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James River Watershed Modeling

Supporting Virginia DEQ's Chlorophyll Study

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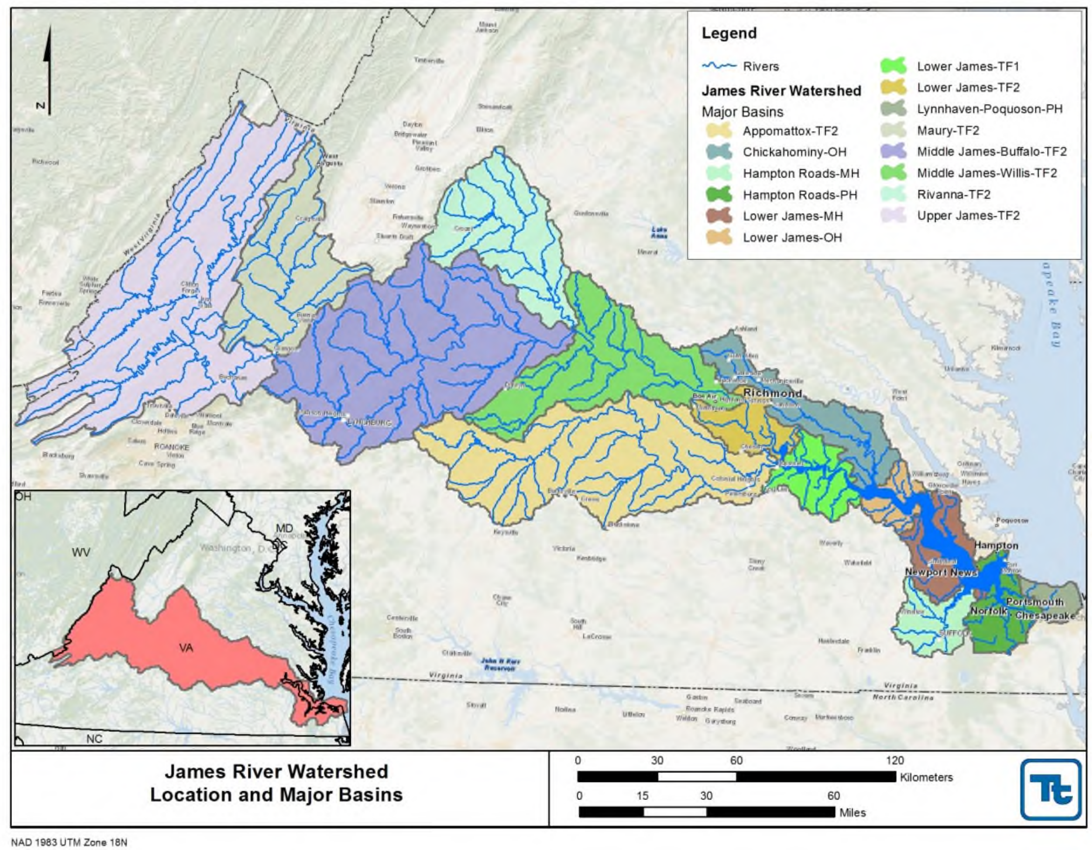
complex world | CLEAR SOLUTIONS™

Presentation Overview

- Background and Objectives
- Model Conceptualization
- Model Structure and Steps
  - Watershed segmentation
  - Hydrologic Response Units (HRU)
  - Point sources and withdrawals
  - Weather data
  - Calibration
- Next Steps

Modeling Objectives

- Simulate boundary conditions for the tidal James River models
- Represent effects of watershed drivers such as:
  - Weather variability
  - Agriculture practices
  - Urban stormwater
  - Large point sources
- Estimate nutrient and sediment loads
- Represent scenarios to assist with criteria development



Loading Simulation Program in C++ (LSPC)

- Streamlined Hydrologic Simulation Program Fortran (HSPF)
  - Snow, flow, temperature, quality (SEDMNT/GQUAL/RQUAL)
  - Coded in a Visual C++ object-oriented environment
  - No limit on model operations
- Relational database for organizing, archiving, and retrieving watershed data
- Potential for very large-scale modeling (HUC8+ scale)
- Streamlined model input and output formats
- Tailored for linkage to receiving water model (EFDC)
  - Handles point and nonpoint sources
  - Stream and direct drainage loads

LSPC Model Opportunities

- Same underlying model structure as HSPF allows for incorporation of CBP Bay Model efforts
  – Agricultural census data
  – Reservoir Bathymetry
  – In-stream model parameters (nutrient sub-speciation)
- Updates also give opportunities to potentially improve representation of the James River watershed
  – Increase resolution (segmentation, weather data)
  – Use local monitoring data (VADEQ, HRSD)
  – Simplify loading simulation (GQUAL vs. AGCHEM)
  – Refine water quality calibration where possible

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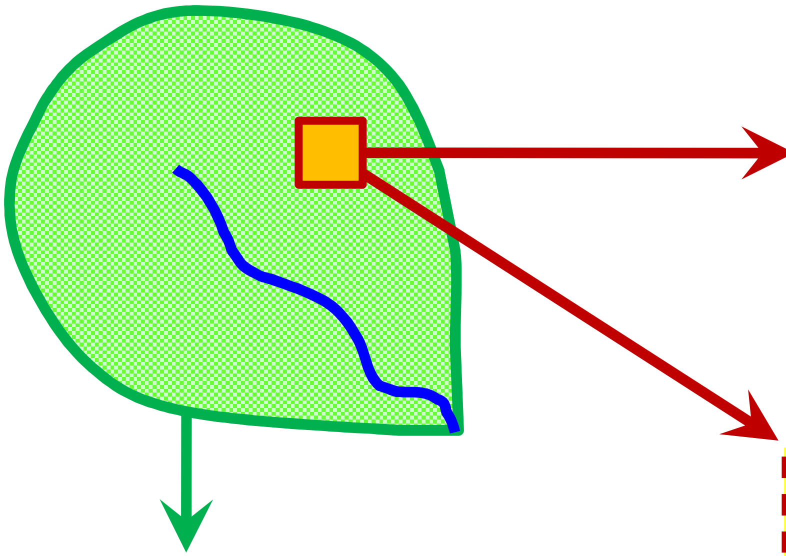
LSPC Model Structure



Land use (physical attributes):

- Average slope
- Average length of overland flow

Unique by subwatershed:

- Land use distribution
- Average elevation
- Weather data assignment
- Representative reach segment

Model parameters

Land use (physical processes):

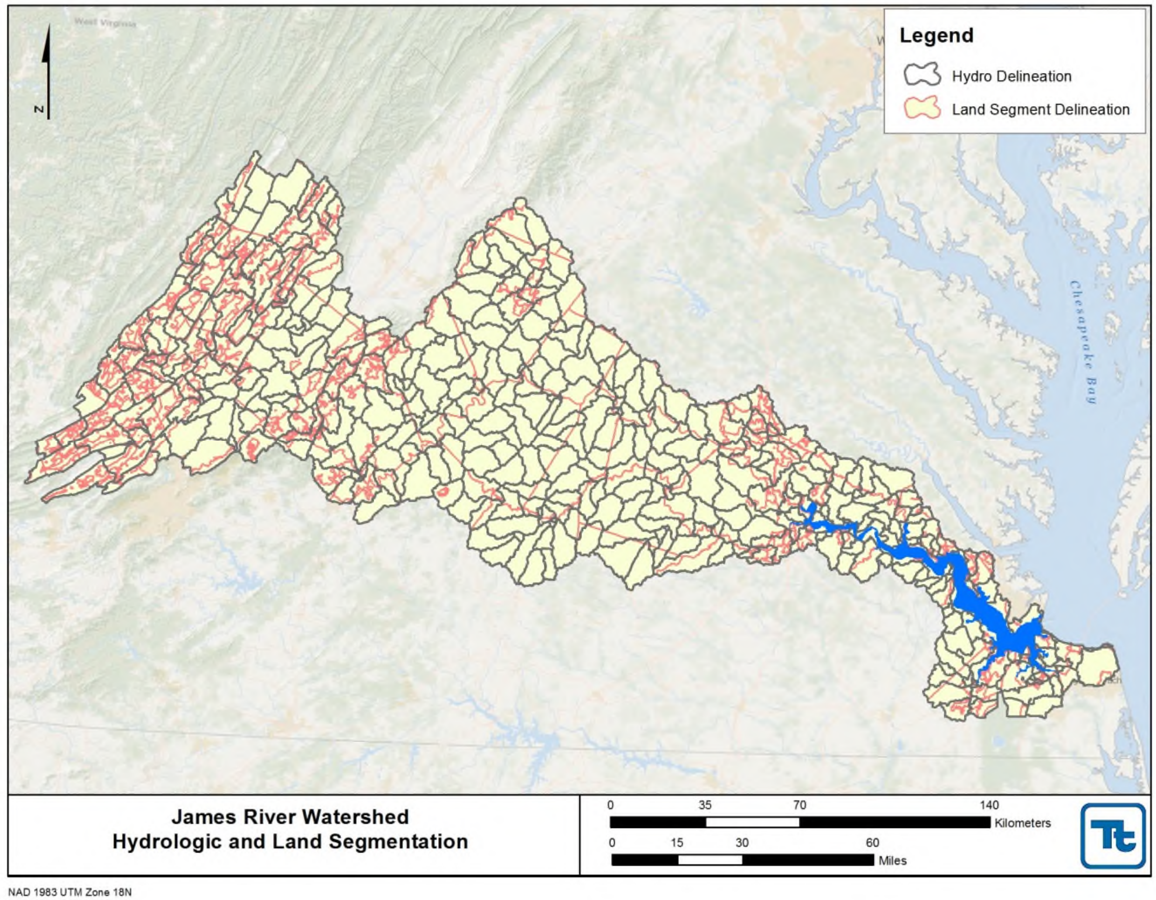
- Hydrology
- Sediment yield
- Pollutant load generation

Major Modeling Steps

- Watershed Segmentation
- Develop Hydrologic Response Units (HRU)
- Represent Weather Data
- Represent Point Sources and Withdrawals
- Model Calibration
  - Snow Accumulation & Melt
  - Hydrology & Water Quality

Watershed Segmentation

- HUC-12 as a starting point
- Further subdivision for:
  - Monitoring locations
  - Major tributaries
  - Bay Model segments
- Two levels of segmentation
  1. Hydro (431)
  2. Hydro + land segments (1,576)
- Average Size
  1. 15,500 acres
  2. 4,250 acres



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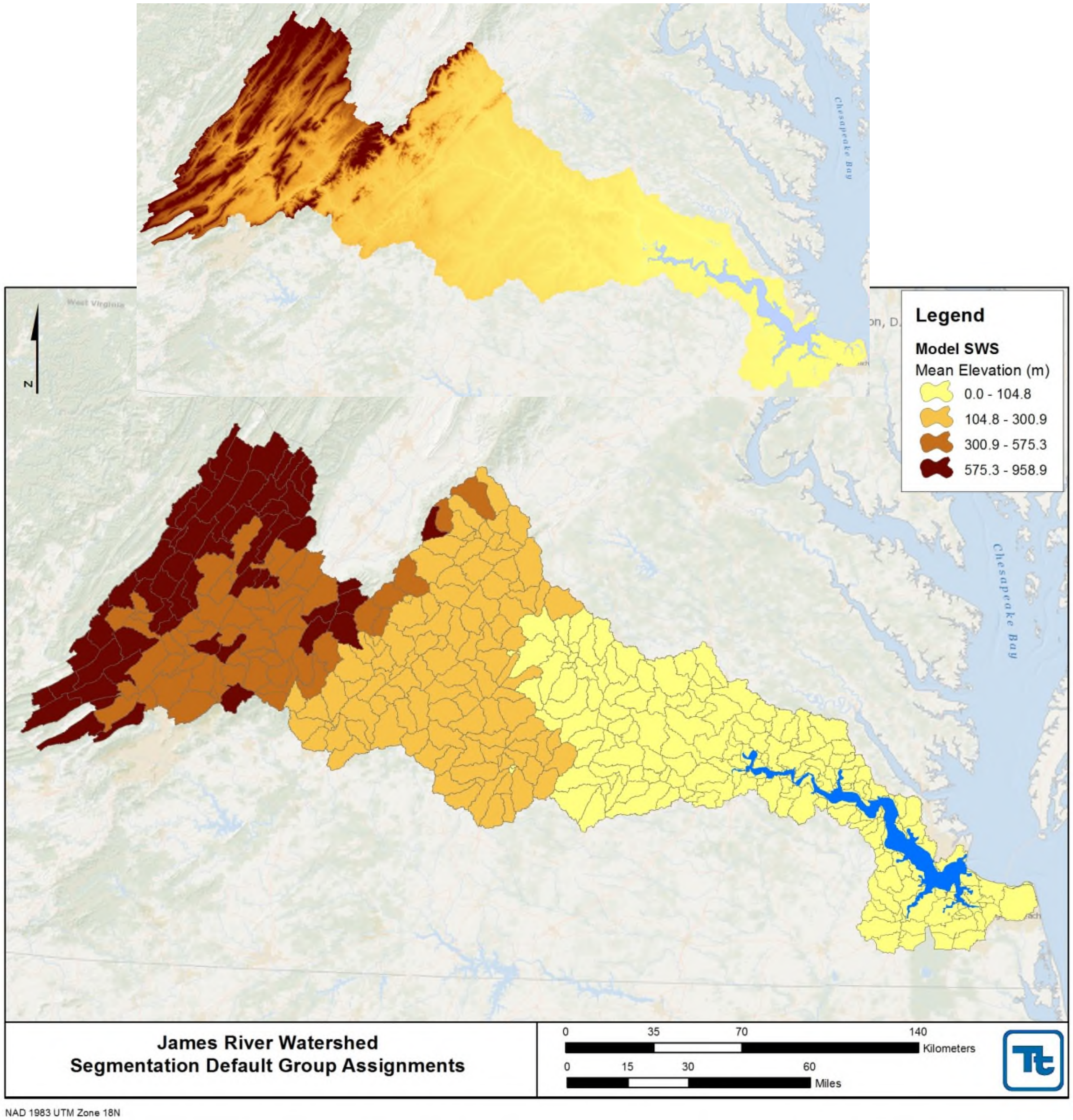
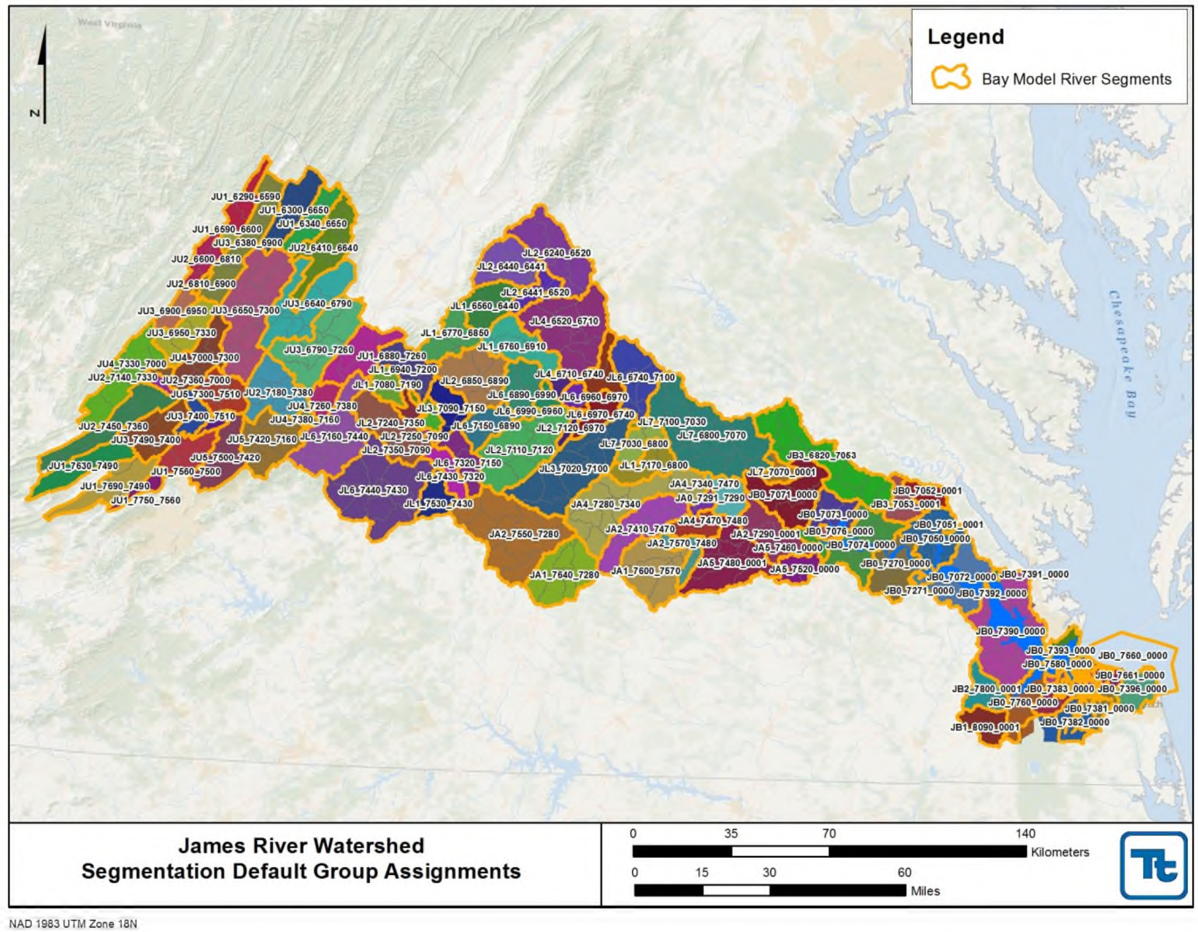
Default Group Mapping

- Segmentation organized by dominant physical characteristic
- Two key factors
    1. Elevation
    2. Slope
- 4 groups represented:
    1. 0-105
    2. 105-301
    3. 301-575
    4. 575-959



Segment Mapping

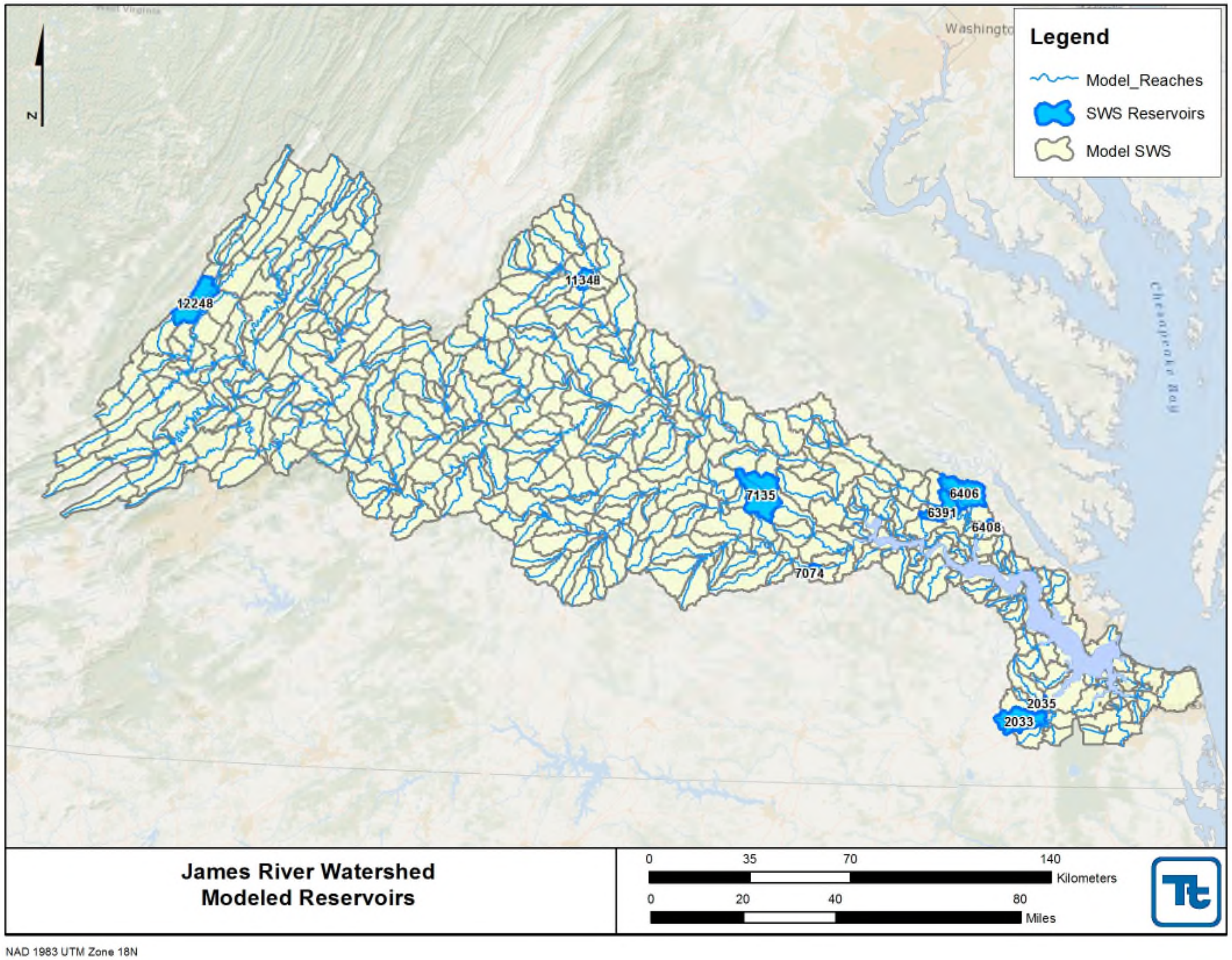
- Segmentation was cross referenced with Bay Model segments
- Allows for the assignment of critical model inputs:
  - Agricultural land use areas
  - Nutrient loading parameters
  - In-stream nutrient parameters
  - Stream channel geometries



Reservoirs

- Bay Model reservoirs included
- Depth discharge relationships retained

Name	Model Reach
Brasfield	7074
Chickahominy	6391
Diascund Creek	6406
Gathright	12248
Little Creek	6408
Mead	2033
South Rivanna	11348
Swift Creek	7135
Western Branch	2035



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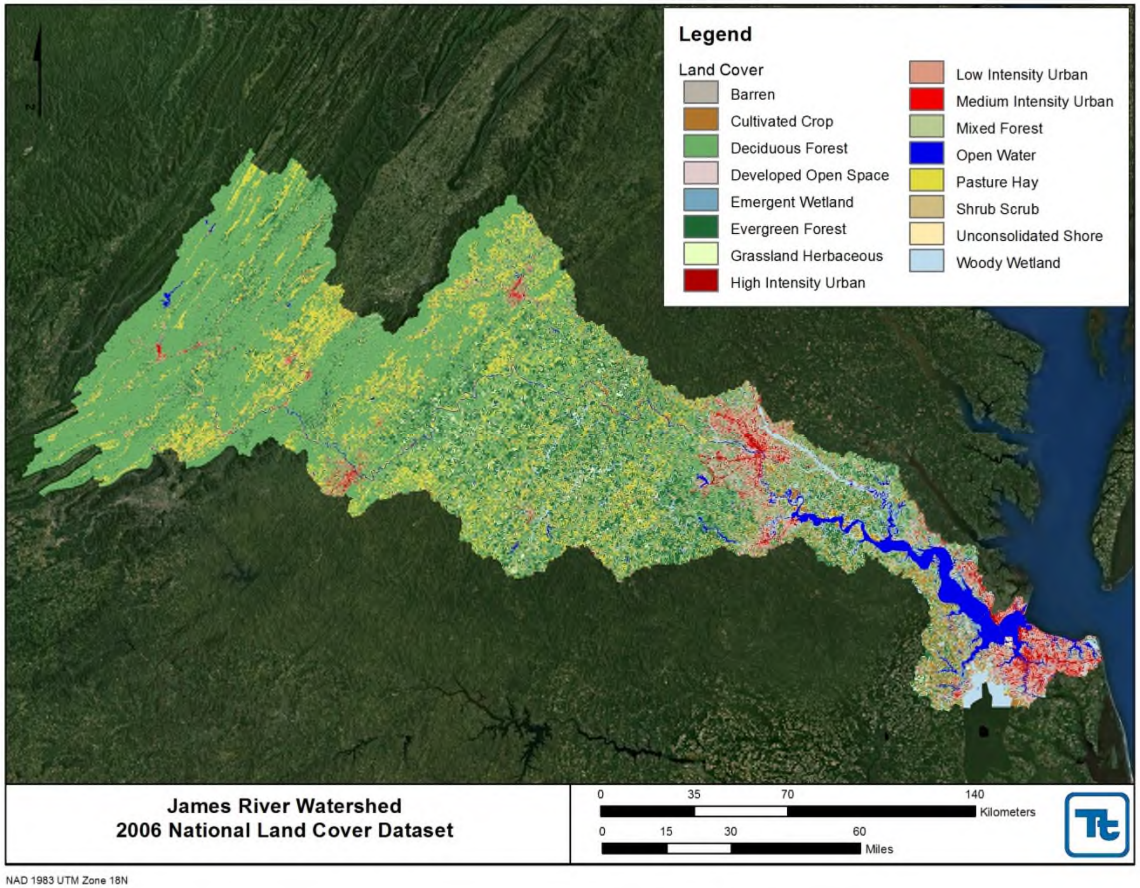
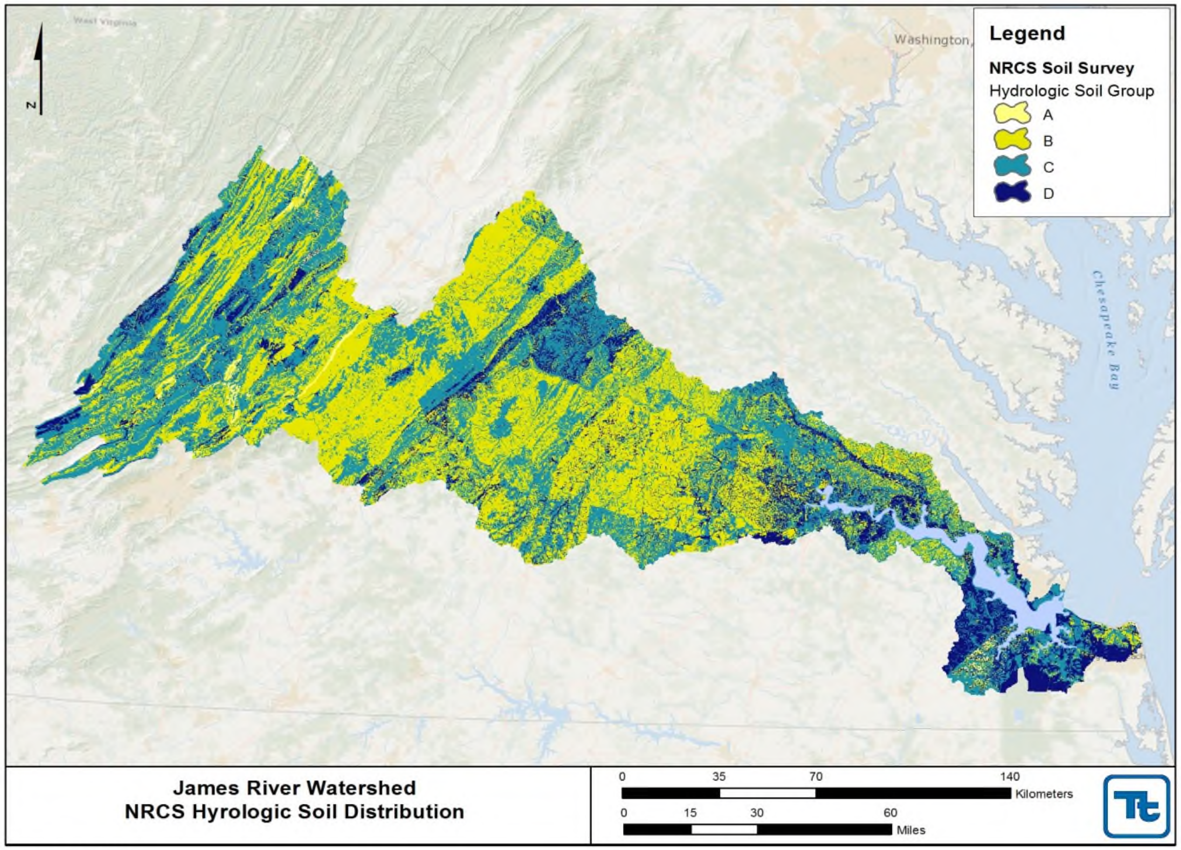
Hydrologic Response Units

- Baseline land cover
  - 1992, 2001, 2006
- Overlay critical features
  - Soils
- Land cover enhancements
  - Riparian pasture
  - Golf courses
  - CAFOs
  - Bay Model Ag



Soils

- Infiltration by dominant HSG (A-D)
- HSG A - a minor component
- Land cover overlaid with soils gives composite HRU

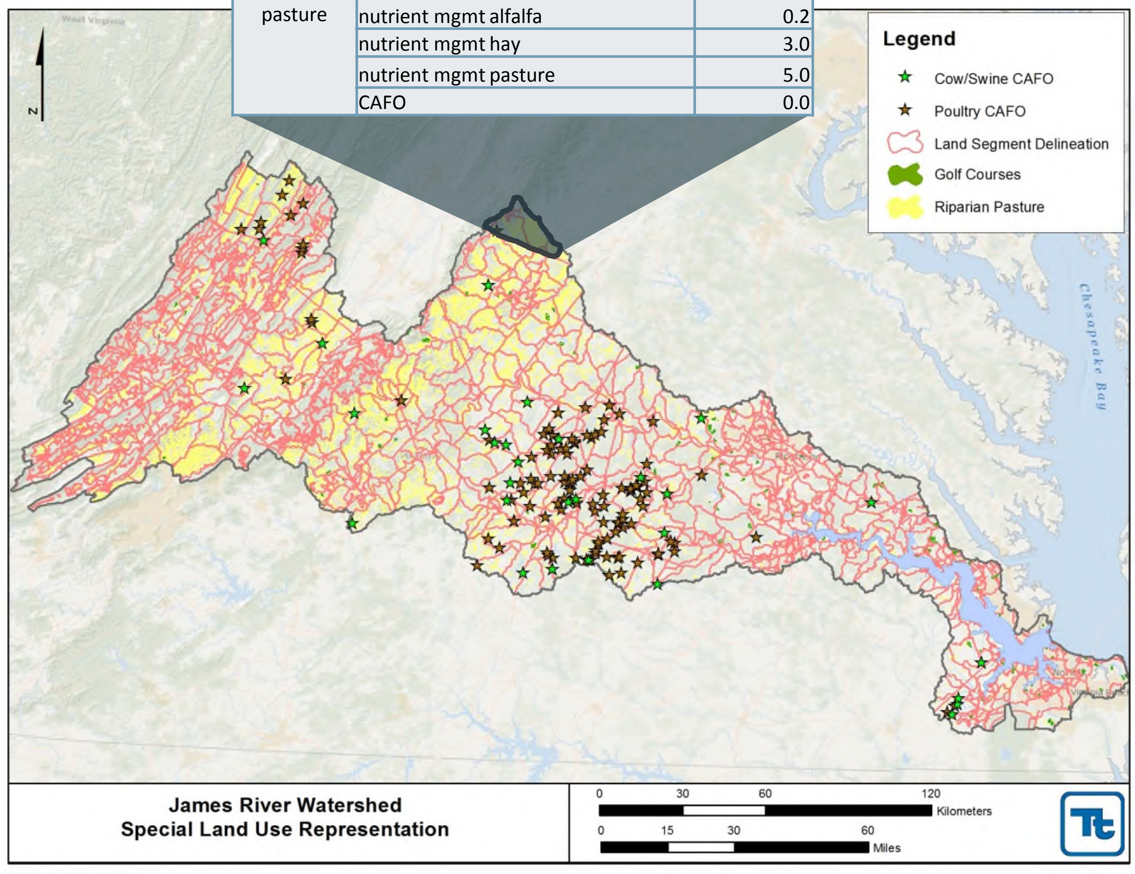


NAD 1983 UTM Zone 18N

Enhanced Land Cover

- ▶ Special land cover
  - Riparian pasture
    - 90 ft stream buffer
  - Golf courses
  - CAFOs
    - DEQ source data
    - CBP area assumptions
  - Bay Model Ag
    - Area weighted assignments

River Segment: JL2_6240_6520 Land Segment: 51079		
General LU	**CBP LU**	**%Area**
crop	hightill w/ manure	45.8
	hightill w/o manure	18.4
	lowtill w/ manure	31.8
	nutrient mgmt hightill w/ manure	1.9
	nutrient mgmt hightill w/o manure	0.8
	nutrient mgmt lowtilll	1.3
	alfalfa	5.8
pasture	hay w/ nutrients	72.3
	hay w/o nutrients	12.8
	AFO	0.9
	nutrient mgmt alfalfa	0.2
	nutrient mgmt hay	3.0
	nutrient mgmt pasture	5.0
	CAFO	0.0



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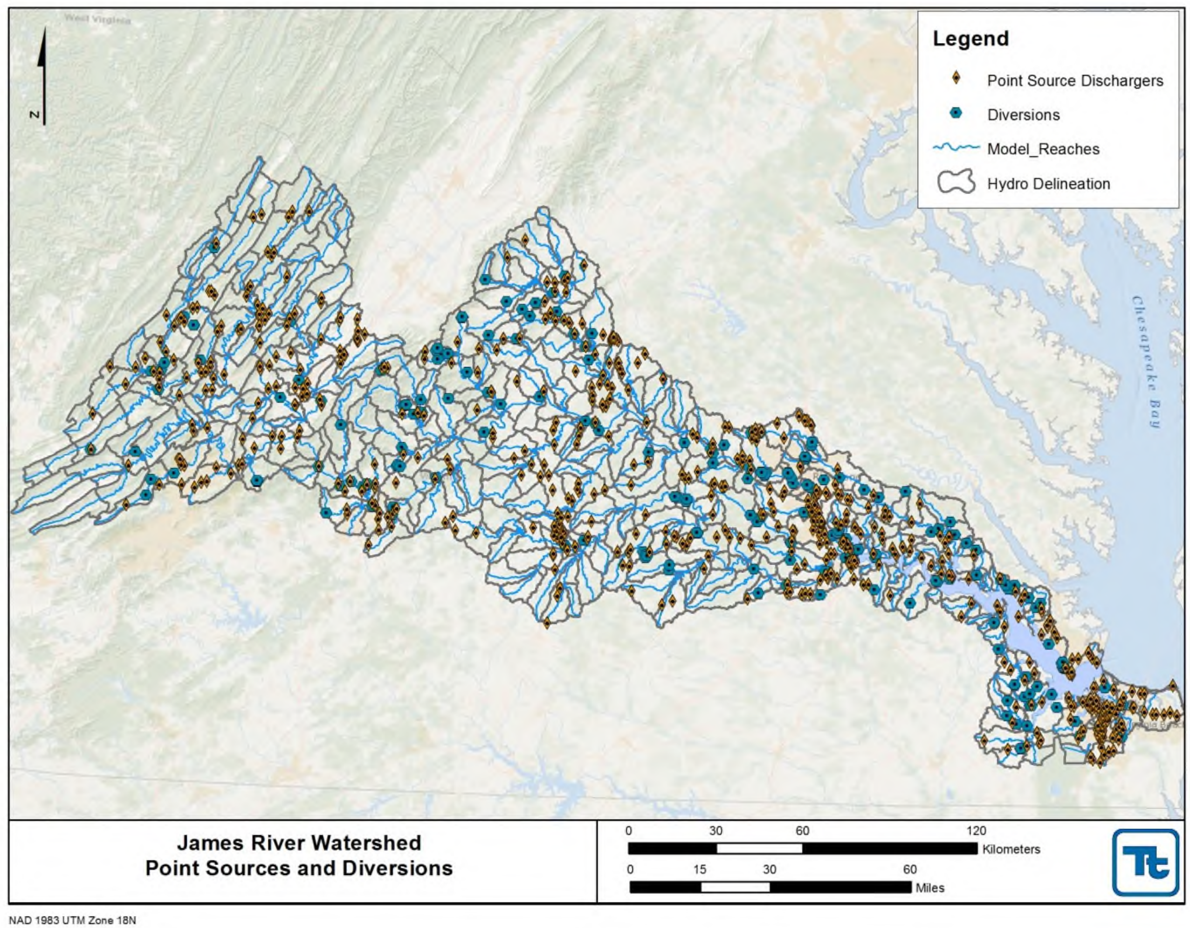
Point Sources and Withdrawals

- NPDES point sources
  - 52 significant
  - 604 non-significant
  - DMRs from CBP and DEQ
- Septic sources
  - Estimated from census block info
  - Area weighted assignments
- 263 withdrawals



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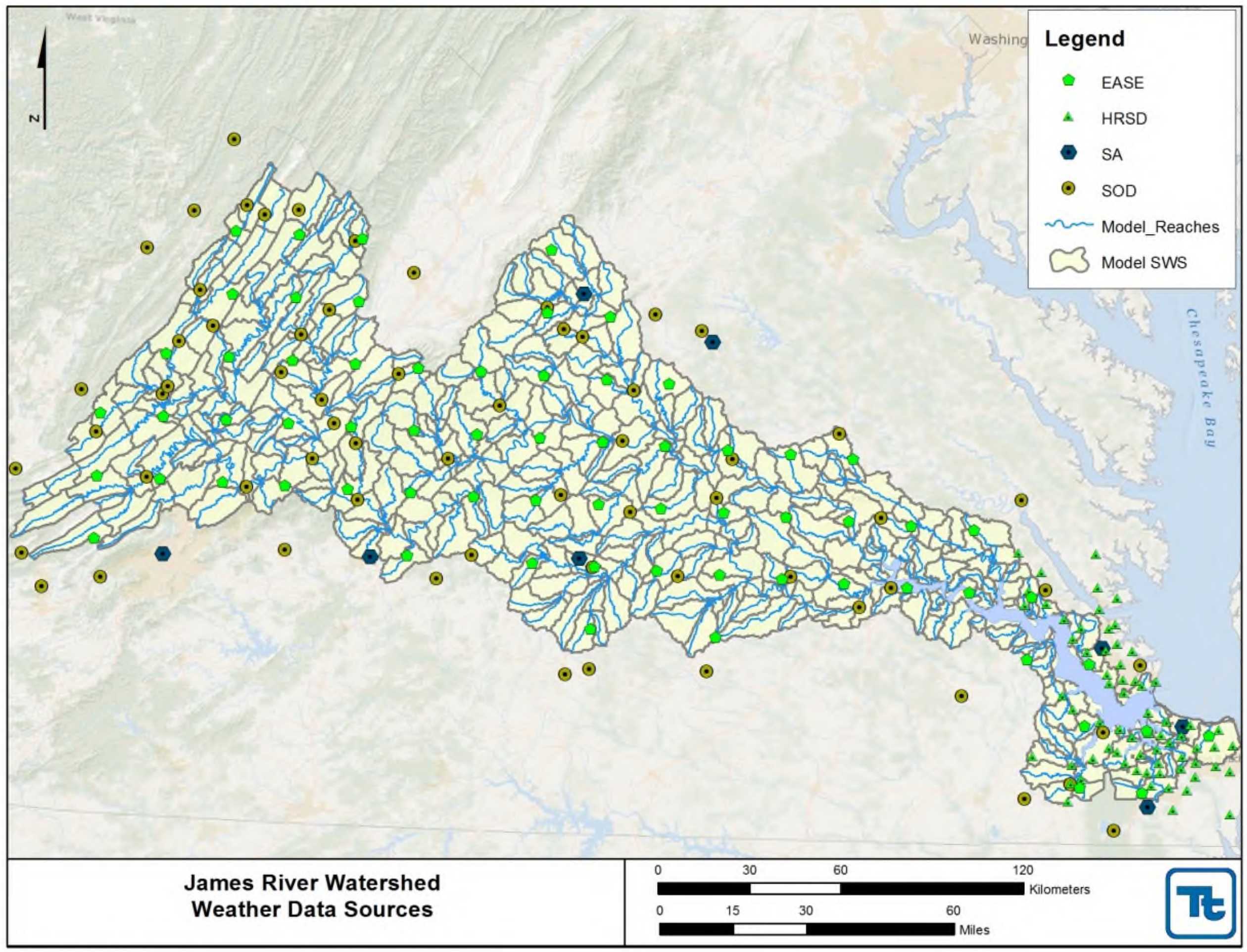
Climate Observations

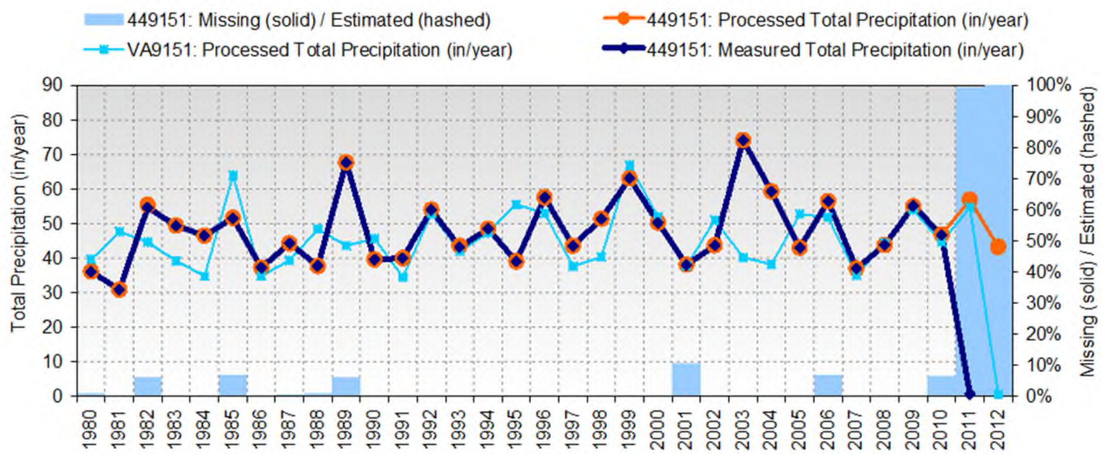
- Weather Data Sources
  - NCDC
    - Daily precipitation and temperature (SOD)
    - Hourly precipitation (HP) and climate (SA)
  - EASE
    - Snow water equivalent
  - HRSD
    - Hourly precipitation

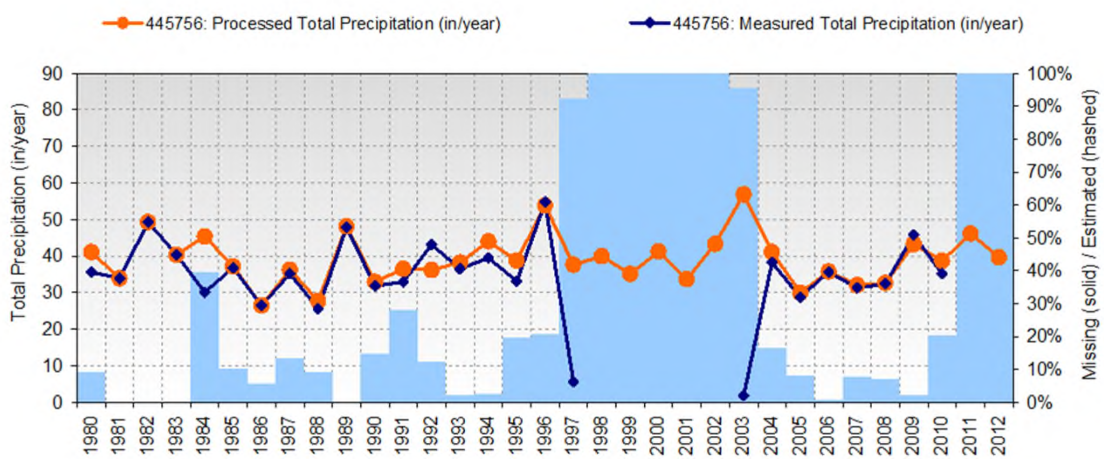


NAD 1983 UTM Zone 18N

Quality Control

- Assess quality of records
- Apply quality criteria to filter sub-set of stations
  - For example, at least 5 years of unimpaired data





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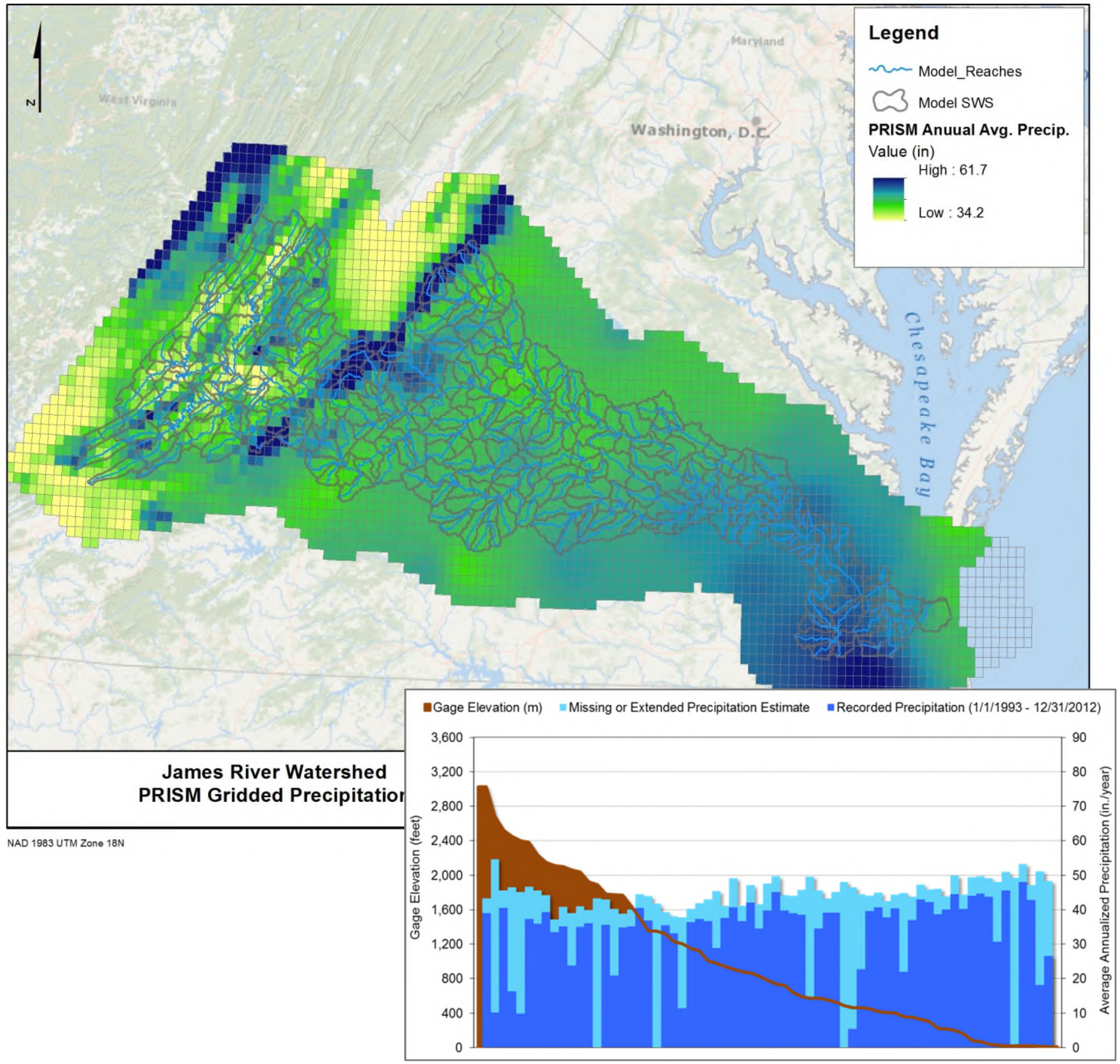
Grid Products

- Used to adjust precipitation for effects of elevation
  - Unique precipitation by subwatershed
  - Provides estimates for ungagged areas



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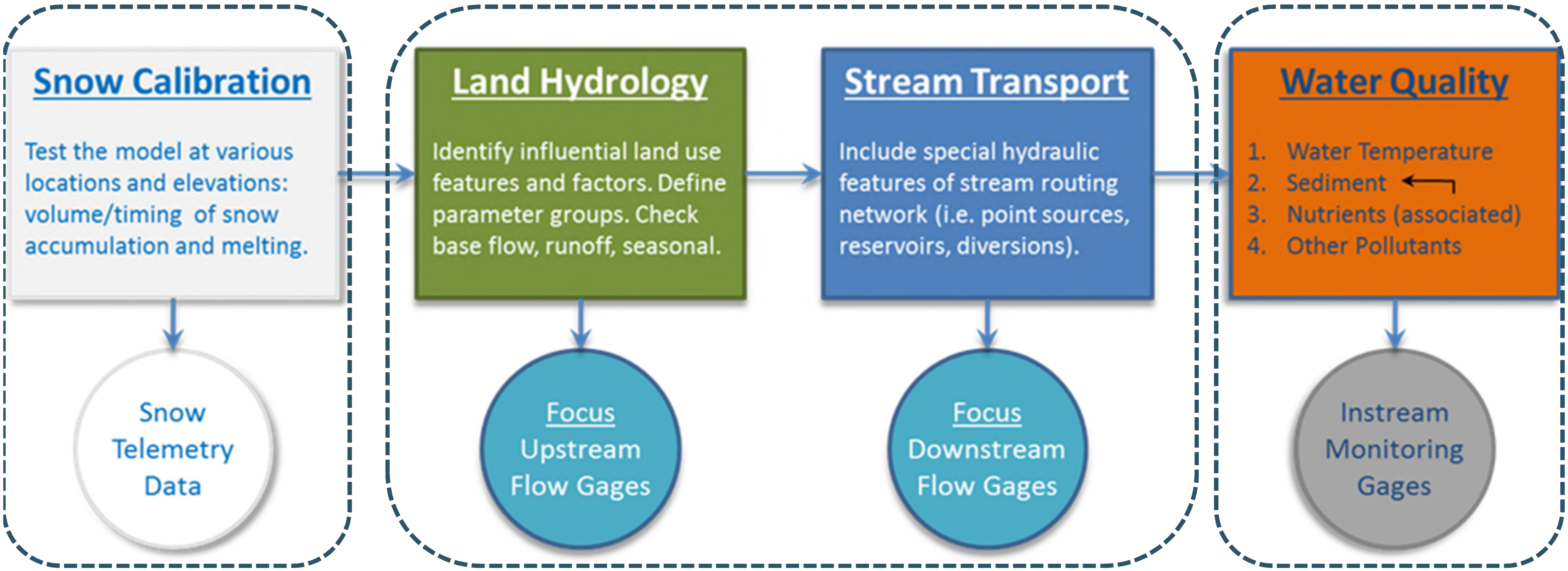
Calibration Components



SNOW

PWAT/IWAT

SEDMNT
PQUAL/IQUAL
GQUAL
RQUAL

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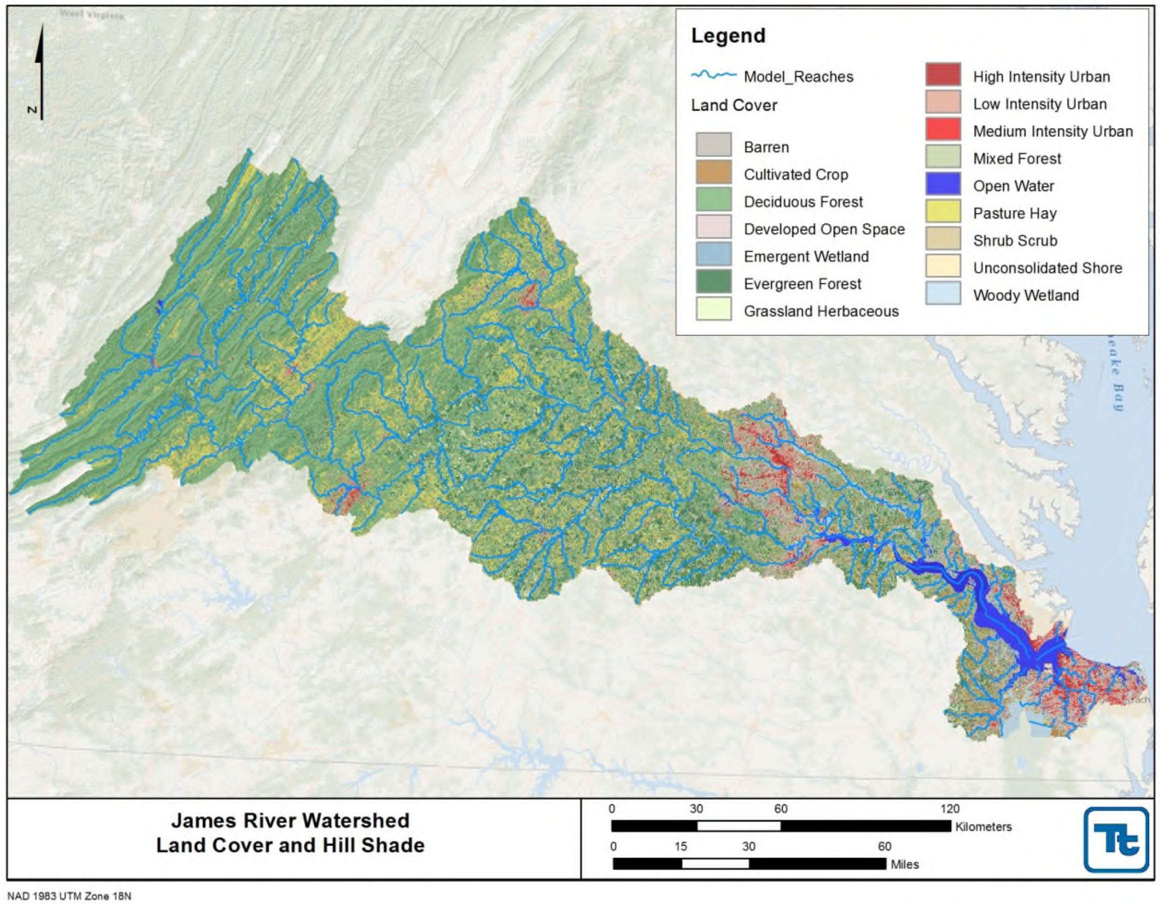
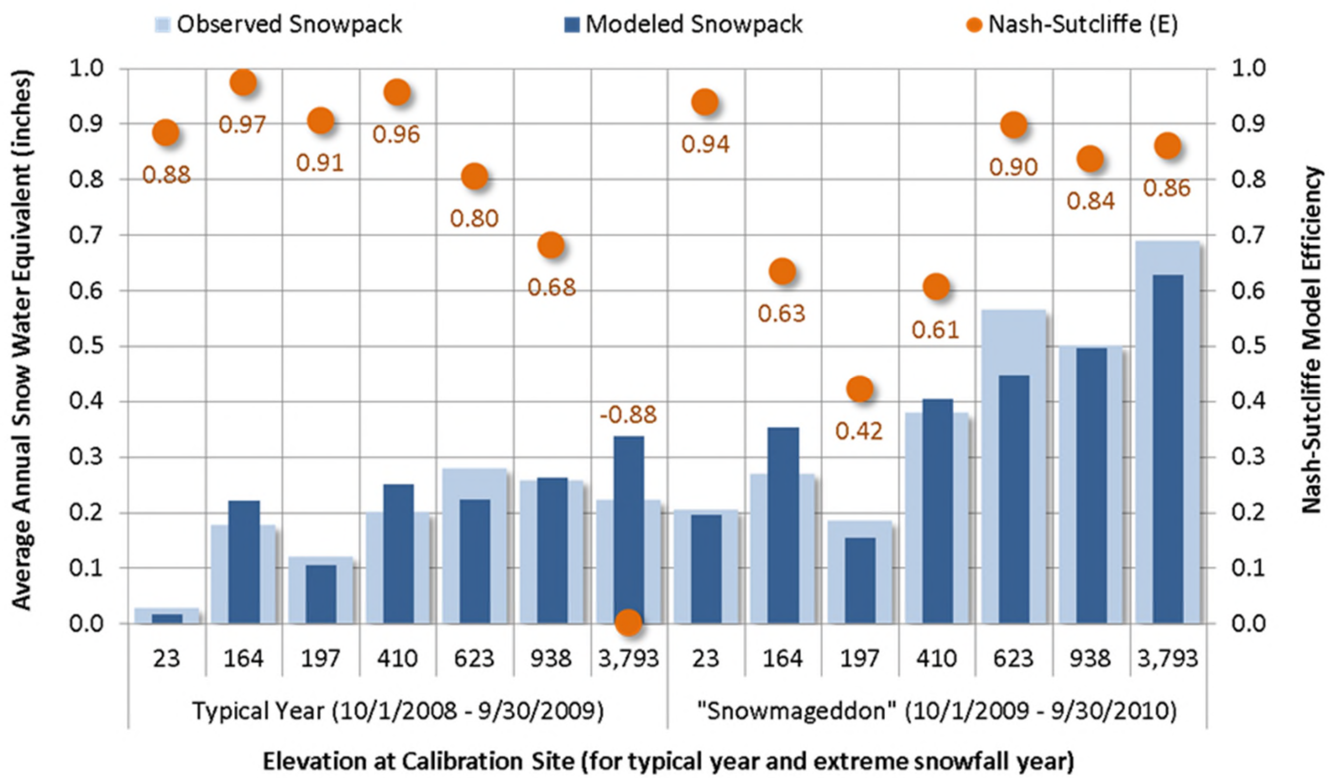
Top-Down Calibration

- Phase I
  - Background conditions (forested head waters)
- Phase II
  - Urban & agricultural areas
  - Septic systems, point sources, etc.
- Phase III
  - In-stream transport
  - Nutrient speciation



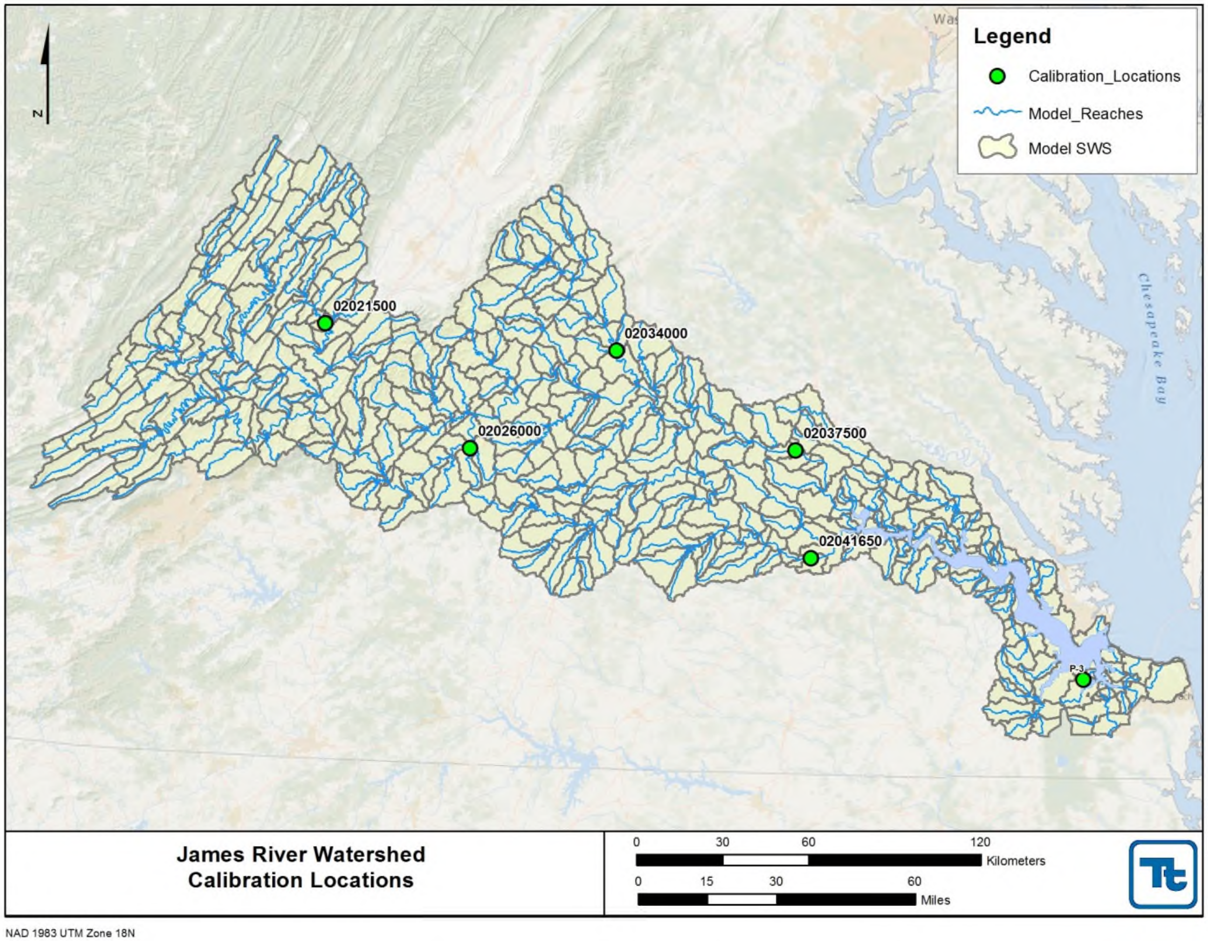
Snow Calibration

- 66 monitoring locations throughout watershed
- Snow-water equivalent
- Use data to calibrate snow accumulation and melt processes



Hydro & Water Quality Calibration

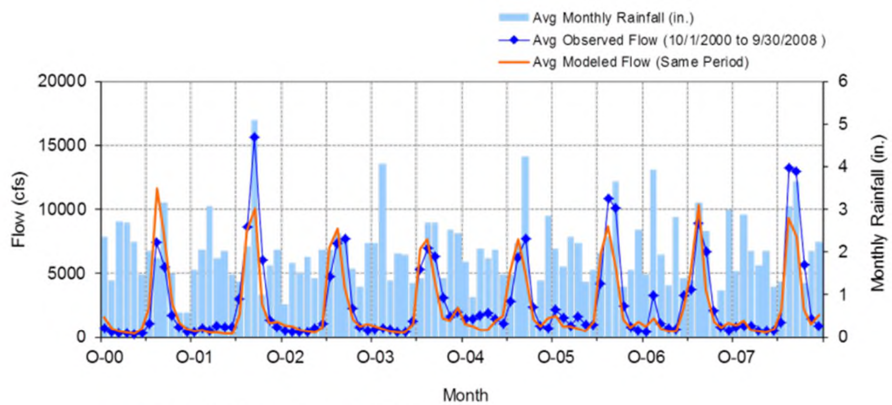
- Compare at fixed, spatially distributed locations
- Observed vs. model daily average stream flow (USGS) and pollutant concentrations (VADEQ, USGS & HRSD)
  - Visual Inspection – hydrographs, flow duration curve, pollutographs, load duration curves
  - Numeric – calculate percent error, etc.

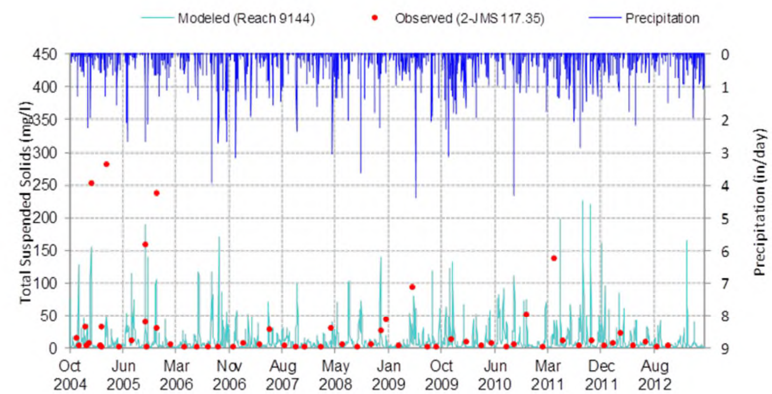


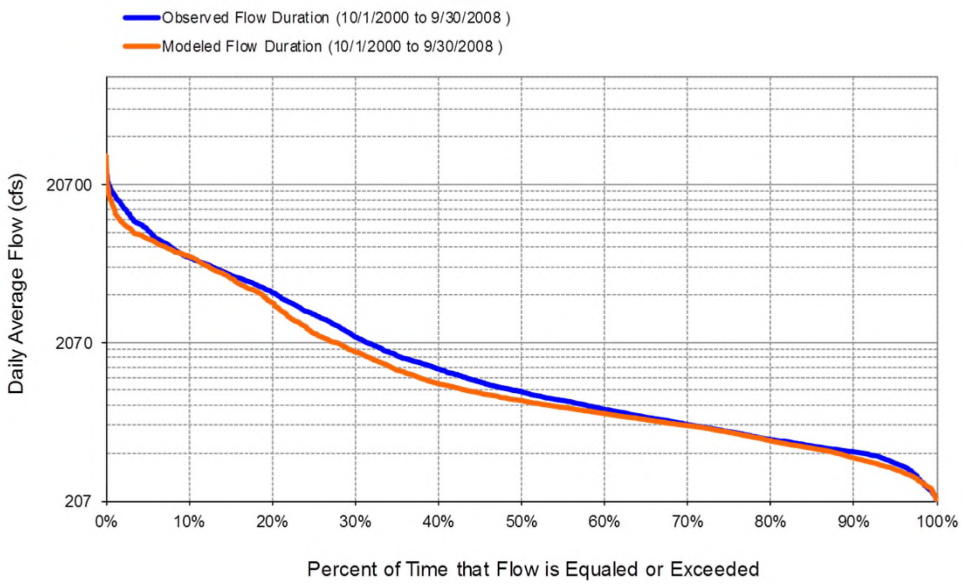
Water Quality Parameters

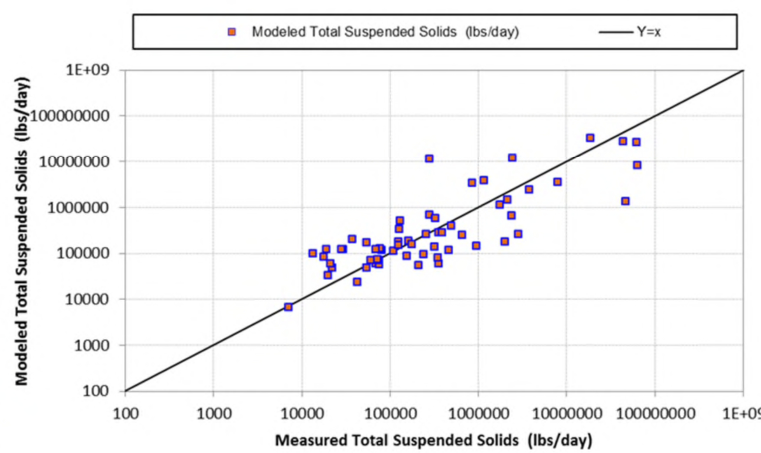
- Modeled water quality parameters included:
  - TSS
  - TN (NO_x, NH_3, organic, inorganic)
  - TP (PO4, organic, inorganic)
  - BOD5
  - TOC (organic, inorganic)
  - Temperature
  - DO
  - Phytoplankton (total biomass, chlorophyll-a)

Visual Calibration Assessment







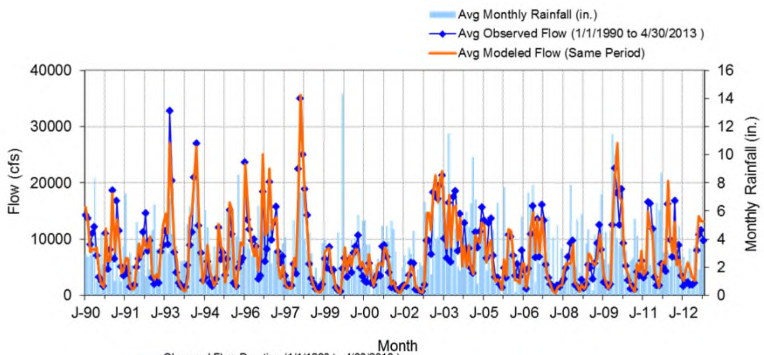


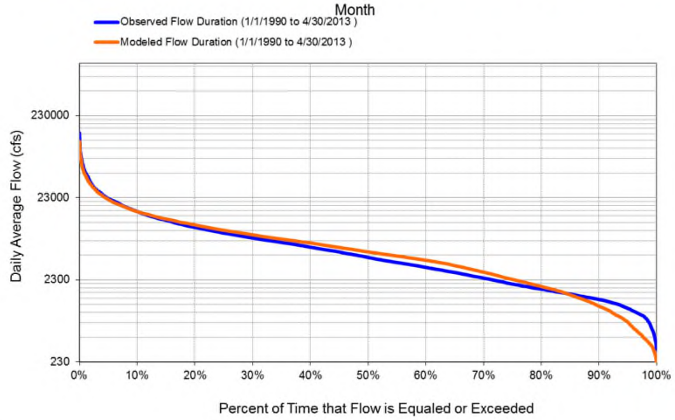
Numeric Hydrology Calibration Criteria

- Compare observed vs. modeled daily average stream flow
- Modeling Period: 1/1/1990 – 4/30/2013

Calibration Metric	Tolerance in Percent Error (Modeled vs. Observed)			
	Very Good	Good	Fair	Below Average
Error in total volume	≤ 5%	5 – 10%	10 – 15%	>15%
Error in 50% lowest flows	≤ 10%	10 – 15%	15 – 25%	>25%
Error in 10% highest flows	≤ 10%	10 – 15%	15 – 25%	>25%
Seasonal volume error (Summer)	≤ 15%	15 – 30%	30 – 50%	>50%
Seasonal volume error (Fall)	≤ 15%	15 – 30%	30 – 50%	>50%
Seasonal volume error (Winter)	≤ 15%	15 – 30%	30 – 50%	>50%
Seasonal volume error (Spring)	≤ 15%	15 – 30%	30 – 50%	>50%
Error in storm volumes	≤ 10%	10 – 15%	15 – 25%	>25%

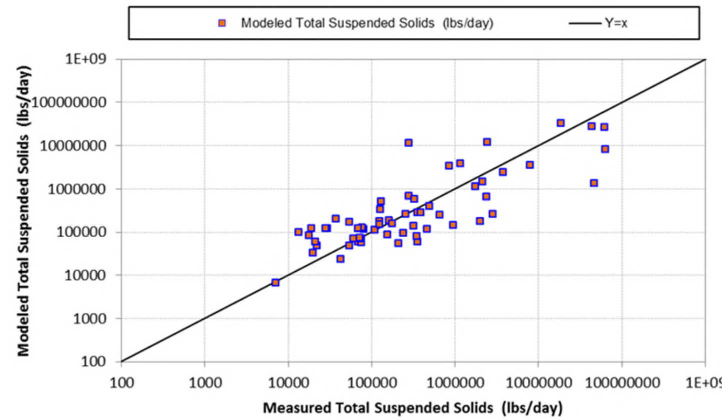
James R. @ Richmond

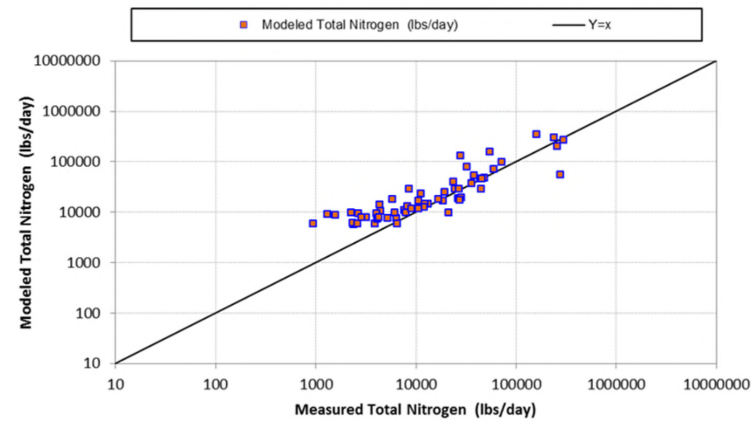


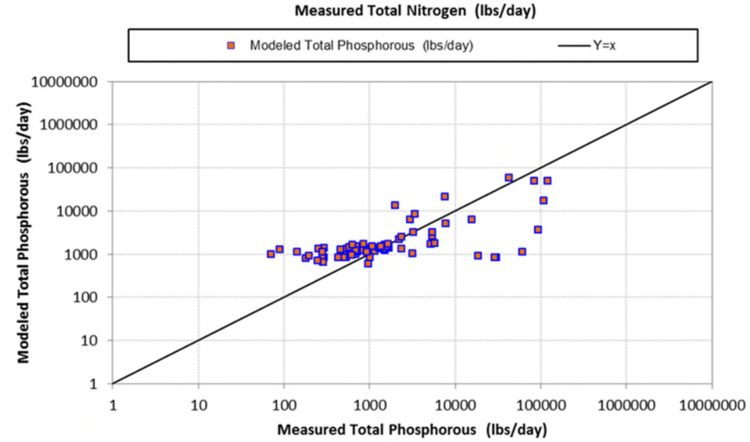


Calibration Metric	James R. (SWS 9144) USGS 02037500
Error in total volume	Very Good
Error in 50% lowest flows	Good
Error in 10% highest flows	Very Good
Seasonal volume error (Summer)	Good
Seasonal volume error (Fall)	Very Good
Seasonal volume error (Winter)	Very Good
Seasonal volume error (Spring)	Very Good
Error in storm volumes	Good

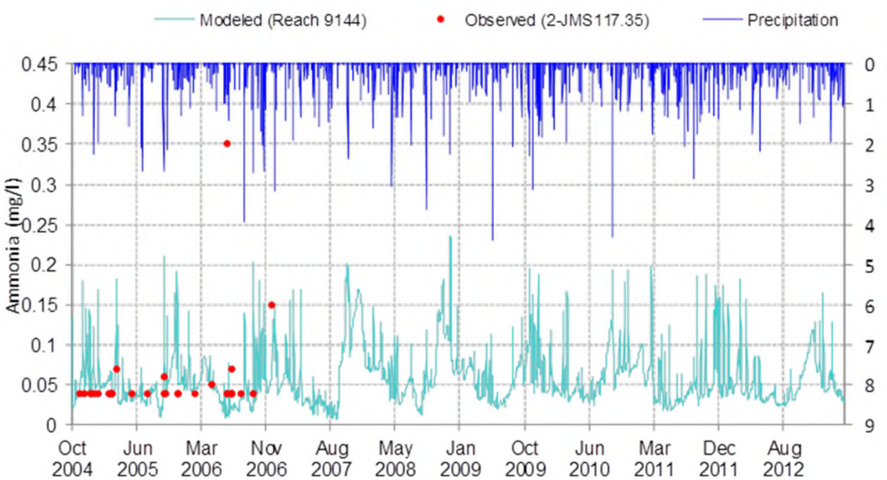
VADEQ 2-JMS117.35

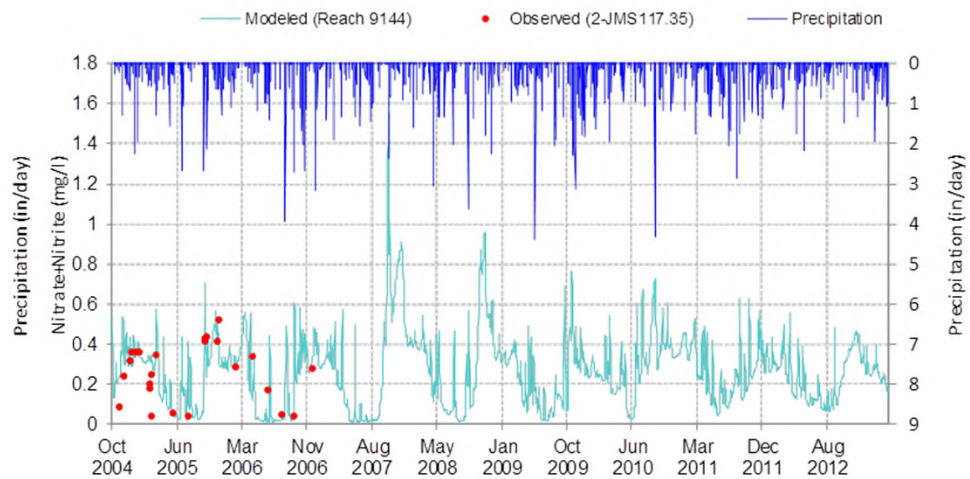


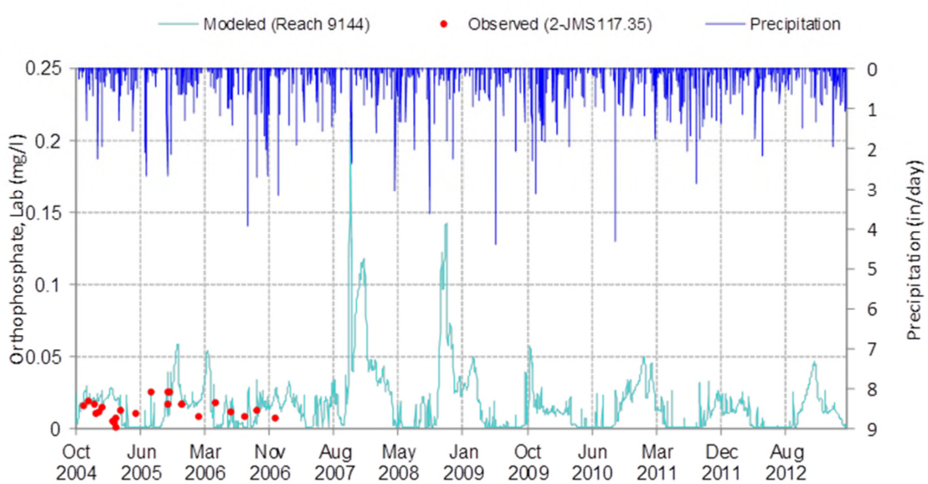




James R. @ Richmond - 2-JMS117.35







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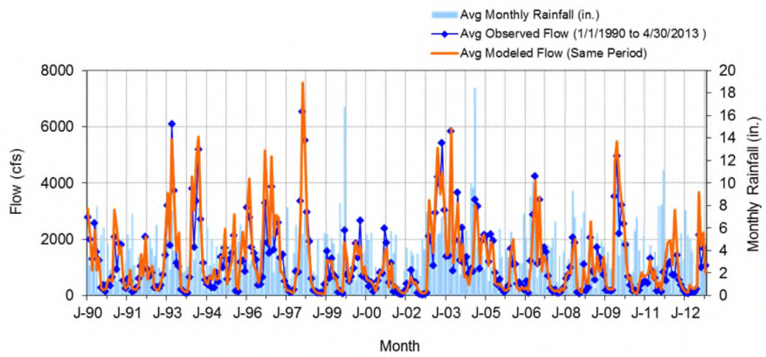
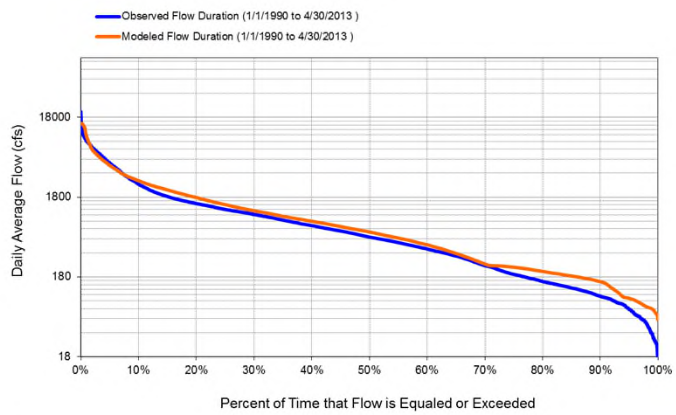
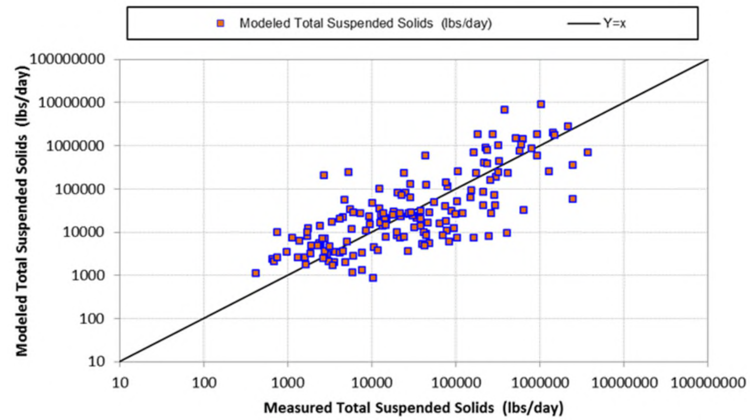
Appom. R. @ Matoaca

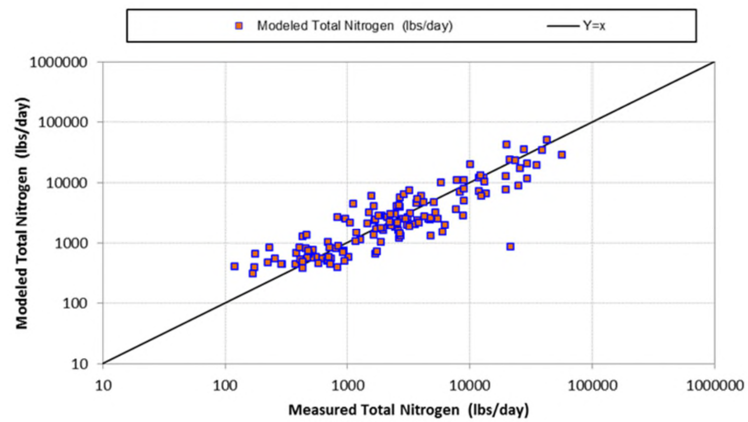


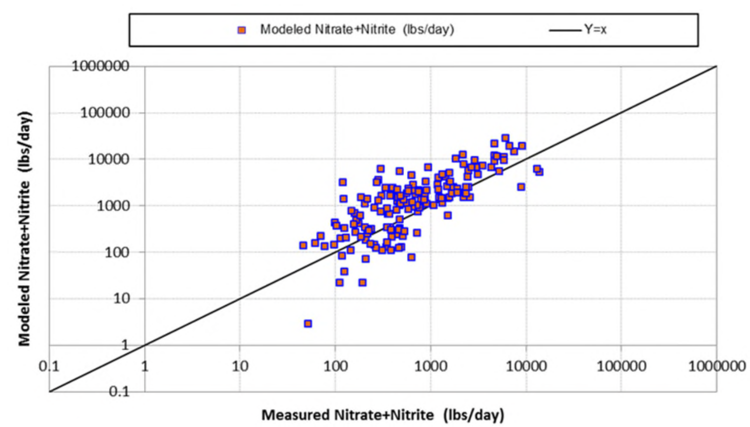


Calibration Metric	Appomattox R. (SWS 7074) USGS 02041650
Error in total volume	Good
Error in 50% lowest flows	Fair
Error in 10% highest flows	Very Good
Seasonal volume error (Summer)	Good
Seasonal volume error (Fall)	Good
Seasonal volume error (Winter)	Very Good
Seasonal volume error (Spring)	Very Good
Error in storm volumes	Good

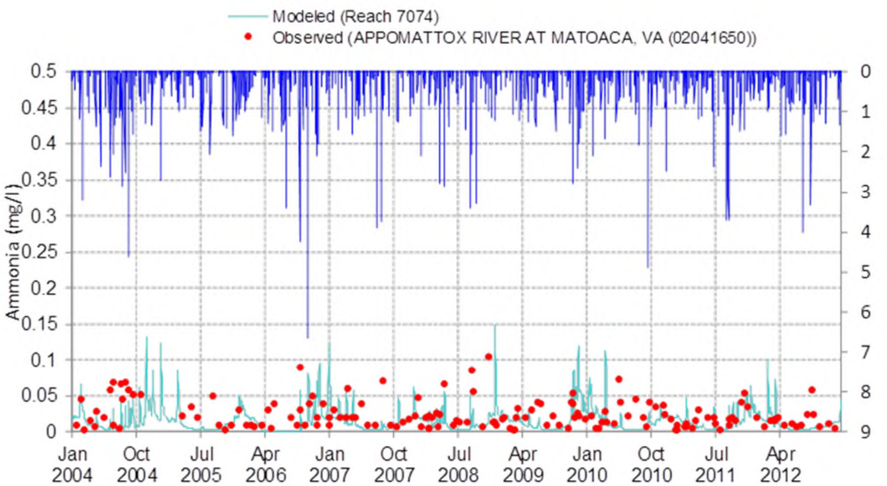
USGS 02041650

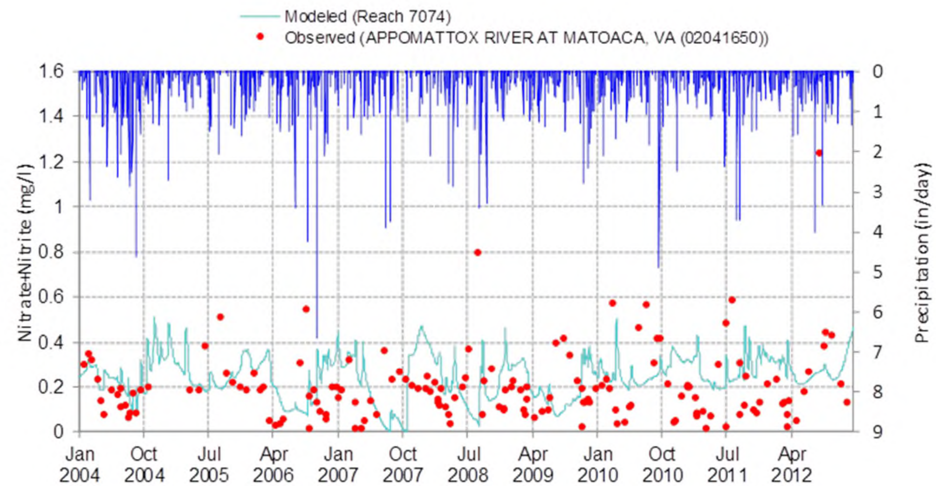


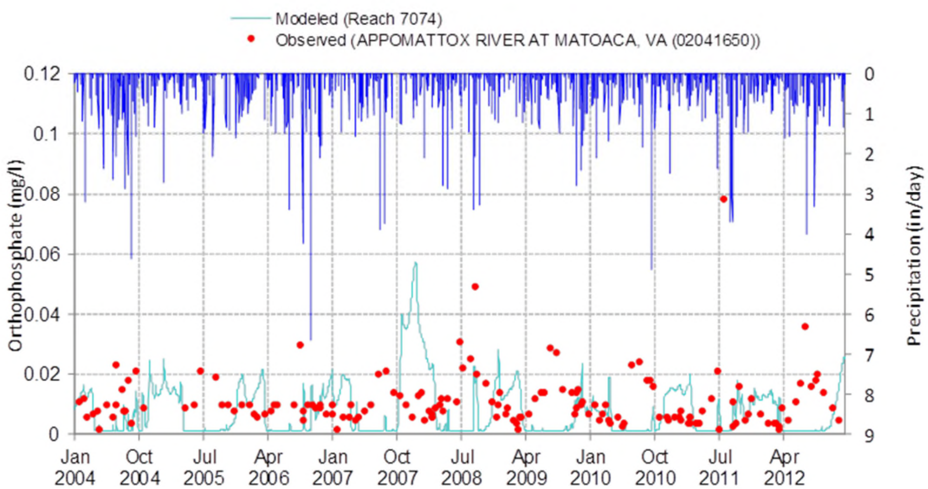




Appomattox R. @ Matoaca – USGS 02041650







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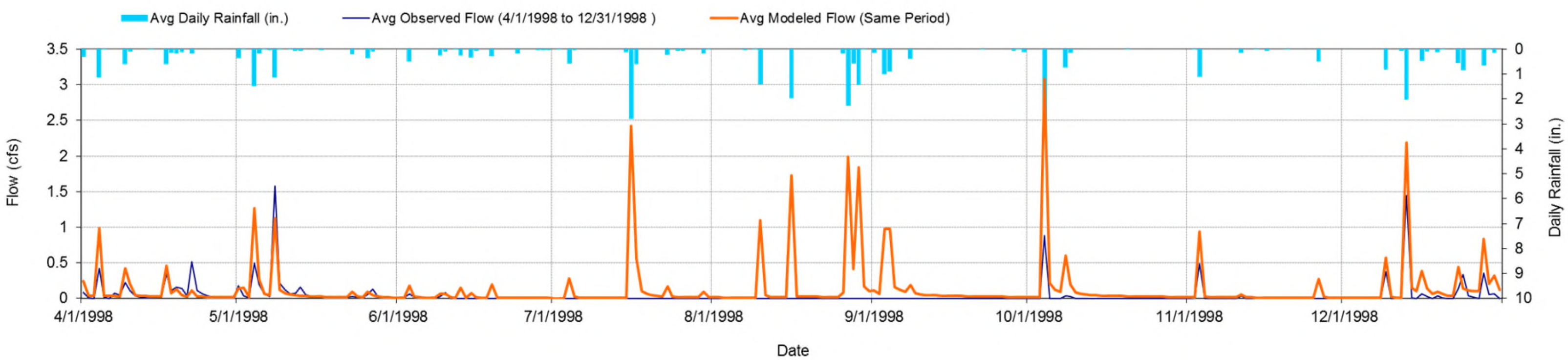
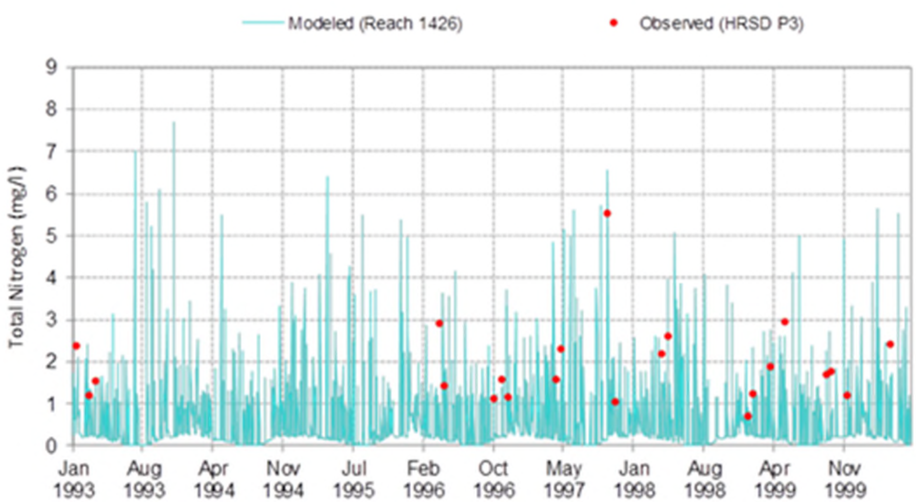
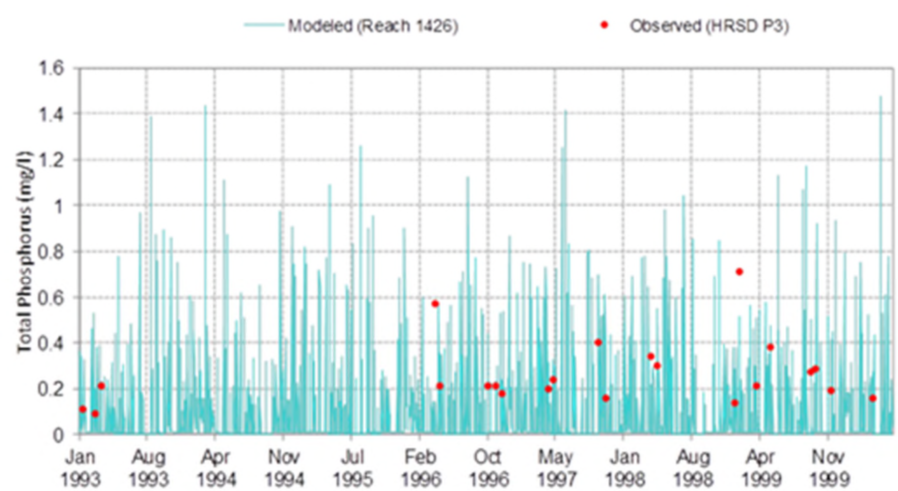
Portsmouth SW Monitoring Site
P-3 @ Pughsville Rd.







Next Steps

- Extend weather data through the fall of 2013
- Refine low-flow simulations, including point source representation
- Refine calibration during linkage with tidal models
- Develop scenario representation (potential scenarios below)
  - VA Tributary Strategy
  - VA TMDL Allocations
  - VA WIP III
  - Climate Change Scenarios
  - James Full and Half Level of Effort Potomac Scenario
  - Others TBD