Mead & Hunt | EXPERIENCE EXCEPTIONAL

H&H Modeling: Operations Model

Pensacola Hydroelectric Project

Project No. 1494

Grand River Dam Authority

April 21, 2021

Operations Model Objectives

- Validate results with USACE RiverWare model data
- Synthesize hypothetical events that inform and set boundary conditions of a Comprehensive Hydraulic Model (CHM)

Operations Model Methods

- Define relationship of physical constraints with inflow at the Pensacola Dam (i.e. friction headloss, turbine generator efficiency, discharge rating curves, etc.)
- Develop a VBA (Visual Basic for Applications) based model in Microsoft Excel
- Calculate hourly outflows and generation based on current license operations represented in RiverWare…
- …and any proposed operation scenarios under several inflow events
- Use Operations Model to inform and set boundary conditions of CHM (Comprehensive Hydraulic Model) for each considered operations scenario

USACE RiverWare Model

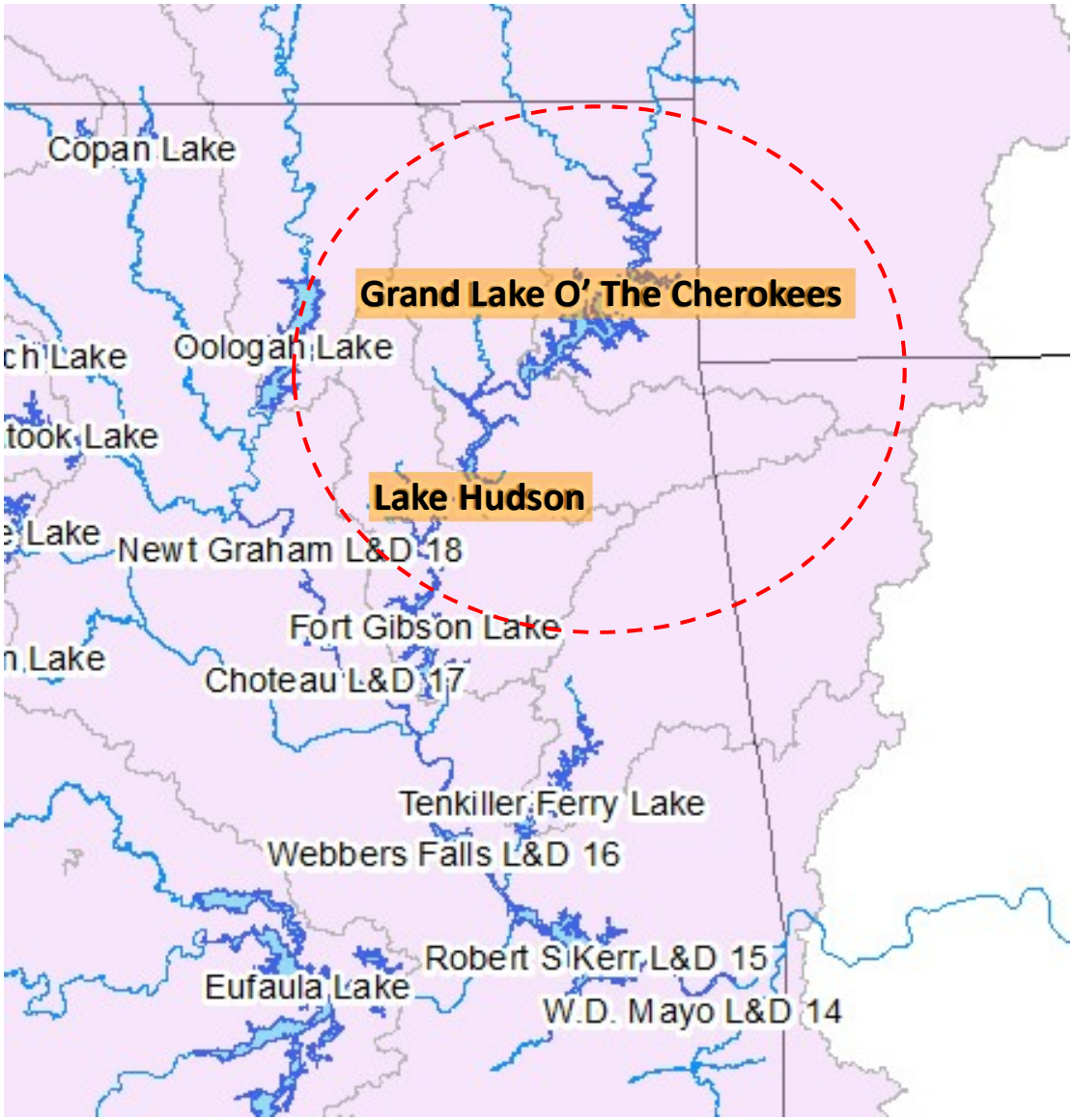
- 1940 through 2017
- Daily time step
- 30+ Reservoirs
- Methods
  - Hydrologic Routing
  - Flood Control
    - Channel Capacity
    - Ramping Rates
    - Balance Levels
    - Control at Van Buren, AR
  - Conservation & Power

Flood Routing Model

- 1940 through 2017
- Daily time step
- **3 Reservoirs** (subsystem)
- Methods
  - Hydrologic Routing
  - Flood Control
    - Channel Capacity
    - Ramping Rates
    - Balance Levels
    - ~~Control at Van Buren, AR~~
  - ~~Conservation & Power~~
  - Excel and VBA

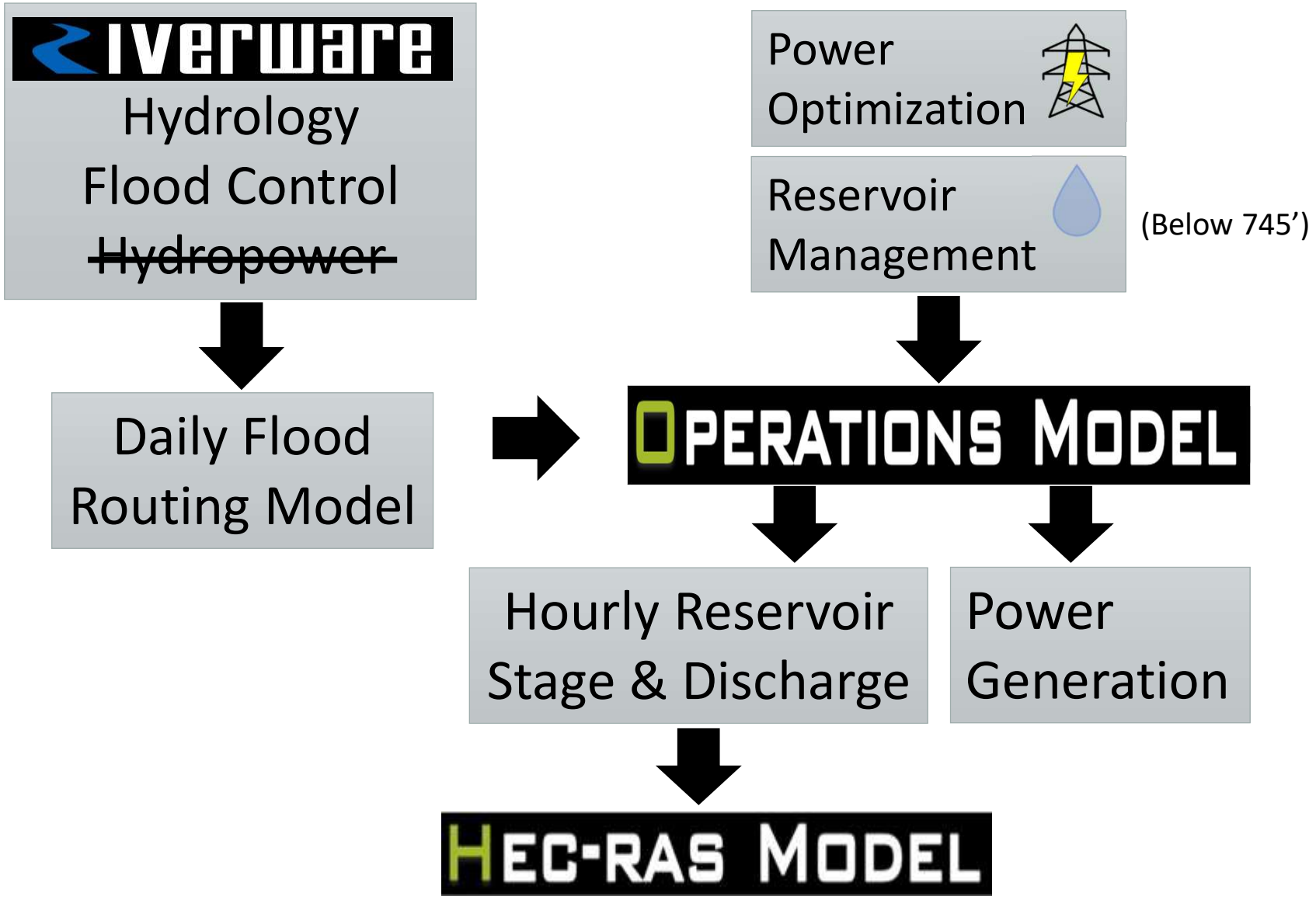
Operations Model

OPERATIONS MODEL



- **2004** through 2017
- **Hourly time step**
- **2 Reservoirs**
- Methods
  - Hydrologic Routing
  - Flood Control
  - **Detailed Hydropower Operations**
  - Excel and VBA

Operations Model Overview

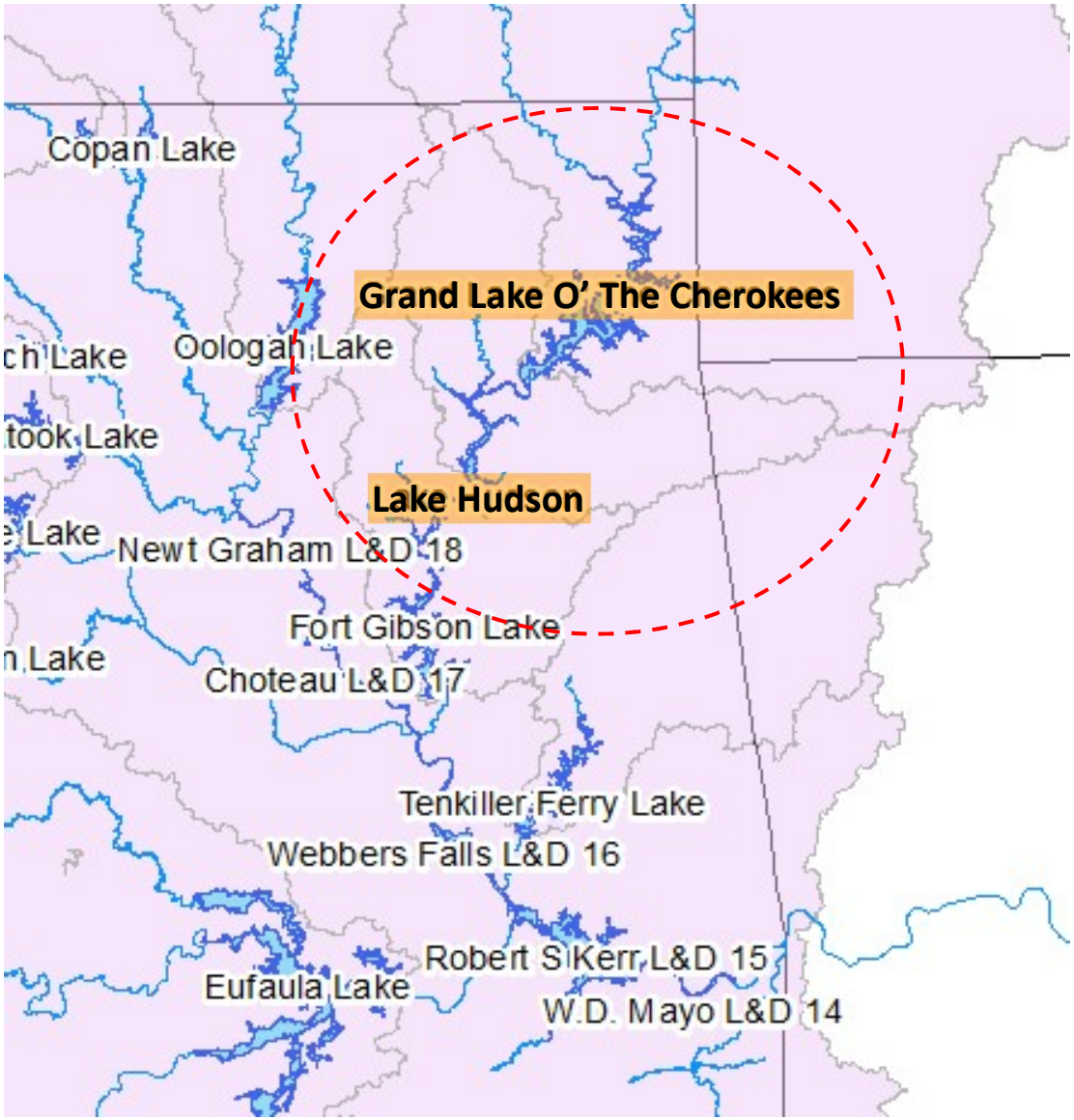


USACE RiverWare – Data Available

- Time series:
  - River discharge
  - Local reservoir inflow
  - Evaporation & seepage
- Rating tables:
  - Elevation-storage-area
  - Operating level-storage
  - Max regulated spill
  - Induced surcharge
  - Seasonal res. elevation
  - Hydrologic routing coefficients

Operations Model – Input Data

OPERATIONS MODEL



- Flood Routing Model
- Other time series
  - Electricity prices
  - Unit outages
  - Dissolved oxygen derate (Pensacola)
- Other rating tables
  - Turbine headloss, max discharge, and efficiency
  - Elevation-storage-area (USGS, 2020)
  - Tailwater rating
  - Spillway capacity

Validation Parameters

Variables

Total Discharge: Hourly *total discharge* averaged over a 24-hour period and compared to corresponding daily value.

Elevation: End-of-day (midnight) *headwater level* compared to corresponding end-of-day value from daily model.

Date Range

Flood Routing Model: **1940 to 2017**

Operations Model: **April 1, 2004 – December 31, 2017**

Validation Performance Metrics

Coefficient of Determination (R^2)

$$R^2 \quad \left[\frac{\sum_{i=1}^{n}(O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}\sqrt{\sum_{i=1}^{n}(P_i - \bar{P})^2}} \right]^2$$

Definition: An index of the degree of linear relationship between observed and simulated data.

Advantage: Correlation between models and dispersion of data relative to that correlation.

Disadvantage: Does not evaluate accuracy, only correlation.

Nash-Sutcliffe Efficiency (NSE)

$$NSE \quad 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$$

Definition: An index of how well the observed versus simulated data fits the 1:1 line.

Advantage: Evaluation of model accuracy. Plotting on a 1:1 line indicates consistent prediction at lower and higher values.

Disadvantage: Sensitive to extreme values.

Source: D. N. Moriasi et al., 2015

Performance Metric Evaluation

Coefficient of Determination (R^2)

Range: 0.0 to 1.0

Optimum Value: 1.0

Optimum Trendline Slope: 1.0

Optimum Trendline Y-intercept: 0.0

Performance Metric Evaluation

$R^2 > 0.85$	Very Good
$0.75 < R^2 \leq 0.85$	Good
$0.60 < R^2 \leq 0.75$	Satisfactory
$R^2 \leq 0.60$	Not Satisfactory

Nash-Sutcliffe Efficiency (NSE)

Range: $-\infty$ to 1.0

Optimum Value: 1.0

Performance Metric Evaluation

NSE > 0.80	Very Good
0.70 < NSE ≤ 0.80	Good
0.50 < NSE ≤ 0.70	Satisfactory
NSE ≤ 0.50	Not Satisfactory

Source: D. N. Moriasi et al., 2015

Conclusions

- Flood Routing Model will simulate RiverWare daily flood routing
- Operations Model will simulate hourly hydropower scheduling while maintaining flood routing decisions
- Model validation against RiverWare model output will use R^2 and NSE to measure correlation of total discharge and elevation

Thank you