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ANALYZING THE EFFECTS OF REGULATED STREAMFLOW ON THE HYDROLOGY OF CONGAREE NATIONAL PARK

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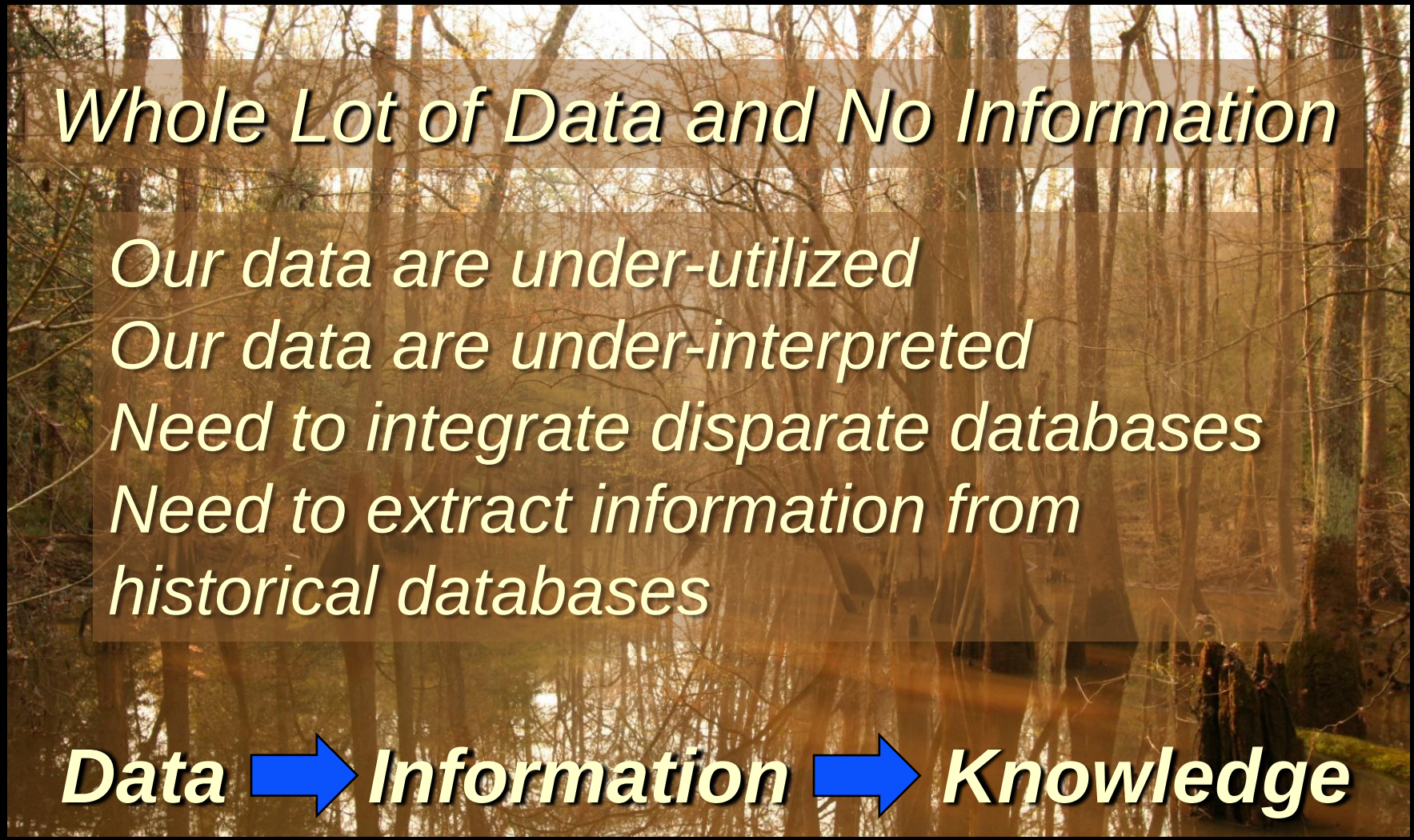
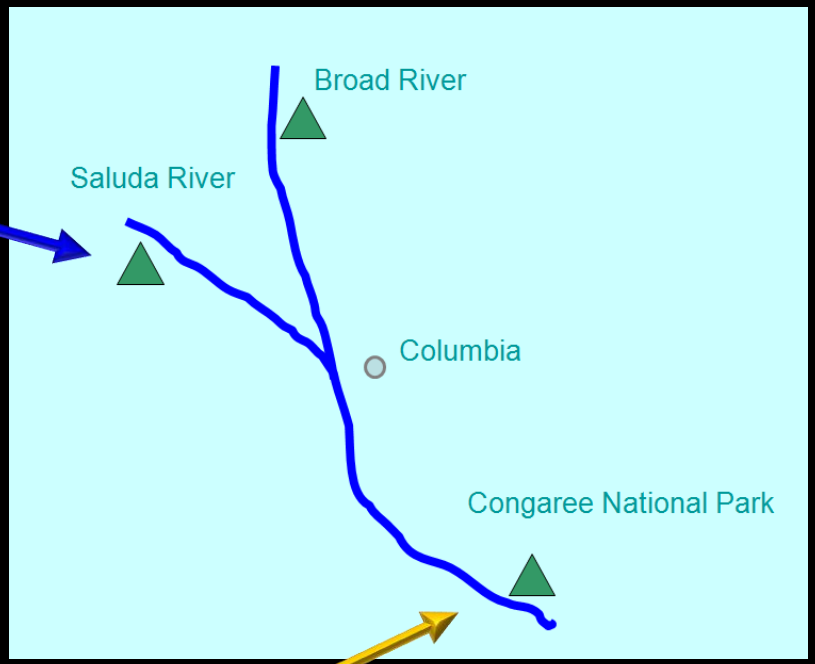
U.S. Department of the Interior
U.S. Geological Survey

Background


Whole Lot of Data and No Information
Our data are under-utilized
Our data are under-interpreted
Need to integrate disparate databases
Need to extract information from historical databases
Data
Information
Knowledge

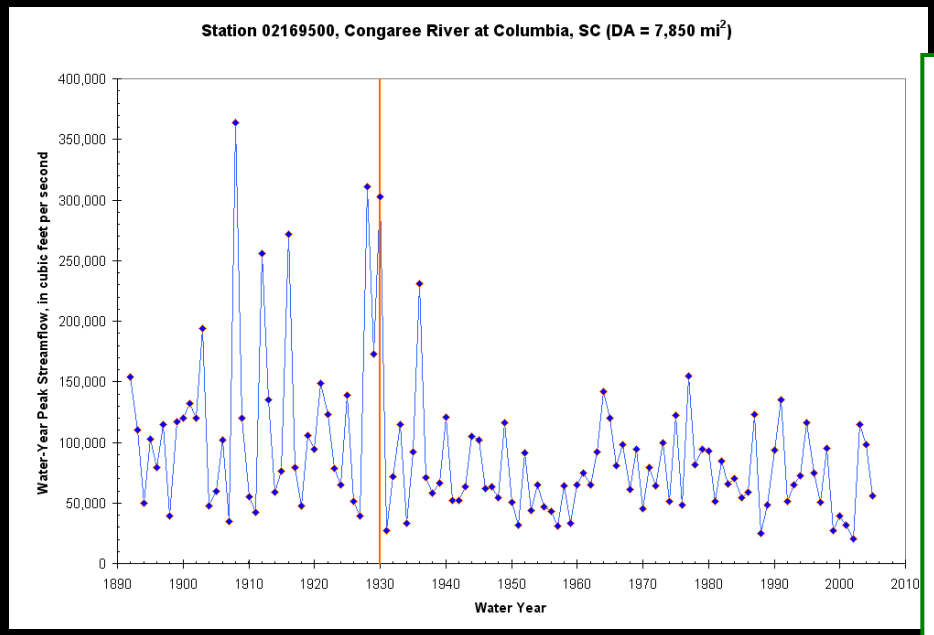
Question?

What effect has the controlled flows from Lake Murray had on the gage heights and ground-water levels of the Congaree National Park?



What are the effects on:
Peak flows
Daily river stages
GW levels

Congaree River at Columbia, S.C.
Station 02169500



Annual Peak Flows

Is this really due to regulation?

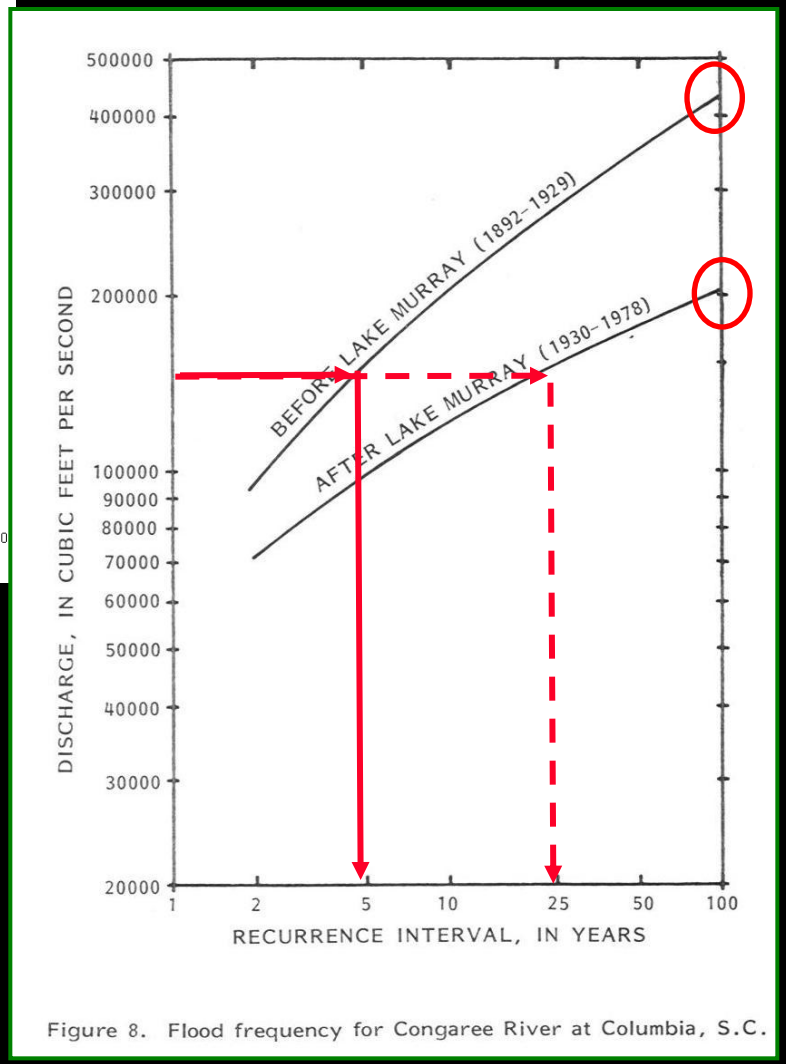
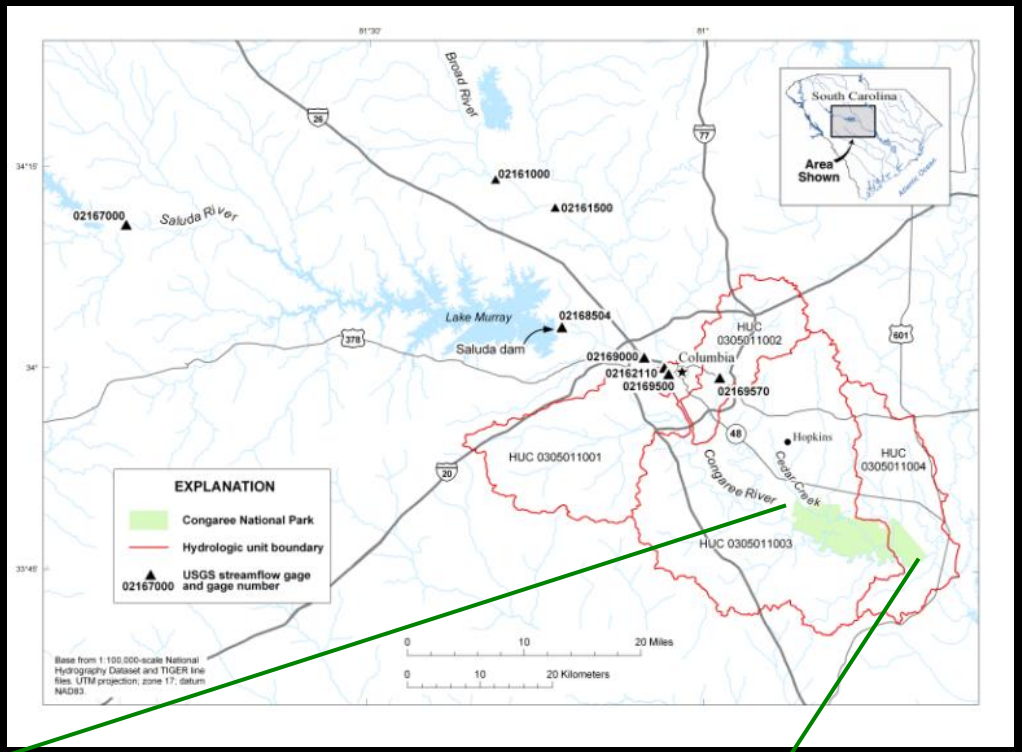


Figure 8. Flood frequency for Congaree River at Columbia, S.C.

Available Data

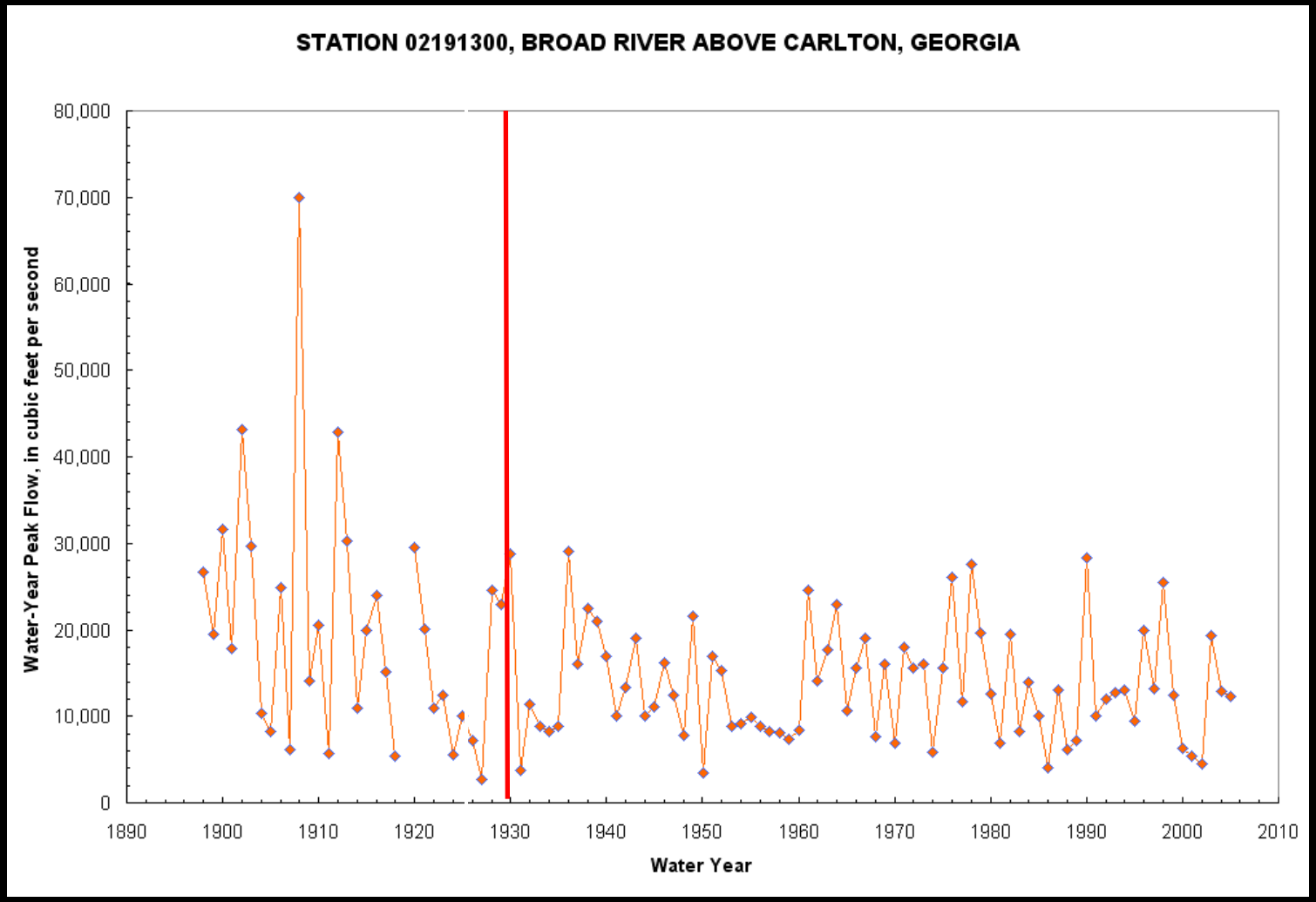
Historical data at 7 Surface-water sites back to the 1900s

Contemporary network of 13 GW wells and 3 SW sites

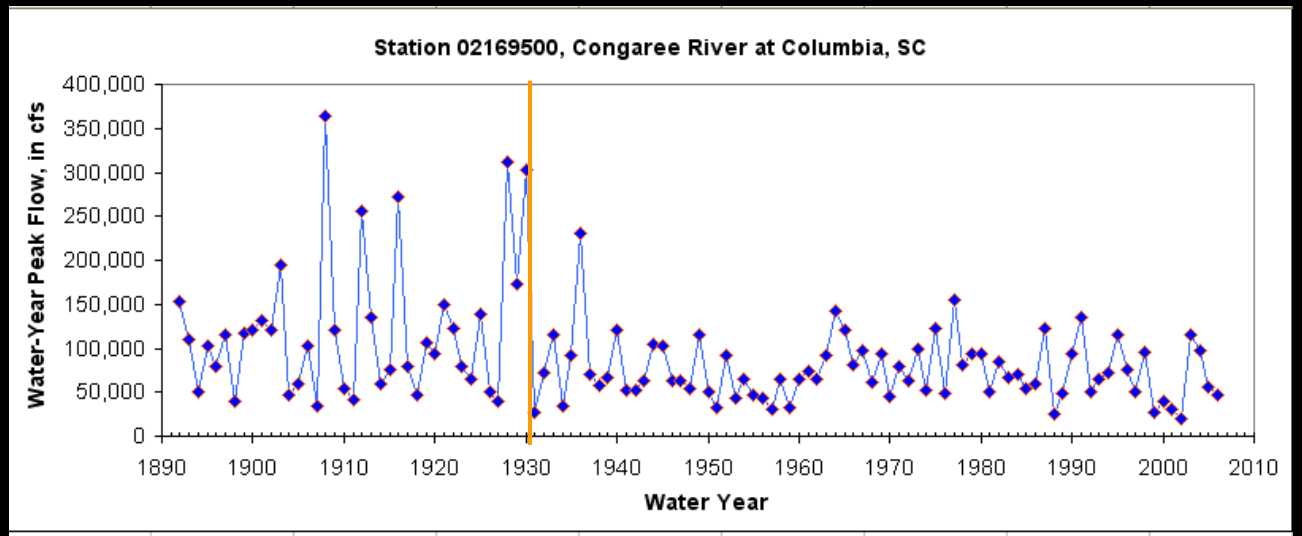


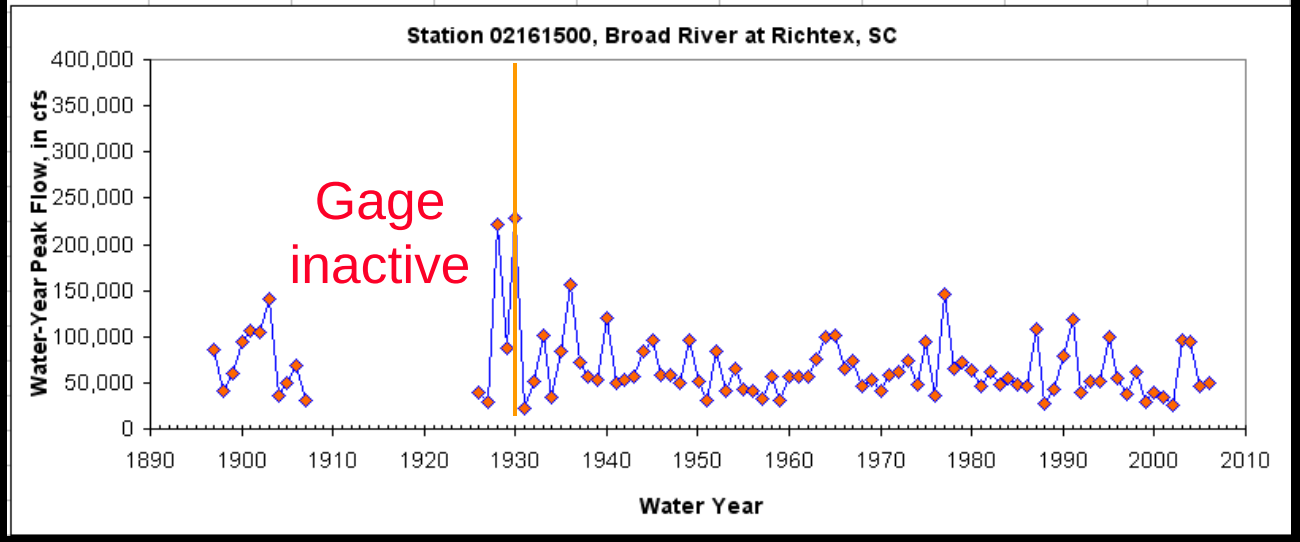
Peak Flows Analysis

Broad River, GA

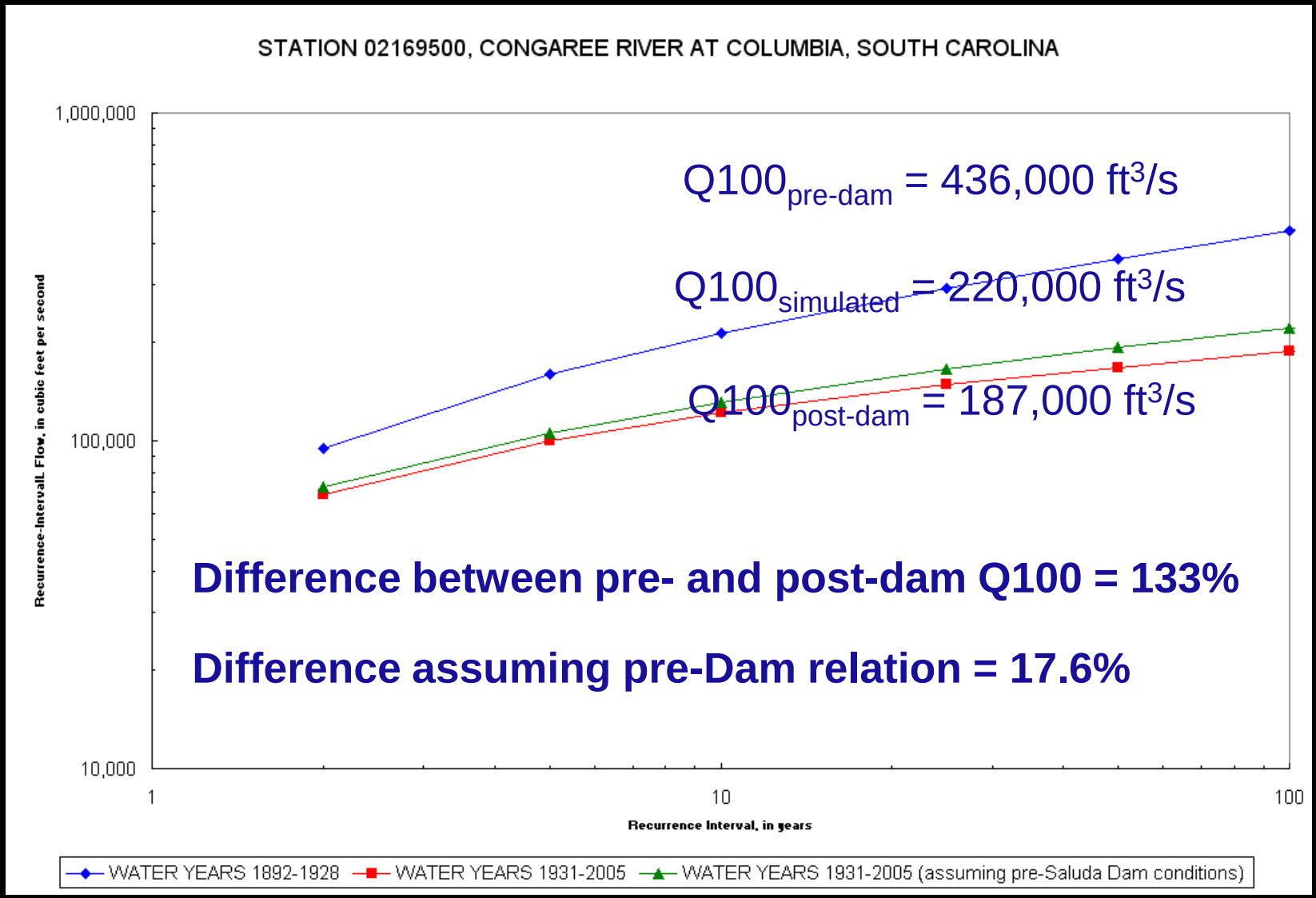


Congaree and Broad Rivers, SC





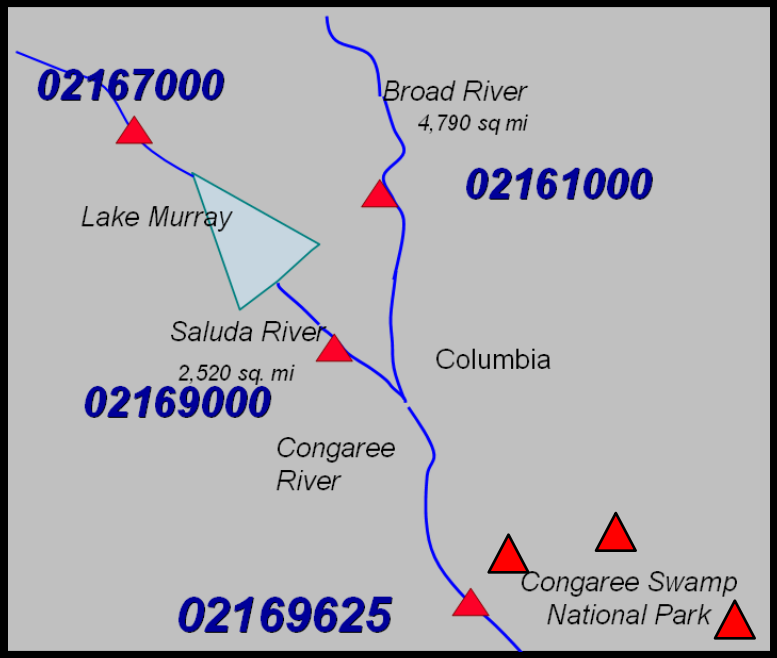
Effect of Saluda Dam on Peak Flows



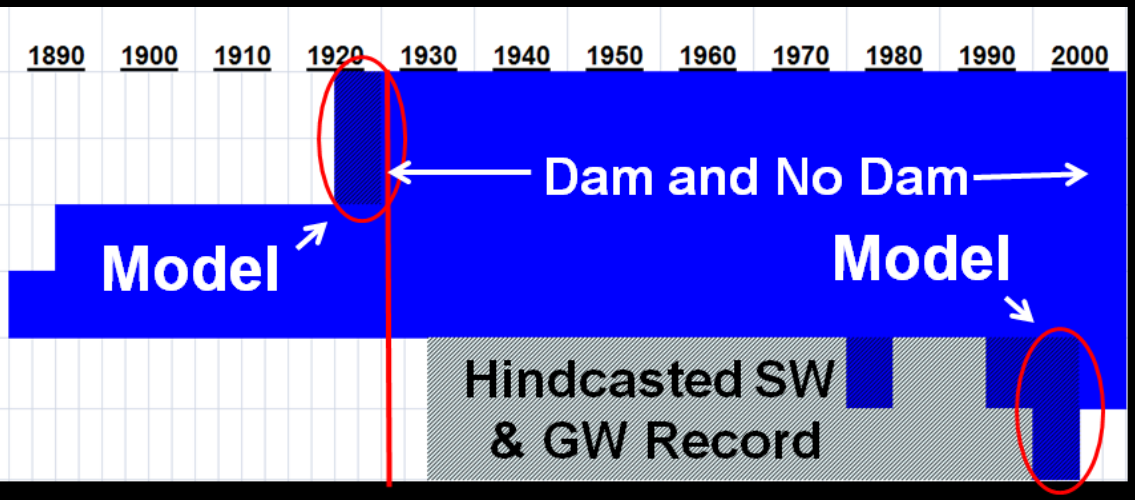
Analysis of Daily River Stages and Ground-water Levels

Filling of Lake Murray – 1930

~3 years of data prior to dam construction



Station	Station Number	Parameter
Saluda River Chappells	2167000	flow
Saluda River Columbia	2169000	flow
Broad River Richtex	2161500	flow
Congaree River Columbia	2169500	flow
Congaree River at CNP	2169625	gage height
CNP GW Network	RIC-###	Ground-water level



Modeling Approach

Prediction Models

Pre-Dam Model

Saluda $Q_{pred1} = F_1[$ Chappells Q $]$ → 75-year "no Dam" hydrograph

Congaree River Model

Congaree $GH_{(pred2)} = F_2[$ Saluda Q + Broad Q$]$

Congaree Ground-water Models

Congaree $GW_{(pred3)} = F_3[$ Congaree GH$]$

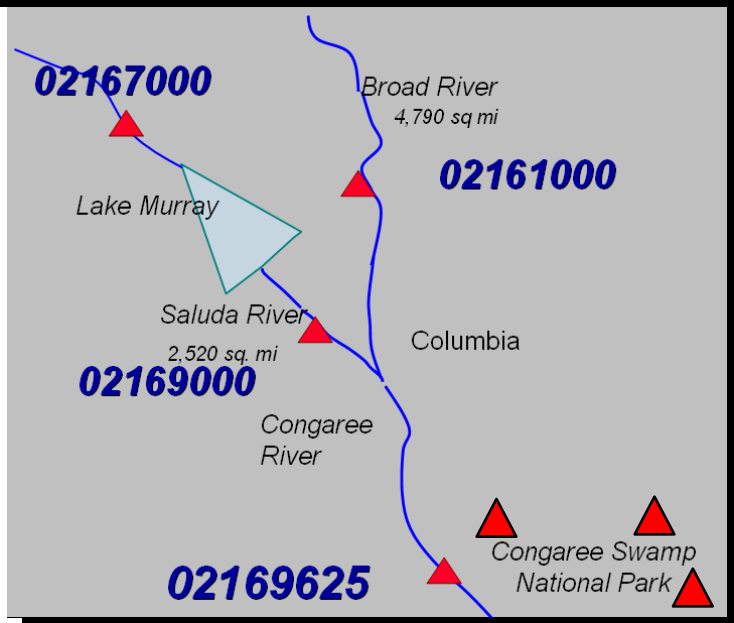
Generation of 75-year Synthetic GH Hydrographs

Congaree GH with and without Dam

Congaree GH = $F_2[$ Saluda Q + Broad Q$]$

Congaree GW with and without Dam

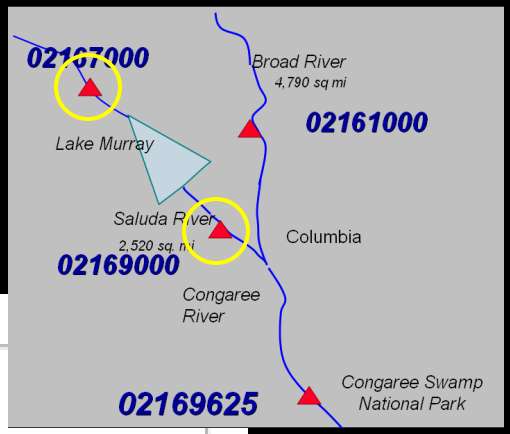
Congaree GW= $F_3[$ Congaree GH$]$

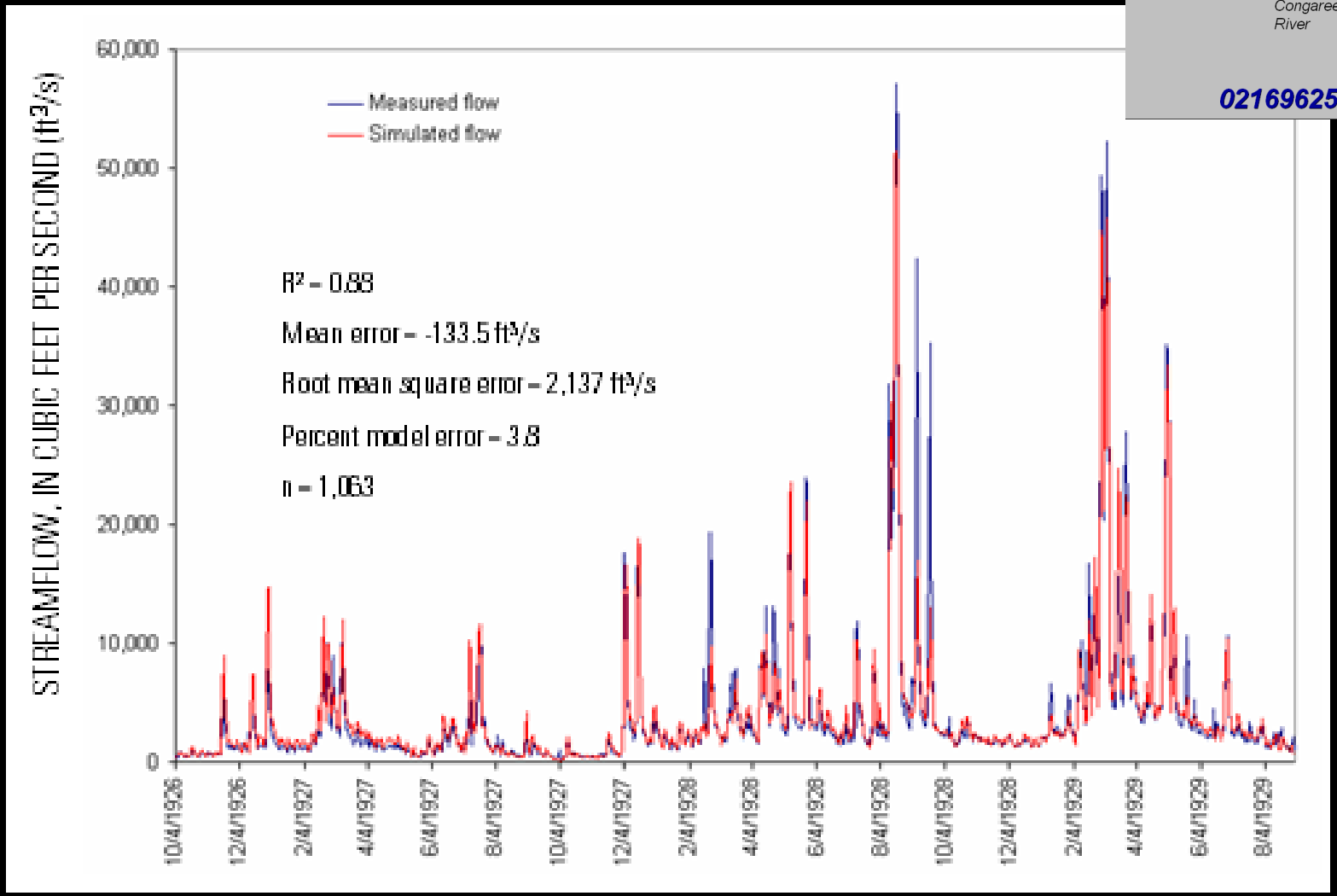


Compare Dam and No Dam Hydrographs

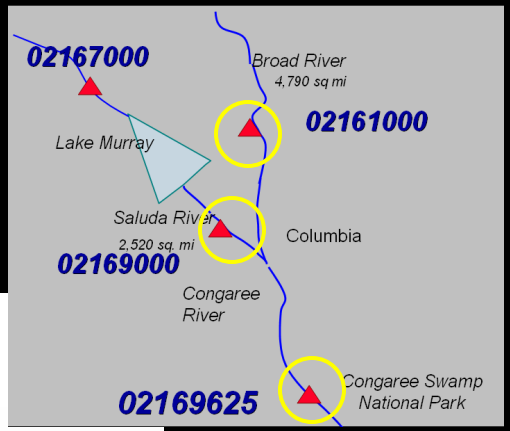
(1930-2005)

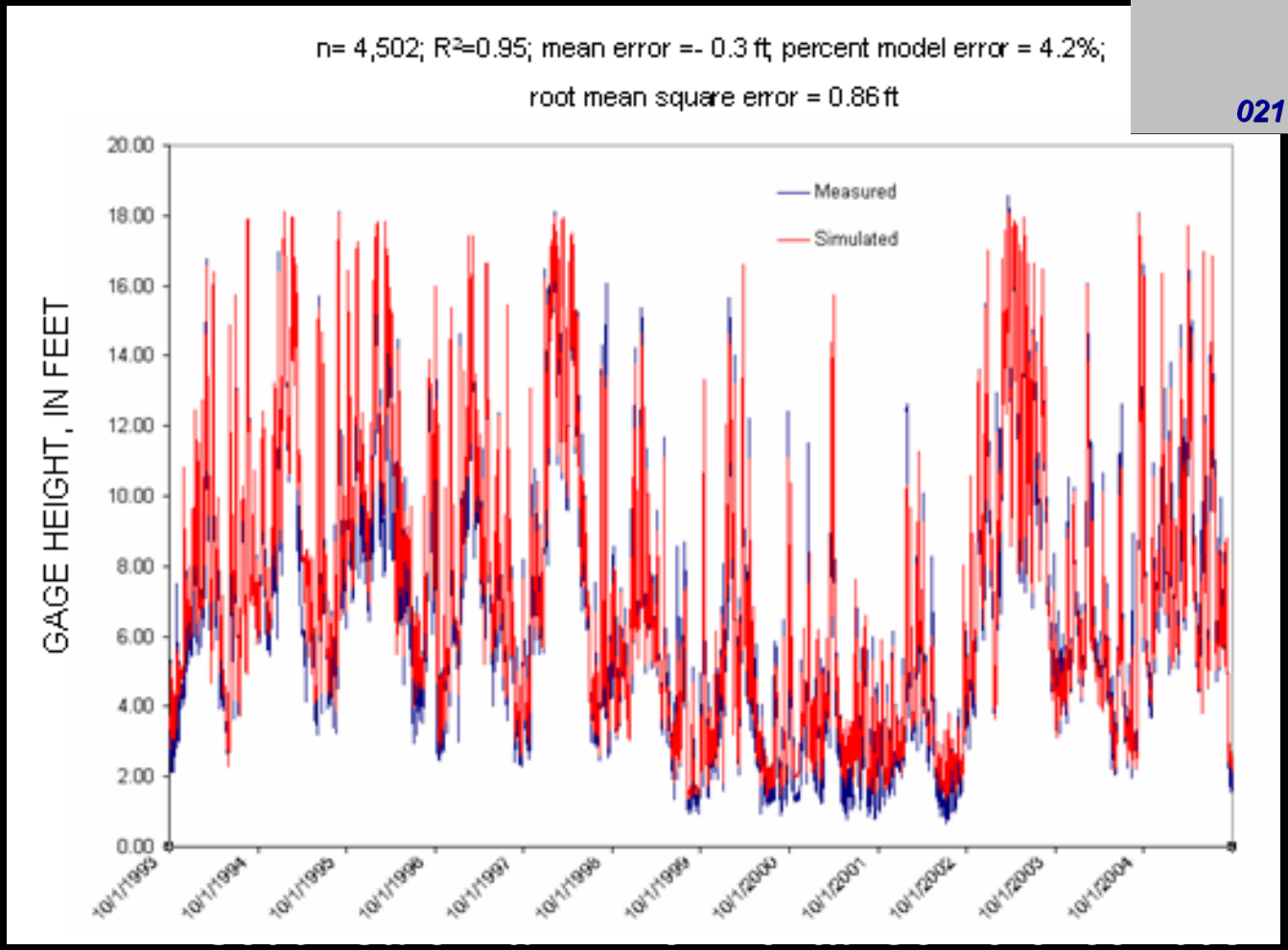
Saluda River Pre-Dam Model Measured and Simulated





Congaree Gage Height Model Measured and Simulated





Dam Removal

Prediction Models

Pre-Dam Model

Training and testing data (Oct 1926 – August 1929)

Saluda Q_{pred1} = F_1[Chappells Q] → **75-year "no Dam" hydrograph**

Congaree Model

Training and testing data (Oct. 1984 to Sept. 1989; May 1993 to Sept. 2005)

Congaree $GH_{(pred2)}$ = F_2[Saluda Q + Broad Q]

Generation of 75-year Synthetic GH Hydrographs

Congaree GH with Dam

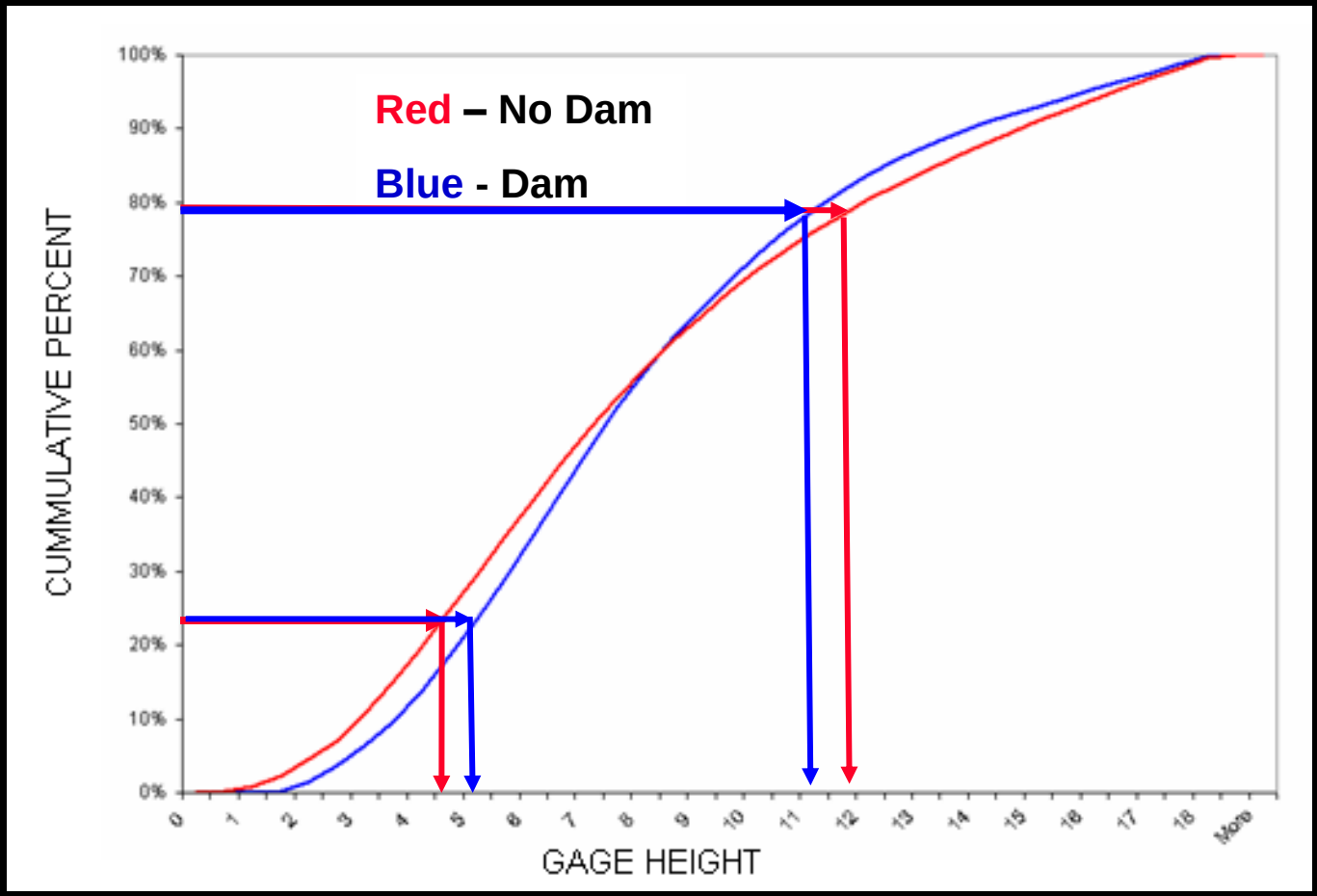
Congaree $GH_{w/Dam}$ = F_2[Saluda Q + Broad Q] → 75-yr Hydrographs for Dam and NoDam

Congaree GH without Dam

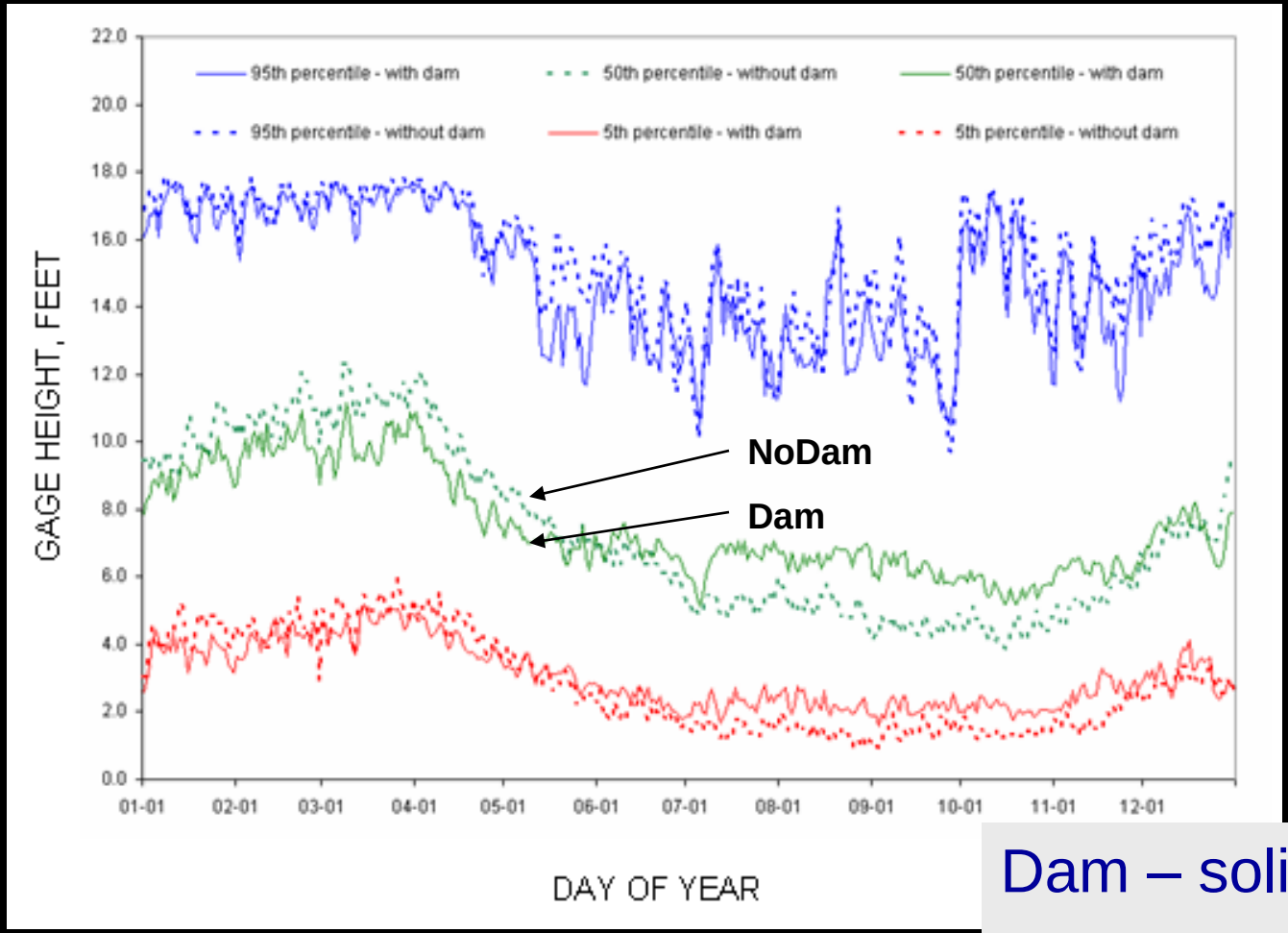
Chappells data (station 02167000) from Oct. 1926 to present

Congaree $GH_{w/o\ Dam}$ = F_2[Saluda Q + Broad Q] → 75-yr Hydrographs for Dam and NoDam

Dam and No Dam Frequency Distribution



Dam and NoDam Duration hydrographs



Dam – solid lines

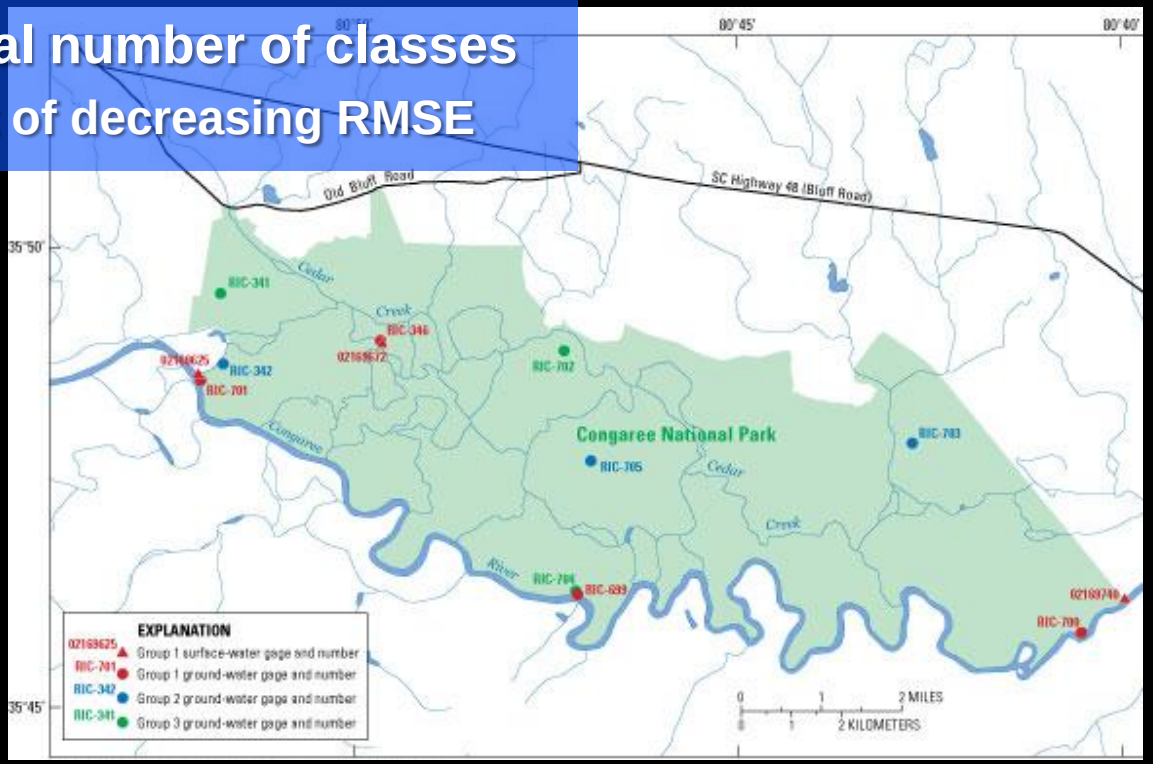
NoDam – dotted lines

Analysis of Ground-Water Effects

- USGS maintained a continuous ground-water network from 2003 to 2005
- Cluster analysis to group wells with similar behaviors
- Compute time delays (tau) and moving window averages (MWA)
- Trained ANN models for 8 wells
  - Input – Gage height station 02169625 (tau, MWA)
  - Output – Ground-water elevation at well
- Simulate 75-year “Dam” and “No Dam” hydrographs

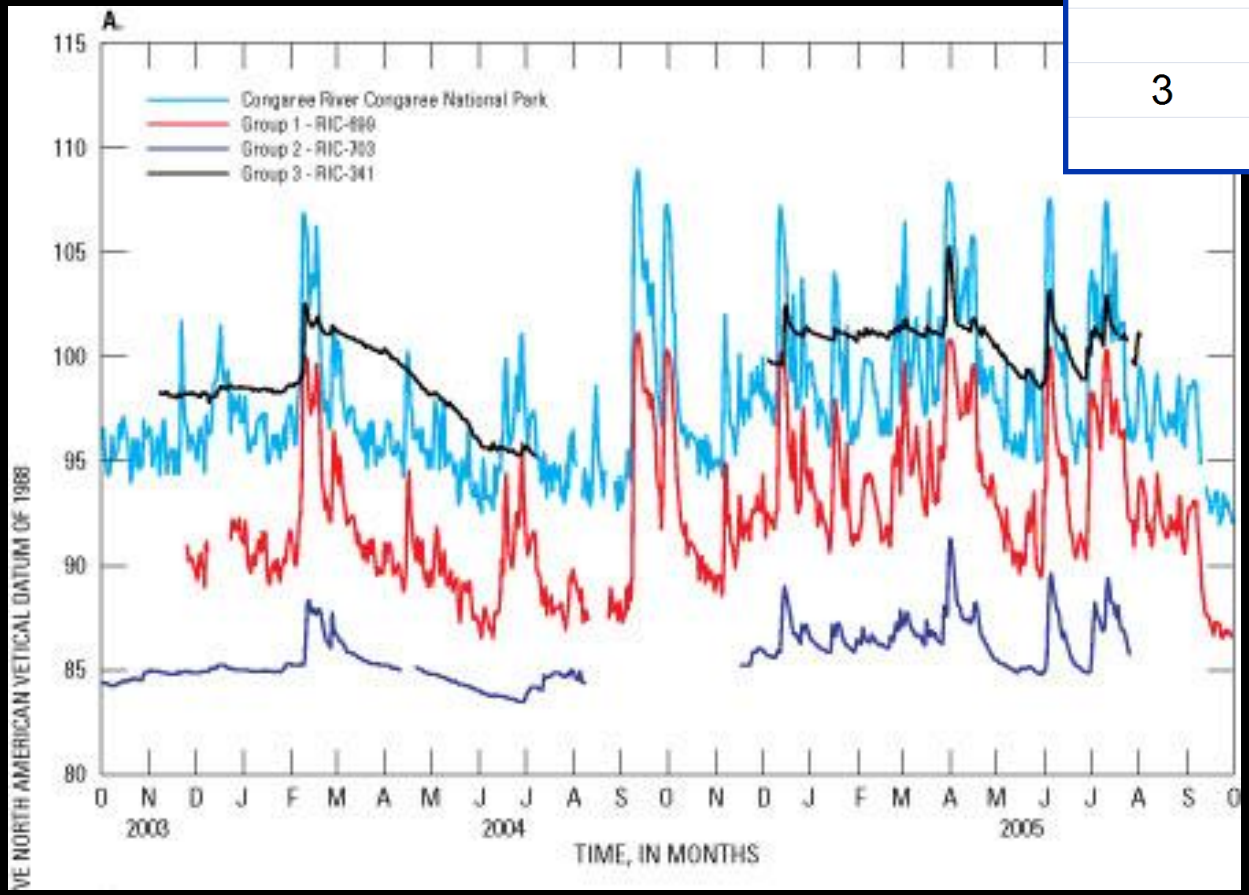
GW Modeling Approach

- Cluster on dynamic response
  - K-means
- Generate cross-correlation matrix
  - Cluster on Pearson's or R^2
- Determine optimal number of classes
  - Inflection point of decreasing RMSE



GW Response by Group

Group	Well	R^2
1	RIC-701	0.96
	RIC-699	0.93
	RIC-700	0.81
2	RIC-703	0.60
	RIC-342	0.54
	RIC-704	0.49
3	RIC-341	0.39
	RIC-702	0.38



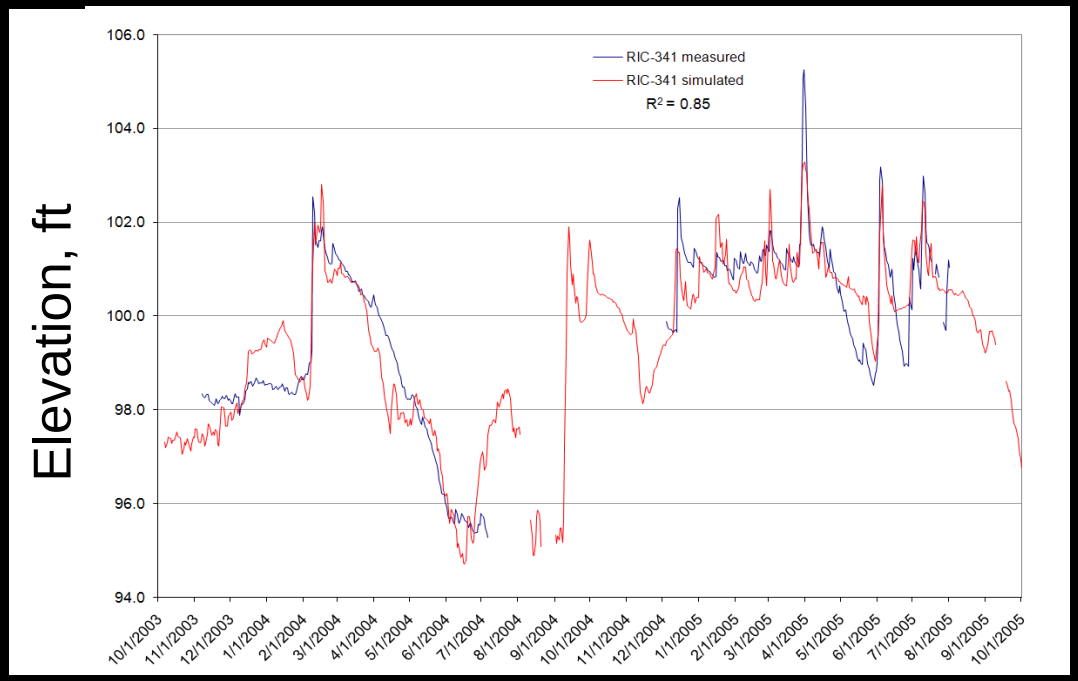
Model Approach

- Input time series – river gage heights
- One time series – decomposed into multiple input signals
  - Improve correlation of signals
    - Moving window average (MWA)
    - Time delay
  - Time derivatives
  - Seasonal variables
- Make sure input signals aren't correlated

(R^2 <0.3)

Final Model: RIC-341
$R^2 = 0.85$

Variable	
MONTH	numerical value for month of the year
GHA38(001)	38-day MWA of gage height lagged 1-day
GHA3DI5	5-day change in 3-day MWA of gage height
GHA10DI5	15-day change in 10-day MWA of gage height



Model Statistics

Group	Well	Data R^2	Model R^2	RMSE, ft	PME
1	RIC-701	0.96	0.97	0.49	3.4%
	RIC-699	0.93	0.98	0.49	3.6%
	RIC-700	0.81	0.96	0.52	3.3%
2	RIC-703	0.60	0.80	0.85	6.7%
	RIC-342	0.54	0.82	0.58	7.4%
	RIC-704	0.49	0.85	1.13	9.3%
3	RIC-341	0.39	0.85	0.74	7.4%
	RIC-702	0.38	0.80	1.14	9.2%

Statistics for testing datasets
Data R^2 is correlation with river input

Model Application Review

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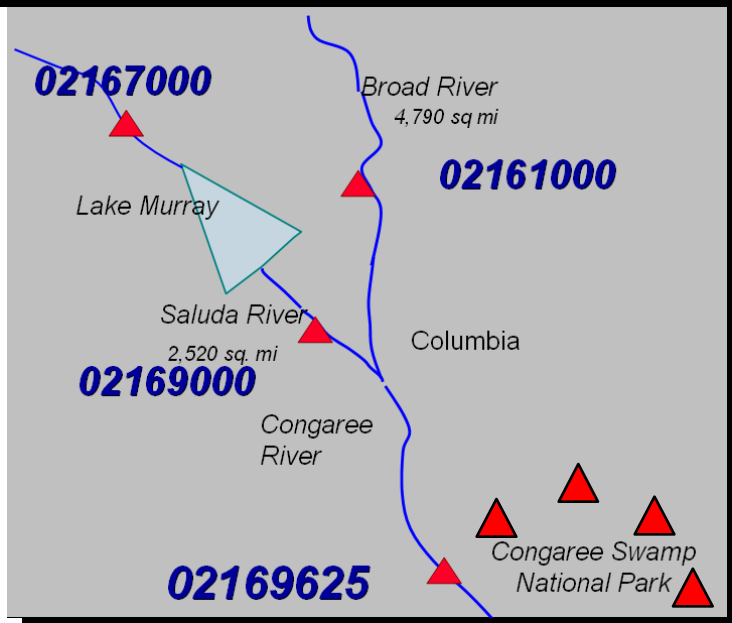


Compare Dam and No Dam Hydrographs

(1930-2005)

Ground-water – Dam and No DAM

RIC-701

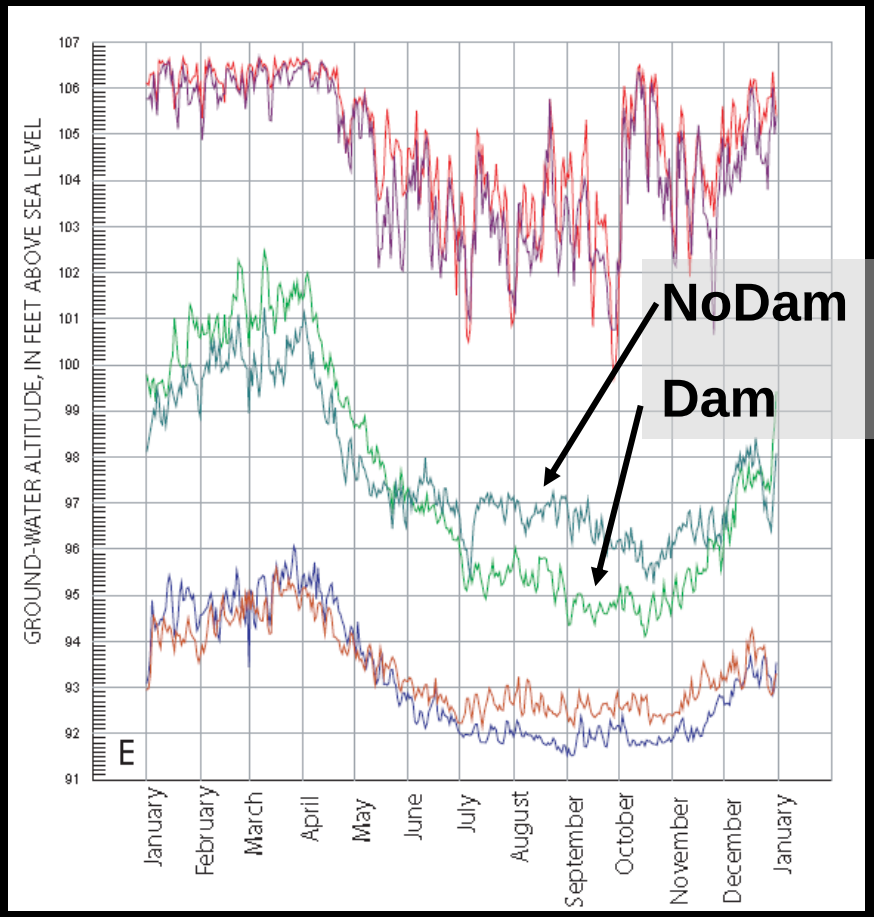
50th percentile

∆ Max: – 1.2 ft

∆ Medium: 0.2 ft

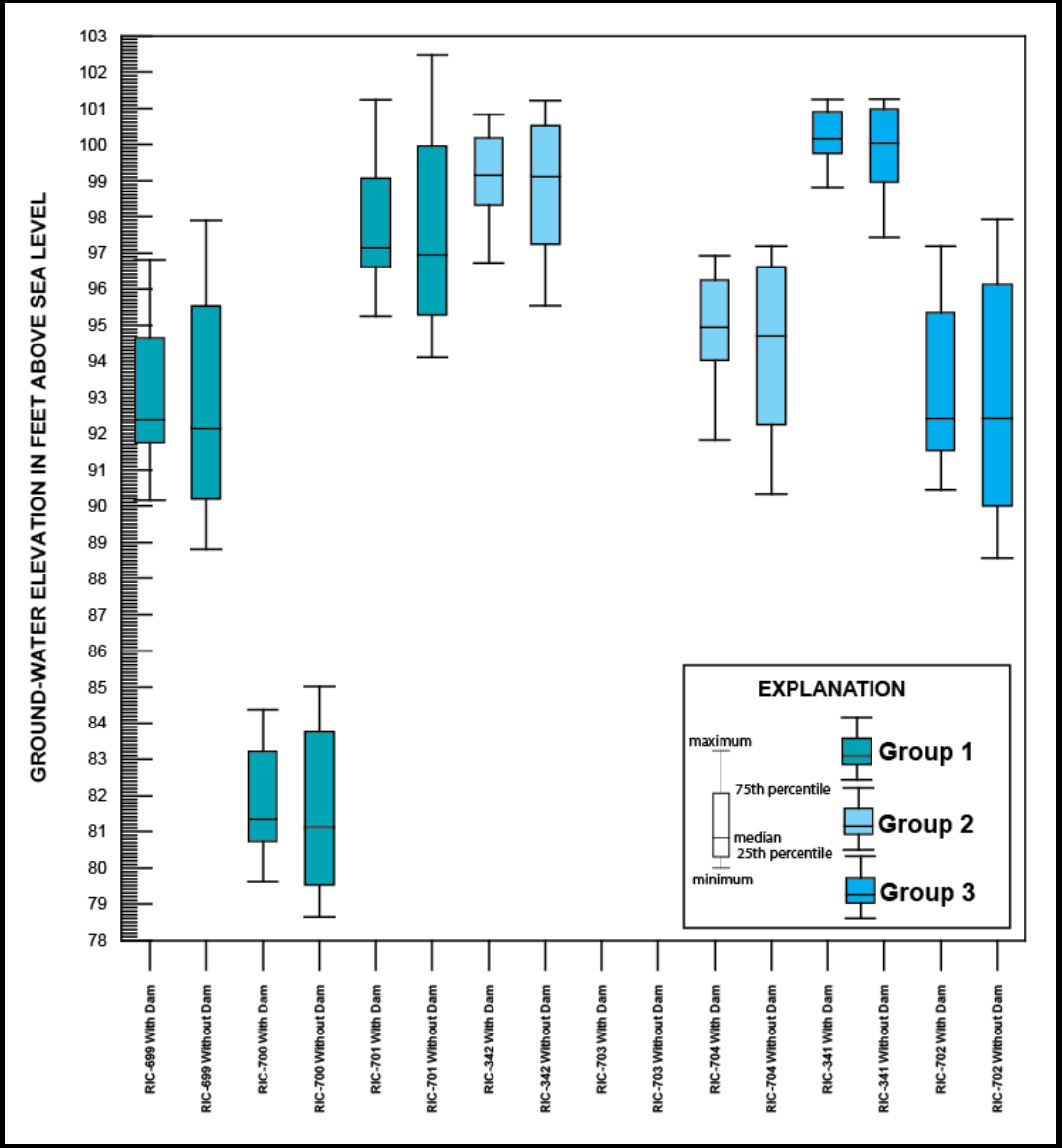
∆ Min: 1.1 ft

∆ Range: -2.4 ft



50th Percentile for all Wells

- Slight increase in median values
- Larger decrease in 25th and 75th and range



Summary

- Demonstrated how historical databases can be utilized to answer contemporary questions.
- Operation of the Saluda Dam has had less effect on annual peak flows than previously reported.
- Operation of Saluda Dam has changed the magnitude and duration of gage heights and ground-water levels
- Effect of the Dam may be greater on the surficial ground-water levels than frequency of flooding of the Park

Questions

Available online
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