American Water Works Association

SUSTAINABLE Water Management Conference

2018

Quantifying the Potential Benefits of Land Conservation in Preserving Long-Term Water Supply to Optimize Return on Investment

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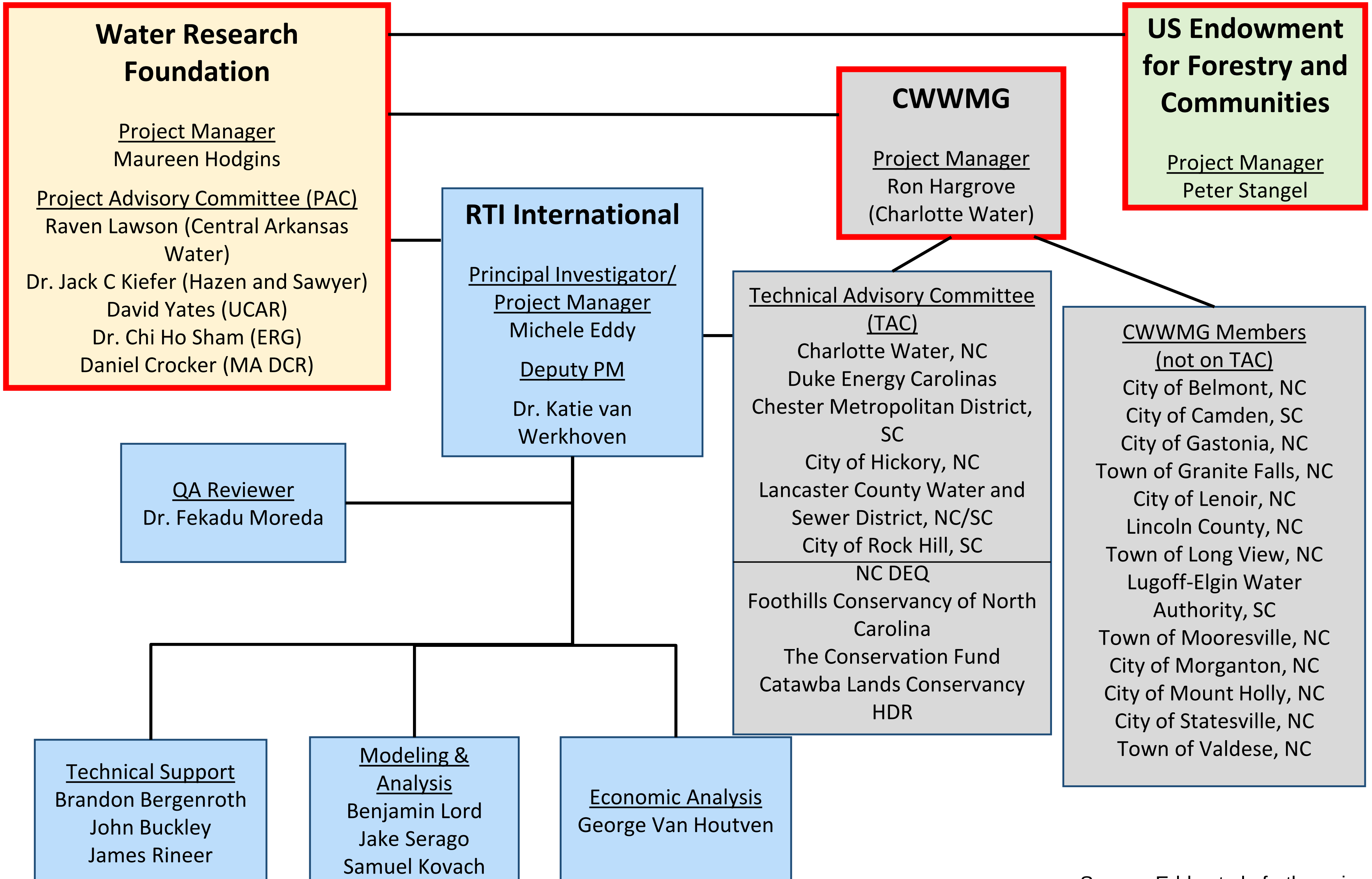
Water Research Foundation Project #4702

Project Manager Maureen Hodgins

Project Goals

1. Estimate potential changes in flow and sediment delivery in the watershed as a result of future change in climate, land use and water use
   - What is the magnitude and trend (increase or decrease) of change? Does it occur the same everywhere?
2. Find areas in the watershed where the impact relative to other areas is disproportionately large ("hot spots")
   - What metrics best capture impacts that are important to this group? Are hot spots different for different metrics?
3. Determine if and to what extent land conservation of "hot spot" could mitigate some portion of the total downstream impact to water supply
   - What percent of the impact is mitigated? What is the cost of mitigation?

Project Funding and Organization

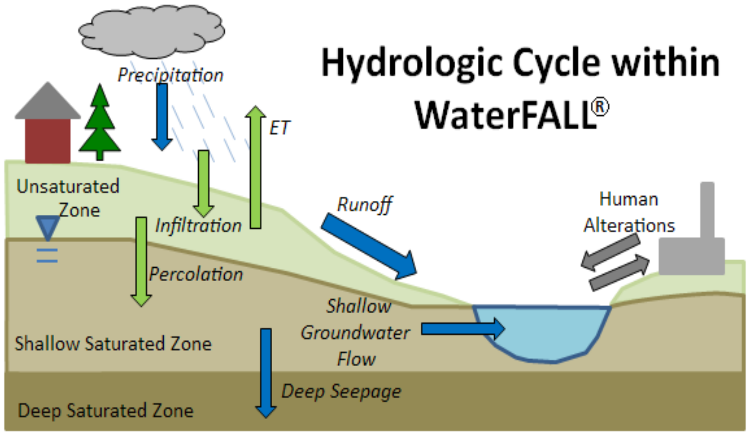


Source: Eddy et al., forthcoming

Background

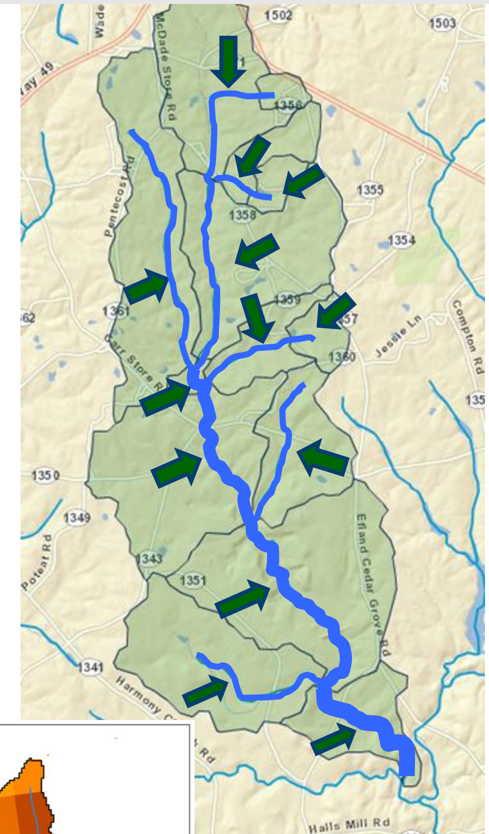
WaterFALL®: Watershed Flow and ALLocation Model

Rainfall-Runoff Watershed Model based on GWLF

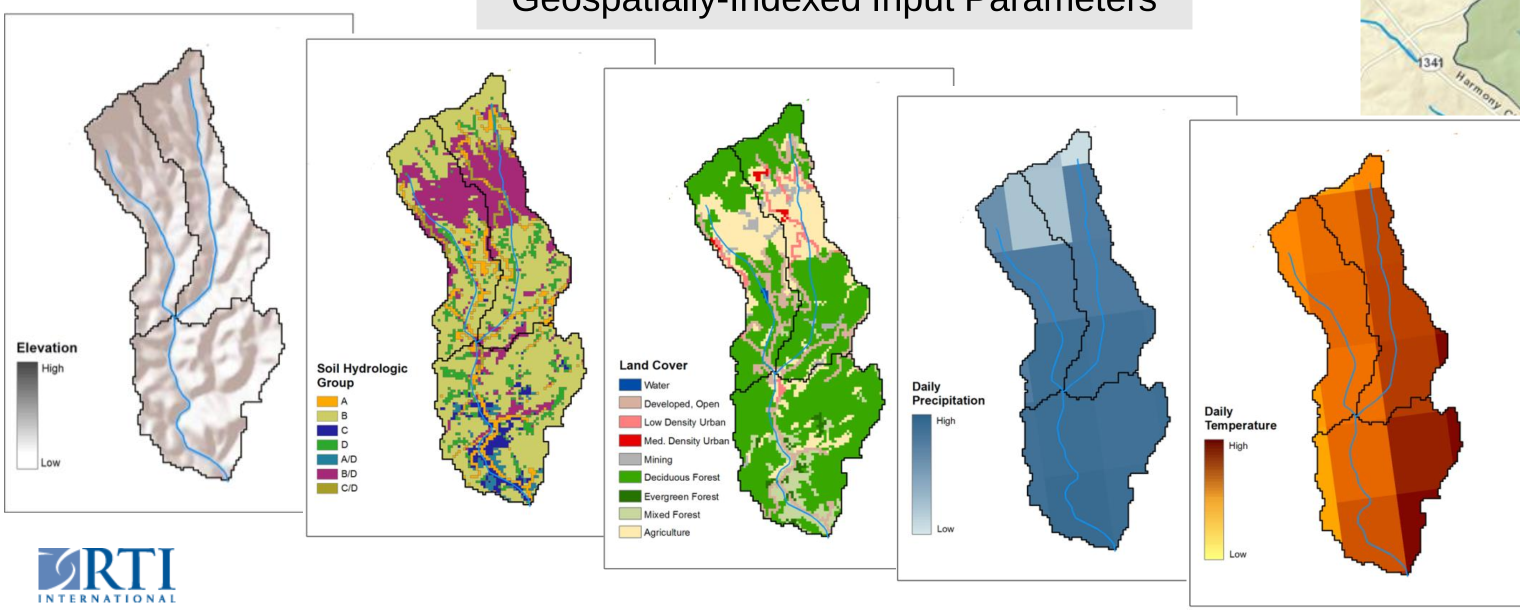


3 main elements combine to provide a fine scale distributed watershed model of intermediate complexity

Digital Hydrologic Network using NHDPlus



Geospatially-Indexed Input Parameters



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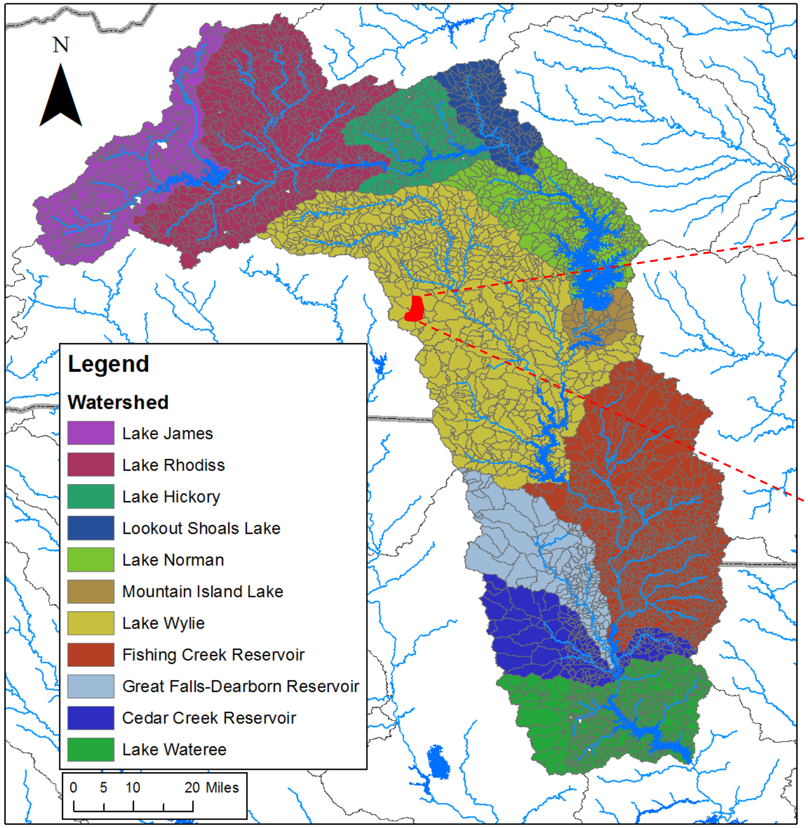
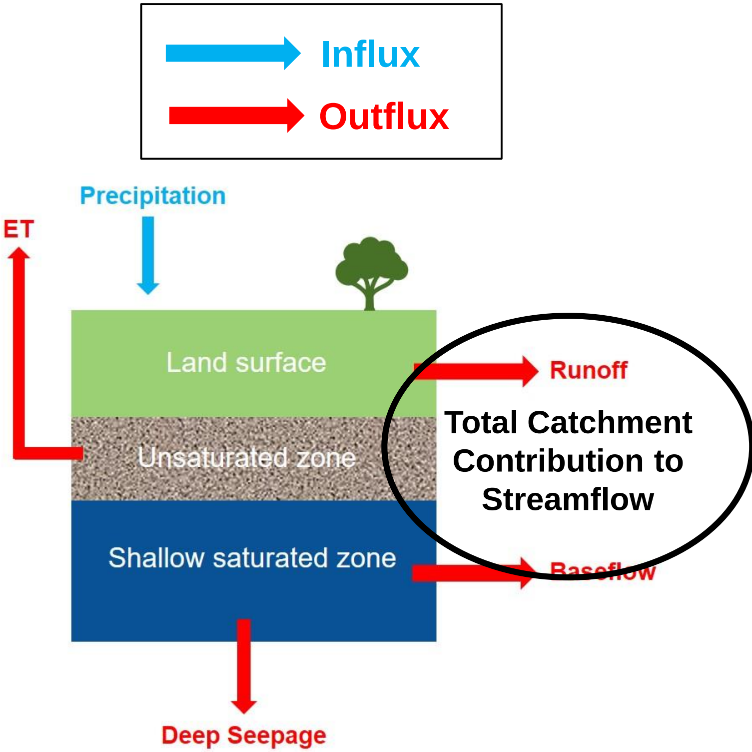
WaterFALL Model Definitions

- The Catawba Watershed is subdivided into ~5,800 catchments in WaterFALL
  - The model simulates runoff and baseflow for each catchment
  - Catchment flows are accumulated through the stream network from upstream to downstream





Source: Eddy et al., forthcoming

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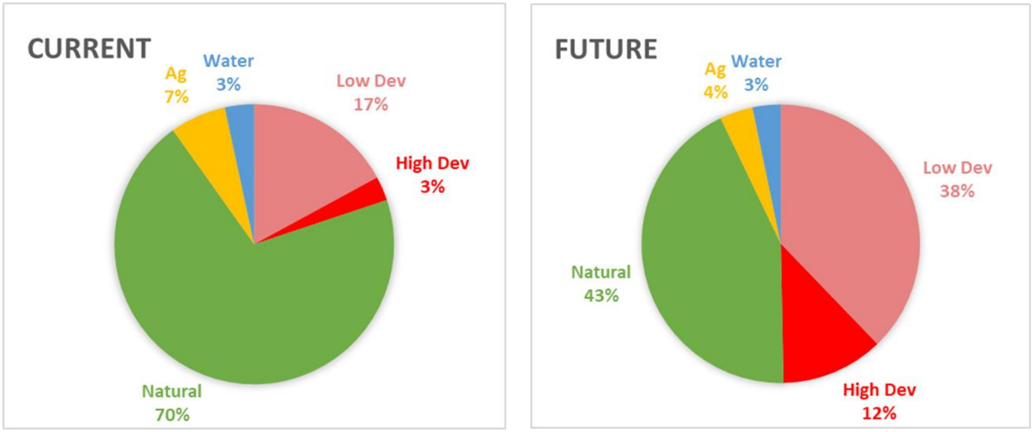
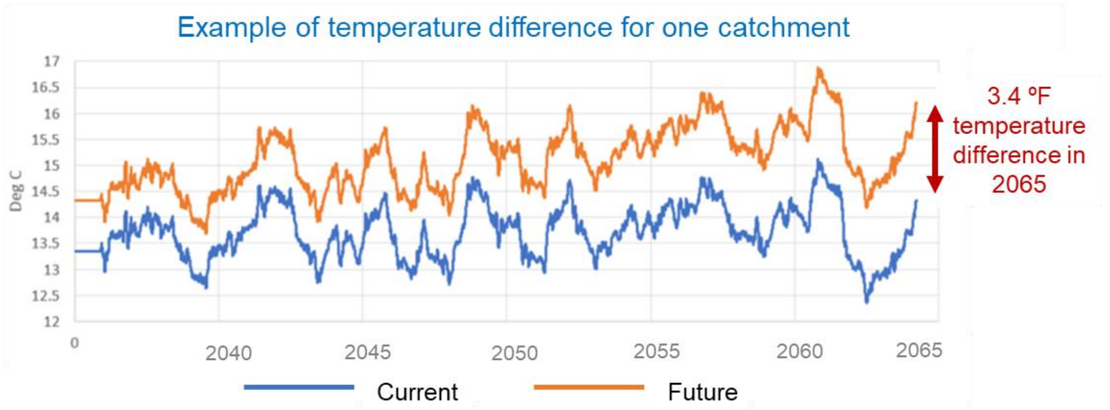
Scenarios

- <u>Scenario 1: Land use change</u> - Increase in developed area based on EPA ICLUS v2 data (Integrated Climate and Land-Use Scenarios)



Source: Eddy et al., forthcoming

- <u>Scenario 2: Climate change</u> - Temperature rise based results of the Intergovernmental Panel on Climate Change (IPCC) RCP8.5 Scenario



Source: Eddy et al., forthcoming

- <u>Scenario 3: Water use change</u> – Projections on existing use points from WSMP and projected agriculture and irrigation values
- <u>Scenario 4: Combined land use, climate, and water use changes</u>

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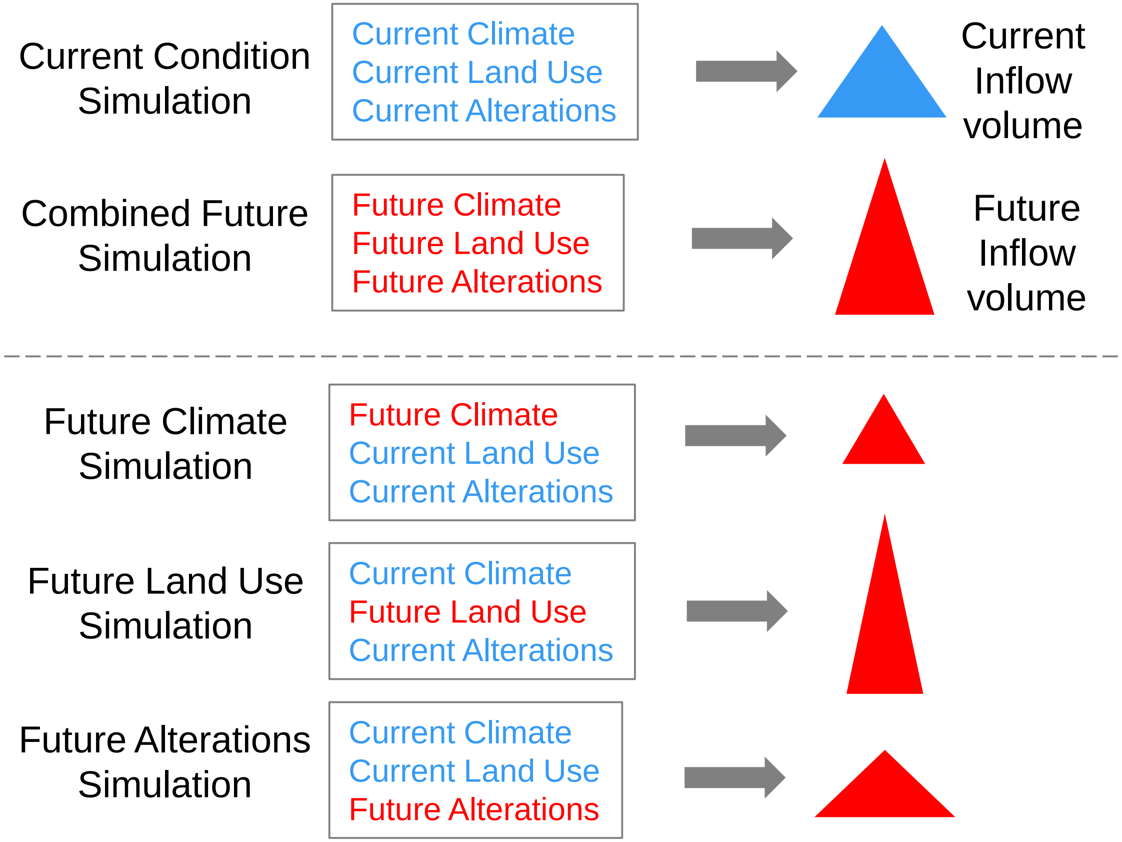
Assessing Change Through Scenarios

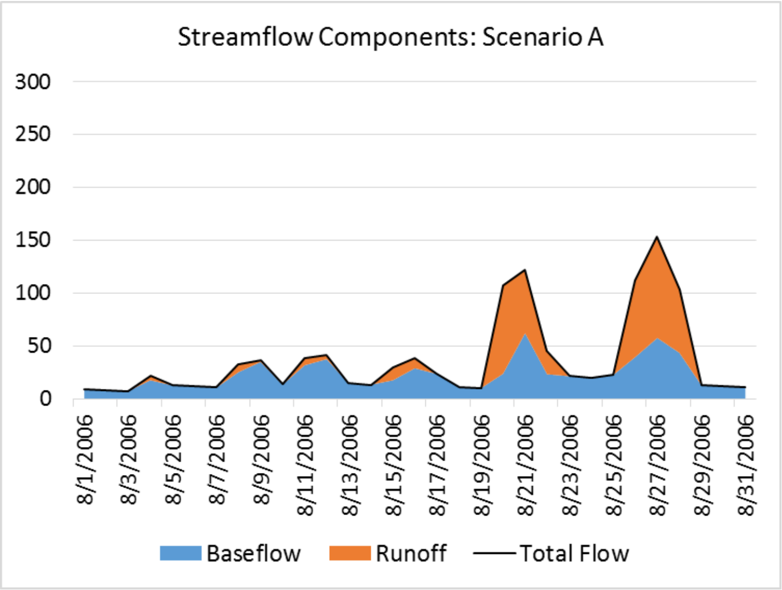
- Five total scenarios → current conditions and 4 future scenarios
- Reason for multiple future scenarios is to answer the questions:
  - What is causing future change in flow? Can it be mitigated?



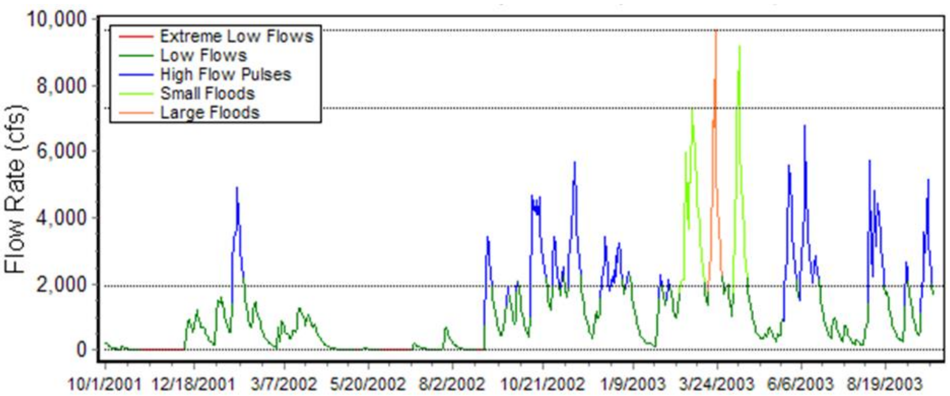
Source: Eddy et al., forthcoming

How Are We Assessing Hydrologic Changes?

- Runoff and baseflow and affect different aspects of total streamflow
  - Baseflow affects low flows, runoff affects high flows
  - Baseflow and runoff respond differently to changing future conditions
    - Important for understanding causes of change in flow and potential for mitigation

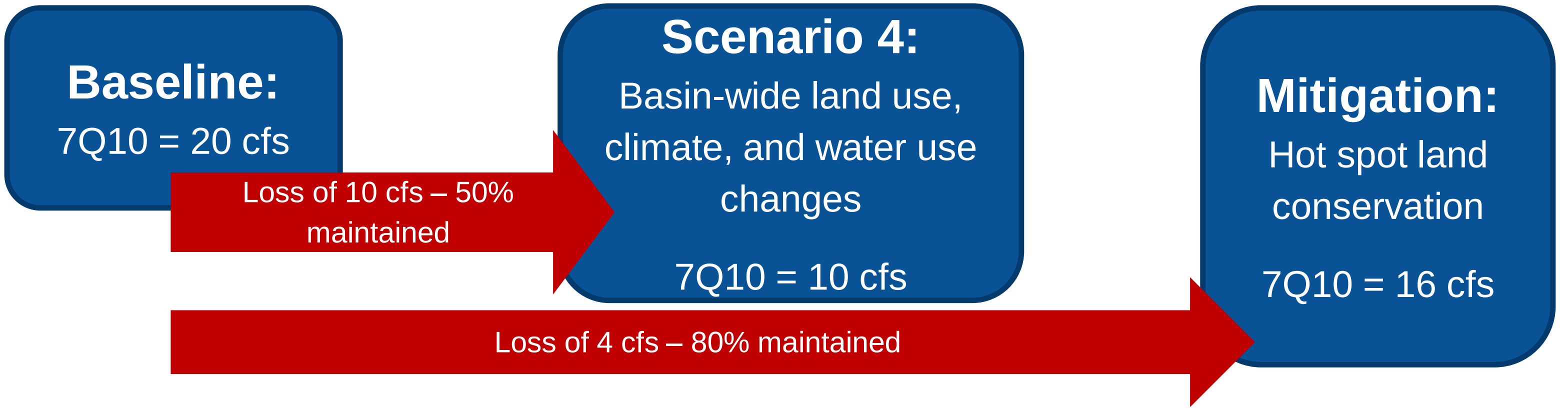


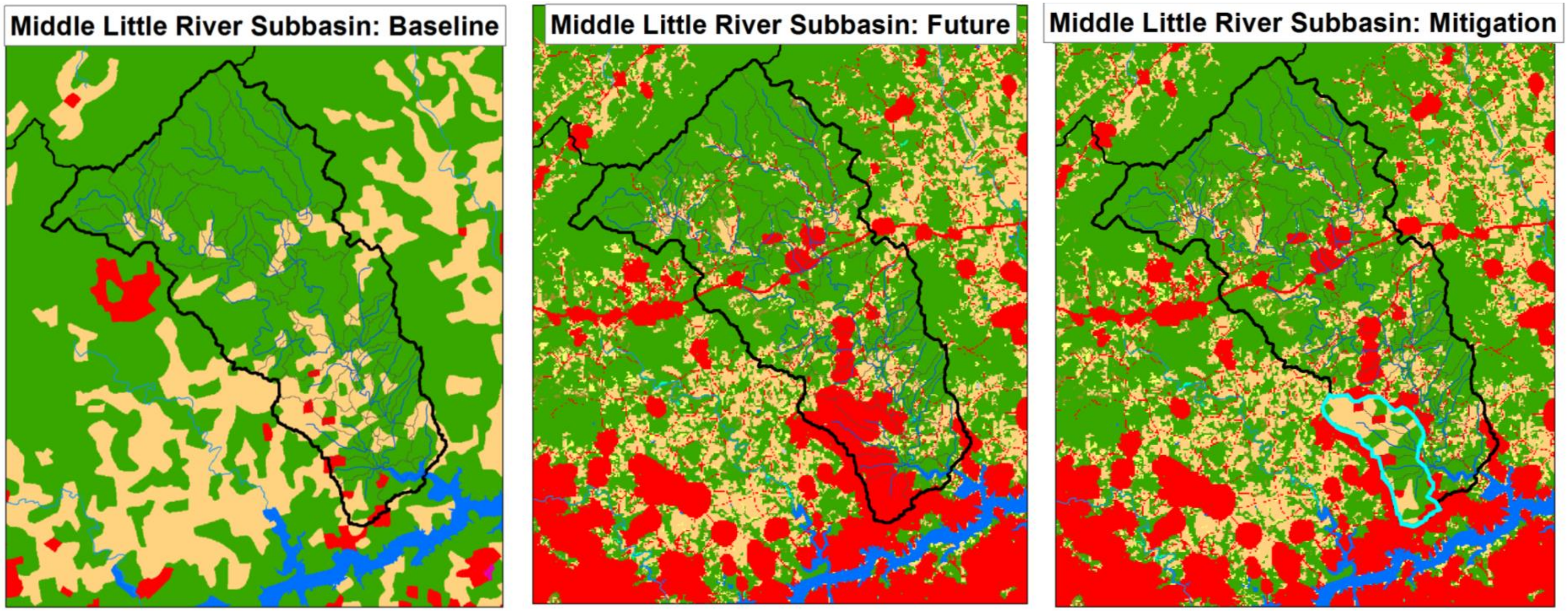
- Hydrologic metrics
  - Distill time series down to single informative values (i.e., metrics) that can be compared across scenarios
  - Characterize changes across different aspects of the hydrologic regime
    - Pulses durations and counts – high and low flows
    - Average values
    - Min and maxes
    - Baseflow quantities



Source: Eddy et al., forthcoming

Example Mitigation Analysis



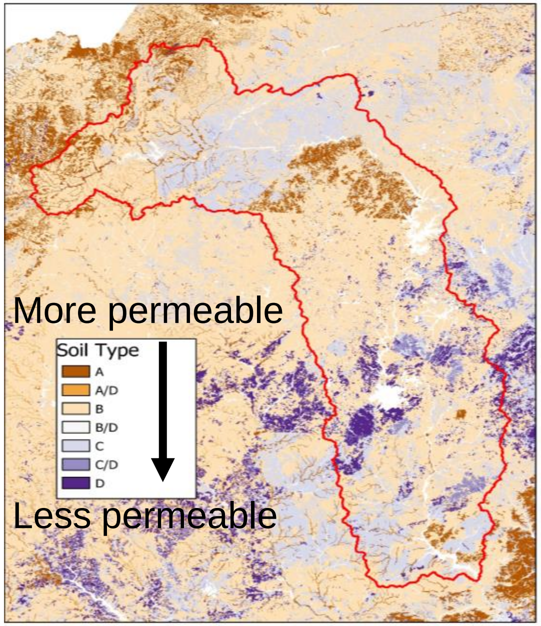


Source: Eddy et al., forthcoming

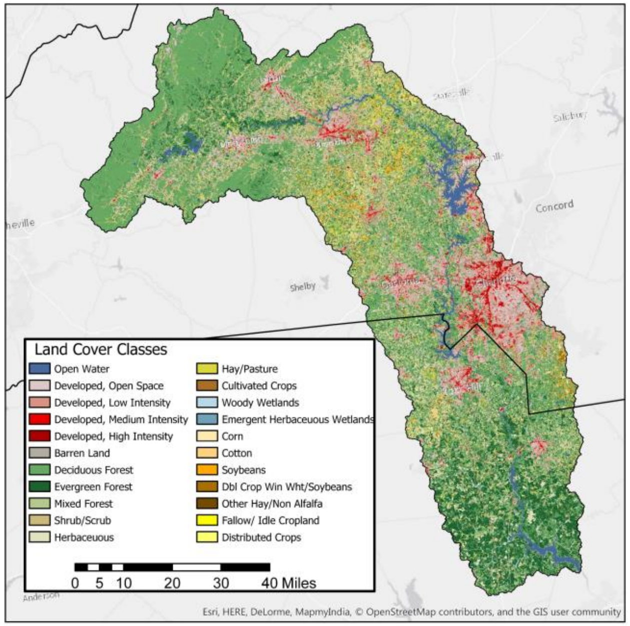
Findings

Current Condition Model

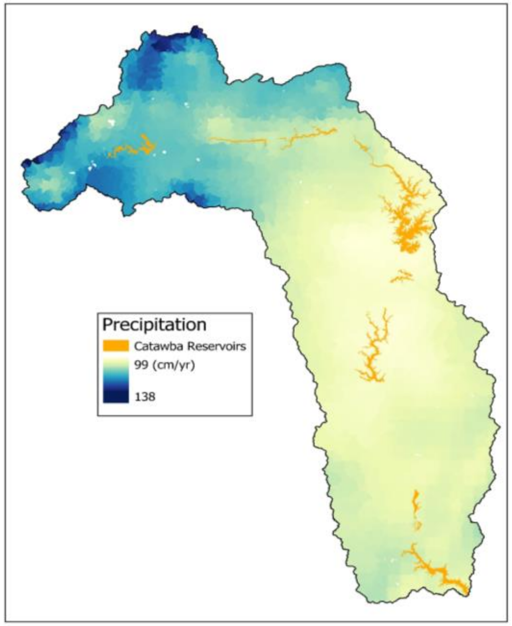
- Land use, soil characteristics and precipitation impact how much flow is generated, and how it is split between runoff and baseflow, in each catchment.



Soil Group



Land Cover



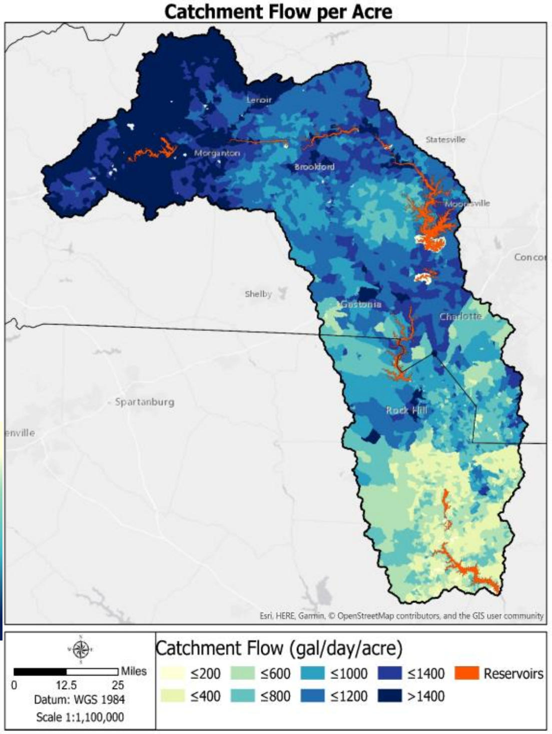
Annual Precip

Source: Eddy et al., forthcoming

Current Condition Catchment Contributions to Flow

- Average daily catchment contributions to streamflow (gal/d per acre)
  - Presented in flow per area so that size of contributing area does not affect results
- How might these patterns change in the future?
  - Impacts to runoff and baseflow due to land cover and climate change?

Current Condition: Average Daily Volume of Catchment Flow per Acre



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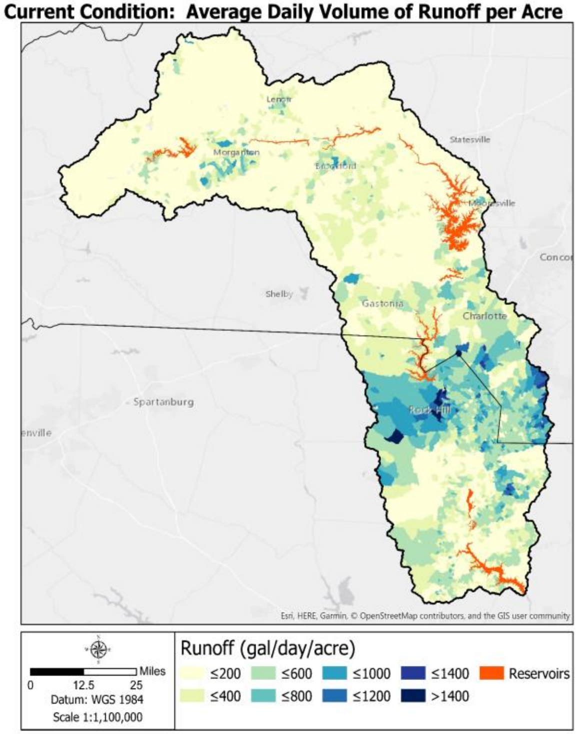
Current Condition: Average Daily Volume of Runoff per Acre



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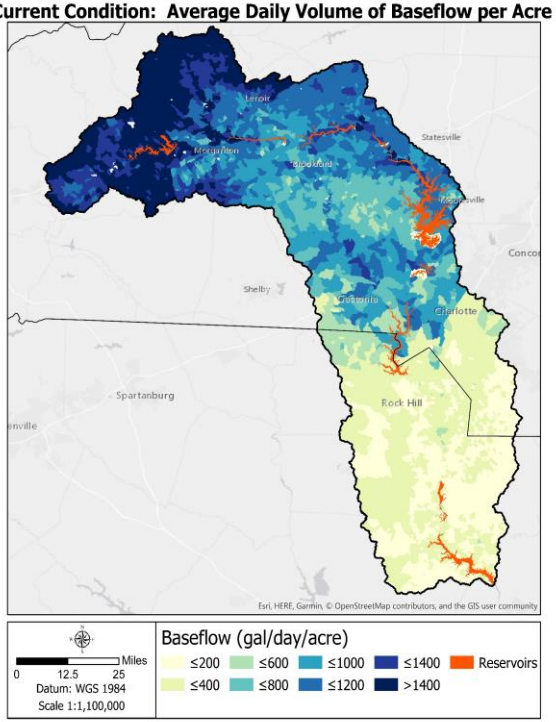
Current Condition: Average Daily Volume of Baseflow per Acre



Catchment Contributions to Streamflow

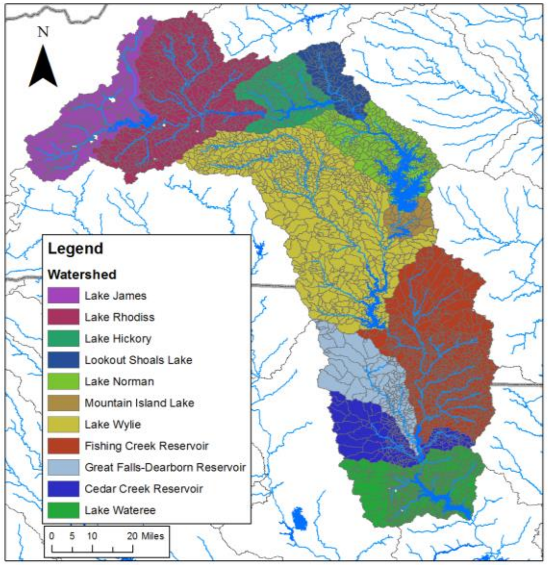
Runoff (25%) + Baseflow (75%)

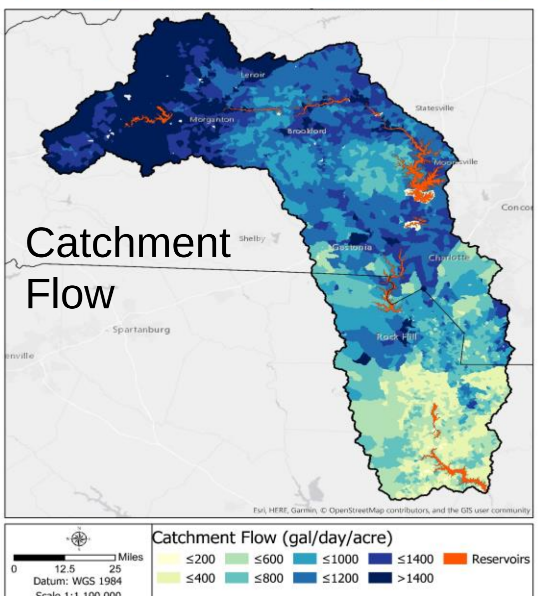
(Watershed-wide % of catchment contributions to streamflow)

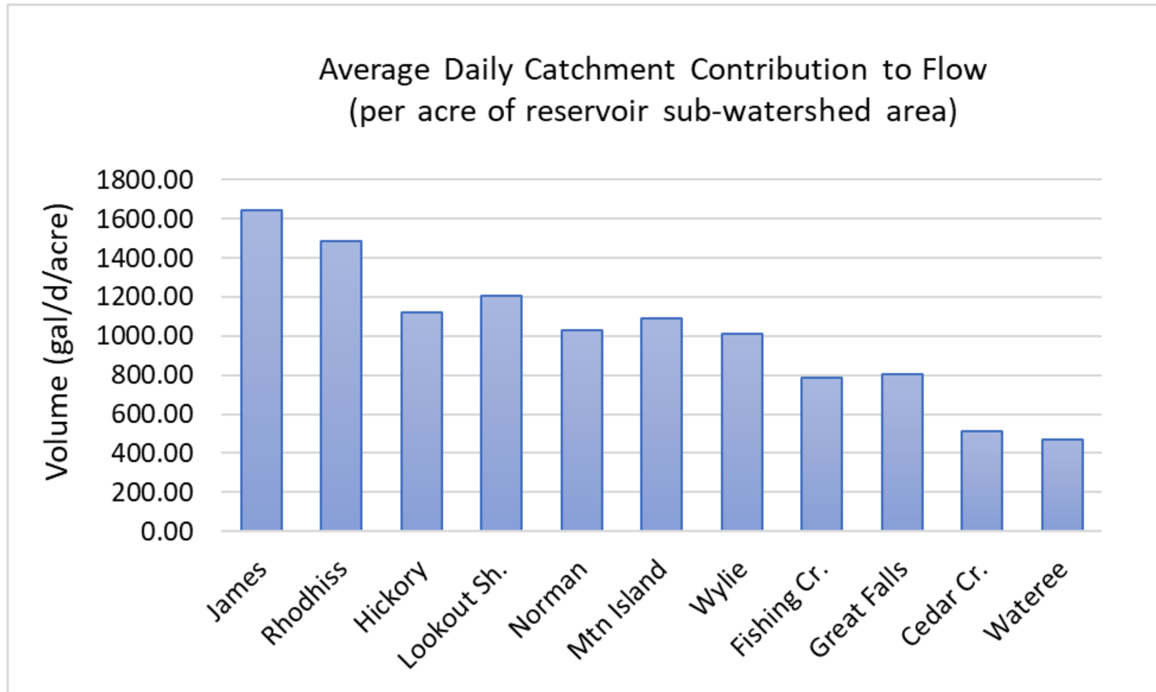
Source: Eddy et al., forthcoming

Current Condition Catchment Contributions by Reservoir

Subwatersheds







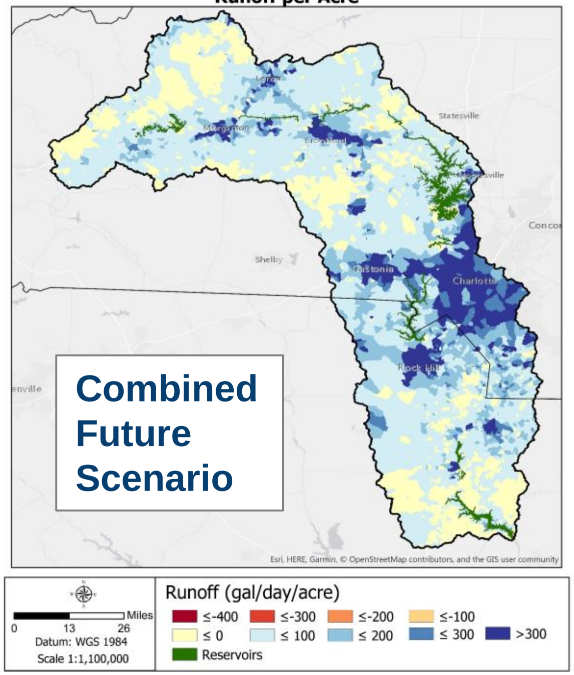
Upstream to downstream

Source: Eddy et al., forthcoming

Future Scenario Runoff Portion of Catchment Contributions

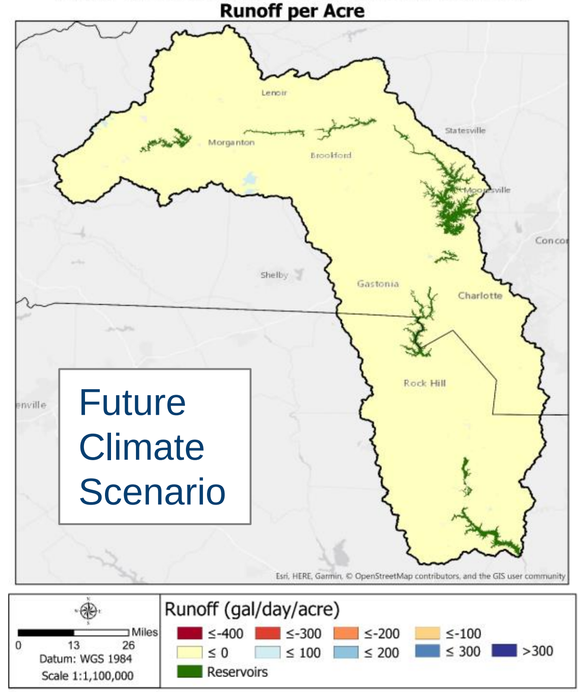
- Maps show the model-simulated **change** in runoff (future – current)
  - Red = LESS water, Blue = MORE water
  - Change in runoff is primarily caused by land use change

Future Combined: Change in Average Daily Volume of Runoff per Acre



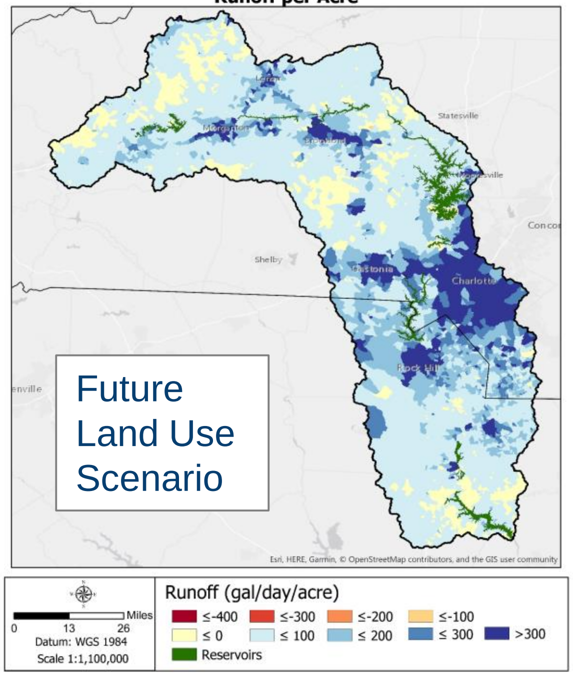
Watershed-wide:
32.9% MORE runoff due to climate *and* land use change

Future Climate: Change in Average Daily Volume of Runoff per Acre



Watershed-wide:
3.9% LESS runoff due to climate change

Future Land Use: Change in Average Daily Volume of Runoff per Acre

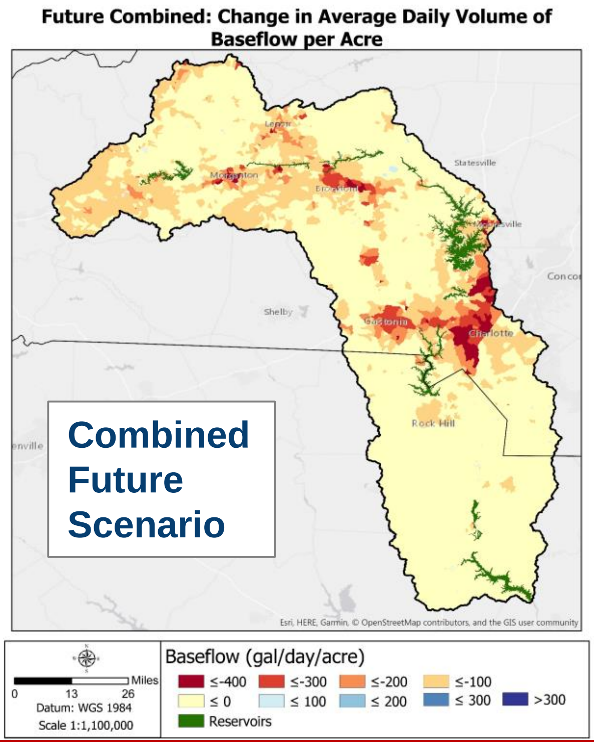


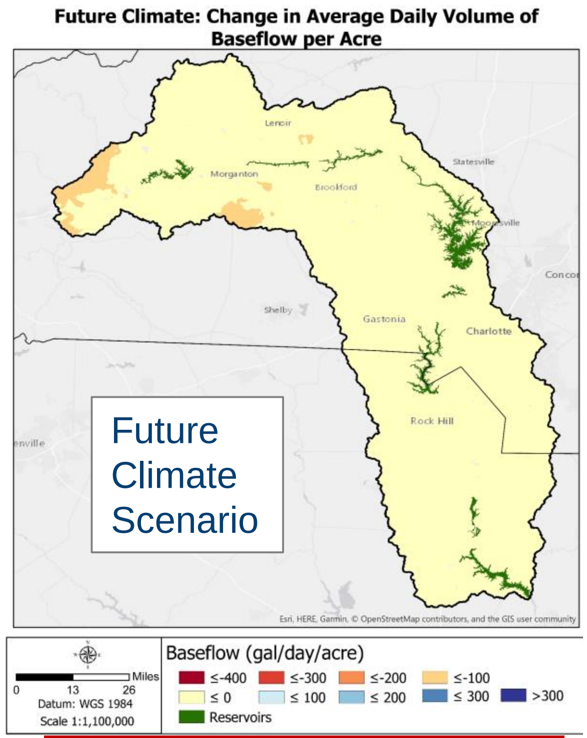
Watershed-wide:
37.5% MORE runoff due to land use change

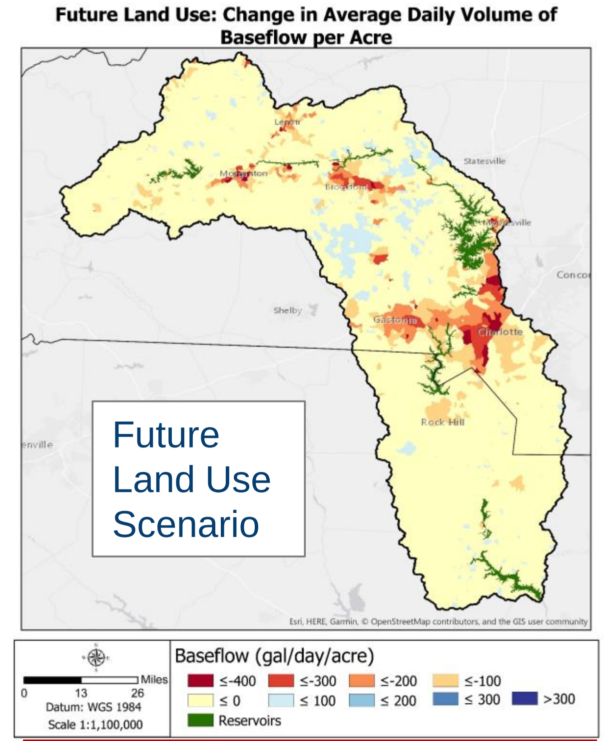
Source: Eddy et al., forthcoming

Future Scenario Baseflow Portion of Catchment Contrib.

- Maps show the model-simulated **change** in baseflow (future – current)
  - Red = LESS water, Blue = MORE water
  - Reduction in baseflow is caused by BOTH land use and climate change







Watershed-wide:
11.5% LESS baseflow due to climate *and* land use change

Watershed-wide:
5.7% LESS baseflow due to climate change

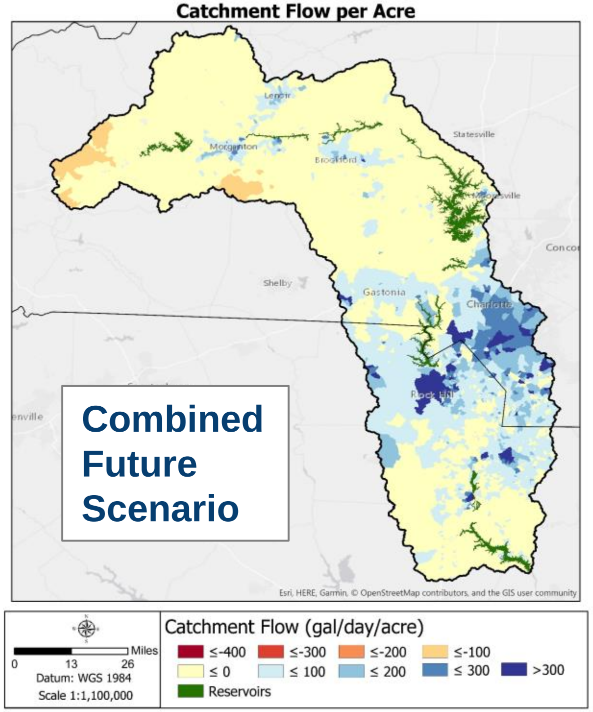
Watershed-wide:
6.1% LESS baseflow due to land use change

Source: Eddy et al., forthcoming

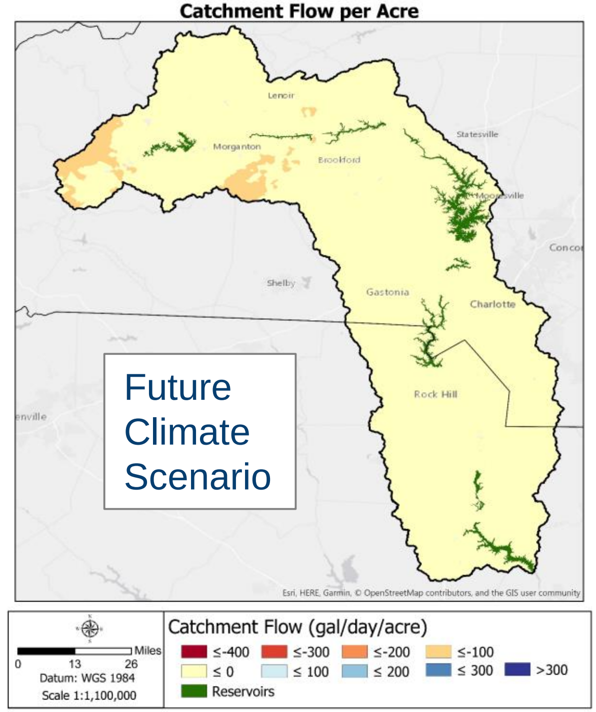
Future Scenario Total Catchment Contributions to Flow

- Maps show the model-simulated **change** in total catchment contributions to streamflow (future – current)
  - Annual catchment contribution to streamflow increases in developed areas due to land use change and decreases in undeveloped areas due to climate change

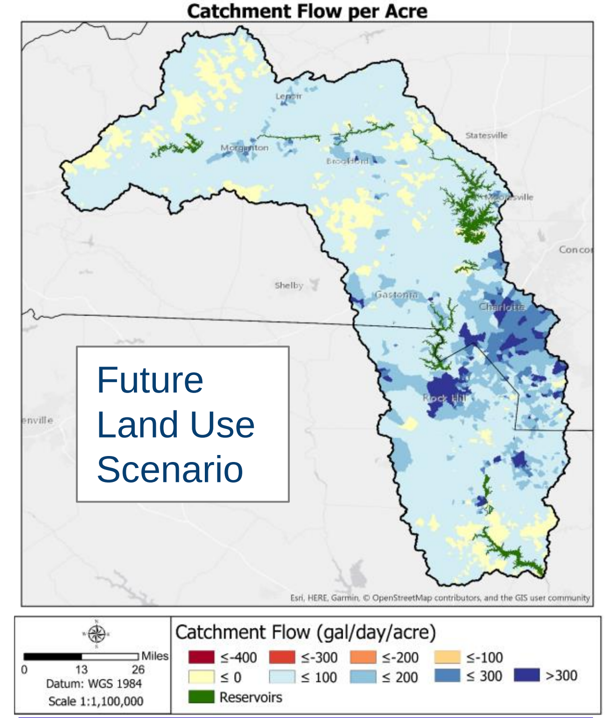
Future Combined: Change in Average Daily Volume of Catchment Flow per Acre



Future Climate: Change in Average Daily Volume of Catchment Flow per Acre



Future Land Use: Change in Average Daily Volume of Catchment Flow per Acre



Watershed-wide:
0.24% LESS catchment contribution to streamflow due to climate *and* land use change

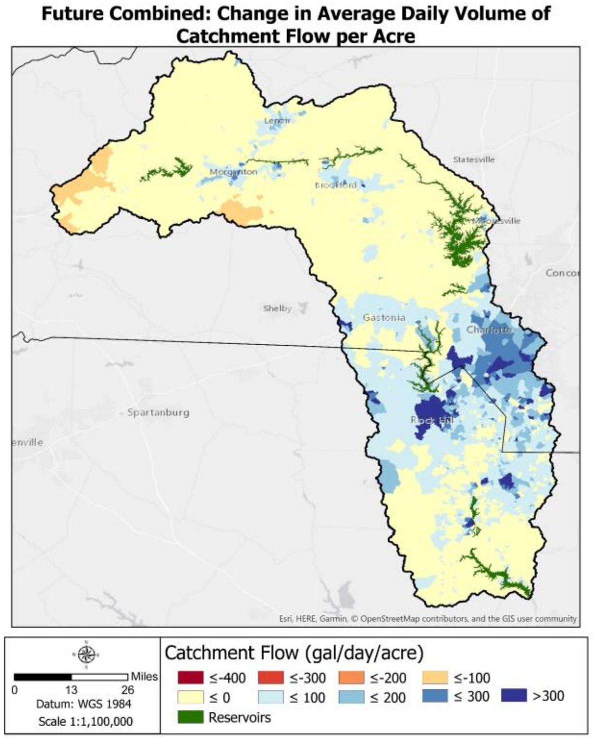
Watershed-wide:
5.3% LESS catchment contributions due to climate change

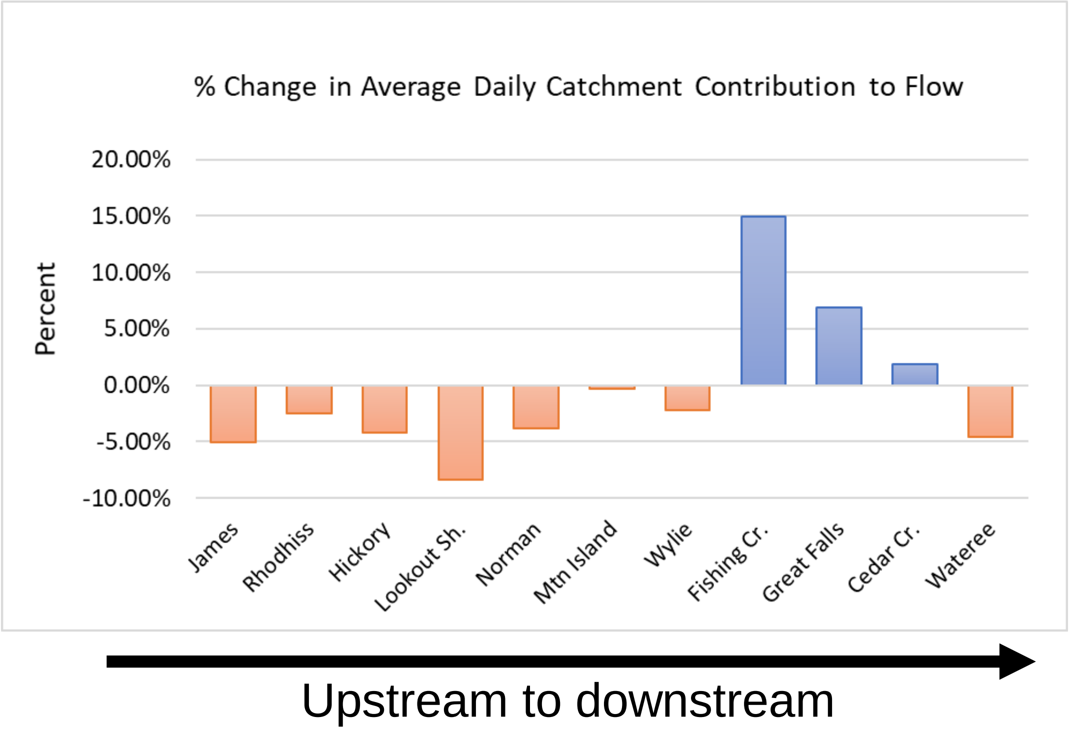
Watershed-wide:
5.0% MORE catchment contributions due to land use change

Source: Eddy et al., forthcoming

Future Scenario Change by Reservoir

- Change in catchment contributions to streamflow varies by reservoir subwatershed
  - Inflow to upper reservoirs is decreasing (by 0.3-5%), inflow to lower reservoirs is increasing (by 2-15%)





Source: Eddy et al., forthcoming

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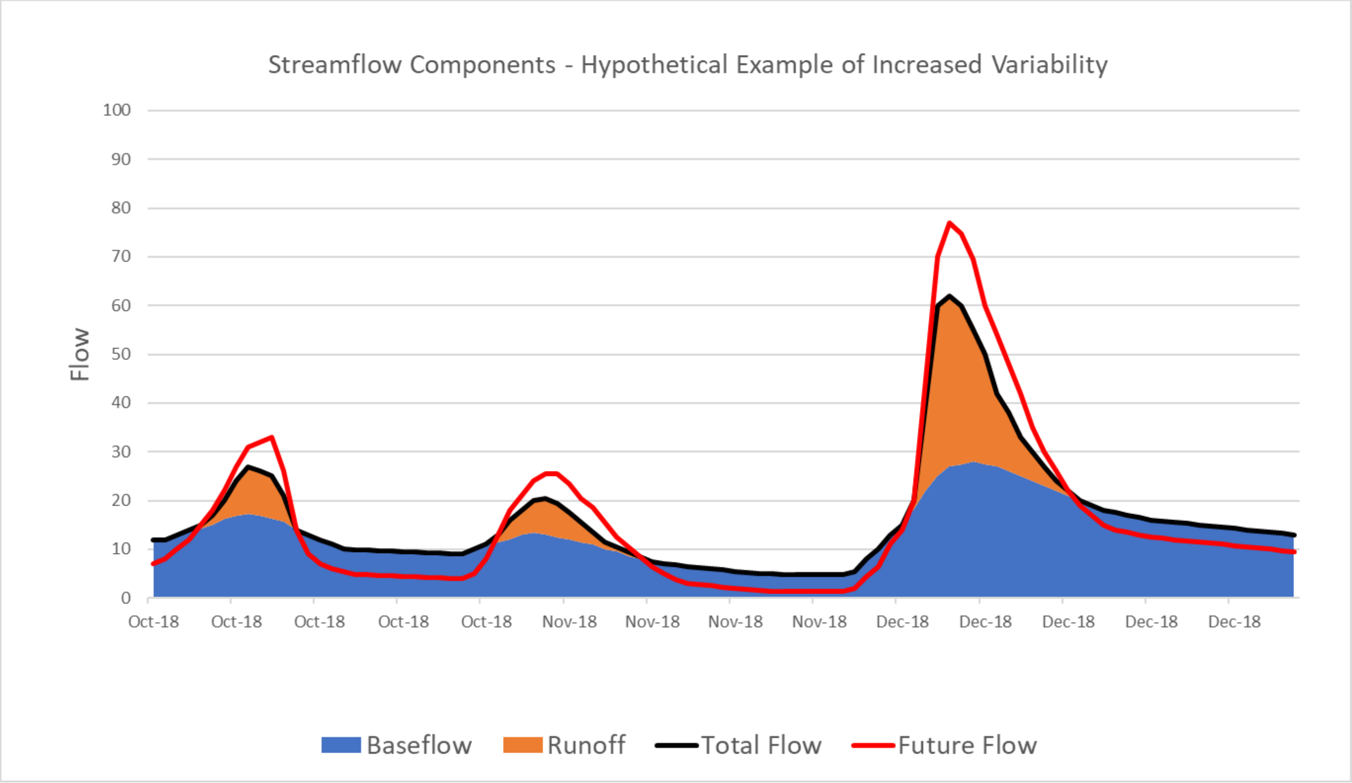
Future Scenario Catchment Outflow

- Runoff is increasing in most of the watershed, while baseflow is decreasing
  - Higher peaks and lower troughs
  - Standard deviation of daily flow is increasing in all subwatersheds

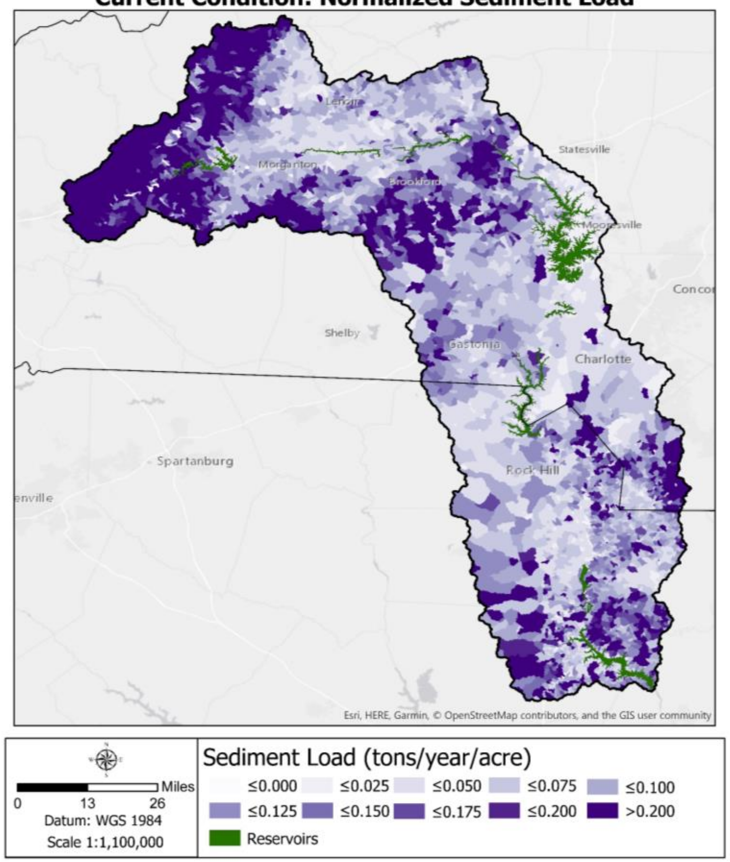


Source: Eddy et al., forthcoming

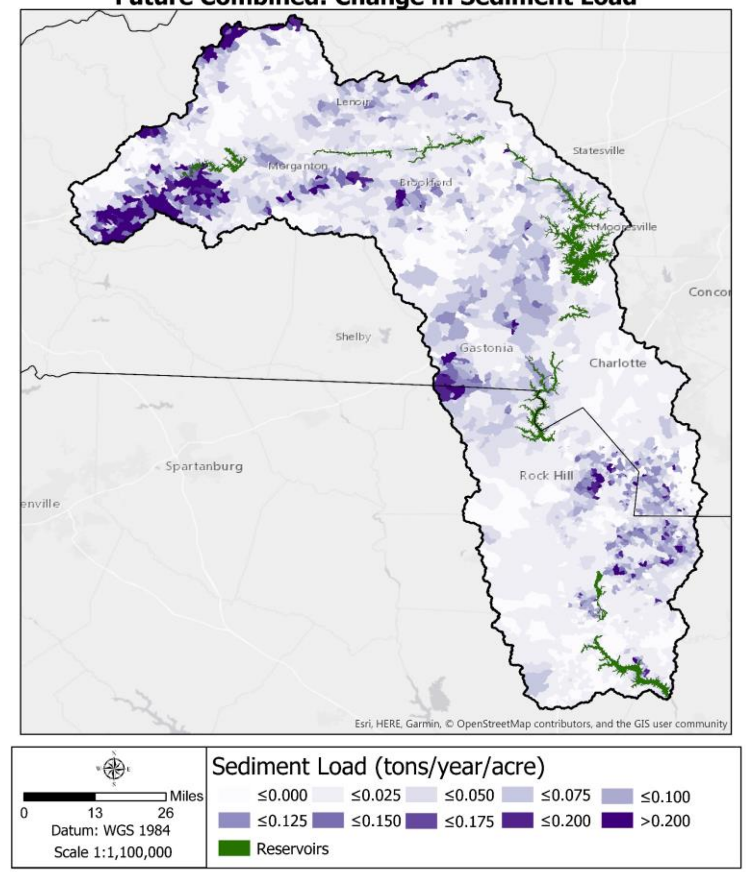
Future Scenario Sediment Load

- Current sediment load (left) and the **change** in sediment load (right)
  - By method used, only land use change affects sediment load
  - Increasing sediment loads are mainly caused by urbanization of natural land cover (non-ag)

Current Condition: Normalized Sediment Load



Future Combined: Change in Sediment Load



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Source: Eddy et al., forthcoming

Summary

Key Points from Scenario Simulations

- Net change in total catchment flow is zero if you look only at watershed-wide total volumes, however that is not the full story
- The spatial pattern of change is important → less flow in the upper watershed, more in the lower watershed
    - Watershed-wide metrics like the LIP may not reflect the spatially varying future change
- Flow variability is predicted to be greater in the future
    - Baseflow is *decreasing* everywhere, runoff is *increasing* in a large portion of the basin → higher peaks and lower troughs
- Sediment load is increasing due to land use change

Next Steps

- Calculation of selected set of hydrologic metrics at varying scales
- Development of approach to interpret metric changes from large (reservoir) to small (catchment) scales
- Spatial analysis to identify ‘hot spots’
- Compilation of applicable conservation options now that we know expected hydrologic changes and watershed characteristics
- Mitigation analysis to apply conservation options within ‘hot spots’ to determine water quantity and quality benefits
- Finalization of economic framework that optimizes choice of conservation efforts based on water benefits and economic costs (and potentially economic co-benefits)
- Final report on conservation priorities for the watershed

Thank You!

Final Questions?

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919-990-8458

Reference:

Eddy, M., K. van Werkhoven, B. Lord, S. Kovach, J. Serago, and G. Van Houtven. Forthcoming. Quantifying the Potential Benefits of Land Conservation on Water Supply to Optimize Return on Investments. Project #4702. Denver, CO: The Water Research Foundation.