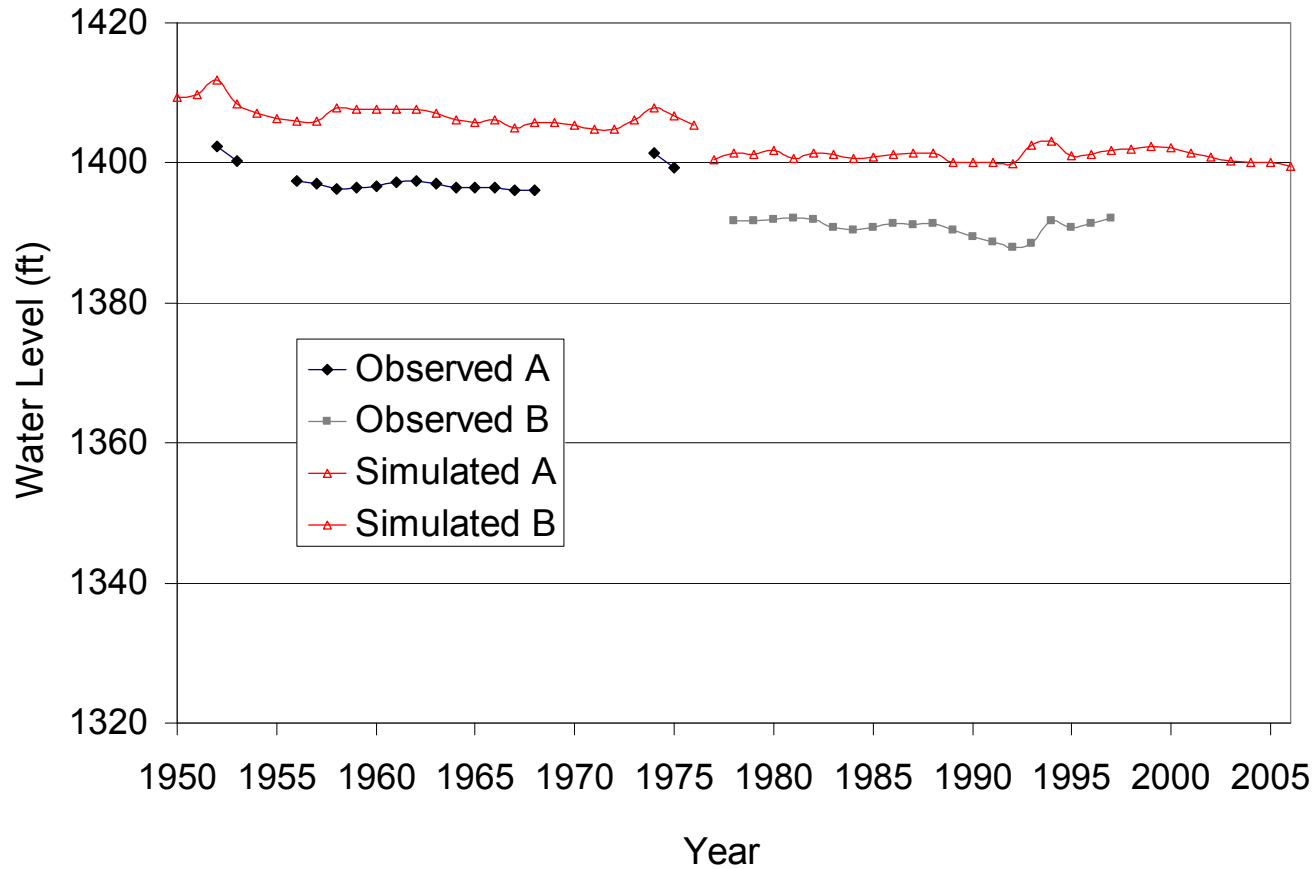


Selected Calibration Wells

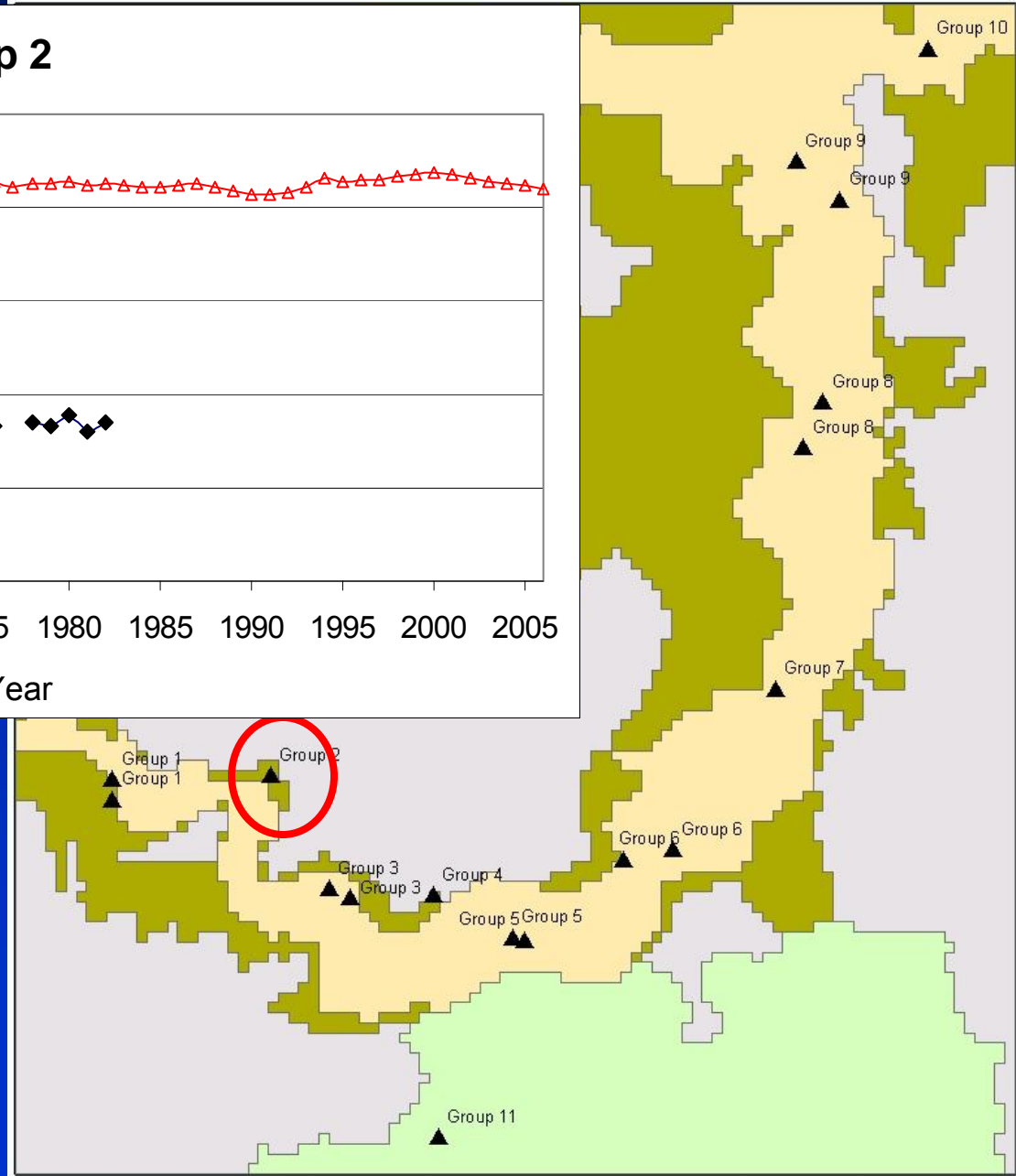
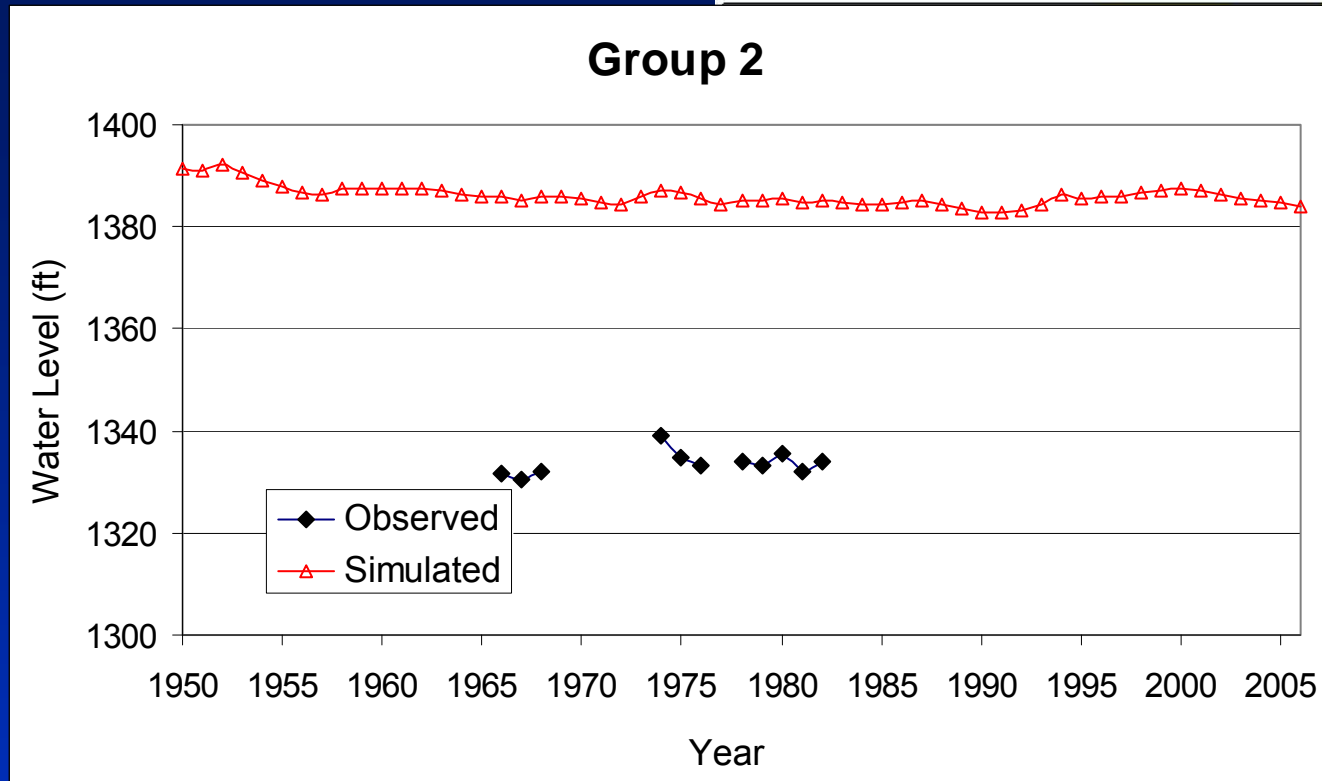


Calibrated Model Results- Hydrographs

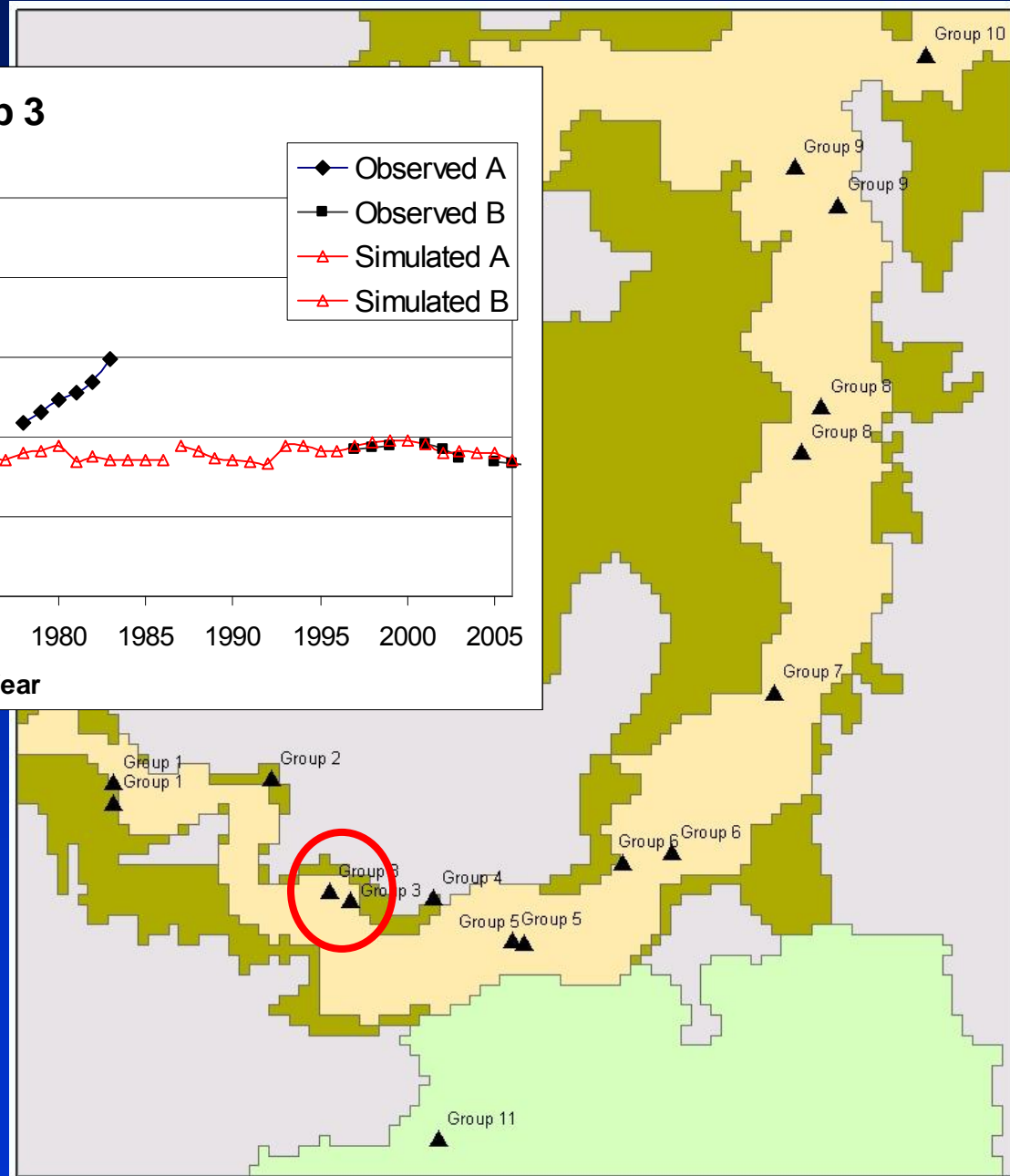
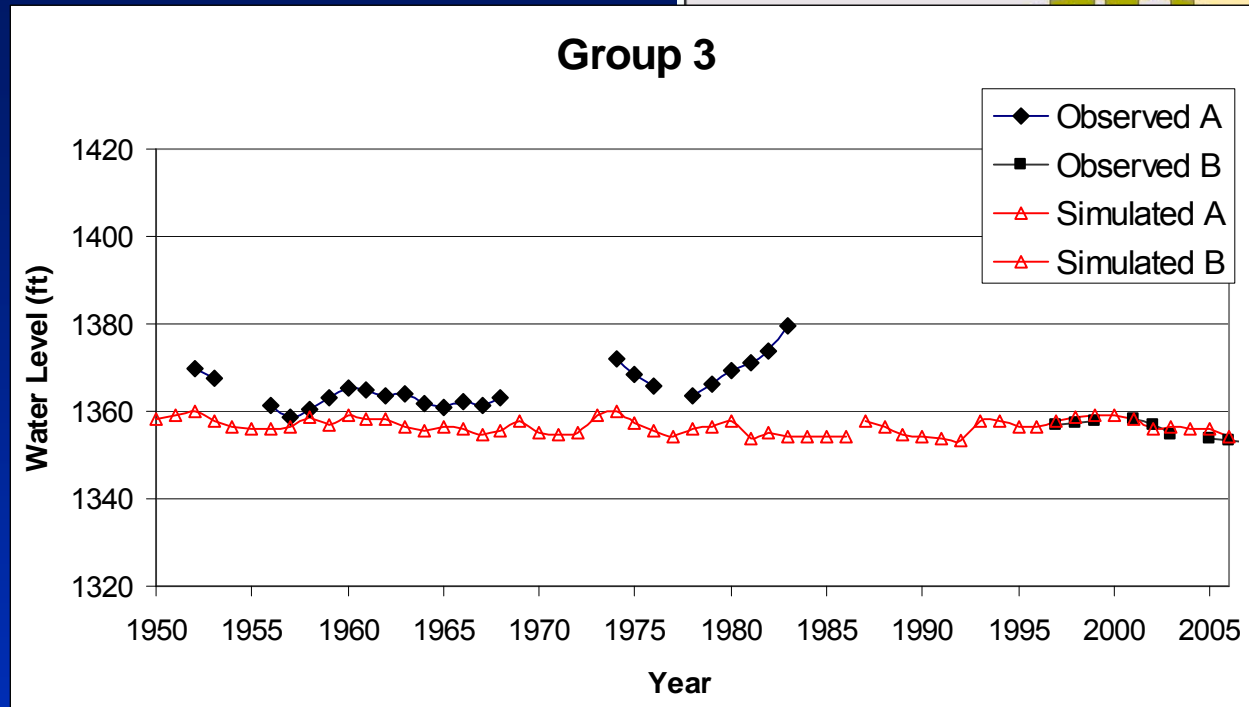
Group 1



Calibrated Model Results- Hydrographs

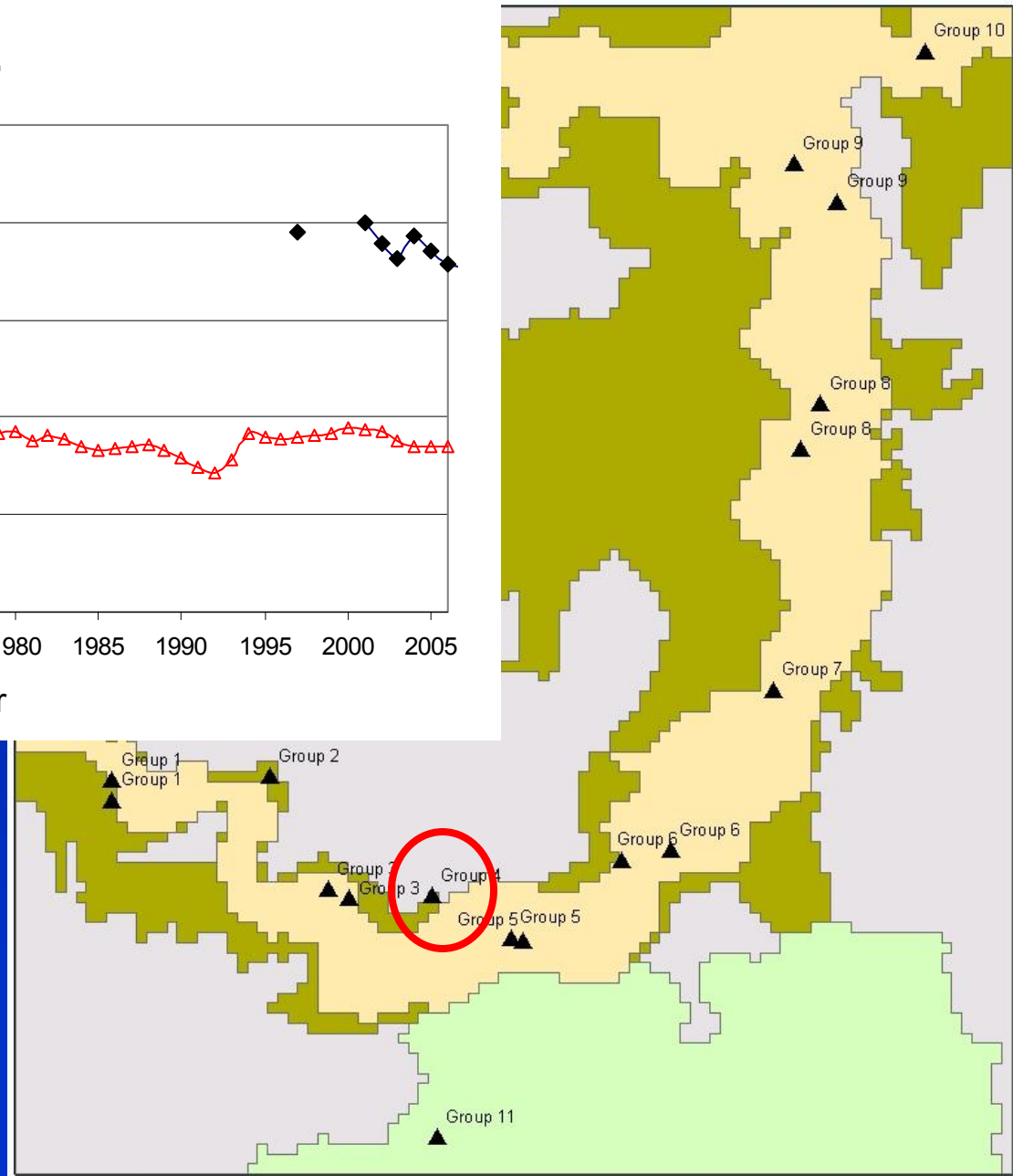
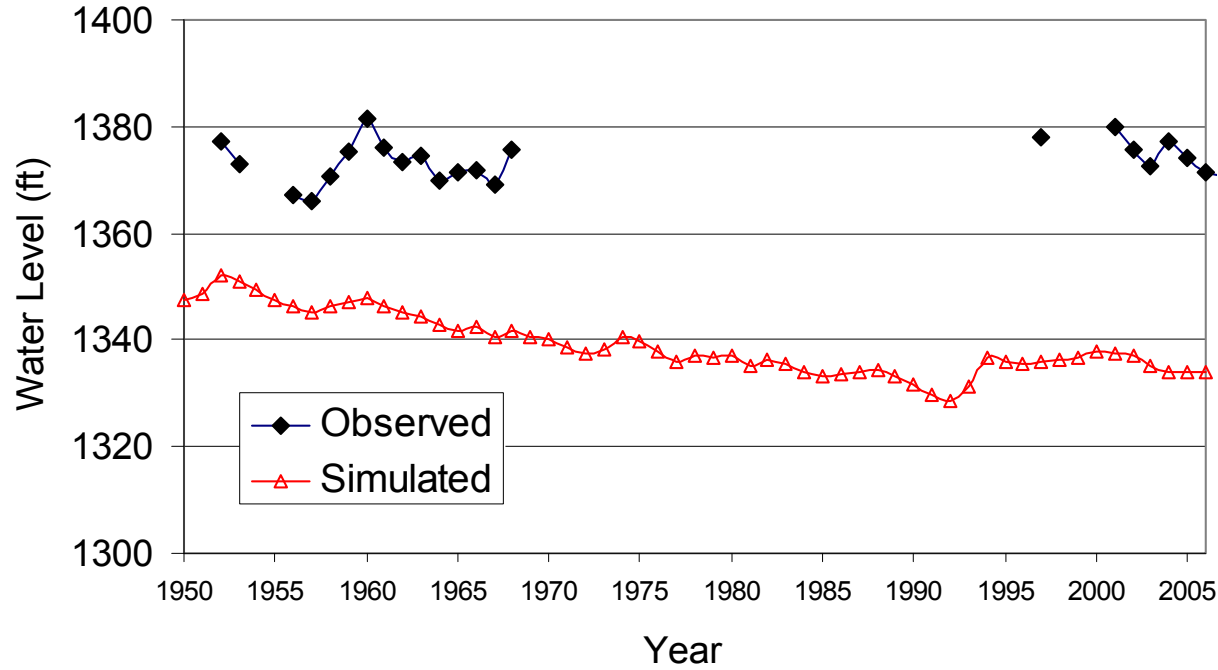


Calibrated Model Results- Hydrographs

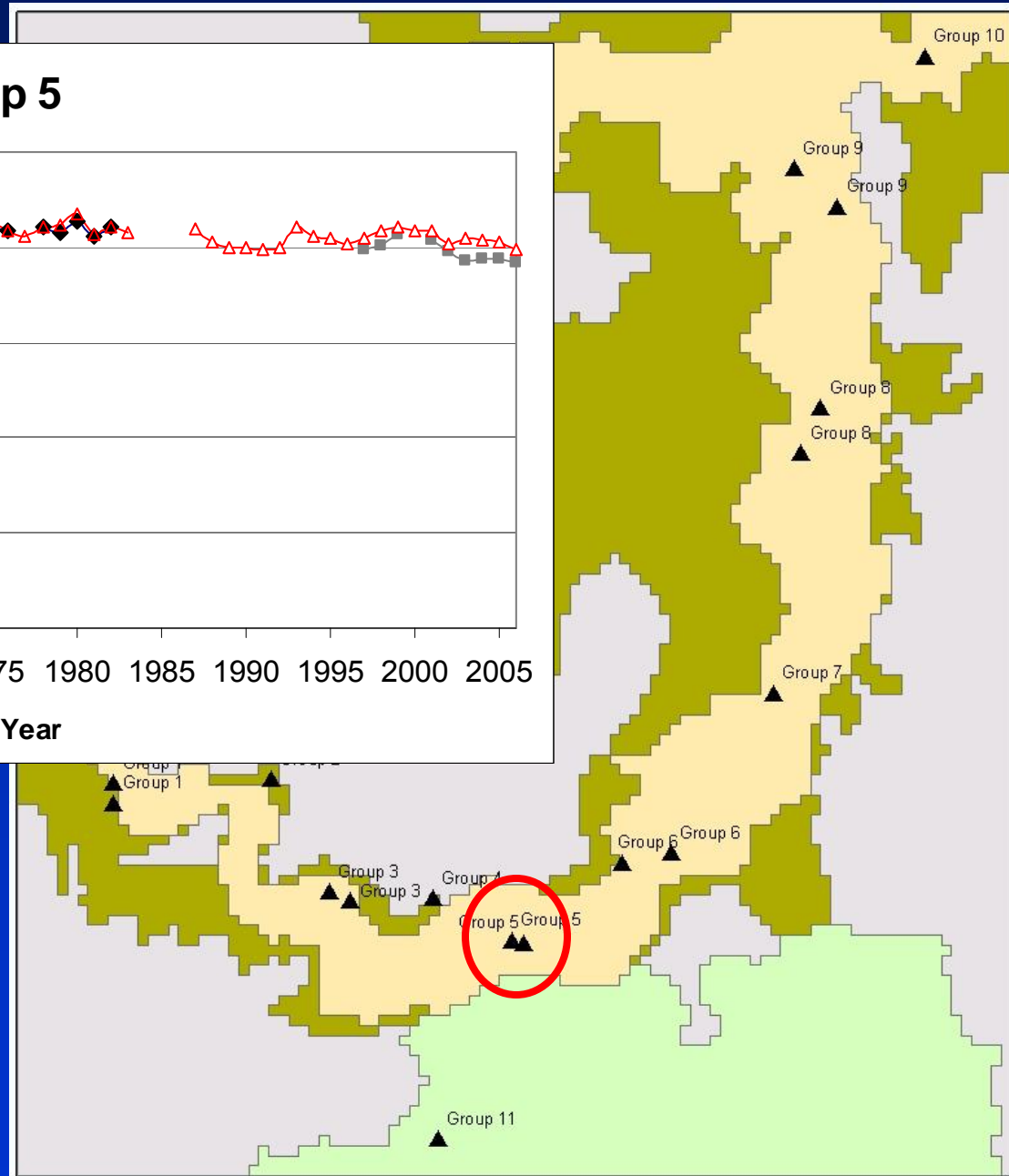
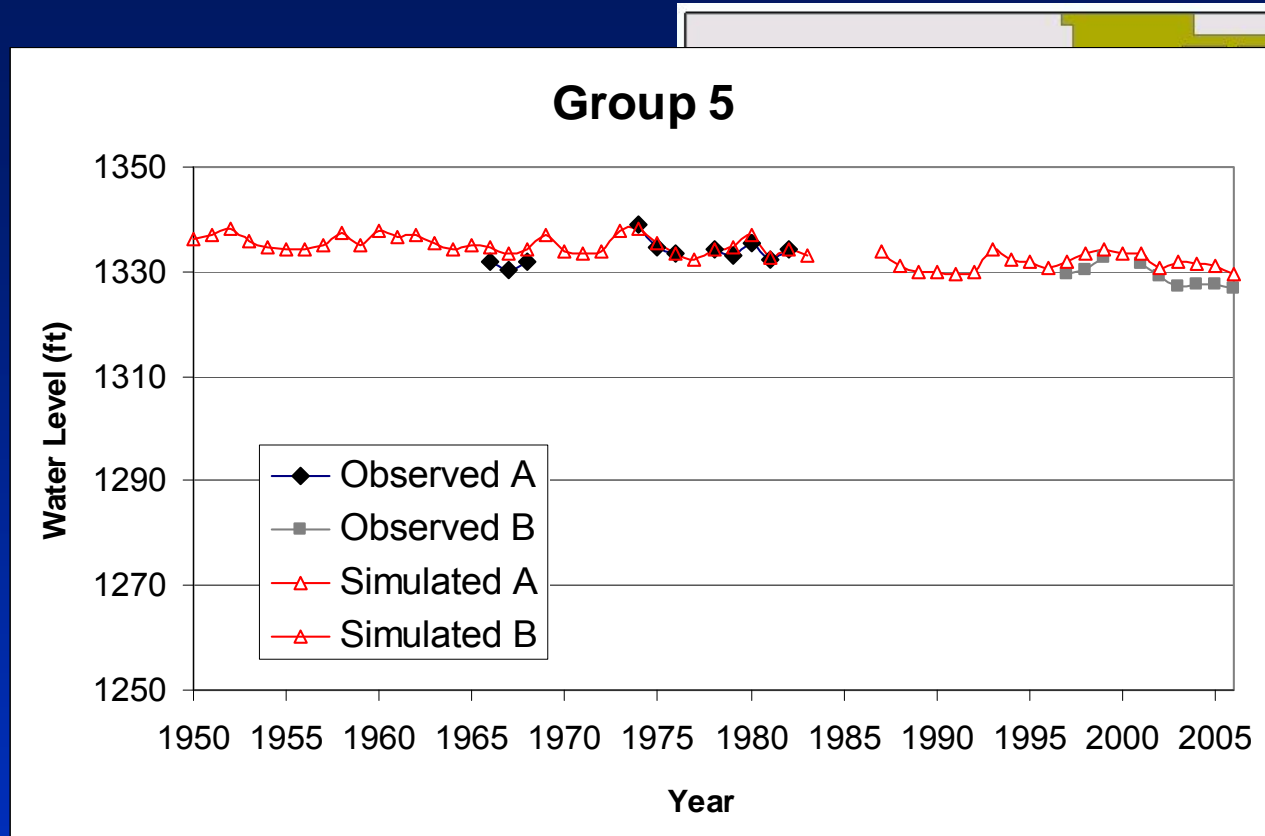


Calibrated Model Results- Hydrographs

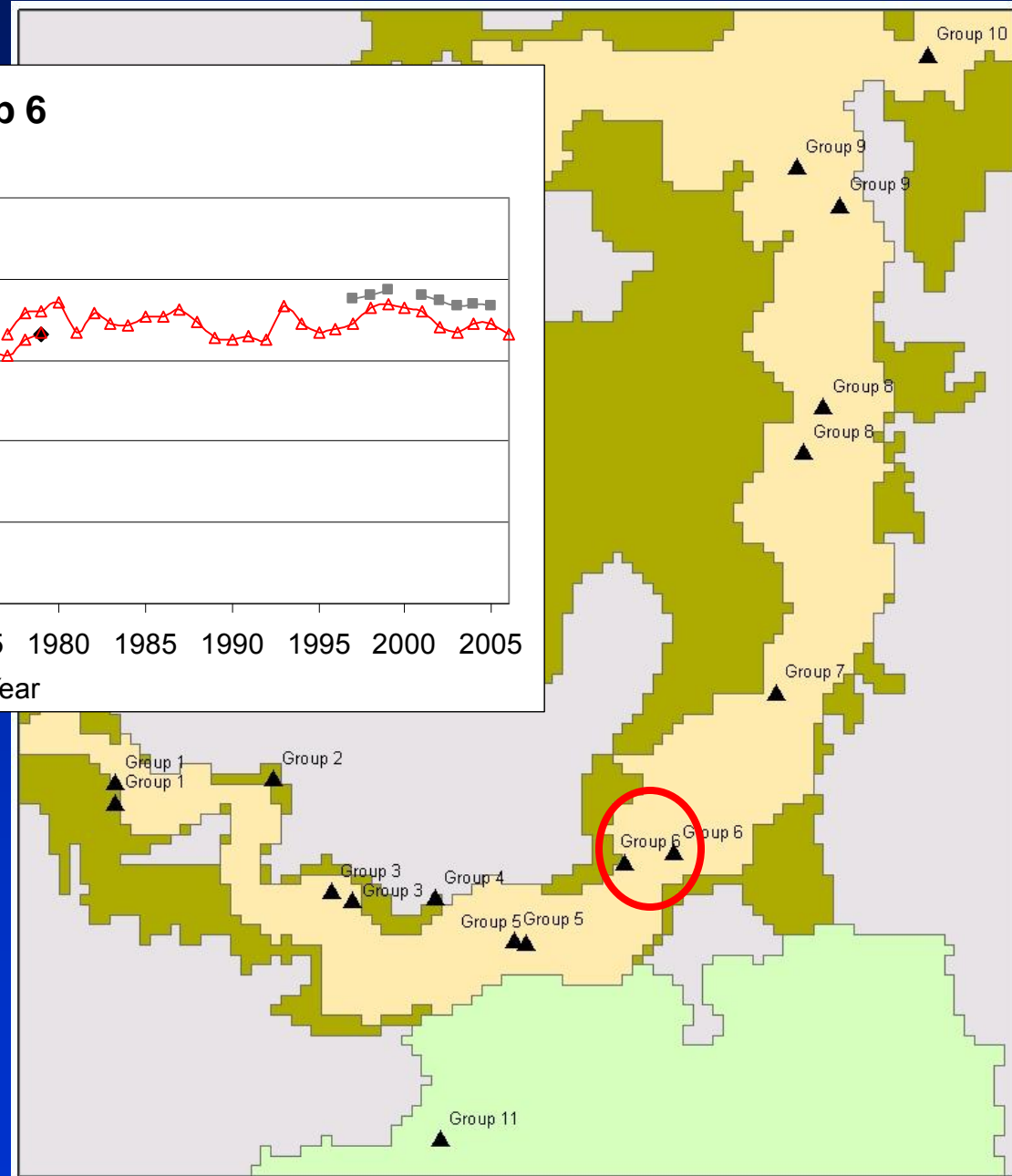
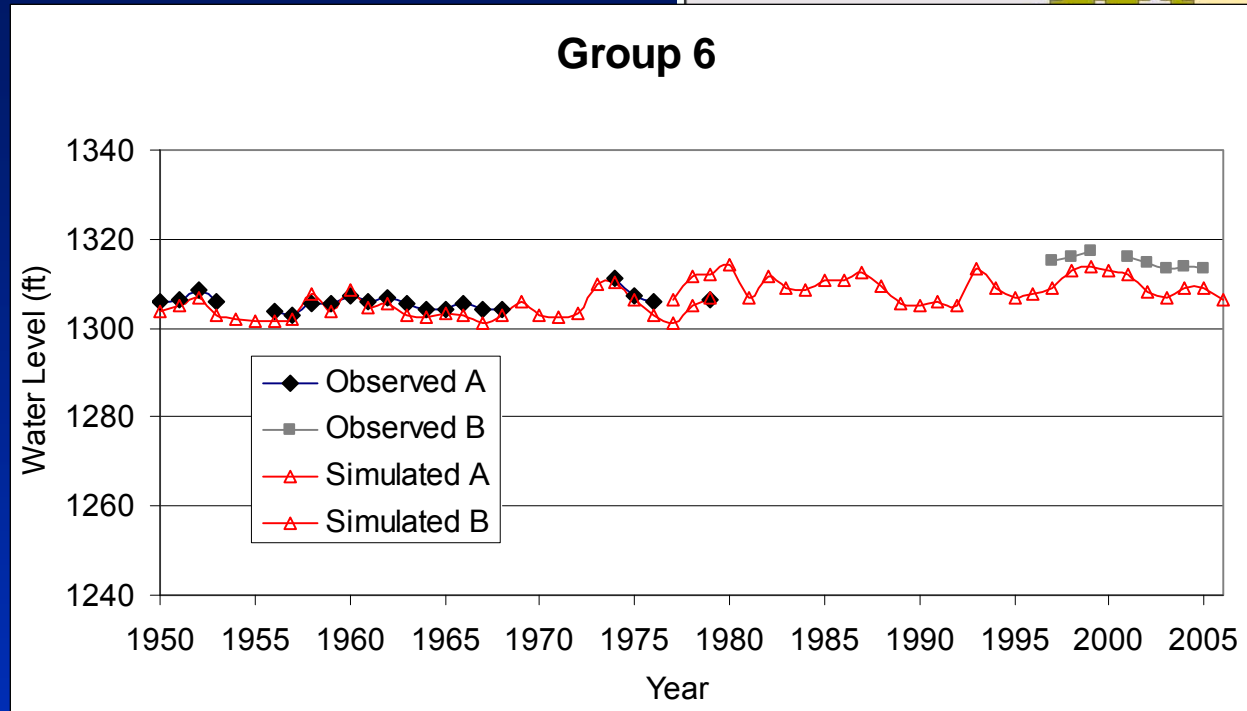
Group 4



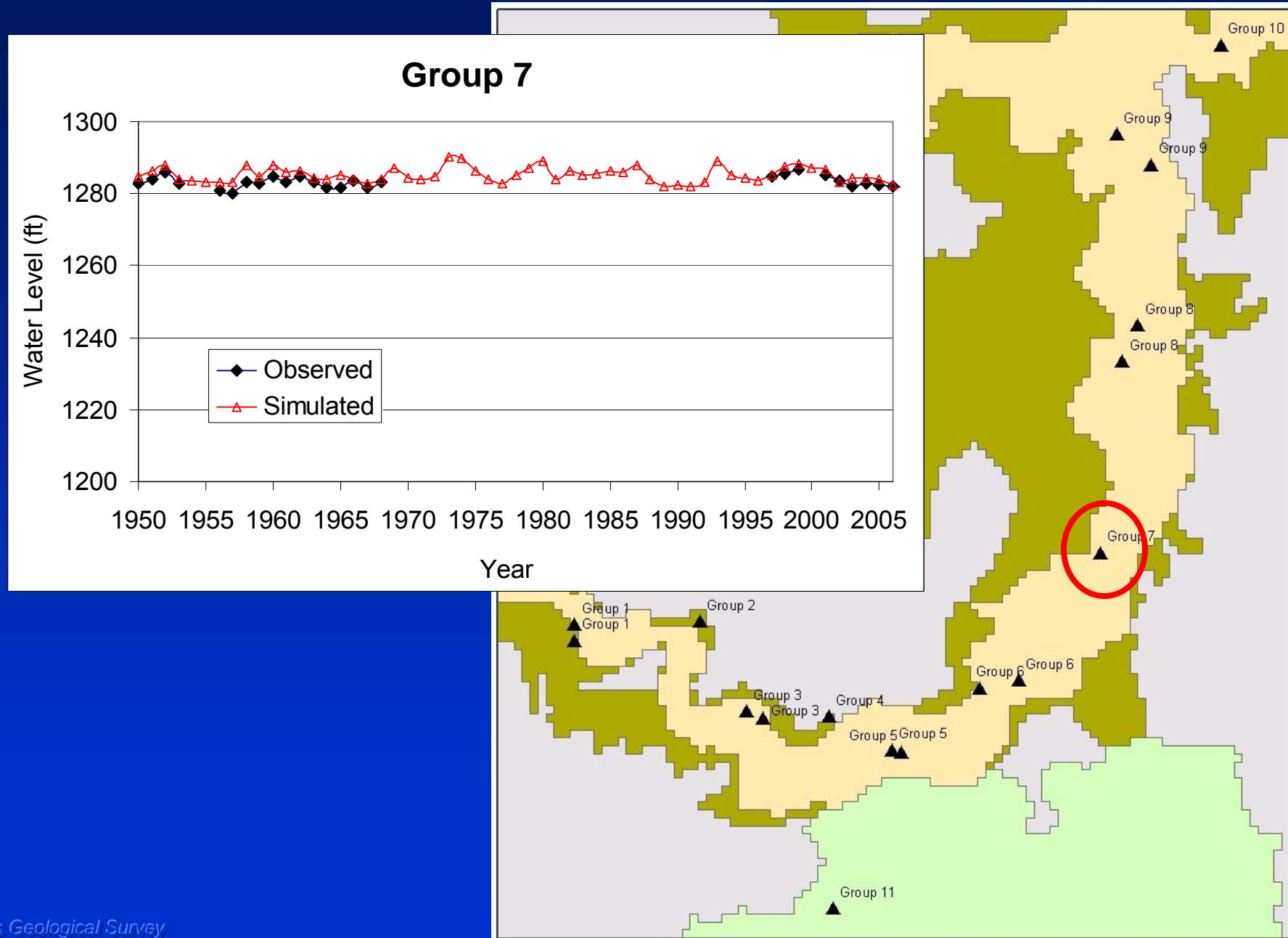
Calibrated Model Results- Hydrographs



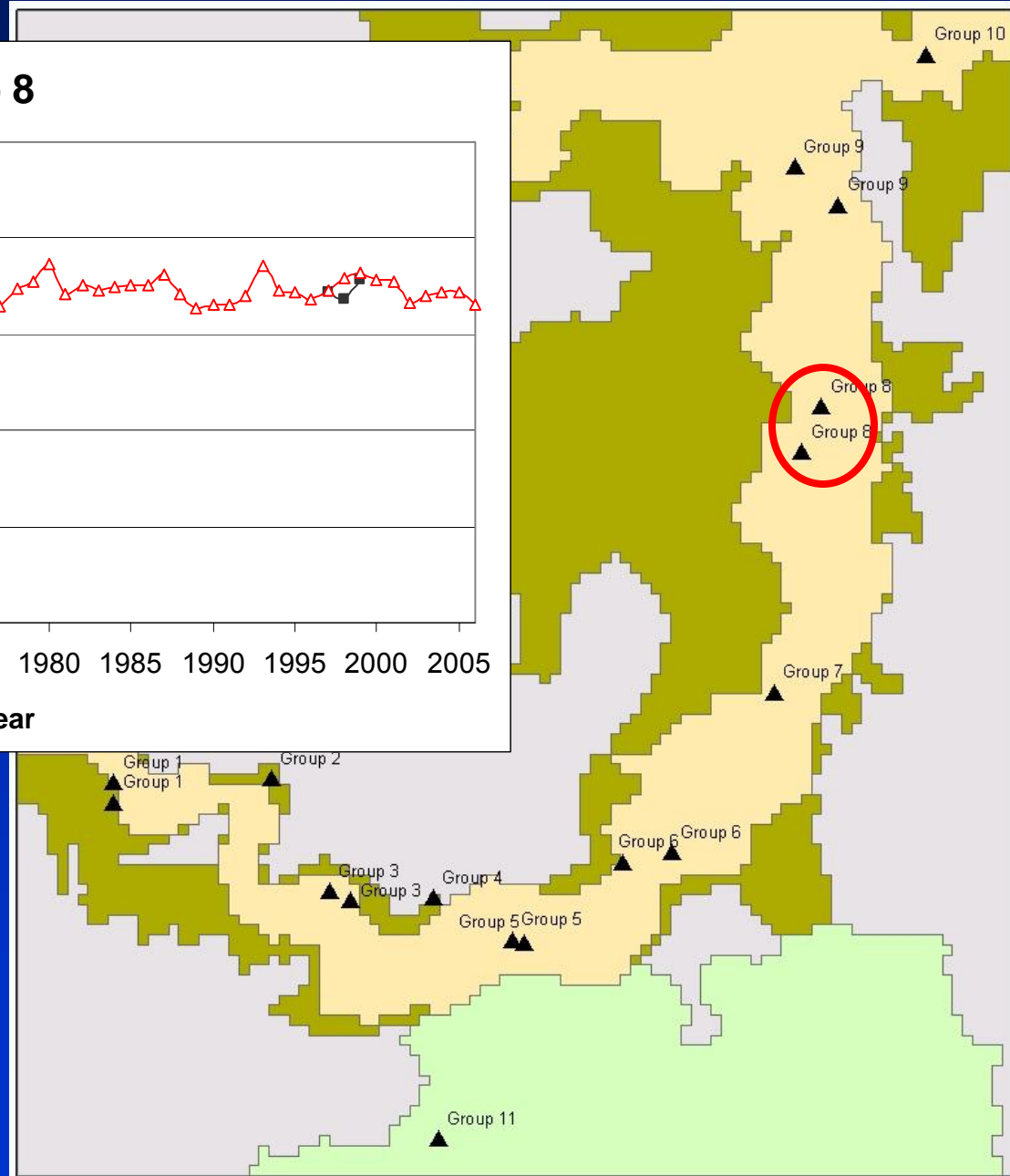
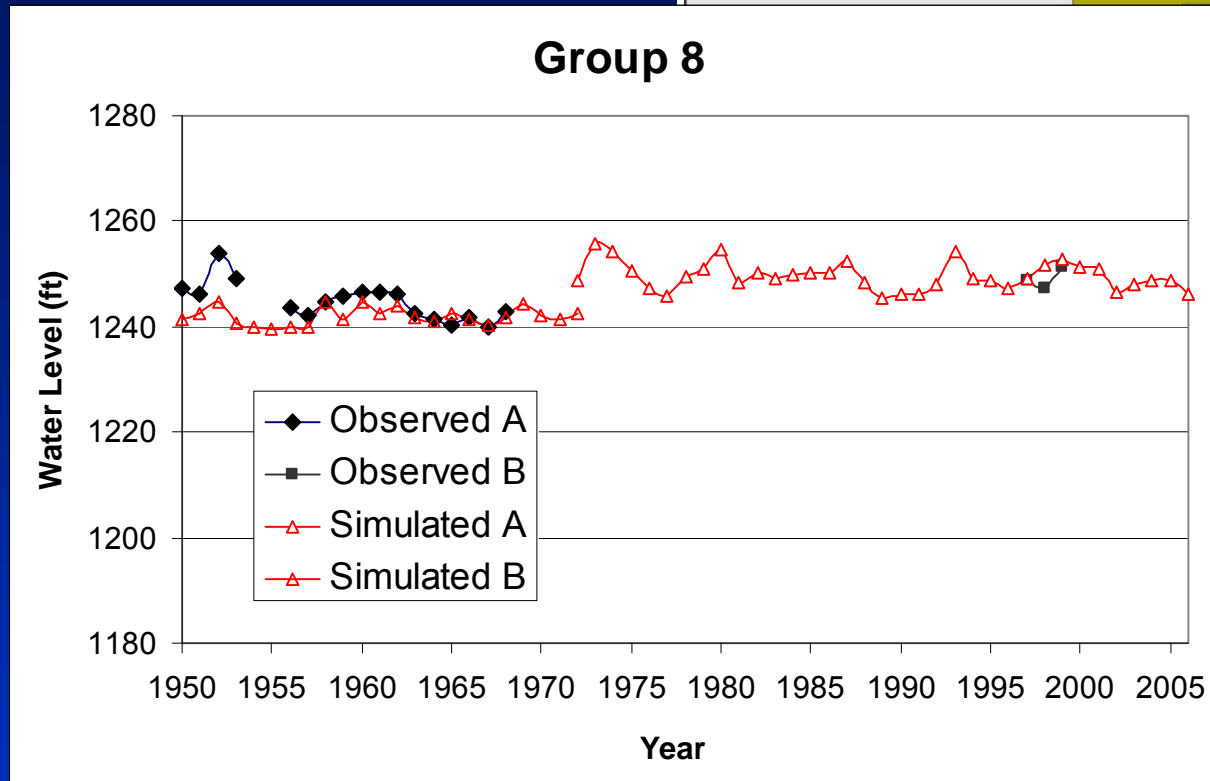
Calibrated Model Results- Hydrographs



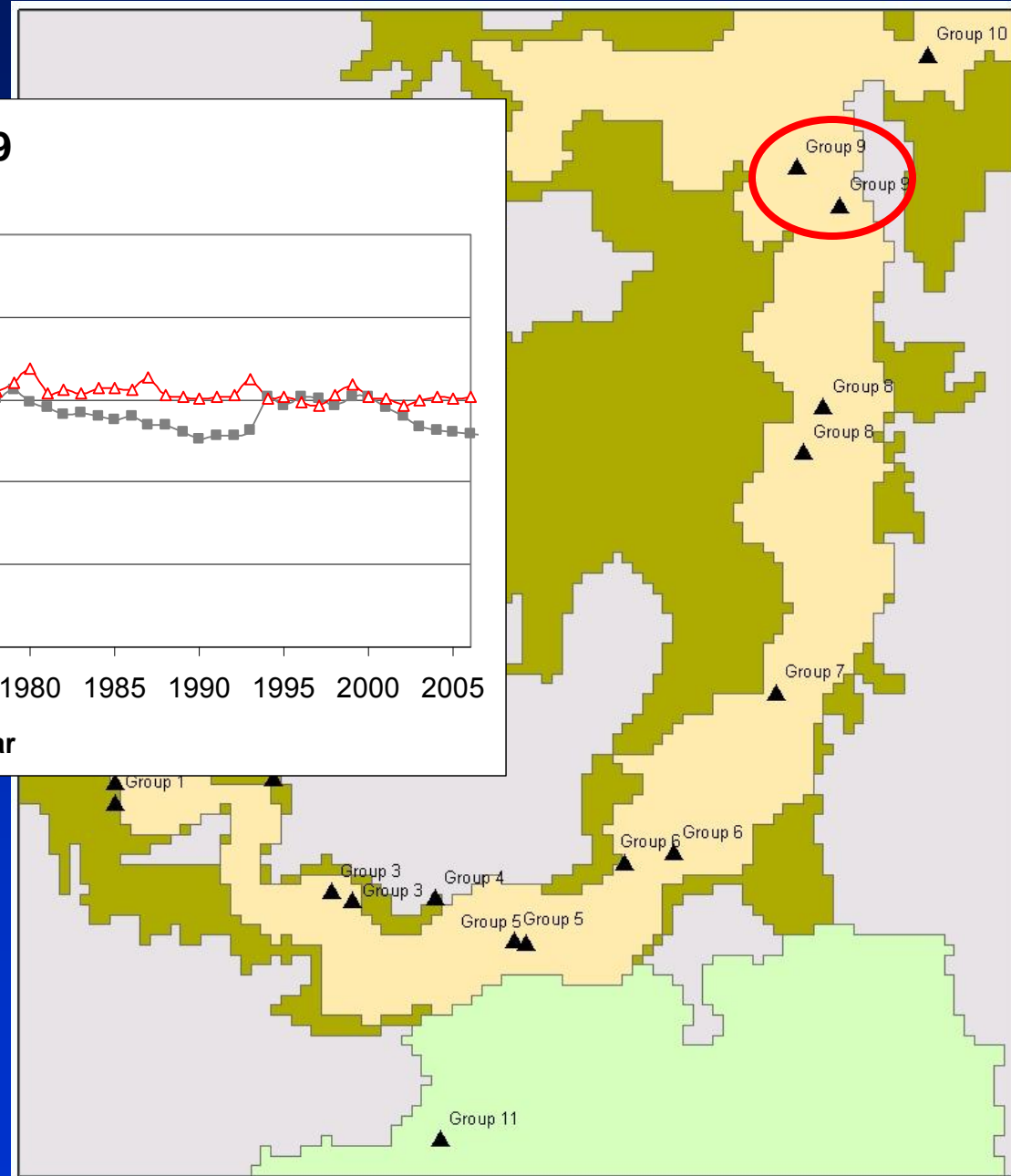
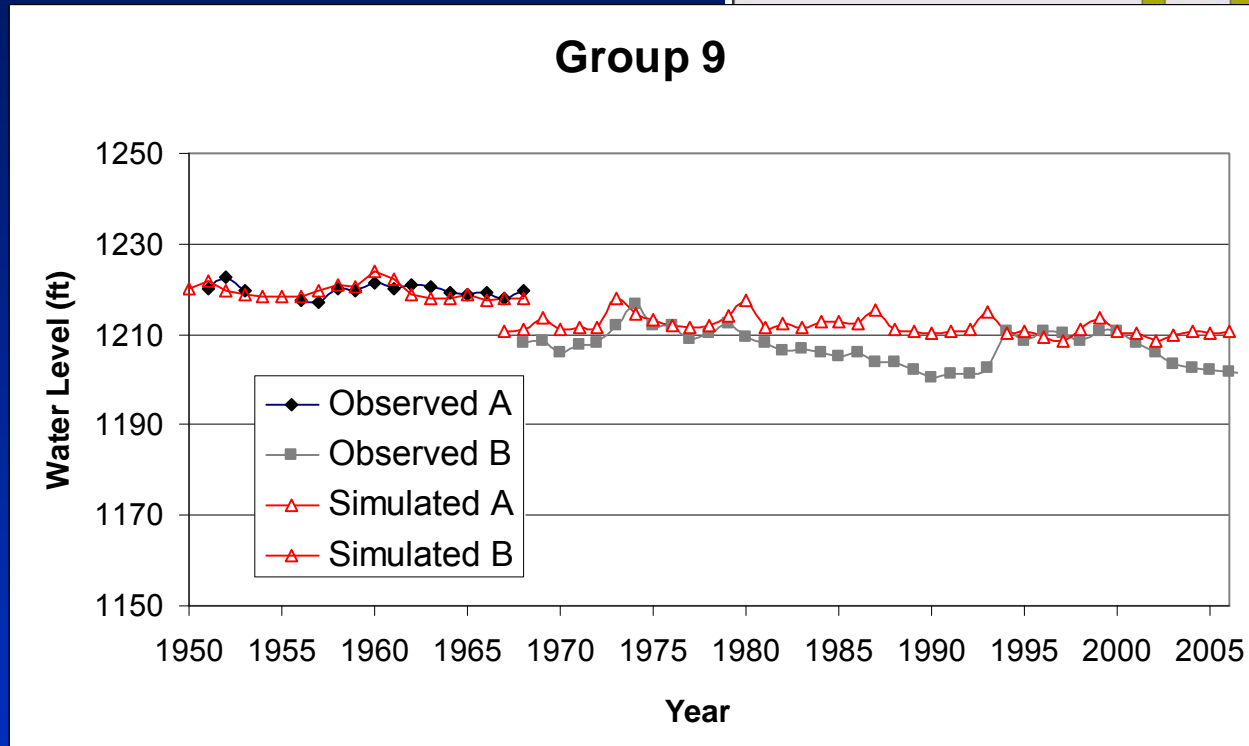
Calibrated Model Results- Hydrographs



Calibrated Model Results- Hydrographs

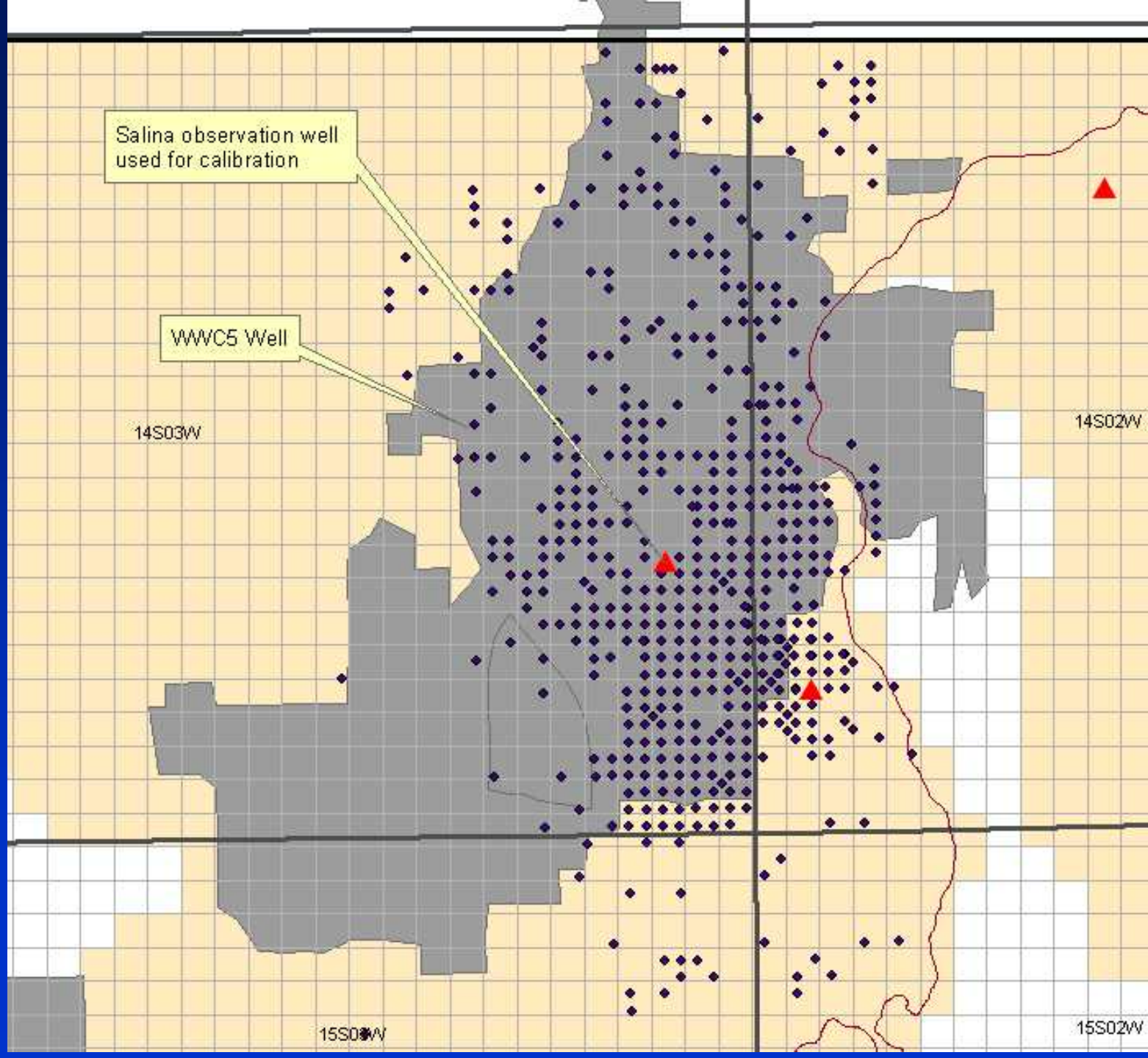


Initially Simulated Well Hydrograph in Salina



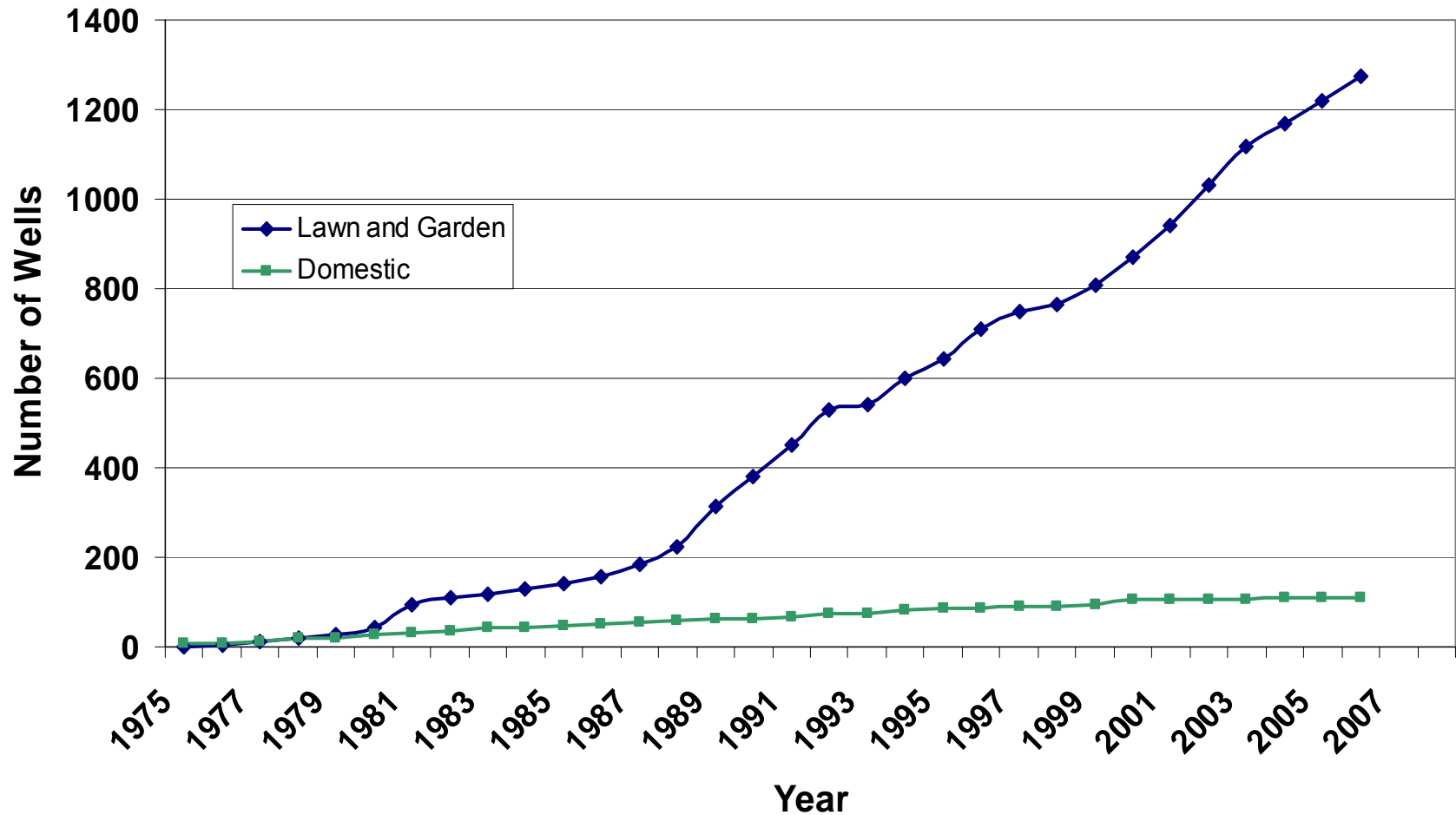
Model Run- April, 2008

WWC5 Wells Near Salina



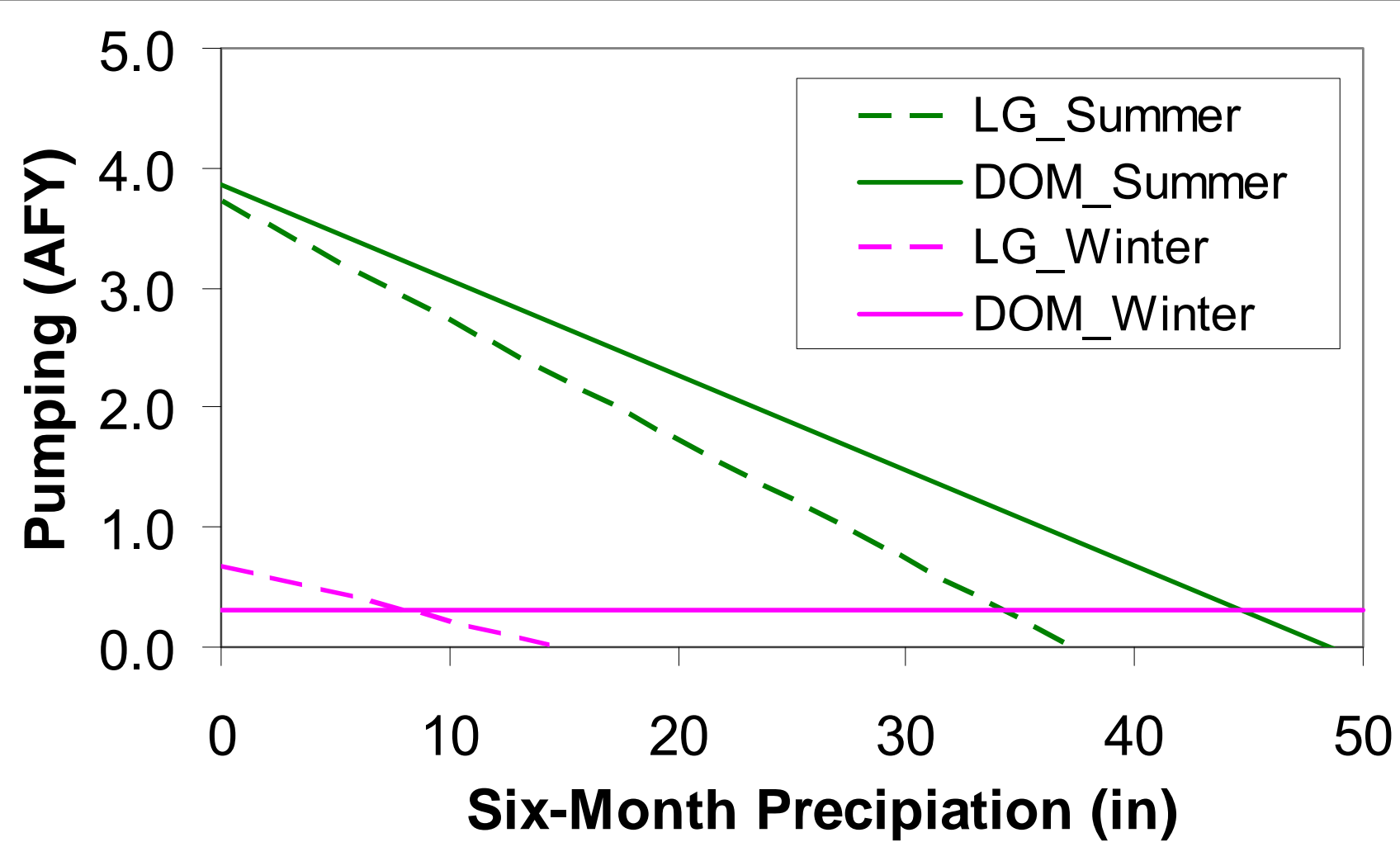
Domestic and Lawn/Garden Well Development

Domestic and Lawn/Garden Well Accumulation
in and around the City of Salina



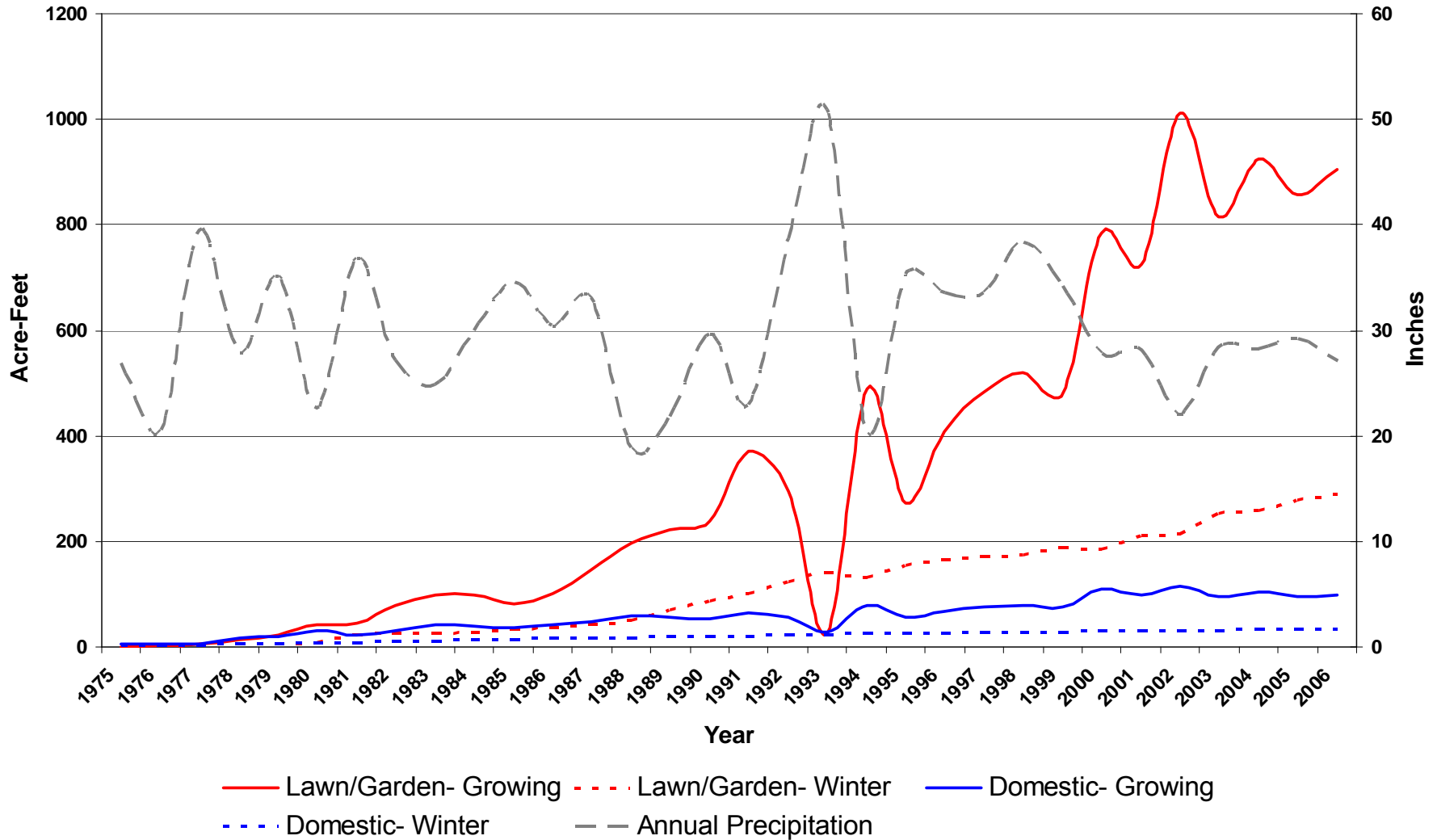
Since 1974, over 1,400 private domestic wells have been drilled in and around the Salina area.

Domestic Water Use Versus Precipitation

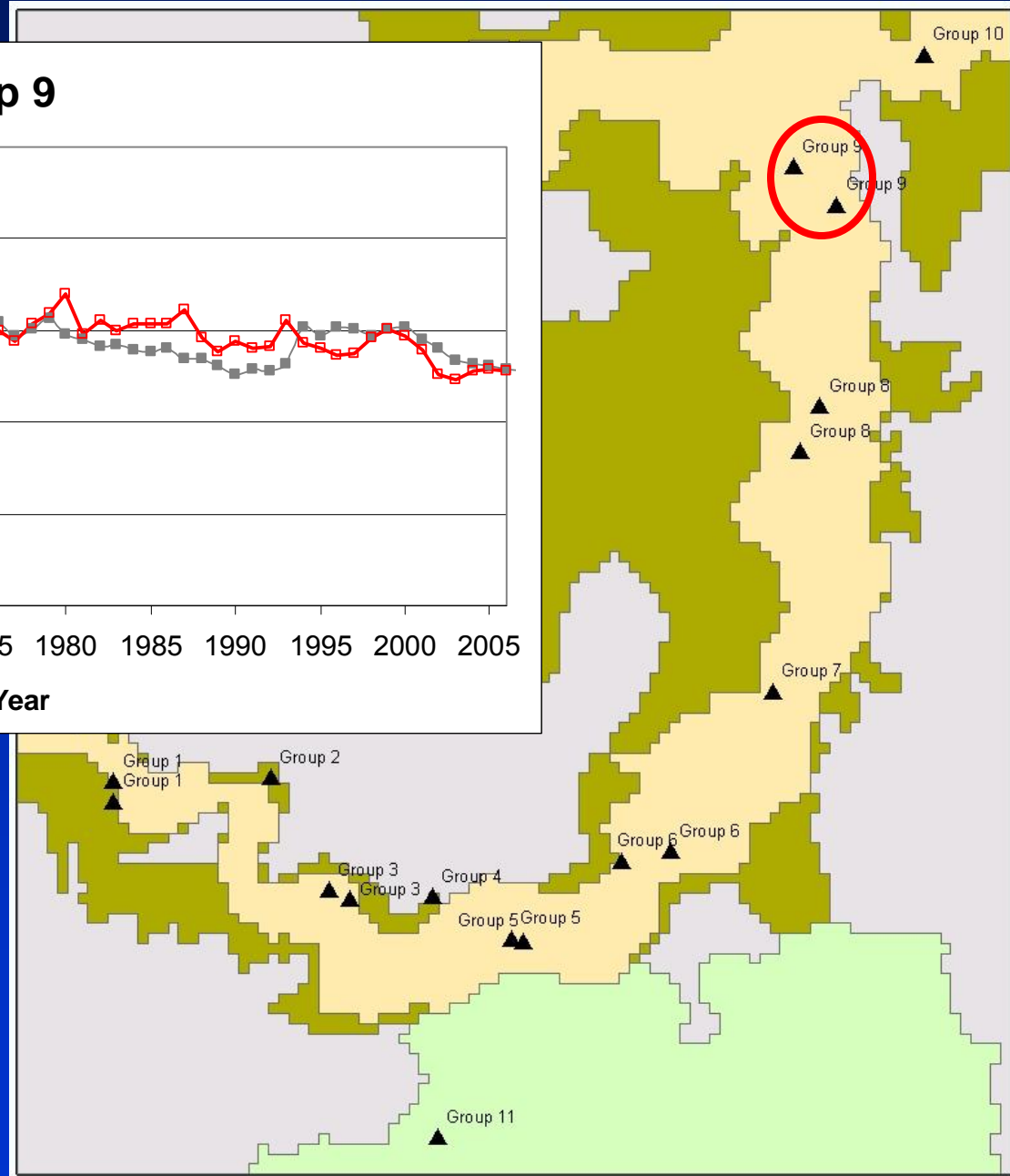
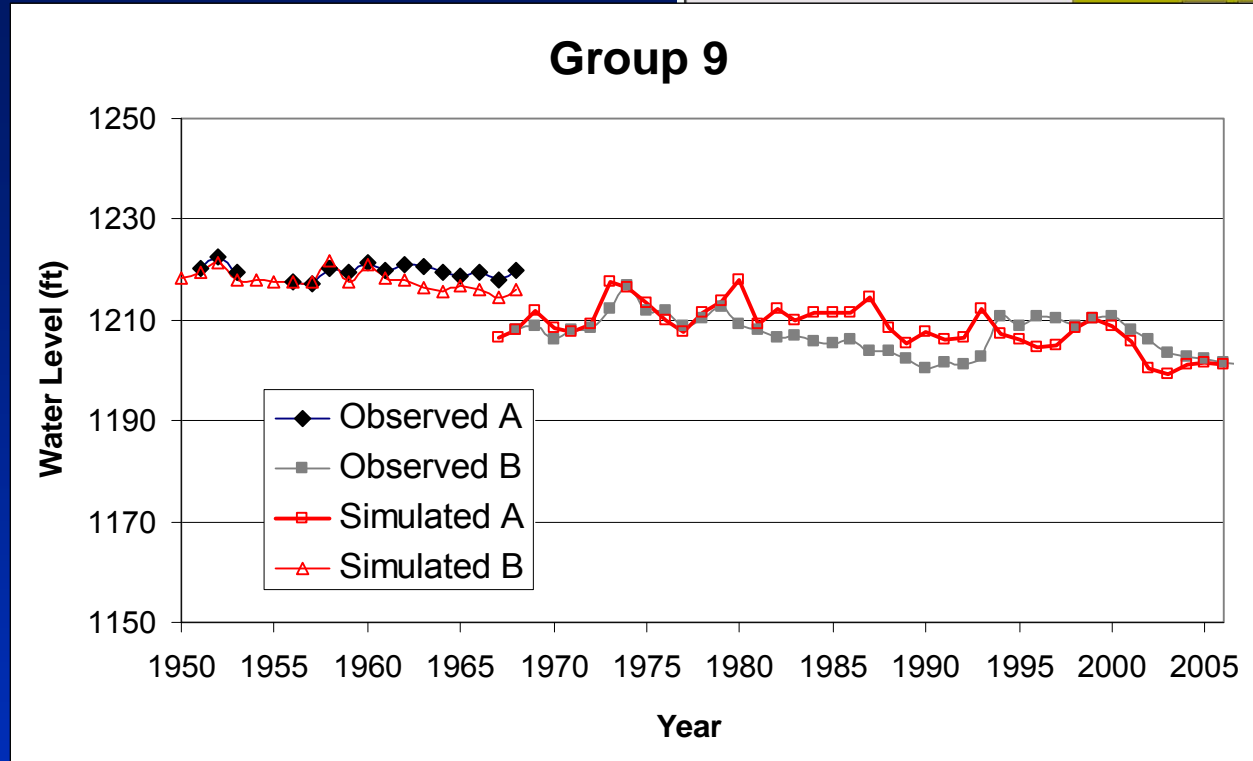


Domestic Pumping, 1975 to 2006

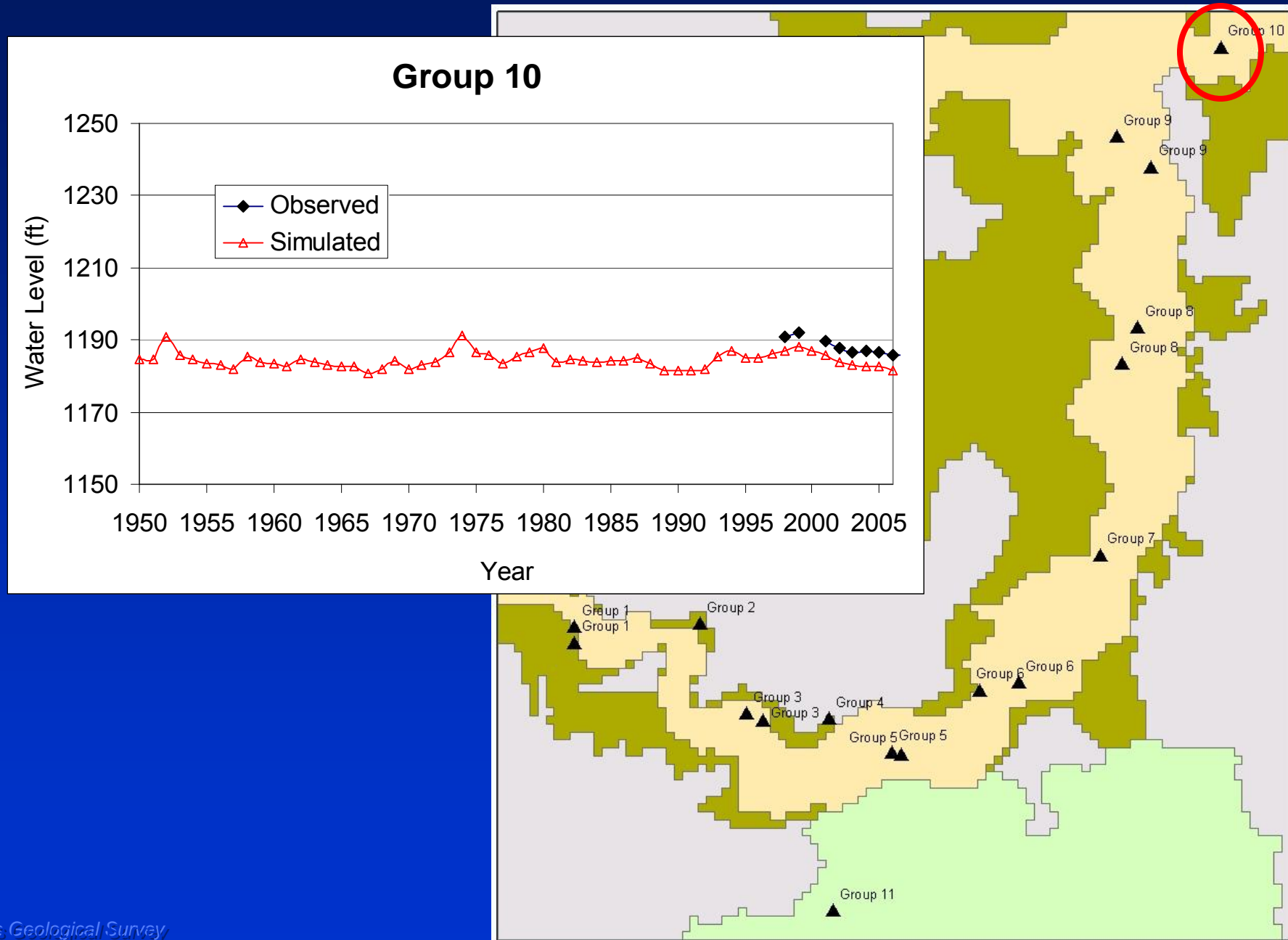
Estimated Private Well Water Use



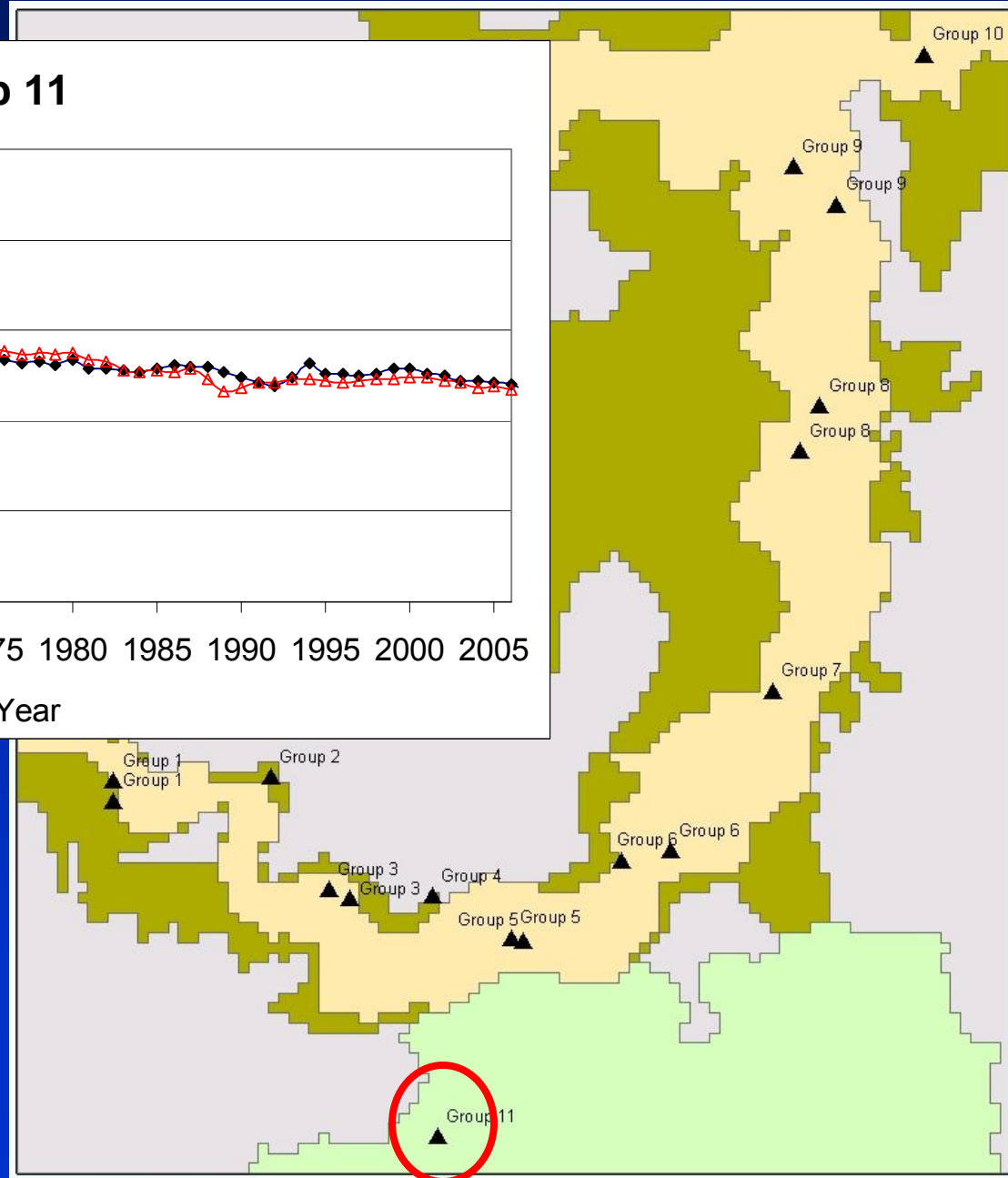
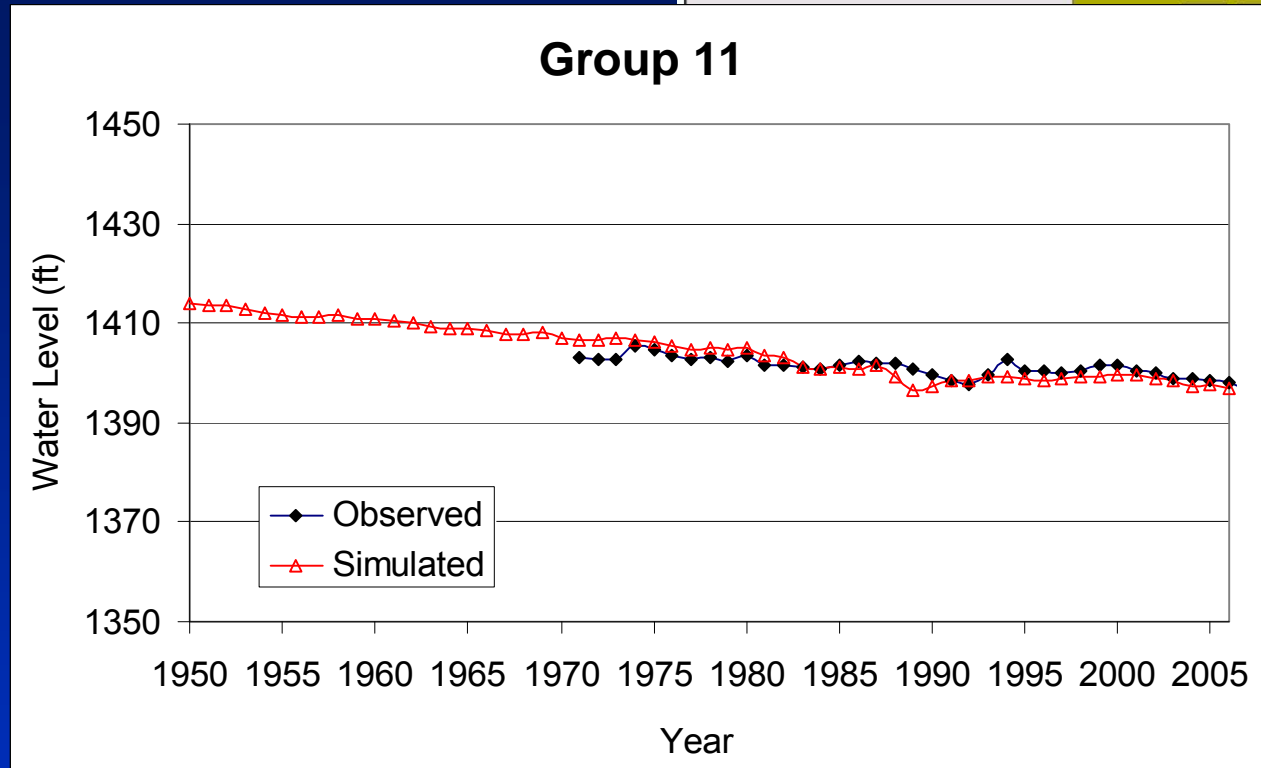
Calibrated Model Results- Hydrographs



Calibrated Model Results- Hydrographs



Calibrated Model Results- Hydrographs

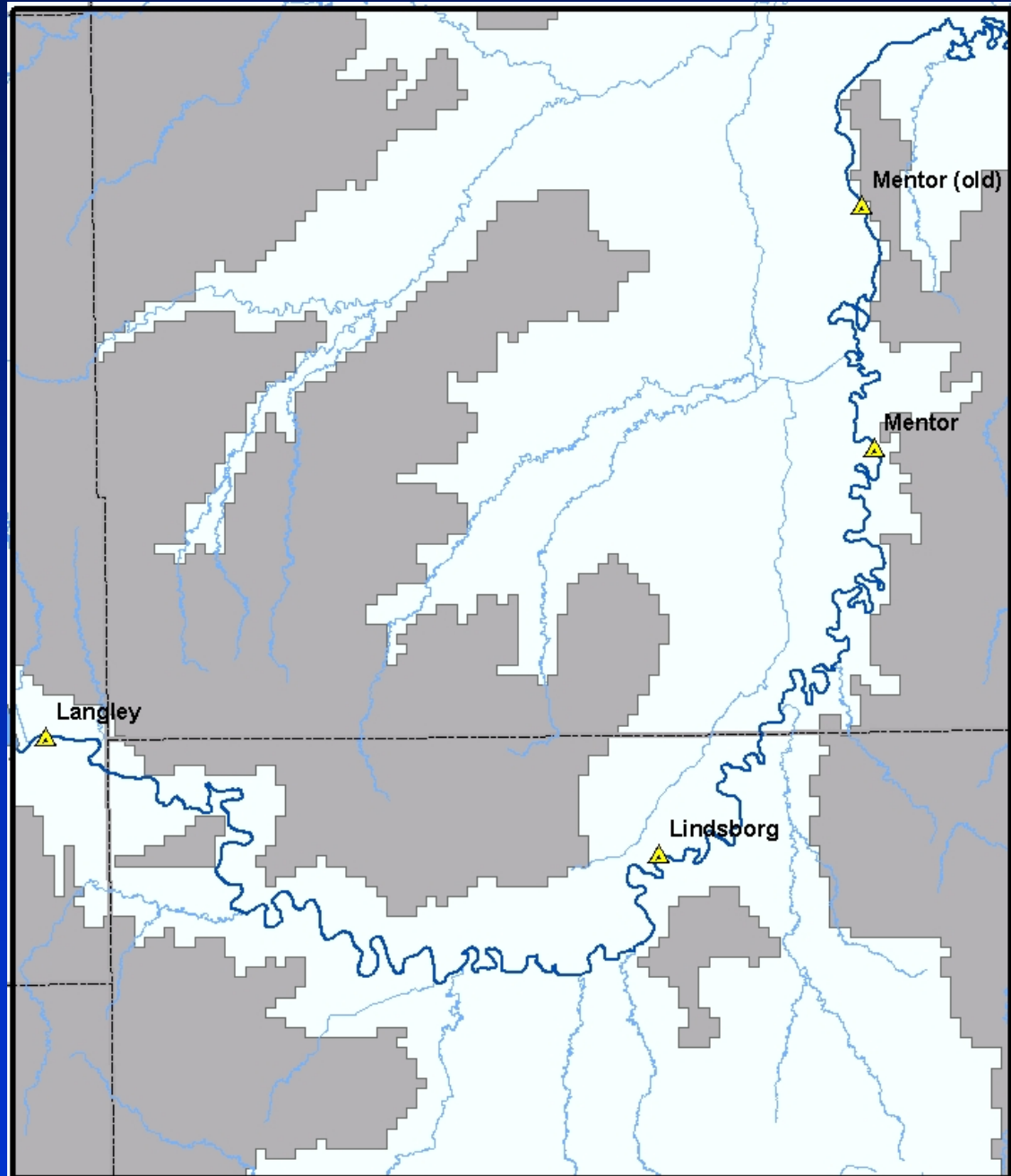


Smoky Hill Ground-Water Model

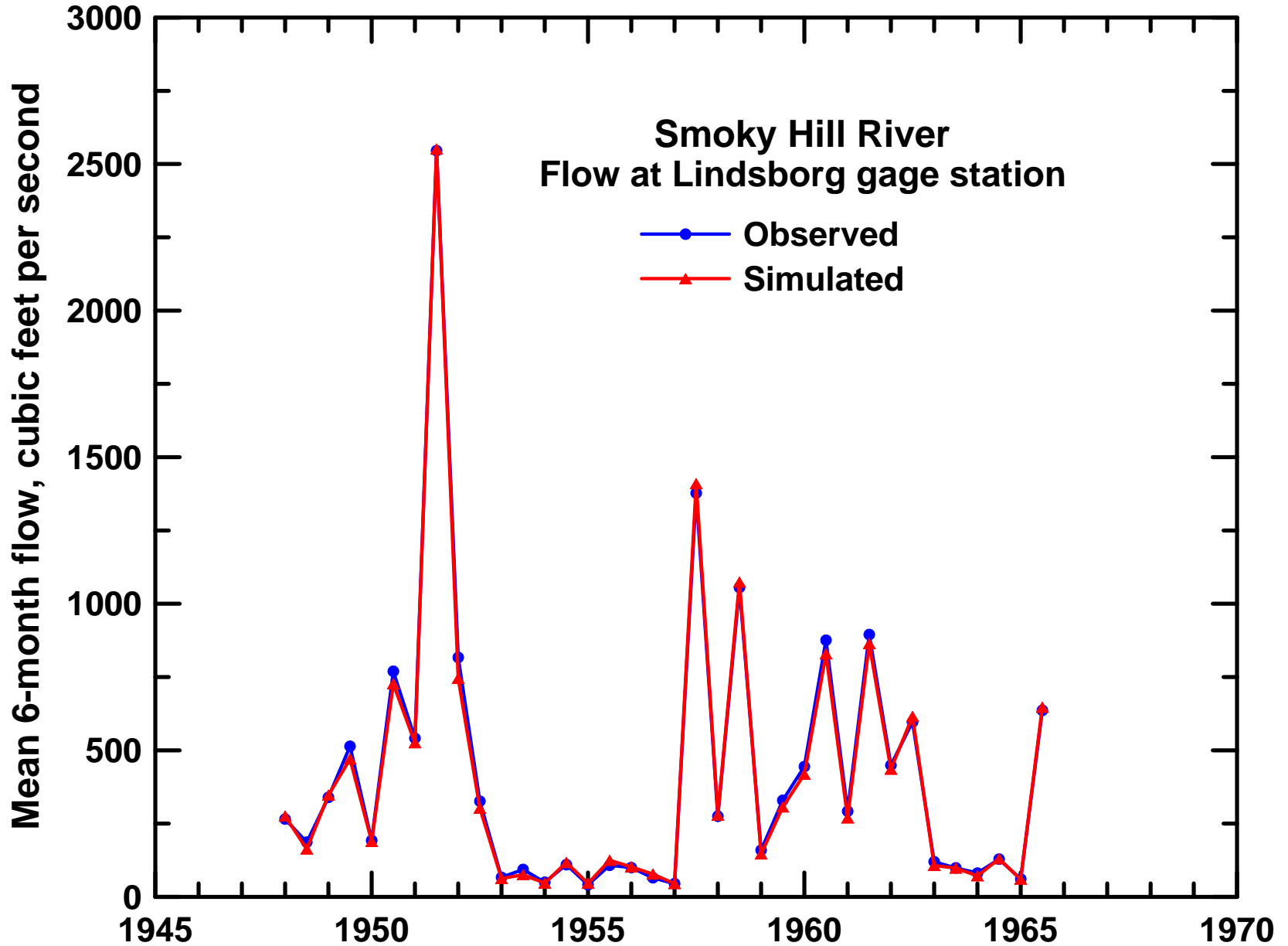
Model Results- Streamflow

Calibrated Model Results- Streamflow

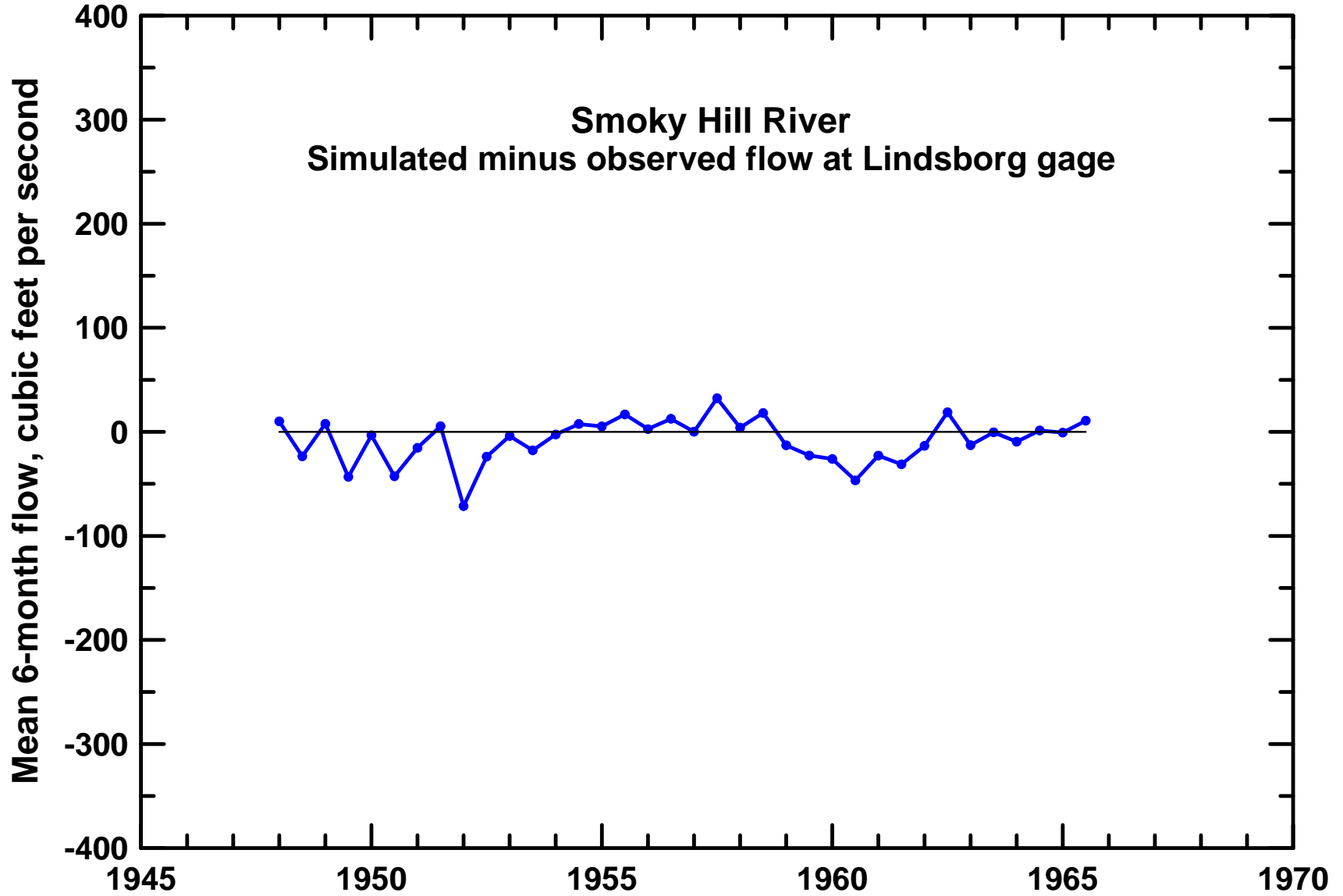
Streamflow Gaging Stations



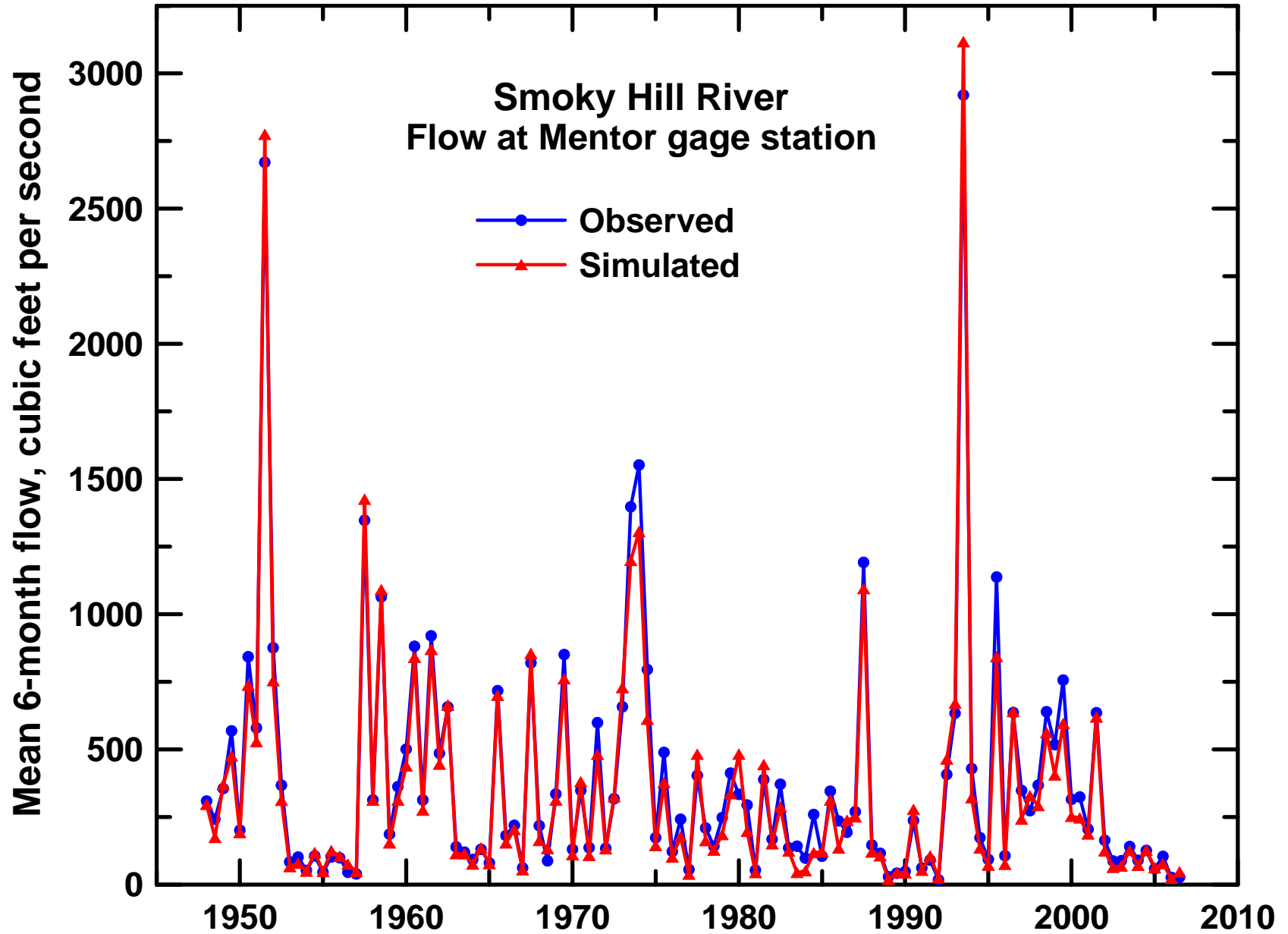
Calibrated Model Results- Streamflow



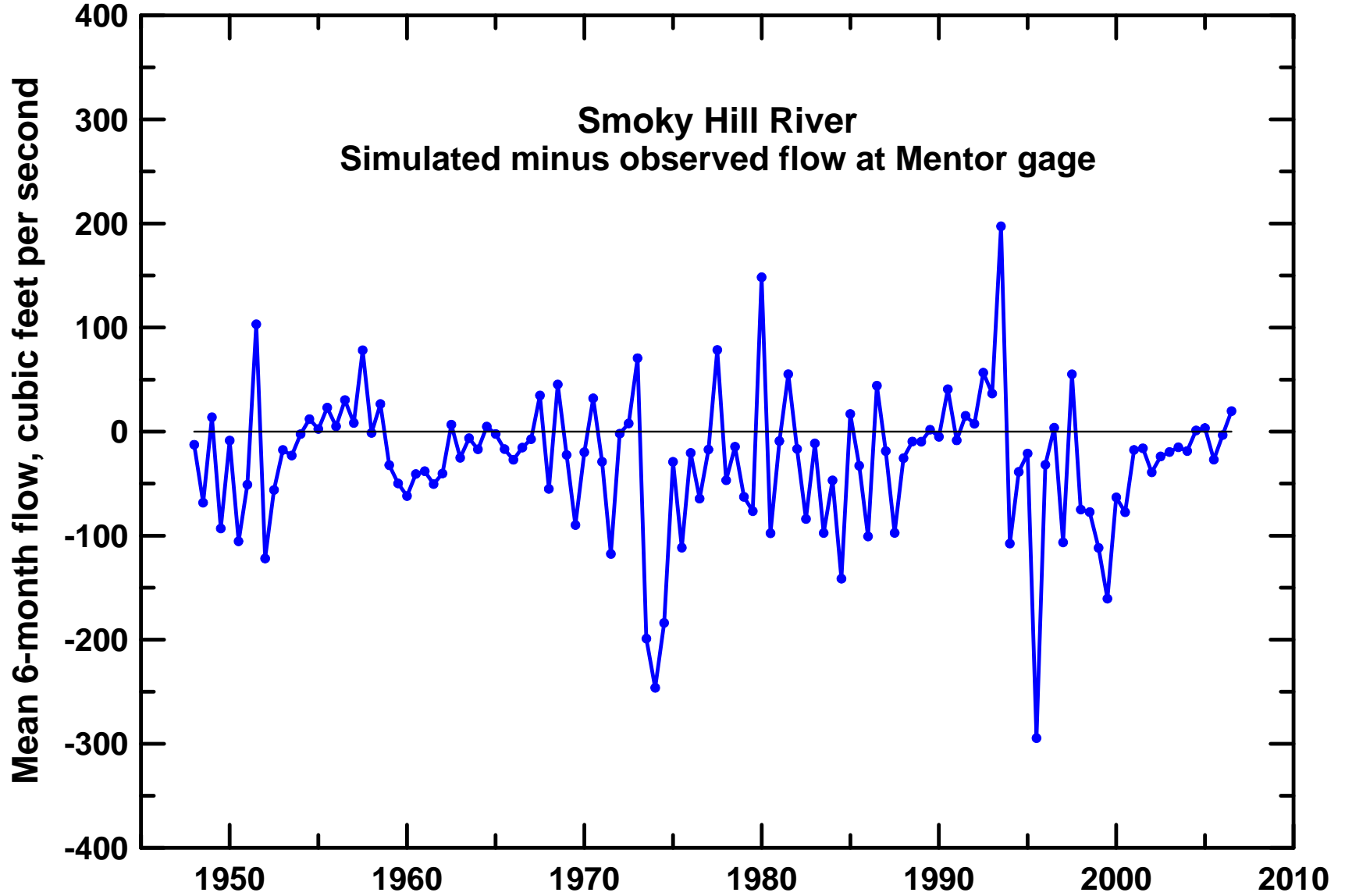
Calibrated Model Results- Streamflow



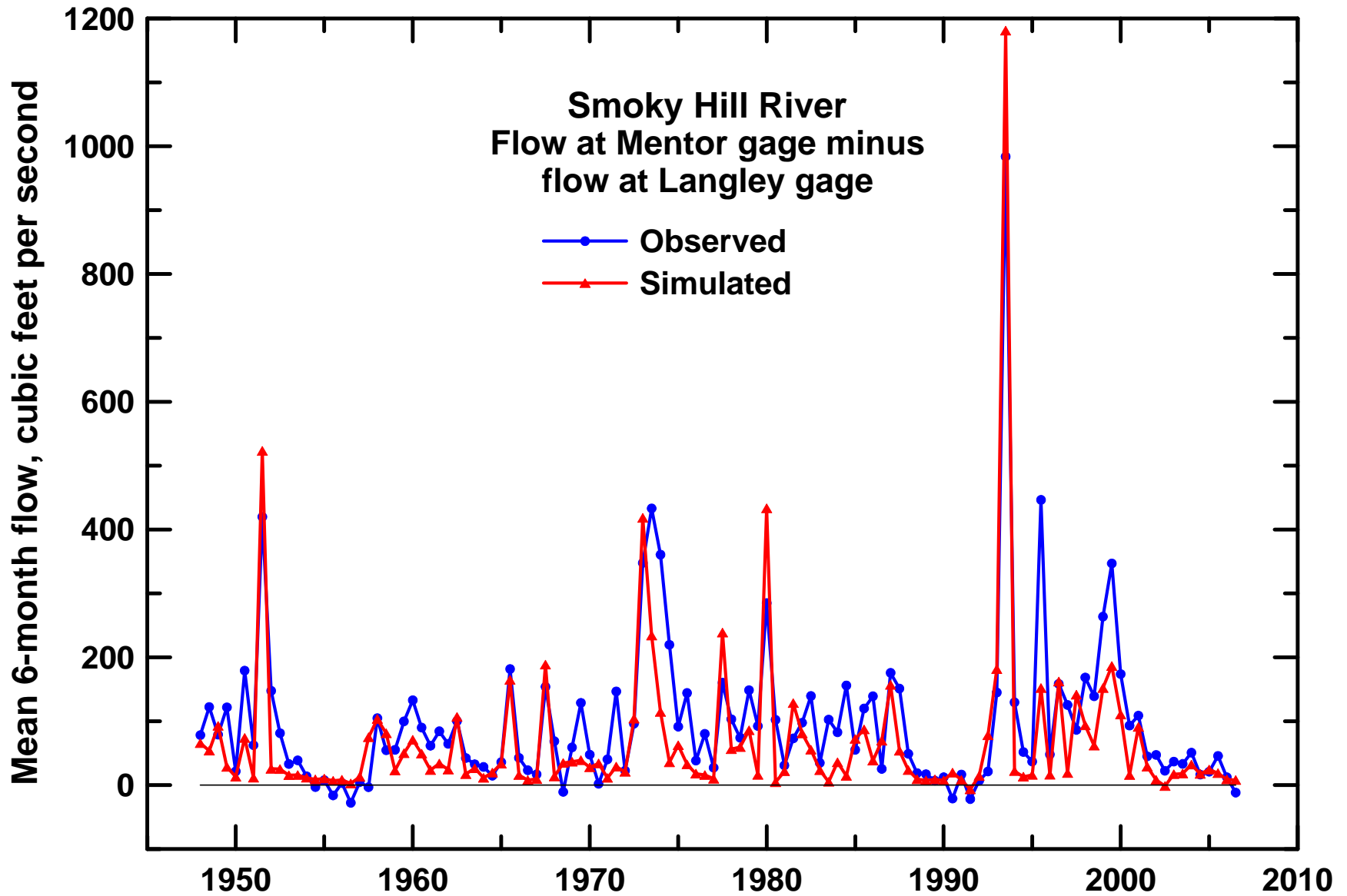
Calibrated Model Results- Streamflow



Calibrated Model Results- Streamflow



Calibrated Model Results- Streamflow

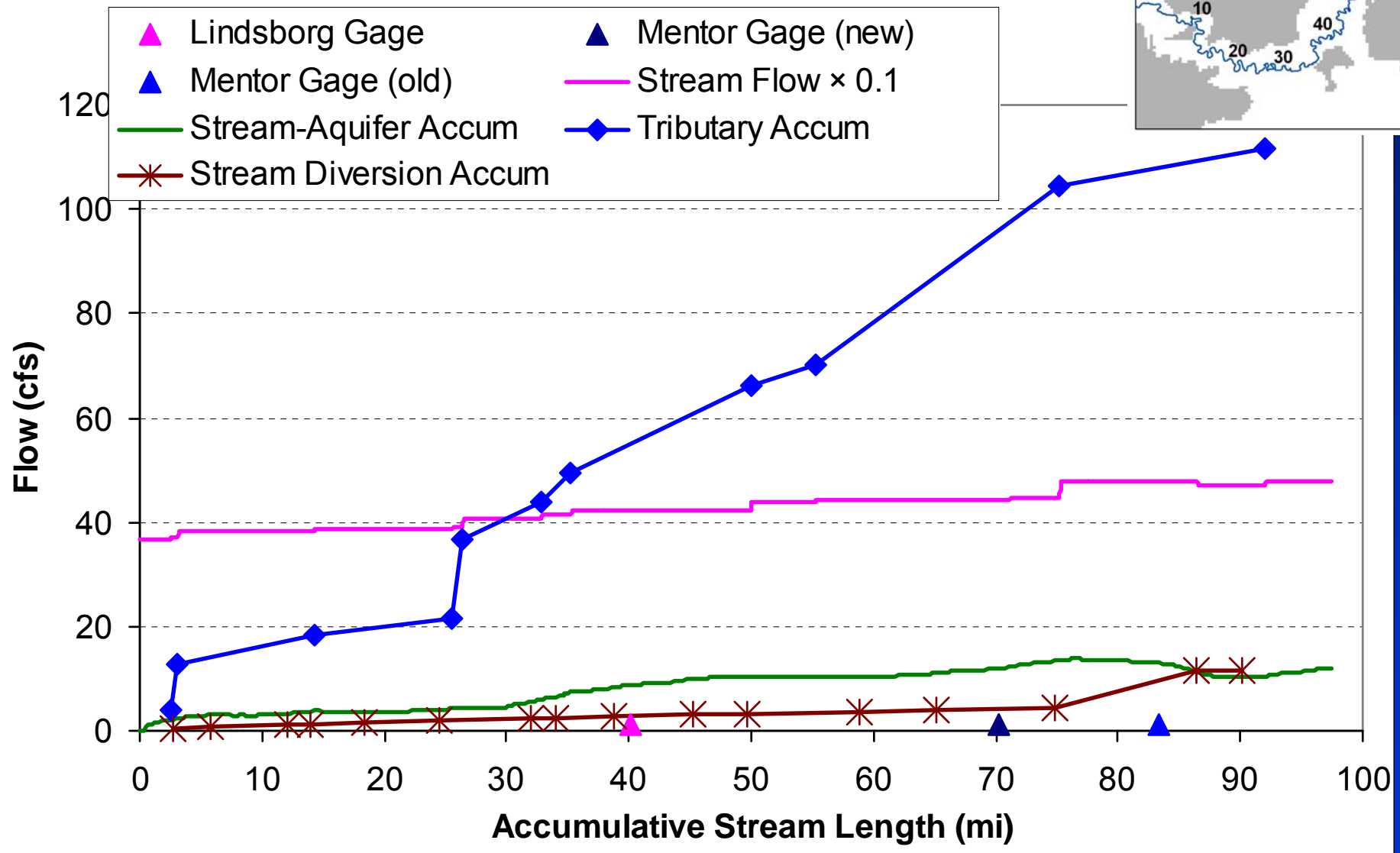
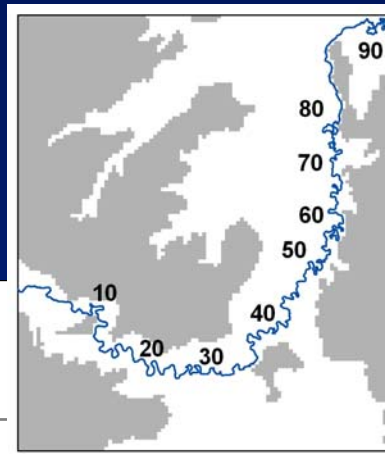


Smoky Hill Ground-Water Model

Model Budgets

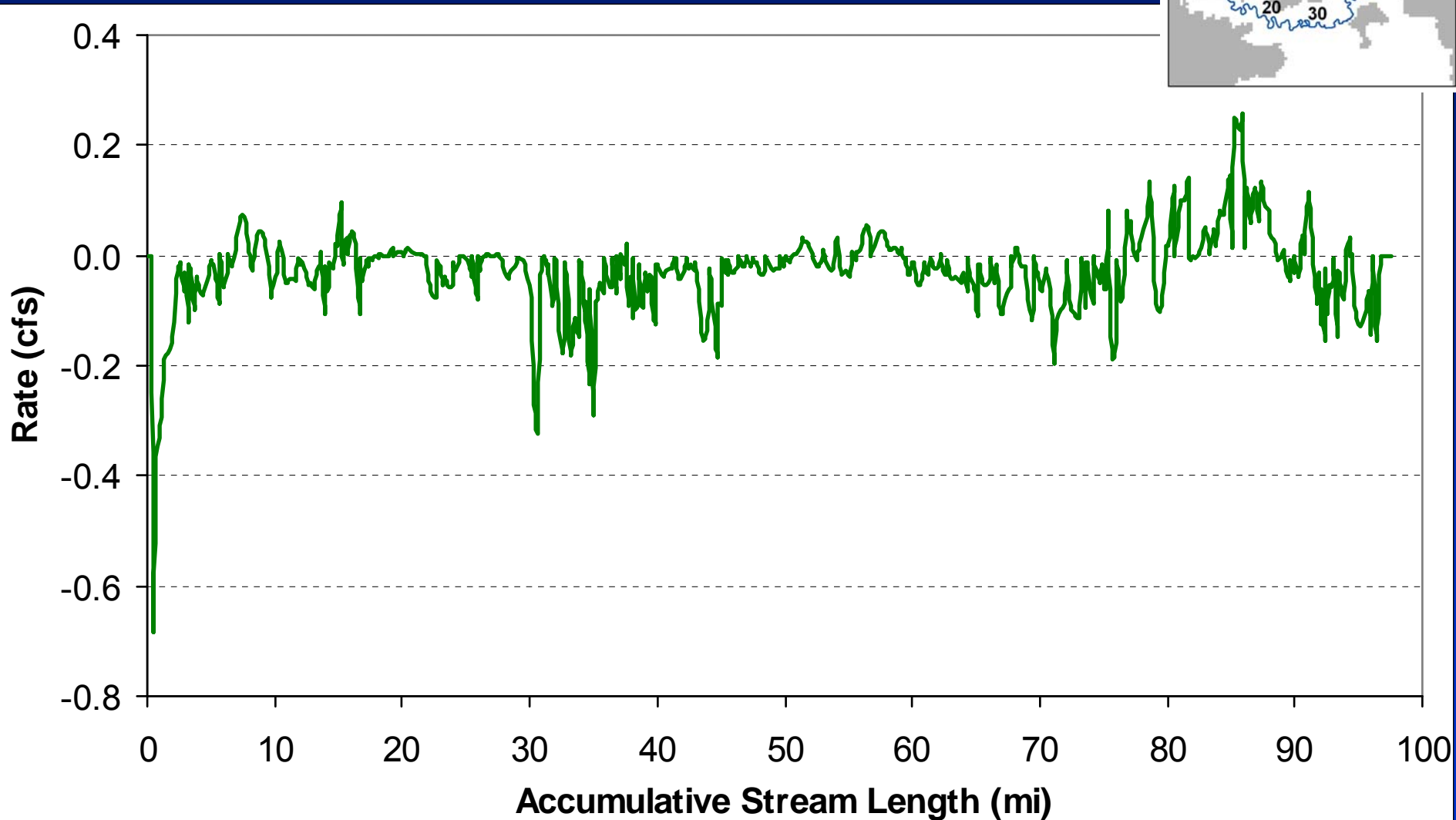
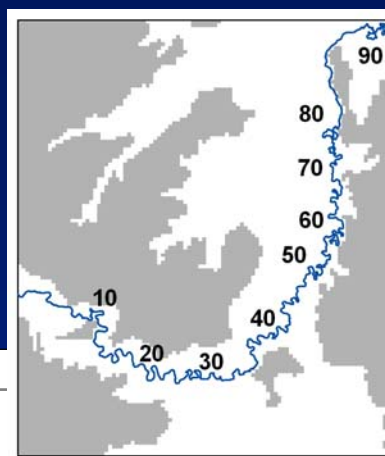
Stream Flow Budget (Post-Mentor Cutoff)

Average for 1962-2006



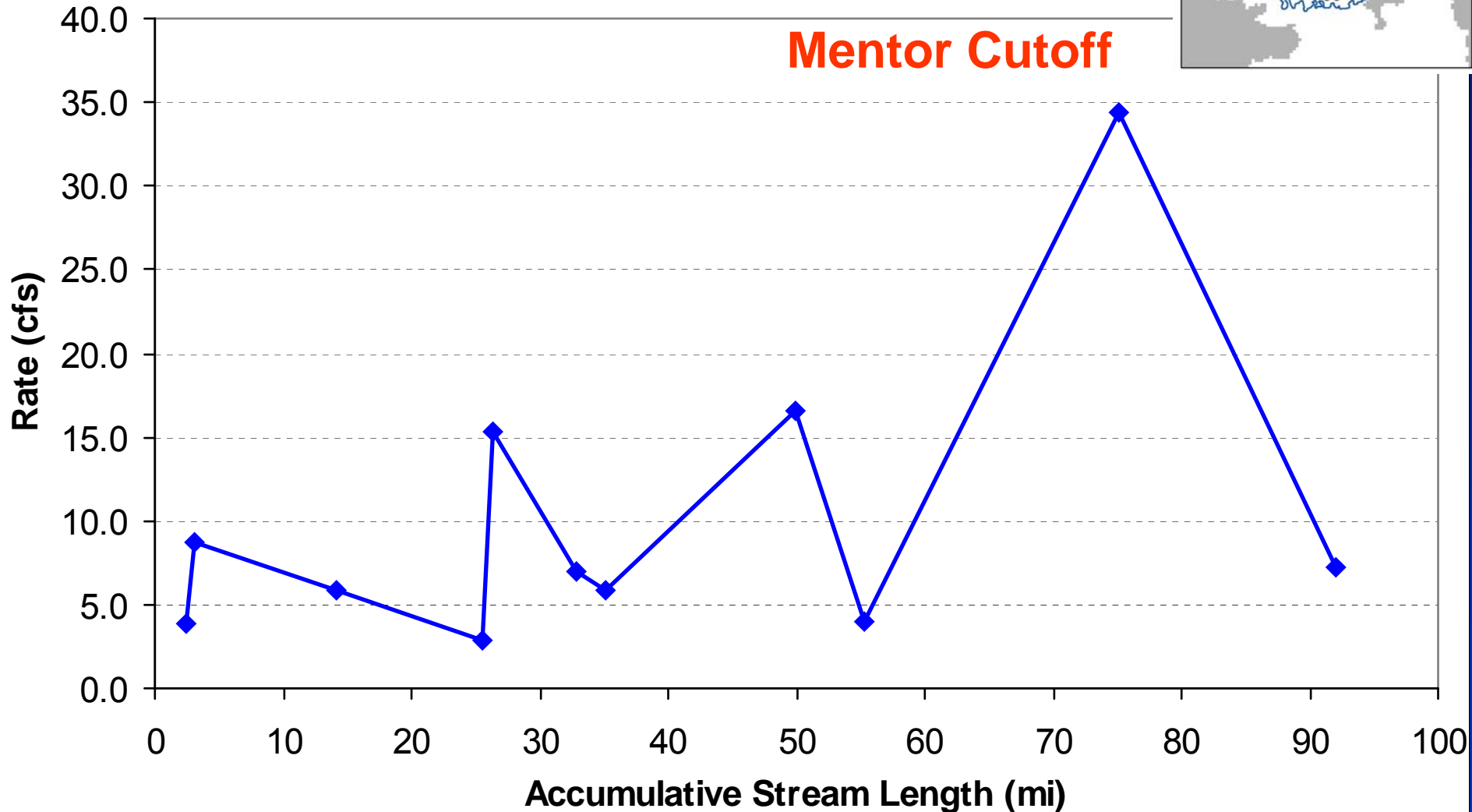
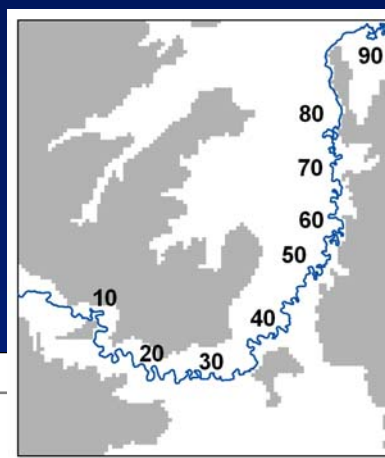
Stream-Aquifer Interactions (Post-Mentor Cutoff)

Average for 1962-2006



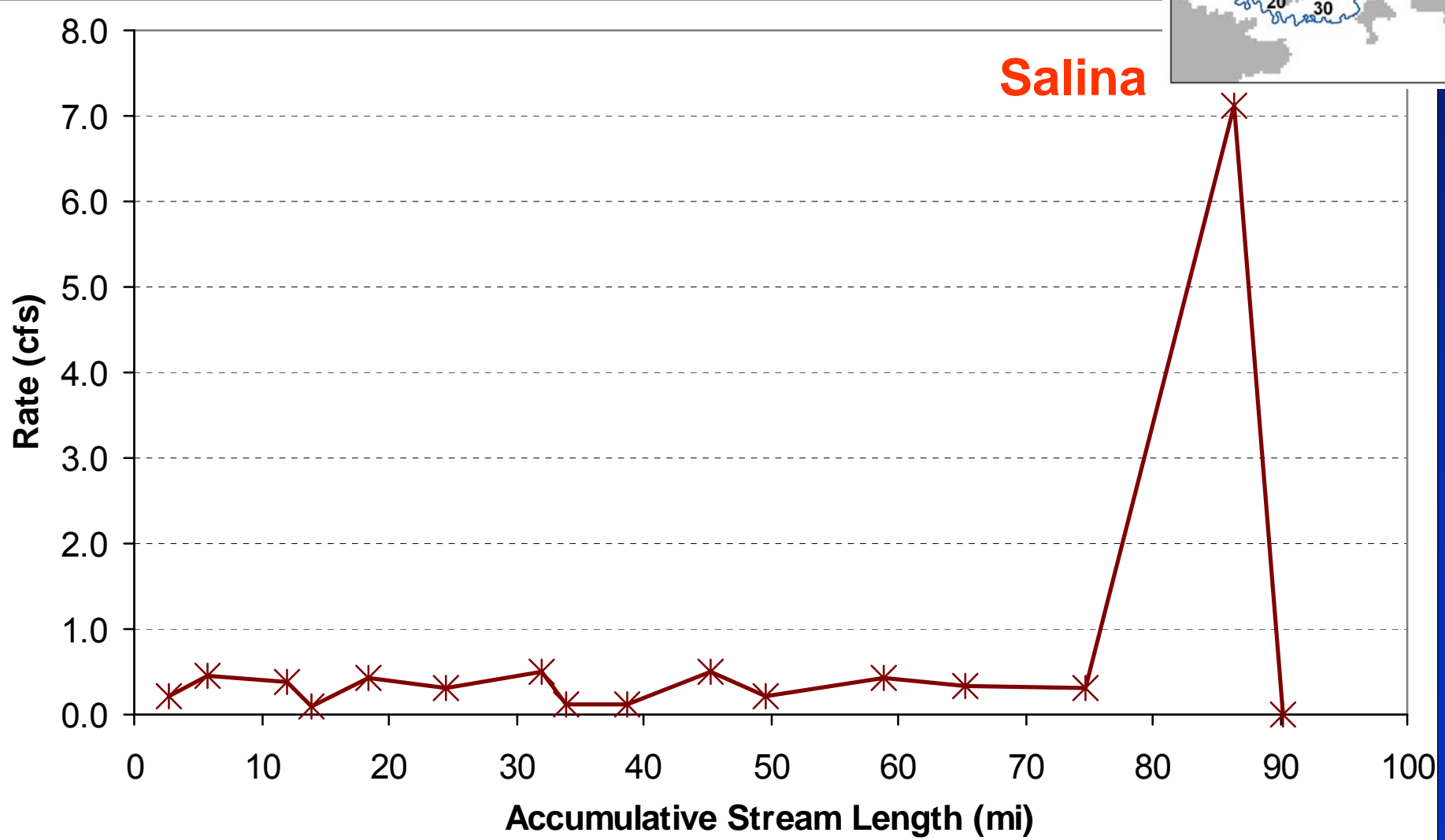
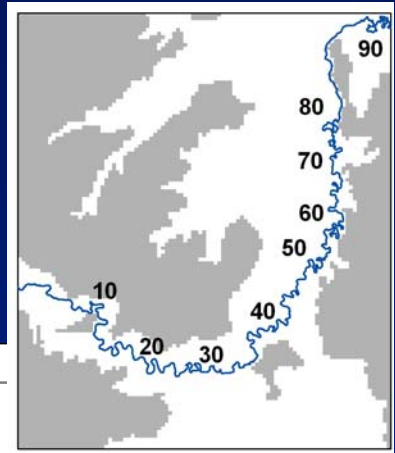
Average Tributary Inflows (Post-Mentor Cutoff)

Average for 1962-2006

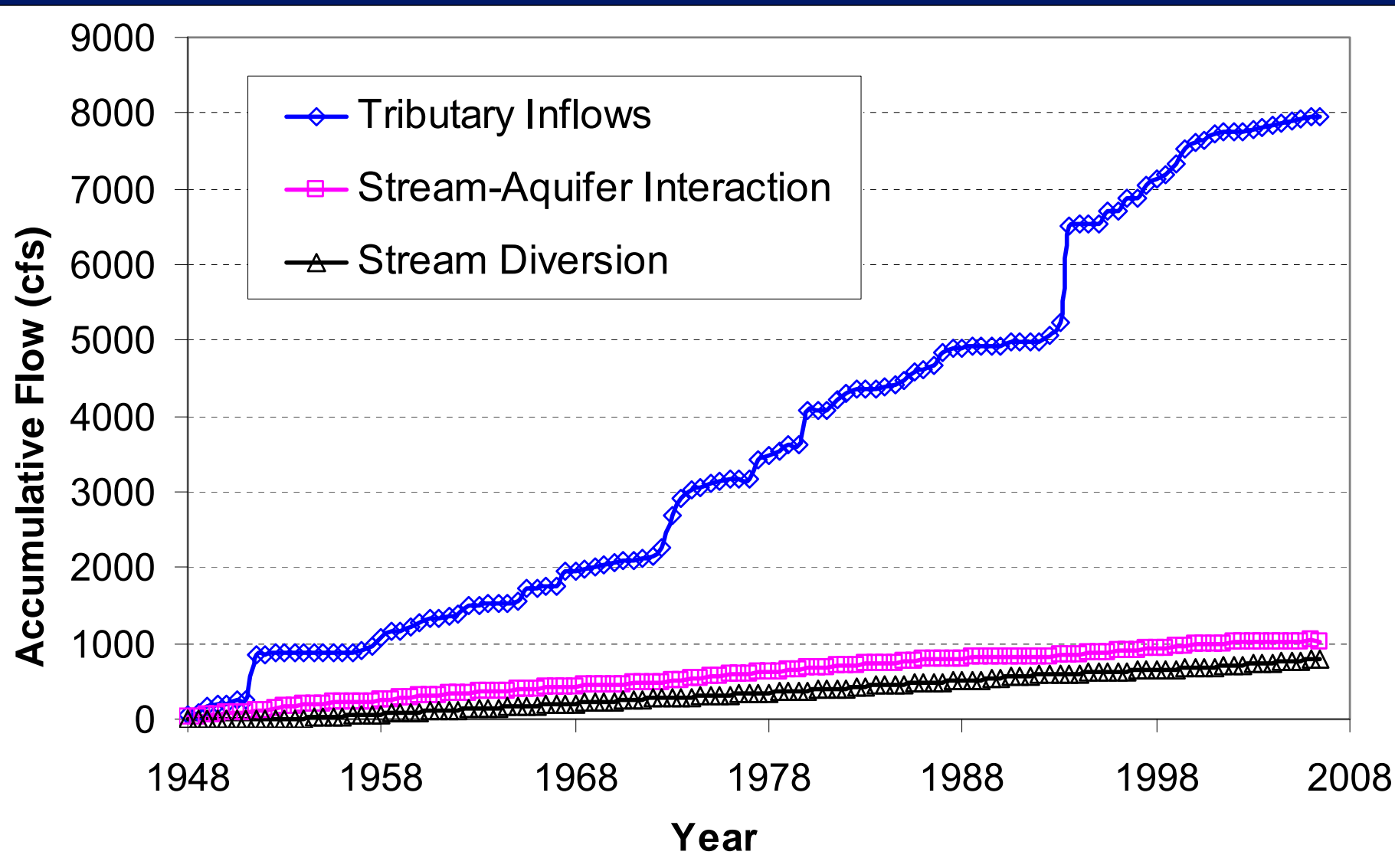


Average Stream Diversions (Post-Mentor Cutoff)

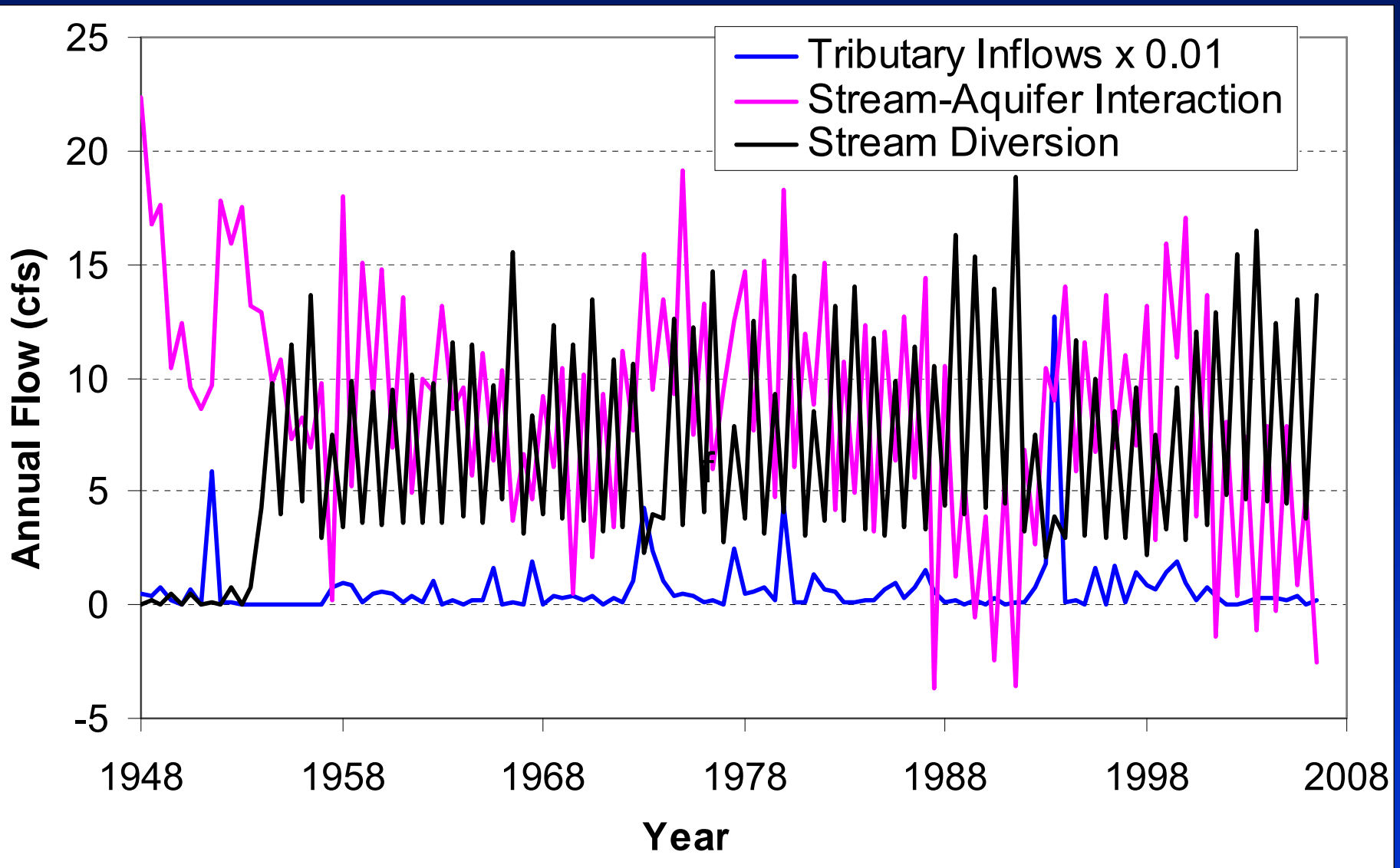
Average for 1962-2006



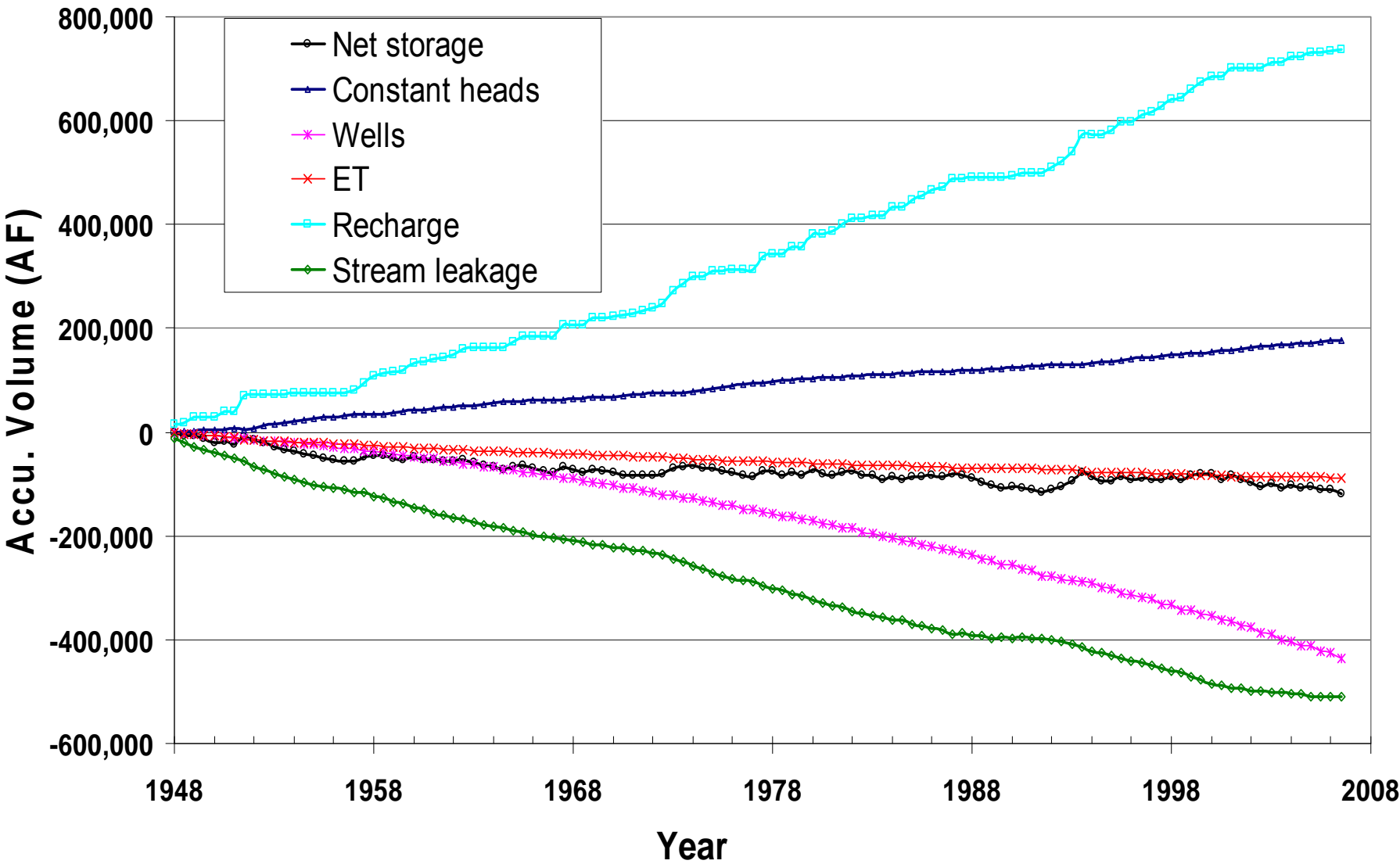
Year-to-year Stream Flow Budget - Accumulative



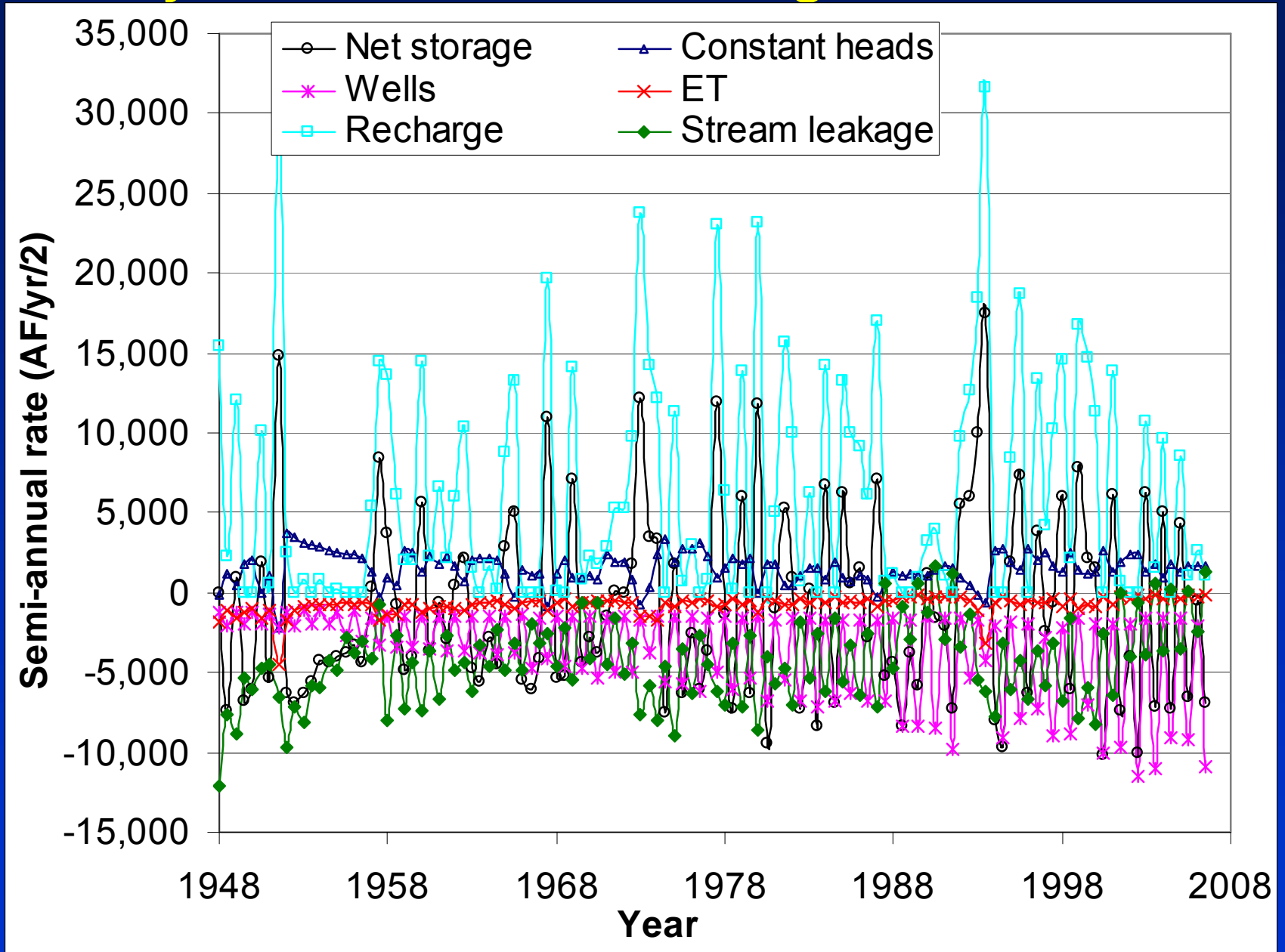
Year-to-year Stream Flow Budget



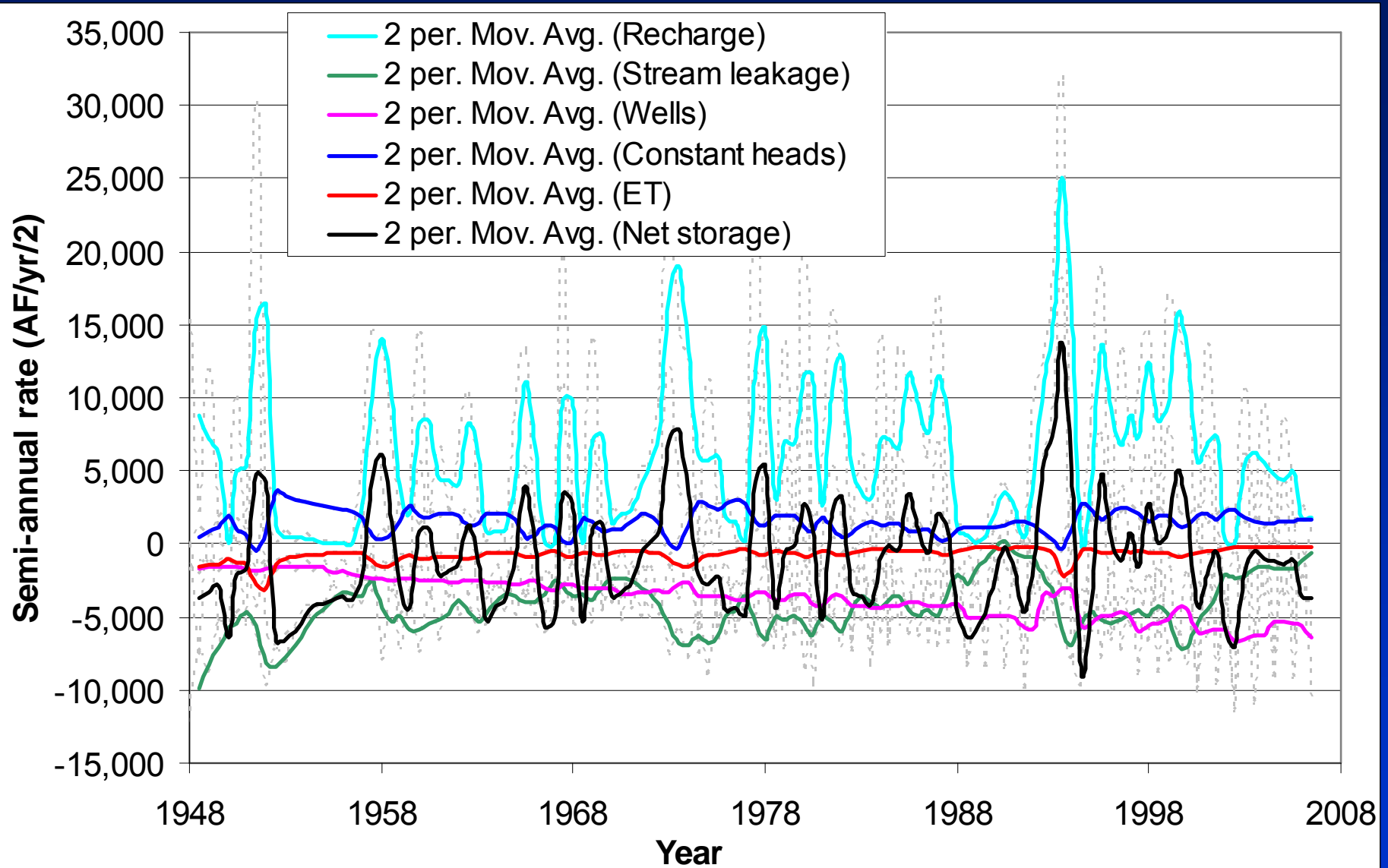
Ground-water Budget - Accumulative



Year-to-year Ground-water Budget



Year-to-year Ground-water Budget



Smoky Hill Ground-Water Model

“Back Calculation Scenario”

Back Calculation Scenario

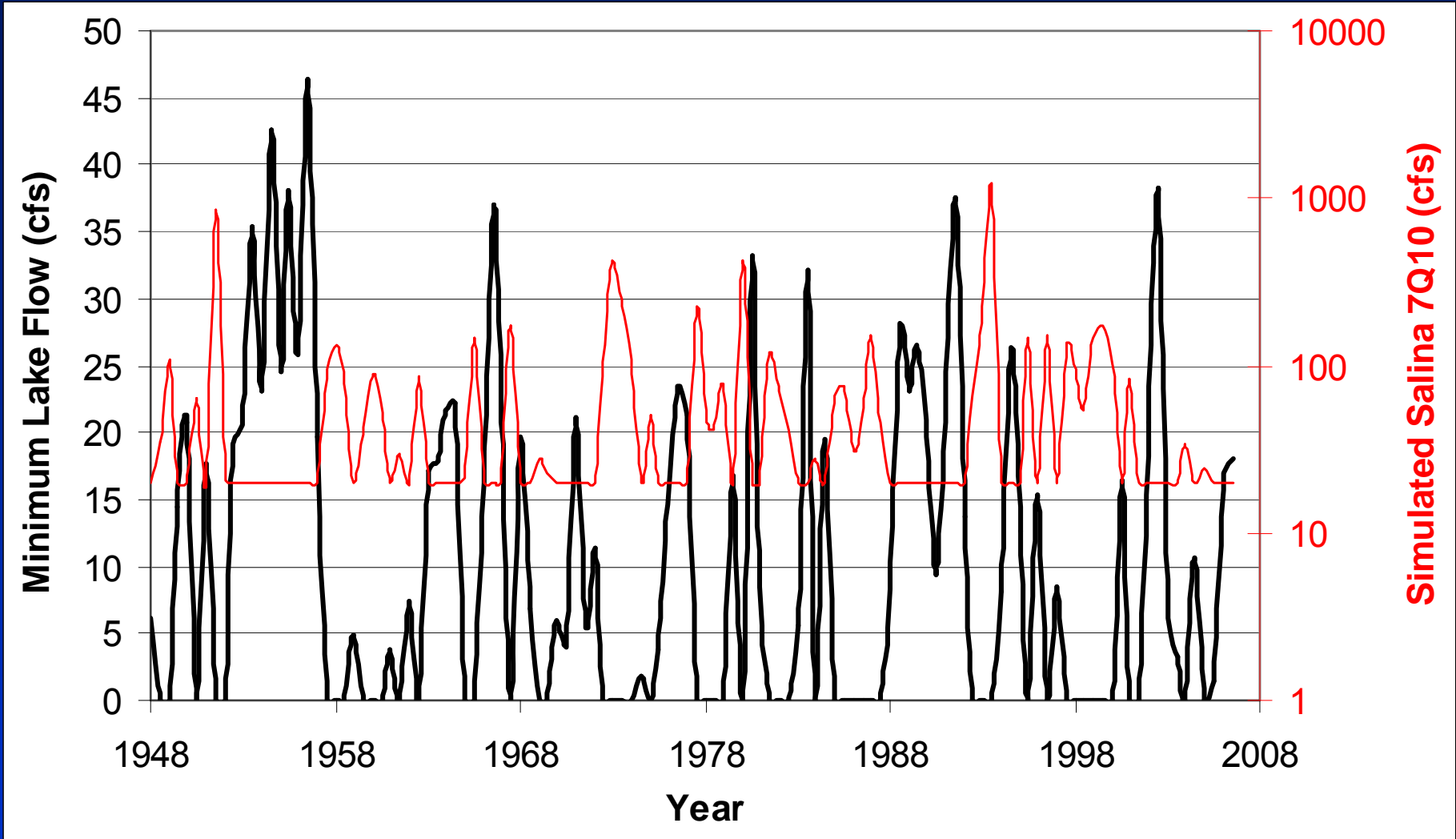
- Determine the minimum flow of the Smoky Hill River into the model (which is the outflow of Kanopolis Lake) that meets the 7Q10 flow at Salina
- Run model for a 59-year period based on the climatic conditions from 1948-2006
- Meet the predicted surface- and ground-water pumping based on current water right development

Back Calculation

- **Main Features**

- **Iterative, requiring many model runs**
- **Repeat of precipitation patterns from 1948 to 2006**
- **Surface- and ground-water pumping are based on the regression of precipitation to the 2006 water right development**
- **Initial ground-water levels are simulated by the calibrated transient model in 2006**
- **Constant head boundaries are based on the interpolated heads in 2006**
- **Stream properties are based on those in 2006**
- **7Q10 flow is 20 cfs, @ Lat, Long (NAD27) 38.854, - 97.56502**

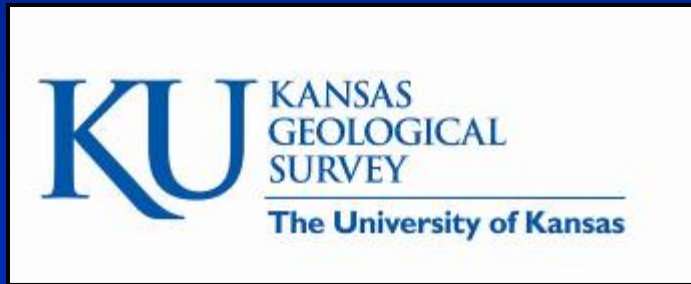
Back Calculation Results



- 65 out of a total of 118 calculated time periods require flow
- 30 growing seasons and 35 non-growing seasons.

Questions????

**Kansas Geological Survey
1930 Constant Ave
Lawrence, KS 66047
785-864-2118**



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