REVIEW OF THE MODEL RAISED A NUMBER OF CONCERNS I WILL SUMMARIZE AFTER EXPLAINING THE MOST IMPORTANT CONCERN WHICH IS IMPORTANT BECAUSE LOW FLOW MATTERS TO FISH HABITAT THE MODEL IGNORES THE UNCONFINED AQUIFER BEHAVIOR OF SHALLOW ZONE SO FOR THE SAME CASE:

Without Unconfined Zone, BASEFLOW 75% exceedance 2.5 cfs

With Unconfined Zone, BASEFLOW 75% exceedance 13.2 cfs

AVERAGE ANNUAL BASEFLOW IS THE SAME FOR BOTH CASES If average base flow is of interest THEN only recharge matters AND WE DO NOT NEED A NUMERICAL MODEL
Aquifer hydraulic properties: Storage coefficient

The volume of water given up per unit area of an aquifer per unit drop of the water-table or potentiometric surface.
Aquifer Hydraulic Properties: Storage Coefficient

- Alluvial aquifer: 0.2
- Arbuckle-Simpson aquifer: 0.008

Not just a matter of Alluvial vs Arbuckle-Simpson
ALSO
UNCONFINED vs CONFINED

1 SQUARE FOOT
ENTIRE THICKNESS

Alluvial aquifer: 1.5 gallons
Arbuckle-Simpson aquifer: 1 cup
Fairchild and others (1990) reported that "information from drillers and land owners suggests that the upper few hundred feet of the Arbuckle Group has a much lower permeability than the lower part."

**K is permeability, also called hydraulic conductivity**

**K is ability to push water through**

**Ss = Specific Storage** is ability to store water per unit of thickness

**S = Storage Coefficient** is ability to store water in entire thickness

\[ S = Ss \times \text{Thickness} \]
ALL HYDROLOGISTS TESTIFYING YESTERDAY AGREED PORES DRAIN WHEN WATER LEVEL DECLINES IN UNCONFINED ZONE

UNCONFINED AQUIFER
PORES DRAIN WHEN WATER LEVEL LOWERS

CONFINED AQUIFER
PORES DO NOT DRAIN WHEN WATER LEVEL LOWERS
UNCONFINED BEFORE WATER LEVEL DECLINE

IN THE UNCONFINED ZONE

WHEN WATER LEVEL DECLINES WATER DRAINS FROM PORES

AFTER 1 FOOT DECLINE

100 FEET

1 FOOT

STORAGE Essentially ALL FROM TOP 1 FOOT

1.5 gallons
CONFINED ZONE

WHEN WATER LEVEL DECLINES AQUIFER COMPRESSES AND WATER EXPANDS TO PROVIDE WATER

PORES DO NOT DRAIN

STORAGE released from entire aquifer thickness

3500 FEET

1 cup

NOT TO SCALE
FEW WELLS ARE COMPLETED IN THE UNCONFINED ZONE IN THE STUDY AREA BECAUSE LOW K MAKES THEM LESS DESIRABLE FOR WATER SUPPLY

ONE WELL IN THIS ZONE
OWRB 85182, 53 FT DEEP
STORAGE COEFFICIENT 0.075

NEARLY ALL WELLS OF STUDY AREA ARE IN THE CONFINED ZONE

MANY MEASUREMENTS OF THIS STORAGE COEFFICIENT RANGE FROM
0.002 to 0.02

0.075 is NOT a very small value as was stated yesterday
It does NOT indicate a confined condition as was stated yesterday
It is indicative of unconfined conditions
USGS used CONFINED MODFLOW layers to simulate the UNCONFINED portion of the Arbuckle-Simpson aquifer.

STATED THIS WAS BECAUSE:
Storage coefficients similar
Drawdown would be small
The model solution will be more stable

Using confined MODFLOW layers is acceptable as long as storage in the top layer represents drainage of water from the pores, but this was not done in the USGS model, so the streams were too sensitive to pumping.

As three hydrologists noted yesterday Storage Coefficient is typically much higher in unconfined zone.

Even if the S values are both 0.008, the Ss value was entered incorrectly in MODFLOW, making S of the top layer only 2% of what it should be.

If S of top layer is 0.008, Ss should be $0.008/20m = 0.0004m^{-1}$, not $0.000008m^{-1}$

This required procedure for input of S of the top layer is demonstrated by the SYTP parameter in the MODFLOW HUF2 package.
When the water table is not considered in the model, stream base flow variation is larger because the buffer provided by unconfined storage is ignored.

Drainage of pore water from the unconfined zone buffers the stream base flow from seasonal pumping.

Unconfined layer ignored

Unconfined Included

Confined zone
I ran simulations to determine the influence of representing the top layer as unconfined

SIMULATION INVOLVED:
Running the transient calibration model with the 0.392 (A-F/A)/Yr, eps
Repeating until the cumulative budget did not change

RUN #1
USGS Model Storage Properties
Storage coefficient of 0.008 and a thickness of 1000m
ALL LAYERS \( S_s = \frac{S}{\text{thk}} = 0.000008 \)

RUN #2
USGS Field Measured Storage Properties
Storage coefficient of 0.075 and a thickness of 20m
TOP LAYER \( S_s = \frac{S}{\text{thk}} = 0.00375 \)
Storage coefficient of 0.011 and a thickness of 1040m
LAYERS BELOW TOP \( S_s = \frac{S}{\text{thk}} = 0.00001056 \)
Blue River @ Connerville Oct 2003 to Oct 2008

USGS Model Storage Properties
Storage coefficient Layers 1-6 = 0.008

EPS = 3.92 AFY
Without unconfined zone, BASEFLOW
75% exceedance 2.5 cfs

USGS Study Storage Properties
Storage coefficient of top layer = 0.075
Storage coefficient Layers 2-6 = 0.011

EPS = 3.92 AFY
With unconfined zone, BASEFLOW
75% exceedance 13.2 cfs
RESULTS OF THE SIMULATION DO NOT PROVIDE INFORMATION ON THE EXPECTED BASE FLOW

The point is not that we have the right values, rather that including the unconfined zone while using reasonable S values, properly input, makes a substantial difference in low flow of streams.

Storage coefficient of unconfined zone needs to be better measured in the field and properly input to MODFLOW.

Storage Coefficients need to be included in the calibration process.
Stream conductance
   Units given in report were incorrect (m/d, should be m²/d)
   A constant value of 1000 was used and not explained C= KΛW/b

Steady State Calibration
   Steady State simulation used 4 time steps, only one is needed
   Unsubstantiated “steady-state” data for steady-state calibration
   Multi-level nature of observation data was not included in the model
   Parameter estimation process was not presented nor files provided
   Residuals exhibited spatial bias
   The guidance for effective model calibration of Hill and Tiedeman 2007 was not followed

Steady state and transient calibrations were not combined

Transient Calibration
   Initial conditions for transient simulation were not generated properly
   Only two transient calibration targets were used, transient head data were not used
   Transient calibration did not optimize the value of storage coefficient

Prediction sensitivities were not provided so we do not know which parameters
   influenced the predictions
Uncertainty in predictions was not presented
CONCLUSION

Given the importance of determining a safe and fair equal proportionate share, the model evaluation should be rigorous.

The model is not ready for use in making policy decisions until storage coefficients have been properly measured and incorporated in the model.

Shortcomings outlined in previous slide are addressed.