Structure and development of CalCAST - Sediment

Isabella Bertani, Gopal Bhatt, Gary Shenk, Lewis Linker

Modeling Workgroup Quarterly Review
07/12/2022

What is CalCAST?

- Relatively parsimonious, spatially explicit, largely data-driven watershed modeling tool calibrated in a statistical framework
- Currently represents > 80,000 National Hydrography Dataset Plus (NHDPlus) catchments within the Bay watershed and leverages data from > 400 USGS monitoring stations for calibration
- Currently time-averaged (but may be extended to predict at the annual time step in the future)
- Currently predicts long-term average streamflow at NHDPlus catchments (but we are extending it to predict nutrient and sediment loads)

APRIL QUARTERLY RECAP

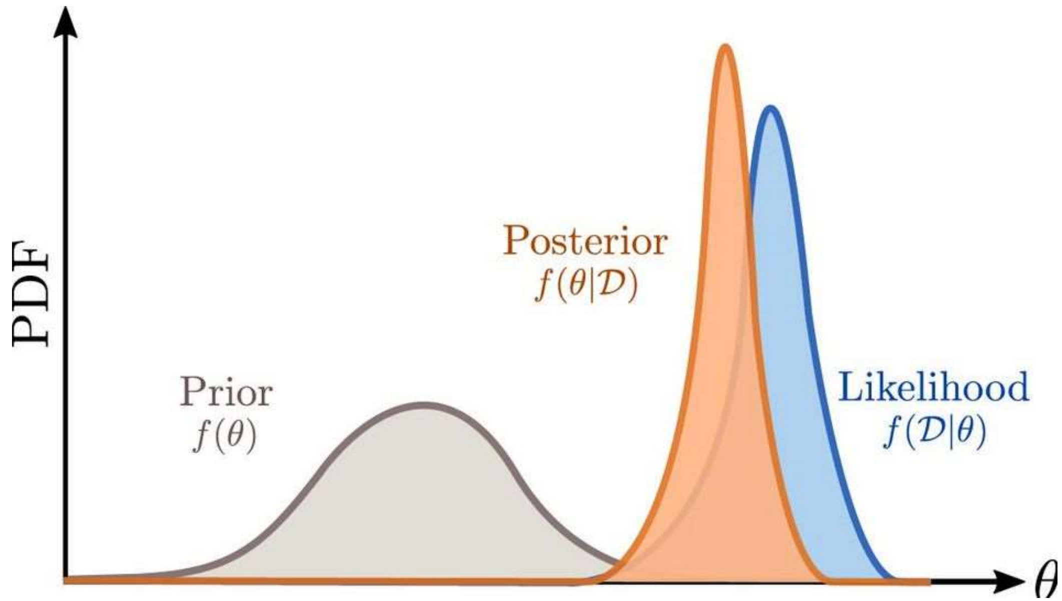
Why CalCAST?

- Primarily used as spatial calibration tool
- Main purpose: probabilistically test hypotheses on factors related to spatial variation in contaminant loads and quantify parameters that describe such relationships
- Spatial parameters estimated by CalCAST will inform CAST and the dynamic model
- Incorporate data-driven line of evidence into modeling approach

Plan for this year

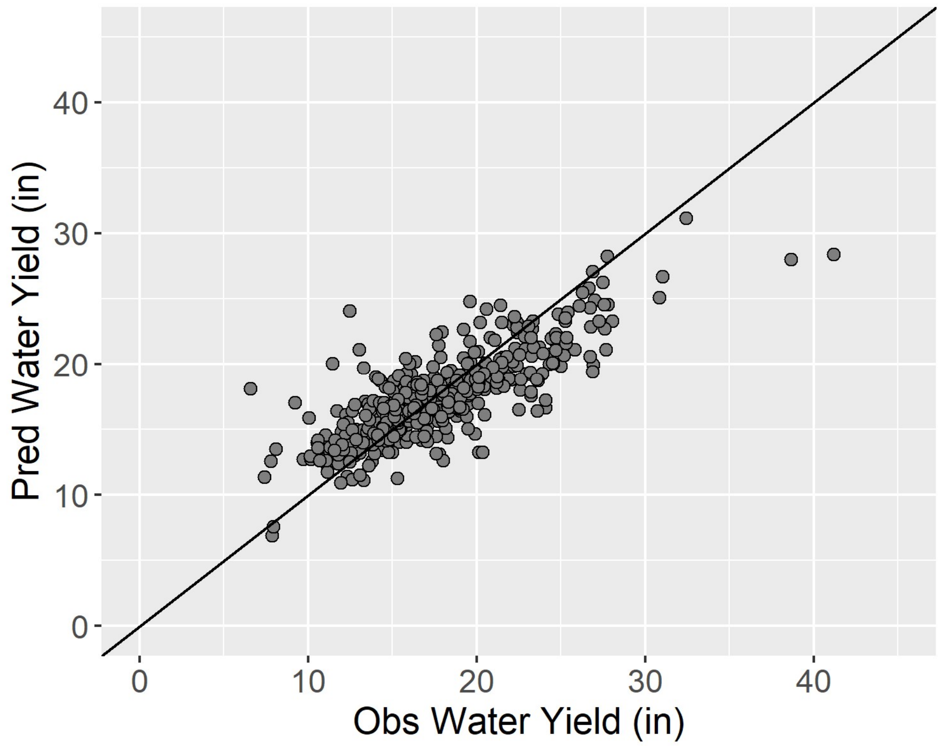
APRIL QUARTERLY RECAP

- Implement Bayesian calibration framework
- Get the code infrastructure up and running
- Get "*on the graph*" results for hydrology, sediment, and nutrients

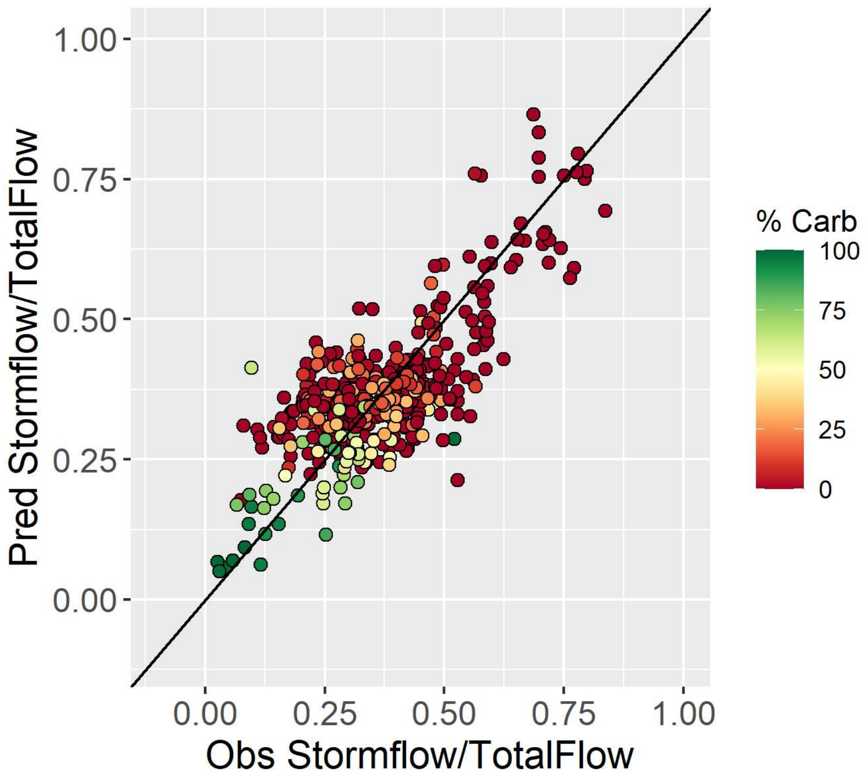


Hydrology – Observed vs. Predicted

Total Flow

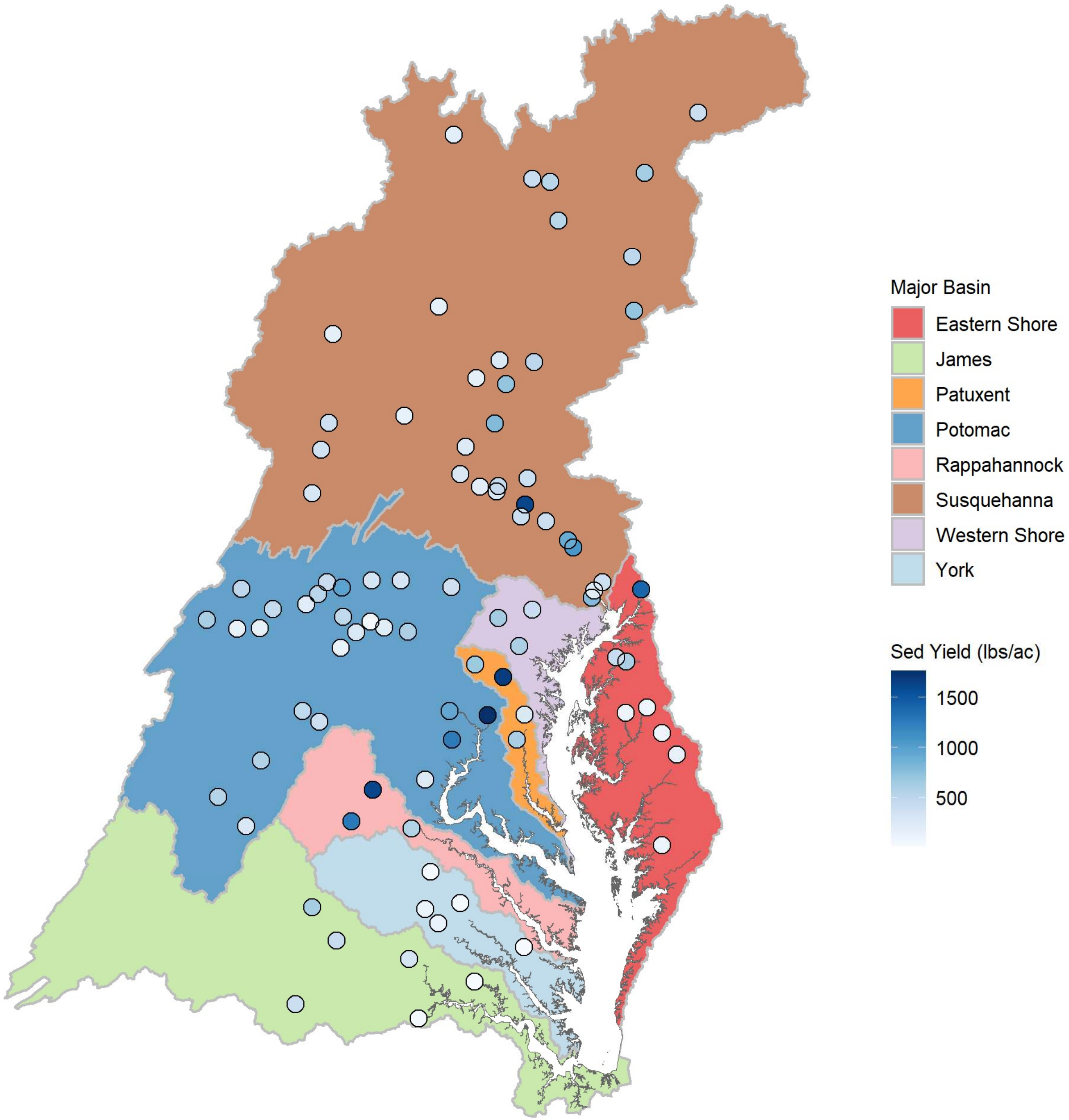


Stormflow/Total Flow



Sediment

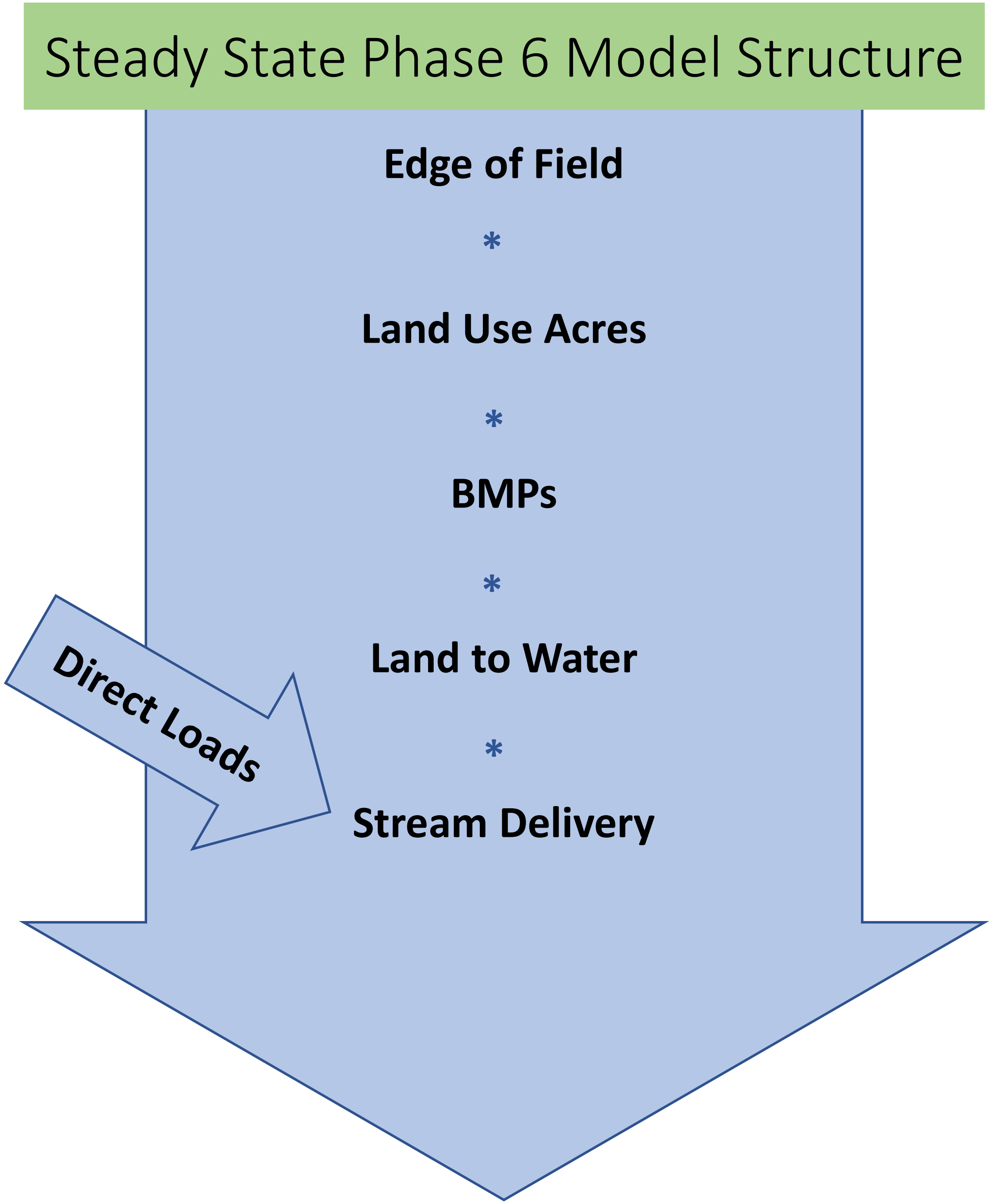
Calibration stations



- Calibration target:

  WRTDS flow-normalized sediment load estimated at non-tidal network stations

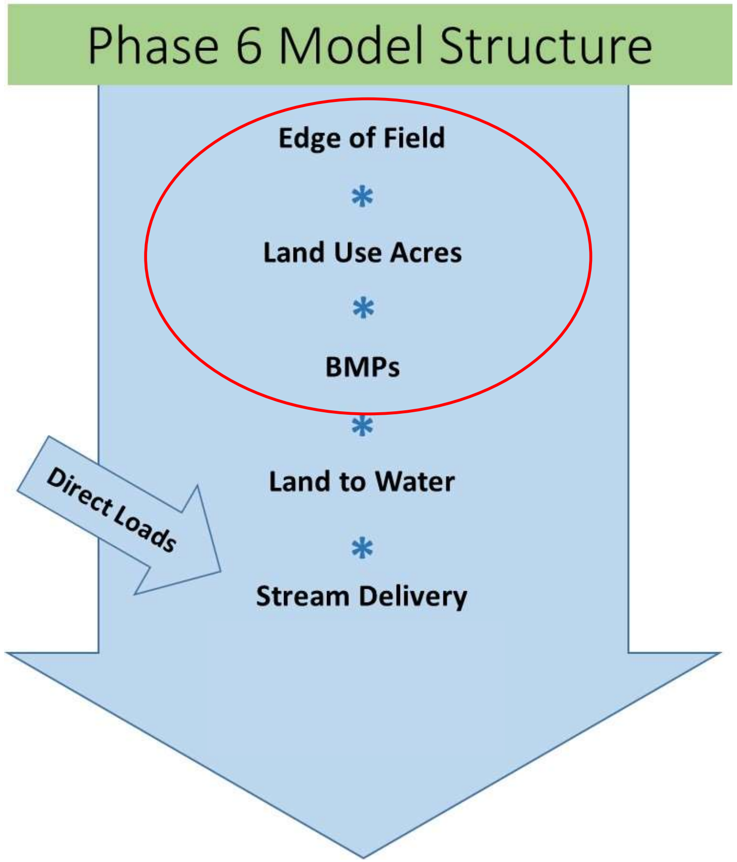
Implementing P6 at NHDPlus scale in CalCAST



RUSLE Edge-of-Field loads

- RUSLE equation evaluated at the 10-m pixel scale and then aggregated up to the NHDPlus catchment scale for 6 land uses:

  Forest
  Mixed Open
  Crop
  Pasture
  Turfgrass
  Tree Canopy over Turfgrass

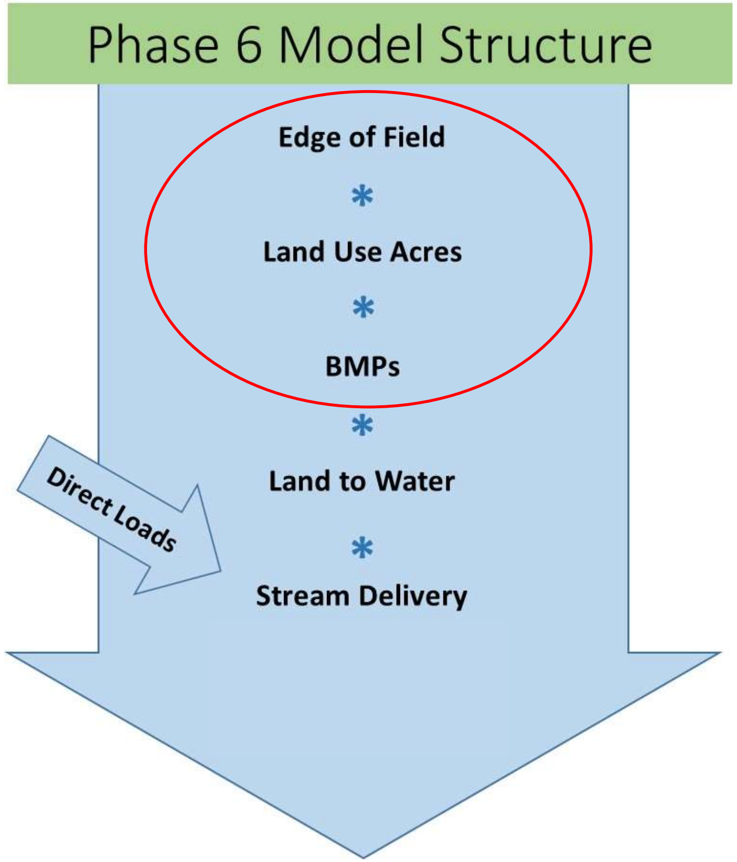


RUSLE Edge-of-Field loads

$$\mathbf{EOF\ NPS_{l,c}} = (R_{l,c} * K_{l,c} * LS_{l,c} * C_l) * Acres_{l,c} * BMP_{l,c}$$

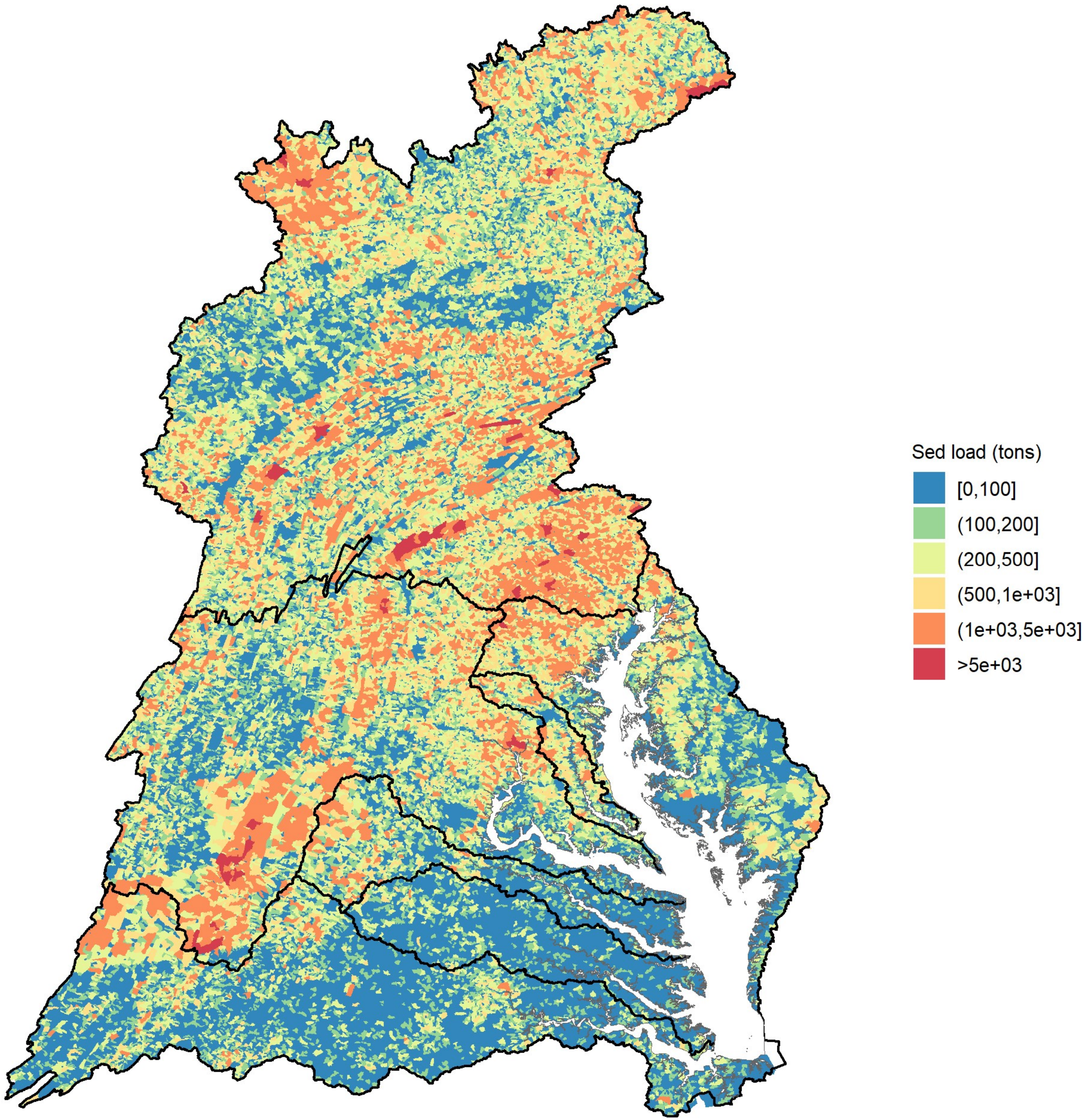
Rainfall erosivity | Soil erodibility | Slope length and steepness factor | C-factor

c: NHDPlus catchment; l: land use



- For now, RUSLE components are the same as in P6, but the Land Use team plans to revise them
- We plan to test replacing R factor with CalCAST-predicted stormflow (or something else?)
- We may test letting CalCAST estimate some of the coefficients in RUSLE (e.g., C-factors?)
- For now, $BMP_{l,c}$ set to 1 for simplicity

RUSLE Edge-of-Field loads



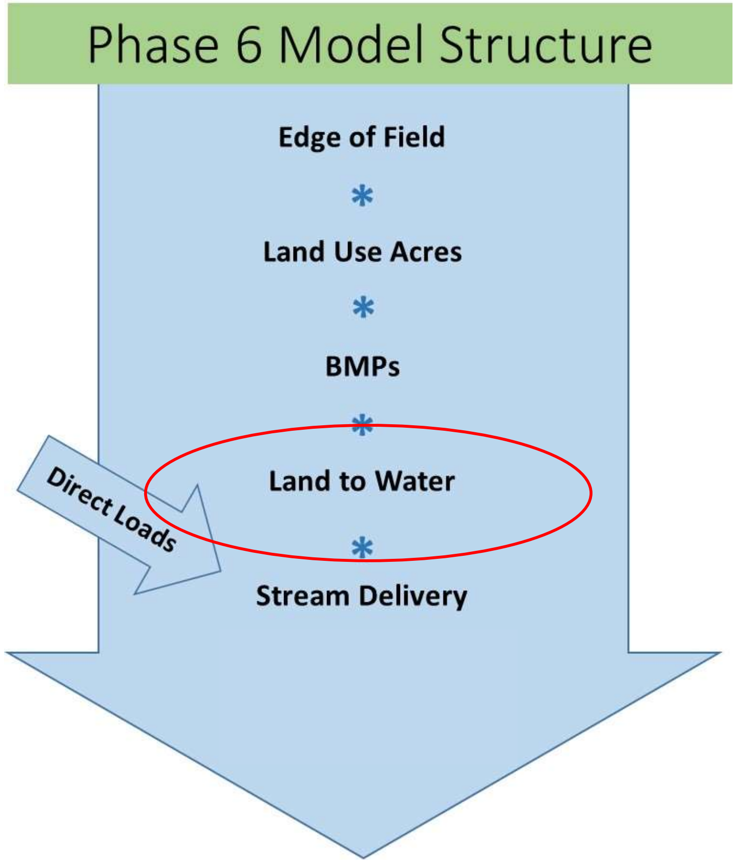
Edge-of-Stream Loads: Sediment Delivery Ratios

$$EOS\ NPS_{l,c} = EOF\ NPS_{l,c} * (0.083 * IC_{l,c} + 0.764)$$

RUSLE EOF nonpoint source load

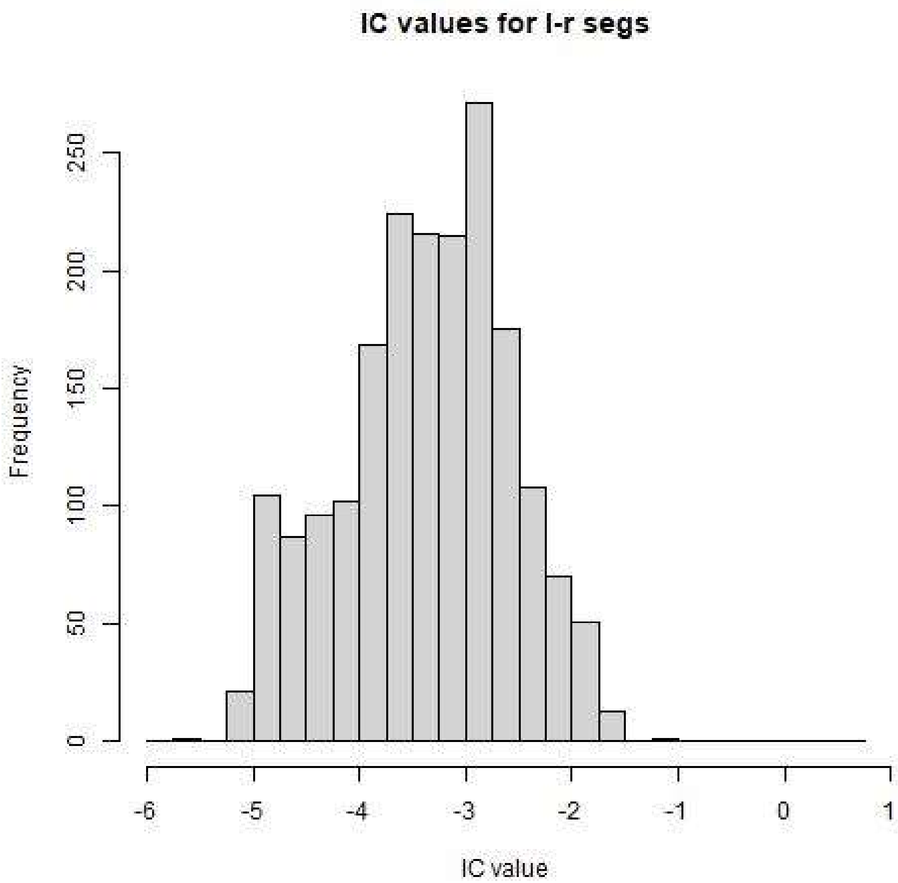
Index of Connectivity

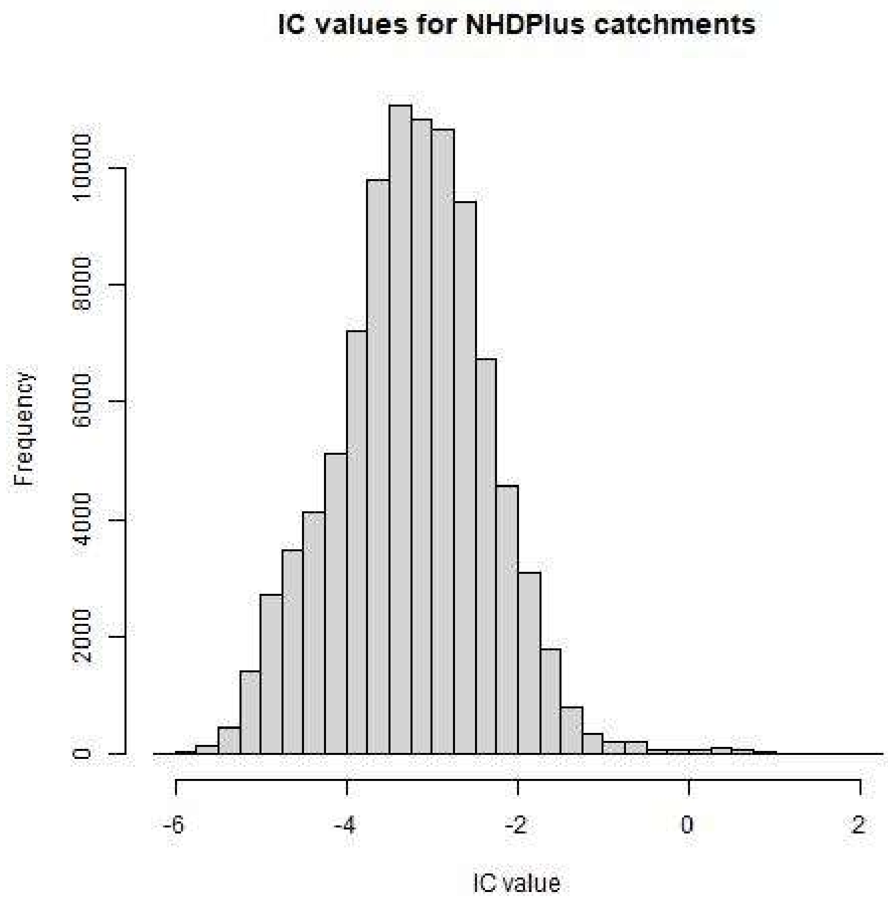
c: NHDPlus catchment; l: land use



- P6 IC values at the 10-m scale aggregated to the NHDPlus scale
- Coefficients that convert IC to Sediment Delivery Ratios may be estimated through CalCAST in the future

Distribution of IC values by l-r segs and NHDPlus catchments





Edge-of-Stream Loads for remaining land uses

- **Water**: EOS loading rate set to **zero**
- **Wetlands:** EOS loading rate set to same as **Forest**
- **Impervious**: EOS loading rate set to **3 times that of Turfgrass** (Impervious Roads, Impervious Non-Roads, and Tree Canopy over Impervious)

- For now, same assumptions as in P6. We may turn those assumptions into priors and let CalCAST estimate coefficients instead in the future

Direct Loads

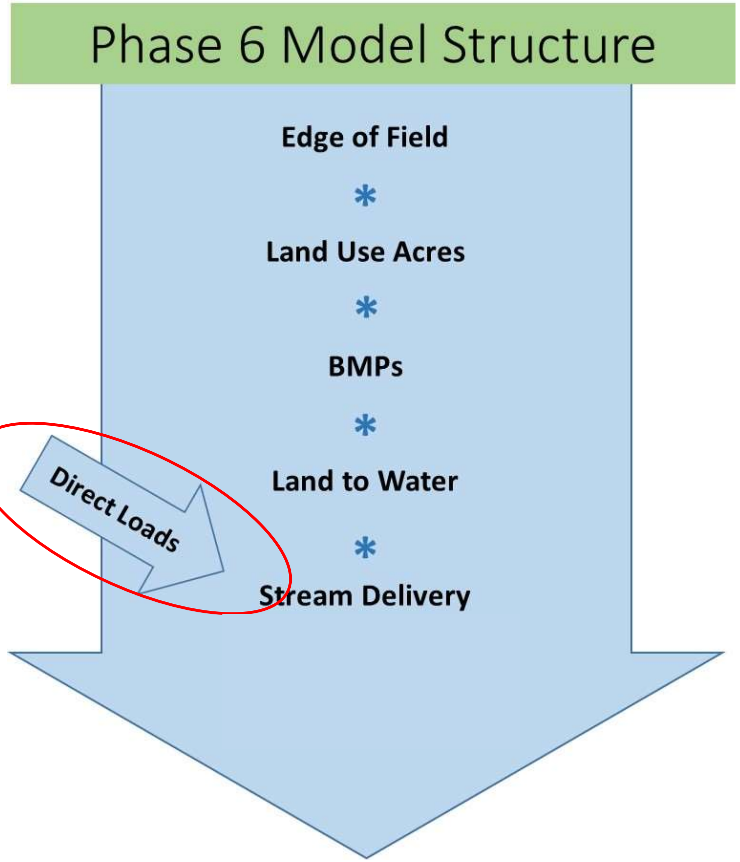
$$\boldsymbol{EOS\ Load_{c,t}} = \sum_{l} \boldsymbol{EOS\ NPS_{l,c,t}} + PS_c + SB_c - FD_c$$

EOS nonpoint source load from all land uses

Point Source loads

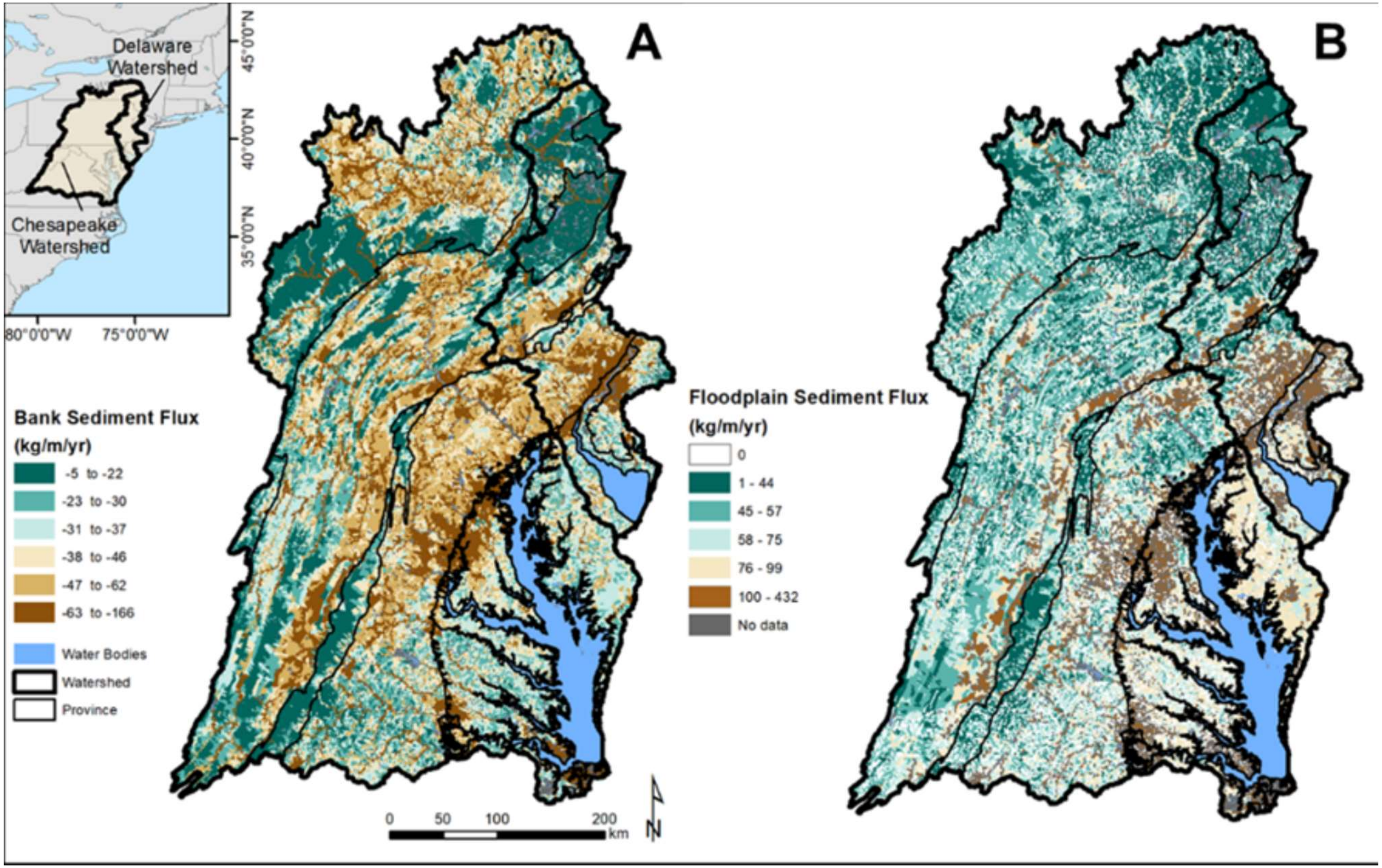
Streambed and bank load & Floodplain Deposition

c: NHDPlus catchment; l: land use



- For now, PS = wastewater only (IND and MUN) for simplicity
- For now, same assumption as in P6 that SBc = FDc. We plan to replace this assumption with loading rates estimated in Noe et al. 2022

Streambank and floodplain sediment flux at NHDPlusV2 reaches in the Chesapeake Bay watershed



Noe et al. 2022

Stream delivery

$$DEL\ Load_g = \sum_c \boldsymbol{EOS\ Load_c} * Del_{g,c}$$

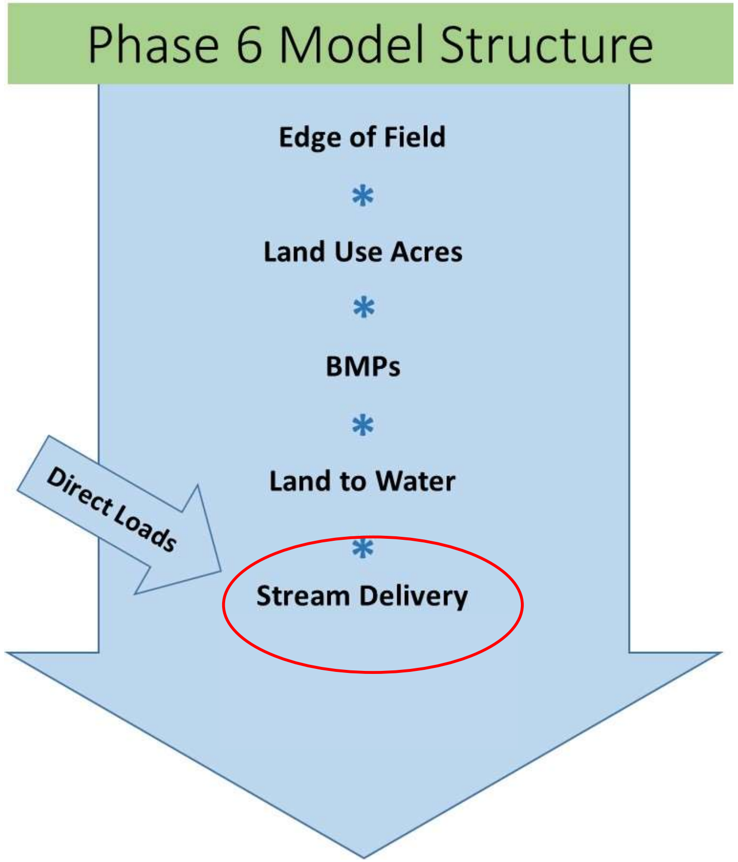
EOS total load

Delivery factor (reservoir deposition)

c: NHDPlus catchment; g: gauging station

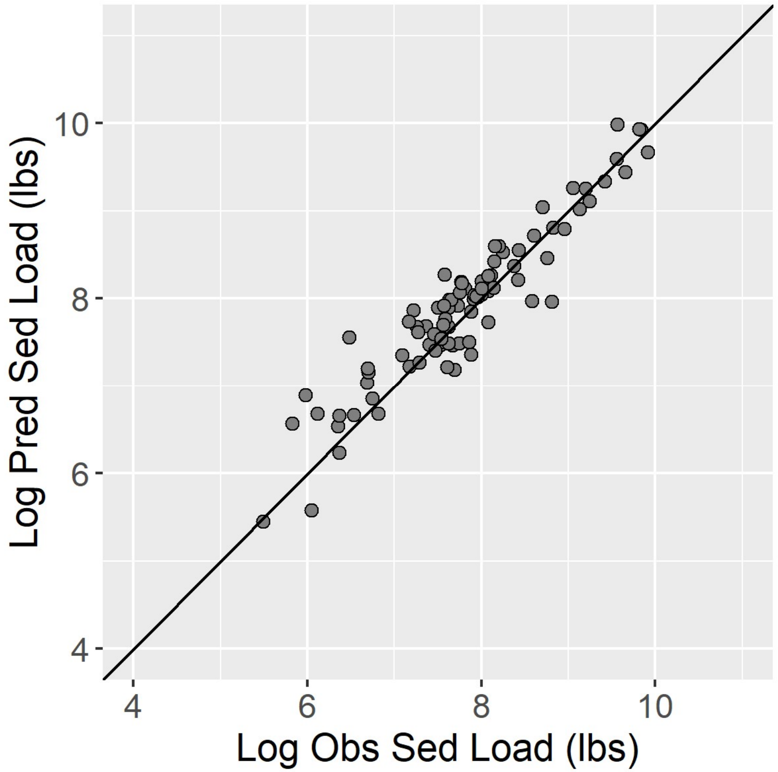
$$Del_{g,c} = \prod_c \frac{1}{1 + bres * IHL_c}$$

Inverse reservoir areal hydraulic load



Sediment observed vs. predicted - Preliminary

Sediment load



Sediment yield

Running CalCAST on cloud resources

- **Dave Kintgen** and **Kevin Asplen** have developed code to run CalCAST on cloud infrastructure (Amazon SageMaker)

- Two parallelization approaches to speed up run time:

    - Launch several independent model instances in parallel - *completed*

    - «Within-chain» parallelization (use more than one CPU per Markov Chain Monte Carlo chain) – *working on it*

Next steps

- Code checking/de-bugging
- Test calibrating some of the RUSLE parameters/components
- Test using CalCAST-predicted stormflow instead of R factor in RUSLE
- Test calibrating parameters that convert IC to SDR
- Use Noe et al. 2022 SB and FD loads
- Start working on nutrient load implementation