Lessons Learned from Transitioning NWS Operational Hydraulic Models to HEC-RAS

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Outline

- What transition?
- Lessons learned from development of 5 HEC-RAS models
- Where do we need new hydraulic models?

What Transition?

- CHPS - Community Hydrologic Prediction System replaces NWSRFS (http://www.weather.gov/oh/hrl/chps/index.html)
- HEC-RAS – Hydrologic Engineering Center - River Analysis System replaces Dynamic Wave Operation (DWOPER) and FLDWAV (Flood Wave) models
  - HEC-RAS contains unsteady flow modeling capabilities based on UNET

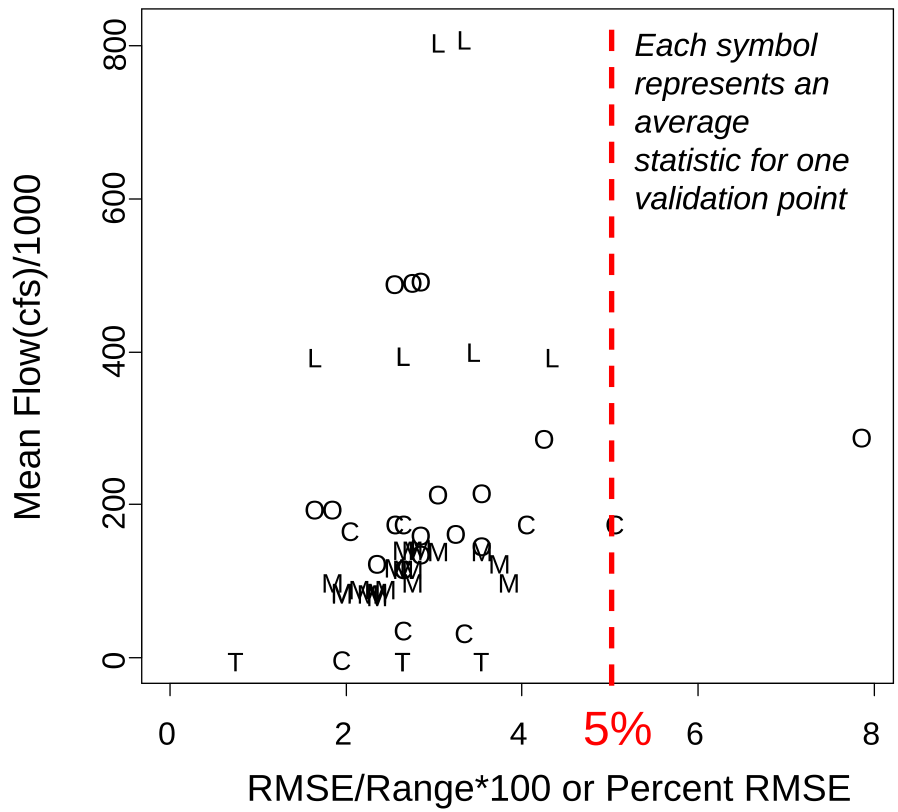
Lessons Learned

Overall simulation accuracy levels for a range of different rivers

What data should we transfer from FLDWAV or DWOPER to HEC-RAS?

What is the relative importance of rainfall-runoff and routing model errors?

Statistical Summary from 5 Calibrated HEC-RAS Models

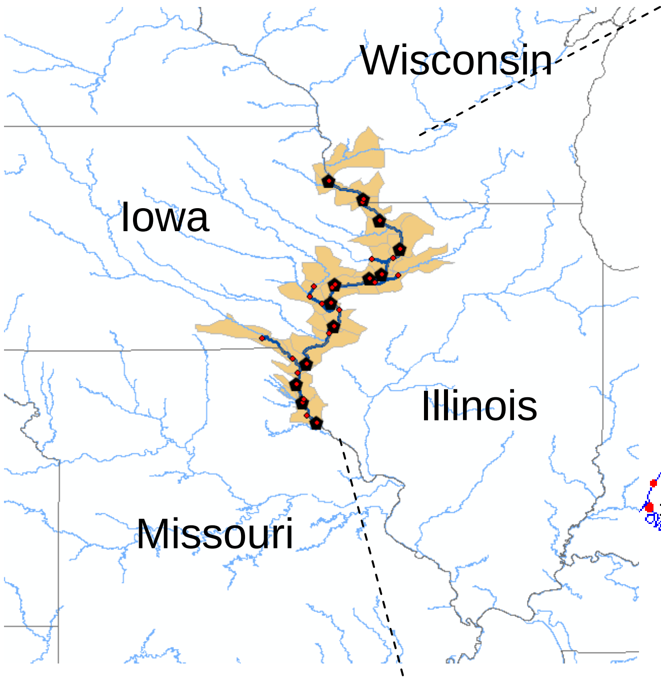


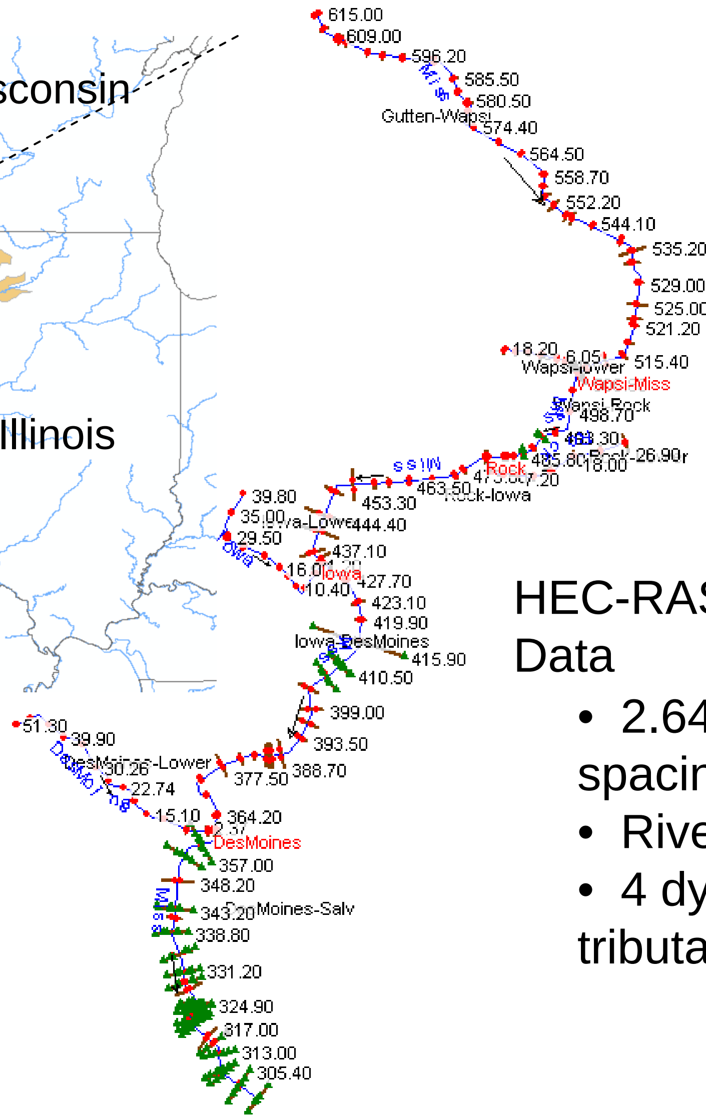
	Model Length (km)	Avg. cross-section spacing (km)
Tar River (T)	77	0.9
Columbia River (C)	304	2.8
Upper Mississippi (M)	724	4.6
Lower Miss-Ohio Smithland (L)	716	14.9
Ohio-Miss Cincinnati (O)	1320	1.4

- Nearly all points less than 5 percent RMSE
- Similar error ranges on different size rivers

Data Transfer from DWOPER to HEC-RAS

Mississippi River from L&D 11 to 22





Scenario 1:

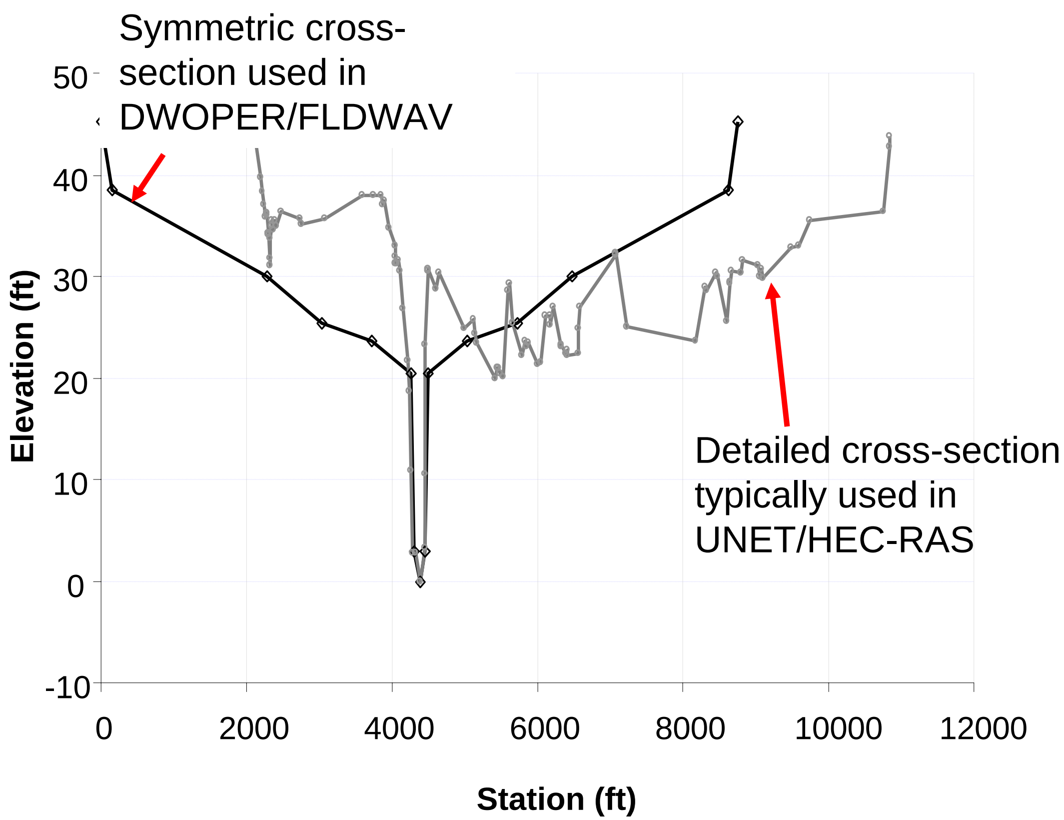
Transfer DWOPER network layout, cross-section spacing, and symmetric geometry

HEC-RAS Schematic From DWOPER Data

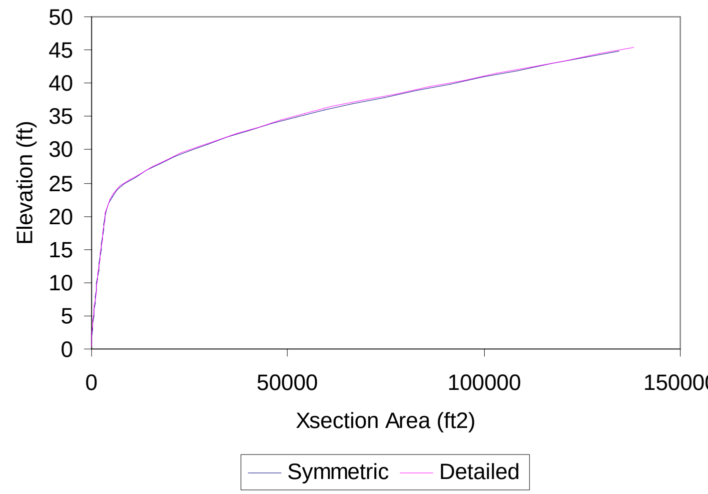
- 2.64 mile cross-section spacing
- River mile 615 to 301.2
- 4 dynamically modeled tributaries

Data Transfer from DWOPER to HEC-RAS

Scenario 2:
Transfer DWOPER network layout, cross-section spacing, BUT GET CROSS-SECTION GEOMETRY FROM UNET



Nearly identical area-elevation curves

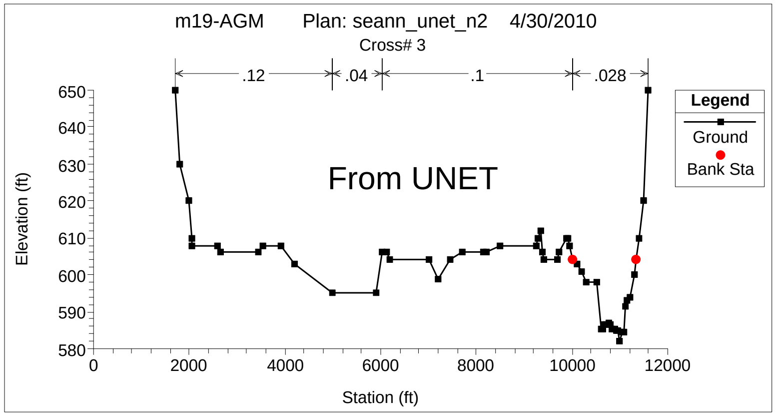


Potential advantages of Scenario 2: Easier to add levees, physical data about ineffective flow areas, storage ponds, and inline structures.

Different Calibration Approaches With Different Cross-section Data

Horizontally varying n values

0.12 0.04 0.1 0.028



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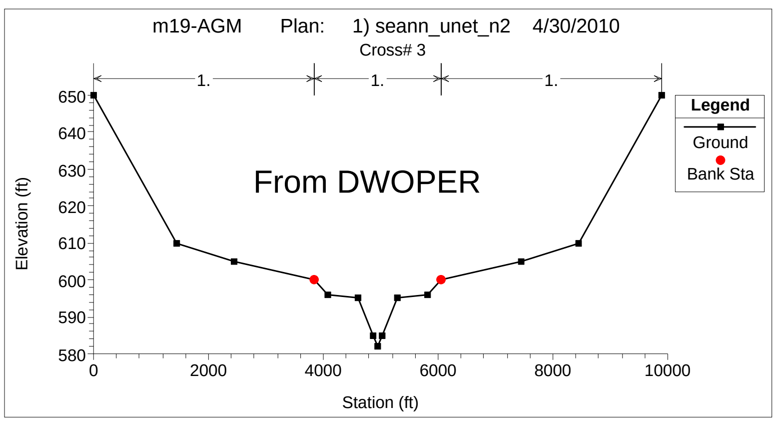
"Plan – Roughness Change Factors"

Flow	R. Factor
0	0.7
50000	0.7
100000	0.8
200000	0.9
250000	0.9
300000	0.9
400000	0.9
500000	0.9
600000	0.9

Common HEC-RAS approach

Applied to multiple sections in a calibration reach

Roughness = 1 in geometry file



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"Plan – Roughness Change Factors"

Flow	R. Factor
-100000	0.023
0	0.023
5000	0.023
10000	0.023
20000	0.023
30000	0.023
50000	0.023
75000	0.023
100000	0.024
125000	0.026
160000	0.026
200000	0.028
300000	0.034
600000	0.034

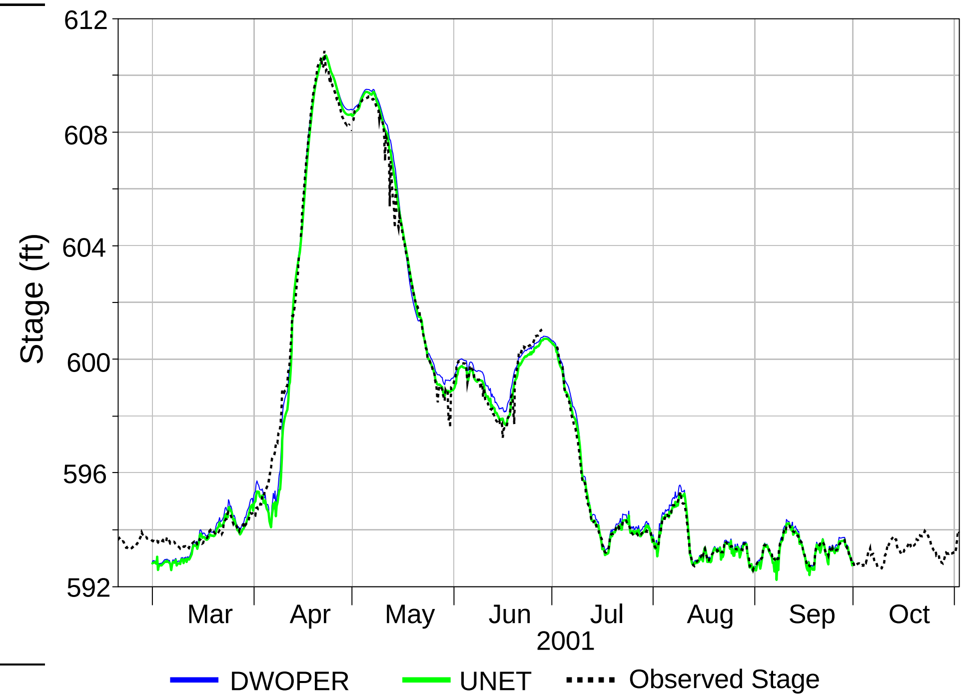
What's been done in the NWS for years

Simulated Stages: UNET Sections vs. DWOPER Sections
(Mississippi River from L&D 11 to 22)

Statistics for March 2001 – September 2001

	RMSE (ft) UNET Uncalibrated	**DWOPER**	**UNET**	**Diff**
Guttenberg, IA; L & D 10 Tail	1.12	0.42	0.48	0.06
Dubuque, IA; L&D 11 Tail	2.07	0.39	0.40	0.02
Dubuque, IA	2.09	0.43	0.41	-0.03
Bellevue, IA	1.78	0.42	0.53	0.11
Fulton, IL; L&D 13 Tail	1.86	0.44	0.50	0.06
Camanche, IA	1.41	0.29	0.33	0.04
Le Claire, IA; L&D 14 Tail	0.44	0.30	0.30	0.00
Rock Island, IL; L&D 15 Tail	1.94	0.40	0.58	0.18
Illinois City, IL; L&D 16 Tail	1.69	0.36	0.44	0.08
Muscatine, IA	2.05	0.50	0.51	0.01
New Boston, IL; L&D 17 Tail	0.96	0.73	0.78	0.05
Keithsburg, IL	1.04	0.44	0.46	0.02
Gladstone, IL; L&D 18 Tail	1.54	0.44	0.56	0.12
Burlington, IA	1.37	0.38	0.47	0.08
Keokuk, IA; L&D 19 Tail	1.70	0.82	0.72	-0.10
Grettory Landing, MO	1.21	0.67	0.58	-0.09
Canton, MO; L&D 20 Tail	2.01	0.56	0.75	0.20
Quincy, IL	0.47	0.43	0.46	0.03
Quincy, IL; L&D 21 Tail	1.20	0.65	0.76	0.11
Hannibal, MO	0.56	0.49	0.45	-0.04
Average	**1.43**	**0.48**	**0.52**	
Max	**2.09**	**0.82**	**0.78**	

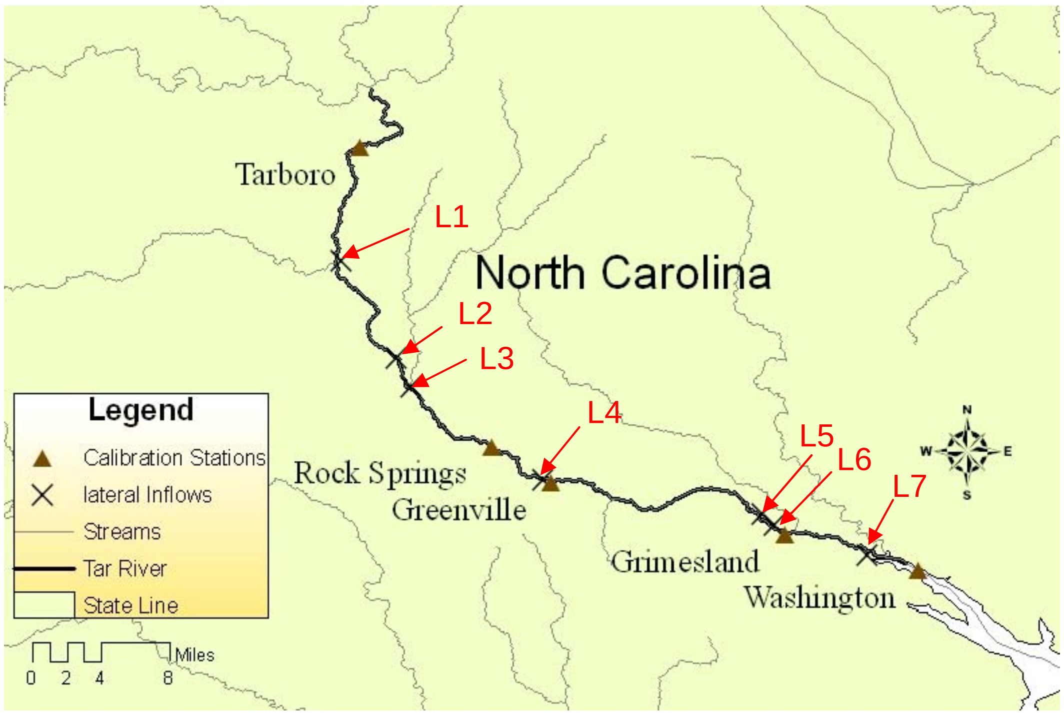
Example Hydrographs for Dubuque, IA



- Big gains from calibration (from 1.4 to 0.5 ft RMSE)
- No substantial difference in DWOPER-based and UNET-based calibrated results

Hydraulic Routing vs. Rainfall-Runoff Inflow Errors

Tar River Model



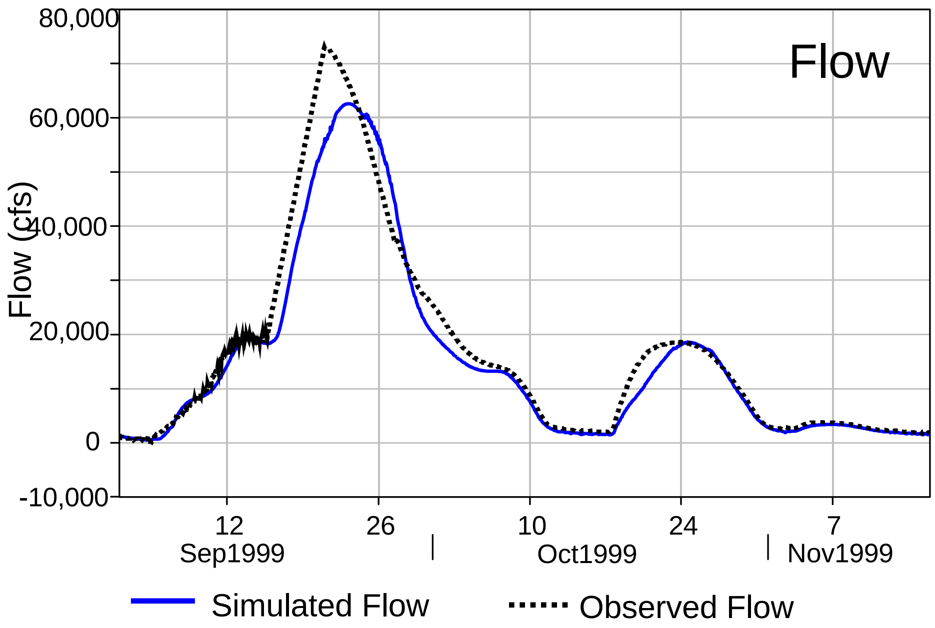
- Original Tar River model runs
  - observed flow only at Tarboro
  - laterals from uncalibrated simulation models
- Greenville station
  - USGS stage and acoustic velocity meter
  - USGS reconstructed record flow during Hurricane Floyd
- New model runs using observed flow at Greenville

$$Q_{avg\text{-}Grnv} = (Q_{Tarb} + L1 + L2 + L3 + L4)_{avg}$$

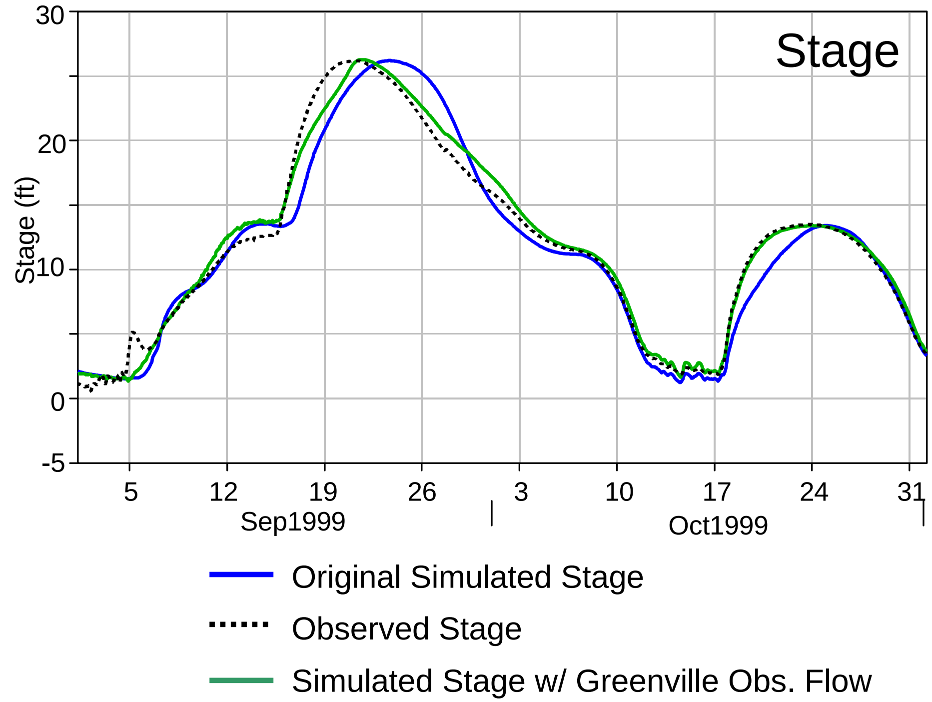
Hydraulic Routing vs. Rainfall-Runoff Inflow Errors

Stage RMSE for the entire run period 9/1999 – 8/2005 dropped from 0.76 to 0.39 ft (49%) when the observed flows at Greenville were included in the model.

9/1/1999 – 11/15/1999 (Hurricane Floyd)
Greenville, NC flow bias = -10.4%



9/1/1999 – 11/15/1999
Greenville, NC

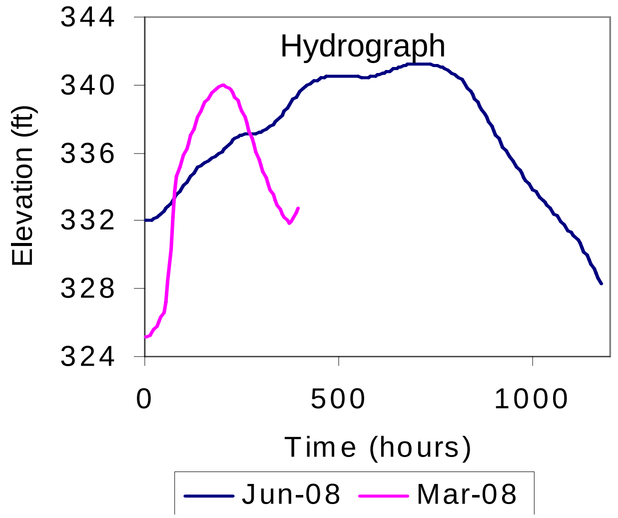


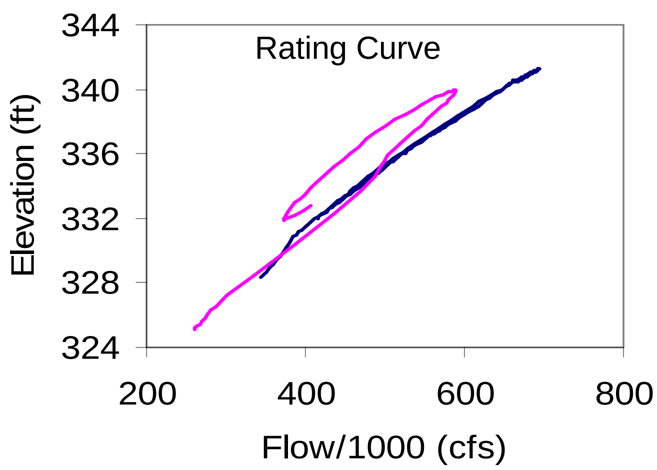
Need to simultaneously calibrate hydrologic inflow and hydraulic models

Factors Influencing the Need for Dynamic Hydraulic Models

- Slope
- Rate of flood rise
- Backwater
  - Confluences
  - Structures
  - Tides

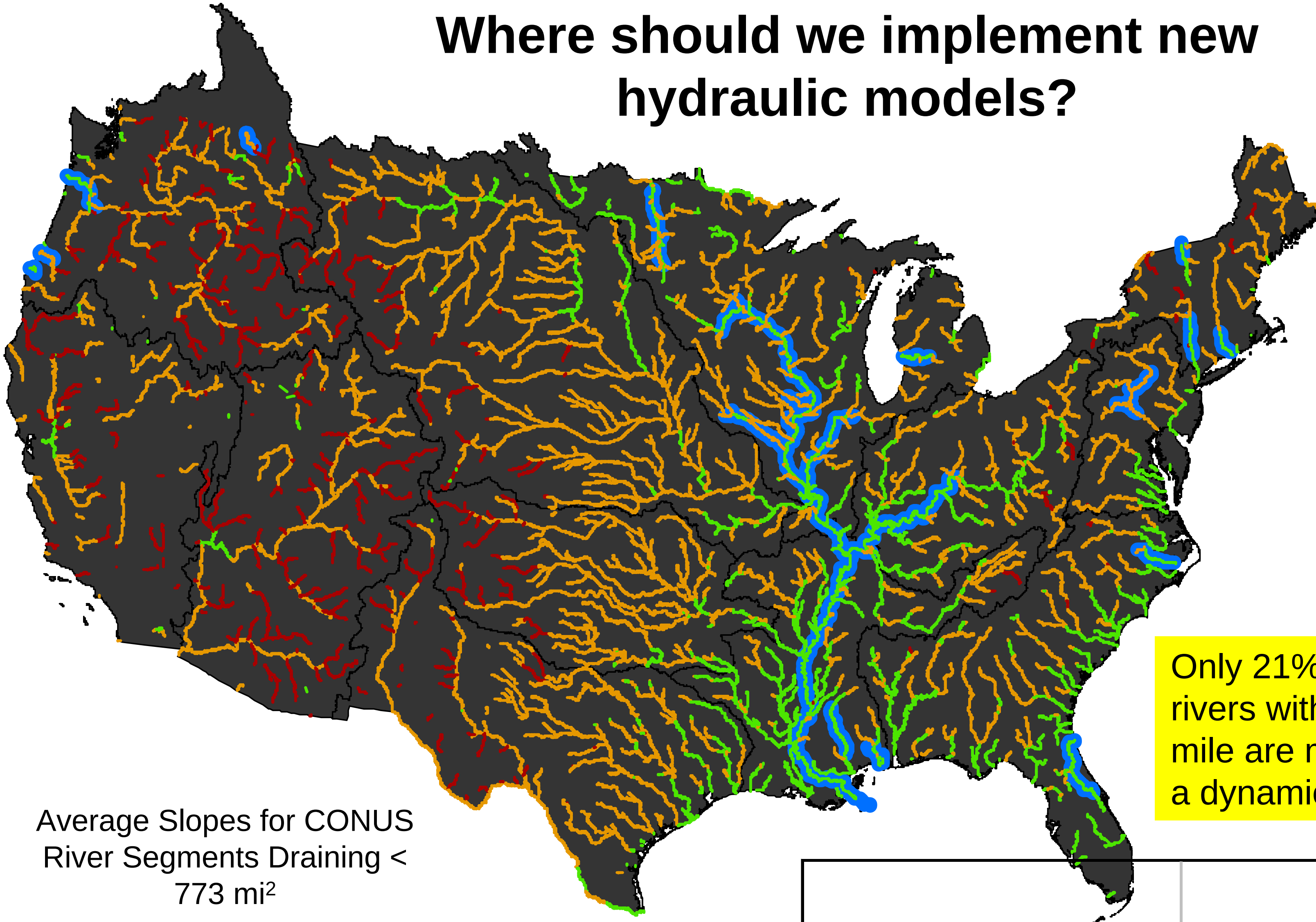
Rate of flood rise impacts example – two events at the same location: Thebes, IL, Miss. R.





Could use Fread (1973) looped rating curve model as a screening tool for locations without backwater

Where should we implement new hydraulic models?



Average Slopes for CONUS River Segments Draining < 773 mi²

- 0 – 1 ft/mile – DYNAMIC WAVE
- 1 – 10 ft/mile – DIFFUSIVE
- >10 ft/mile -- KINEMATIC
- Domain of NWS Hydraulic Models

USACE Rules of Thumb

Only 21% of CONUS rivers with slopes < 1 ft mile are modeled using a dynamic technique

	Miles	% of Total Modeled
NWS Dynamically Modeled Miles	5500	
Total Miles < 1ft	26200	21
Total Miles < 10 ft/mile	97300	6

Why haven't hydraulic models been implemented more widely for NWS operational forecasting?

- Forecasters adjust hydrologic routing parameters to compensate for model inaccuracies
- Lack of convincing cost-benefit documentation for river forecasting applications (Hicks and Peacock, 2005)
- Dynamic hydraulic models have a "reputation for being difficult to learn and apply" (Hicks and Peacock, 2005)
  - Specialized knowledge required
  - Higher computational requirements (no longer an issue)
  - Cross-section data required (becoming much easier to get)

Next Steps

- Develop new models
  - Prioritize implementation
  - Community modeling efforts (e.g. OHRFC Community HEC-RAS Model)
  - Leverage data from existing studies (e.g. FEMA)
  - Leverage GIS-based model building tools (e.g. HEC-GeoRAS)
  - Understand cost-benefits of increased model complexity
- Improve training
  - model building
  - use in a forecasting environment)

Conclusions

- Calibration should yield < 5% RMSE
- FLDWAV/DWOPER to HEC-RAS Conversions
  - Keeping network layout, cross-section spacing, and symmetric cross-section geometry is useful in many cases
  - Potential advantages in substituting more detailed cross-section geometry in some cases
- Need simultaneous rainfall-runoff inflow and hydraulics calibration for rivers where a large portion of the lateral inflows are ungauged
- Many candidate rivers for new hydraulic forecast model implementation in the U.S. – working towards smart, efficient implementation