Kentucky: working towards better hydrology
INTRODUCTIONS

- Carey Johnson, KY Division of Water
  - State CTP Program Manager
  - Managed flood risk identification for all 120 counties in KY

- Jimmy Stahl, URS
  - Program Manager for KDOW
  - Water Resources, Dams, Risk MAP, Wet Weather, Storm Water, Master Planning and Design, Green Infrastructure, Scour, Stream Restoration
  - Public Sector BD for KY
OVERVIEW

- Kentucky’s Approach to Risk MAP
- What is “WATER”?  
  - The WATER Software  
  - TOPMODEL  
  - The Variable Source Area Concept
- Our Study  
  - Objectives  
  - Methods
- Results & Conclusions  
  - Results of Analysis  
  - Conclusions  
  - Direction for Moving Forward
KENTUCKY’S APPROACH TO RISK MAP
Better Input = Better Output

Part of the Risk MAP Vision

“High-quality elevation data form the foundation for increasing the quality of the flood maps...” – FEMA’s Risk MAP Report to Congress (3/15/11)

Acquisition of LiDAR

- Acquired for portions of Kentucky
- Has been a catalyst for new Statewide LiDAR acquisition

Innovative methodologies
Long-term strategic partnerships

- USGS and KDOW
  - Development of WATER tool, funding from KDOW
  - Gage Data

- NWS and KDOW
  - KDOW’s contribution to the Ohio River Community Model
  - Receipt of NexRAD data for entire OHRFC area

- Silver Jackets
Credibility
- Floodplain Managers, City Engineers, etc.
- The Public

Actions to reduce risk
- Currently developing Action Strategy

Should regression equations be the default answer?
- What about ungaged, unmodeled areas?

What about a software package:
- ...developed by a partnership between KDOW and USGS
- ...utilizing NWS data
- ...incorporating a model “driven” by topography
- ...tested in an area for which we have LiDAR data
- ...efficiently?
WHAT IS “WATER”? 

“WATER”, TOPMODEL, and the VSA Concept
THE “WATER” SOFTWARE

- Developed by USGS in conjunction with KDOW
- The Water Availability Tool for Environmental Resources

Prepared in cooperation with the Kentucky Division of Water

The Water Availability Tool for Environmental Resources (WATER): A Water-Budget Modeling Approach for Managing Water-Supply Resources in Non-Karst Areas of Kentucky (Phase I)—Data Processing and Model Structure Documentation

Scientific Investigations Report 2009-5248

U.S. Department of the Interior
U.S. Geological Survey
Originally Intended for Water Budget Modeling
- “A Water-Budget Modeling Approach for Managing Water-Supply Resources”
- Based on daily inputs of precipitation, evapotranspiration, withdrawals, and other data; used to estimate shortages

Phase 1
- Initial Software Development
- Calibrated for Non-Karst Areas
- Includes basin delineation tool
- Uses TOPMODEL for simulation

Phase 2
- Calibration updated to include Karst Areas
- Construction of Estimated Flow-Duration and Load-Duration Curves

Has seen widespread application in USGS
- Water availability estimation in KY and AL
- Load-Duration Curves for TMDLs
- Flood Assessments in some states
SCREENSHOTS OF WATER
TOPMODEL

- Developed by Keith Beven and Mike Kirkby in 1979
- Has been used in more than 30 countries worldwide
- Simulates the Variable Source Area concept
- Topographically-driven
- Semi-distributed

Note: There are many “implementations” of TOPMODEL
Infiltration-Excess:
- Developed by Horton (1933)
- “Typical” method

Figure from Wolock, 1993
Variable Source Area

- Initial concepts developed by Hursh
- John D. Hewlitt coined the phrase
  - Early career: Mountainous watersheds in the southern Appalachians
  - Struggled with developing model that incorporated VSA concept

Figure from Wolock, 1993
3 types of flow are computed:
- Direct Flow
- Return Flow
- Subsurface Flow

Soil parameters that are typically used:
- Hydraulic Conductivity
- Available Water Capacity
- Transmissivity
- ... and others.
ILLUSTRATION OF THE VARIABLE SOURCE AREA CONCEPT
Topographic Wetness Index (TWI)
- Contributing drainage area
- Slope

High values of TWI = High potential for saturation
Low values of TWI = Low potential for saturation

Summary – Large drainage area and low slope yields high saturation potential
- Groups areas that are hydrologically similar
- TWI Histogram
  - Typically, 30 bins
  - Mean
  - Fraction of total watershed area

Figures from USGS
How does the WATER software need to be modified to fit FEMA needs?

- Need: Computation of peak discharges
  - Annual peaks
  - Recurrence interval events (1%-AEP, aka 100-year)
- Need: Efficient methodology
  - Placement of pour points
  - Delineation of watersheds
- Need: “Better” answers
  - Better than regression equations?
  - As good as other rainfall-runoff models?
  - How does LiDAR affect the answer?
    - Paper by Bhaskar indicated need for using more resolute elevation data
OBJECTIVES

Two Tests

1. Does better elevation data provide better answer
   - WATER results (baseline) – USGS Topo quad
   - LiDAR re-sampled at same resolution as WATER DEM (30’ x 30’ DEM)
   - LiDAR at “native” resolution (5’ x 5’ DEM)

2. Does better precipitation data provide better answer (NEXRAD: Hourly Timestep vs Daily)
   - Mimic WATER results using TOPMODEL (baseline)
   - Replace daily precipitation data with hourly
STUDY AREA
Levisa Fork Watershed

7 Gages – from 0.8 to 56 square miles in drainage area
RESULTS & CONCLUSIONS

What we discovered
Graph of TWI-results (% error vs drainage area)
Peak Annual Discharge – Grapevine Creek @ USGS Gage 03207965
Peak Annual Discharge – Johns Creek @ USGS Gage 03210000
### RESULTS – HOURLY RADAR DATA

#### Grapevine Creek @ USGS Gage 03207965

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<th>Chance Exceedance</th>
<th>Qgage (cfs)</th>
<th>Regression</th>
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#### Johns Creek @ USGS Gage 03210000

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CONCLUSIONS

- WATER does produce accurate results of flow estimation in some cases
- Better elevation data did not result in better answers
- Better (more resolute) precipitation data did result in better answers
- Higher peaks were not estimated well

- WATER is calibrated to predict daily flows.
- Recalibration of WATER to predict high flow events could yield better results than regression.
- Future KDOW/USGS joint efforts on WATER:
  - Calibrate model to high flow events
  - Test in other geographic areas
REFERENCES/CREDITS

- Thanks to Jeremy Newsom, Mike Griffin, and Pete Cinotto, USGS KY Science Center!
- Thanks to Tom Adams, NWS Ohio River Forecast Center
- Sources:
Questions?