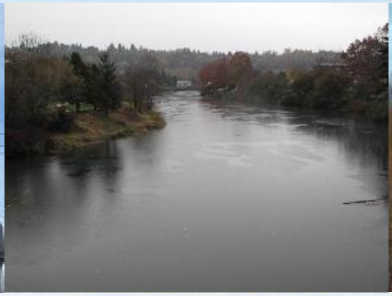
Green/Duwamish River Watershed



Pollutant Loading Assessment: Setup and Development of LSPC Model for Hydrology

Technical Advisory Committee Meeting
October 5, 2016

DEPARTMENT OF ECOLOGY State of Washington

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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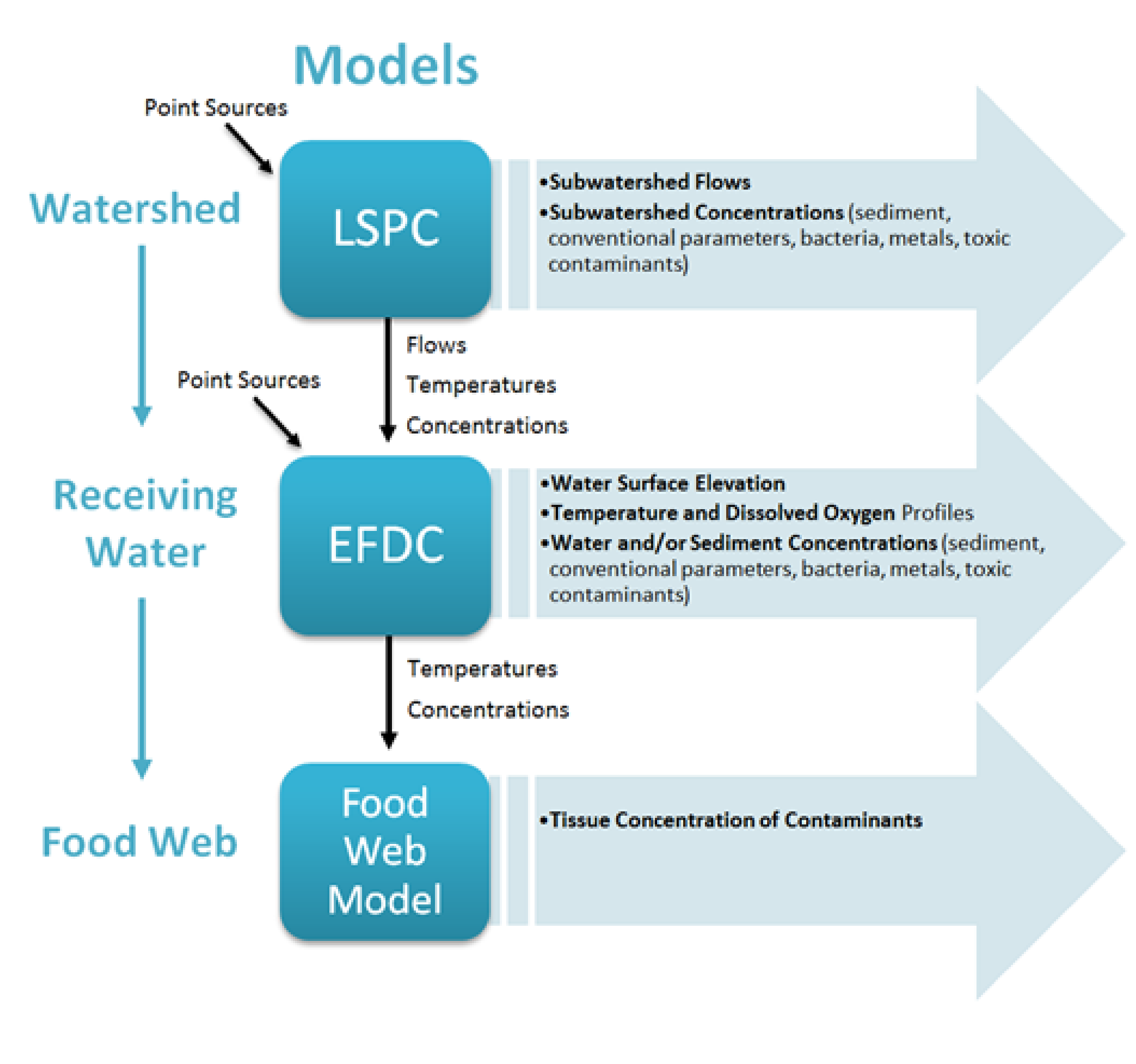
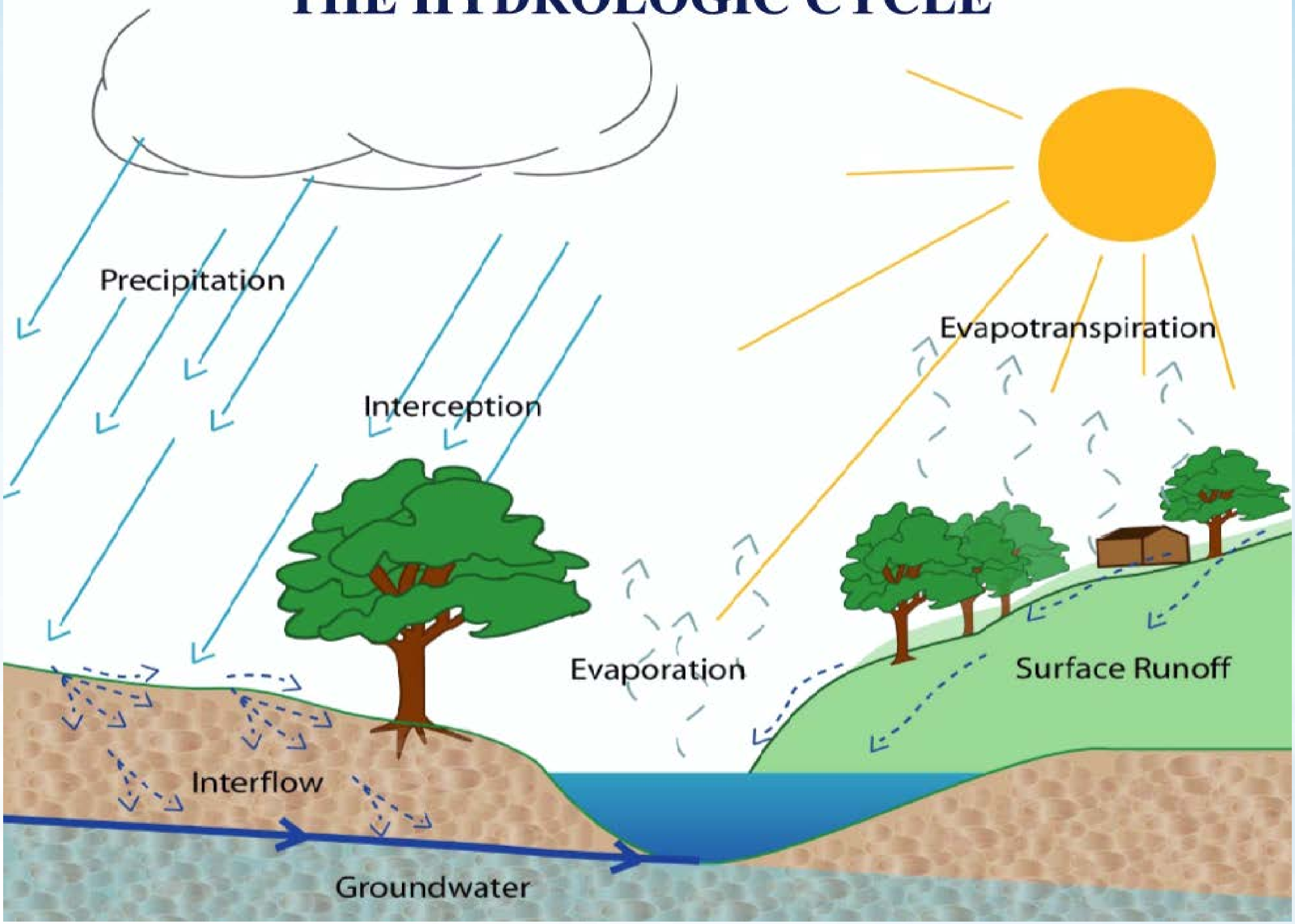
Where we are:

- Previous TAC meeting (4/6/2016) laid out the modeling framework and presented the draft QAPP
- QAPP approved 7/11/2016
- First phase: watershed hydrologic model
  - Configure, calibrate and validate the hydrology portion of the watershed model (LSPC)
  - Produce interim TM on model setup
  - Next step: Adjust, refine, and improve the hydrology model
  - Develop draft watershed hydrology model documentation report for formal review and comment

LSPC Watershed Model

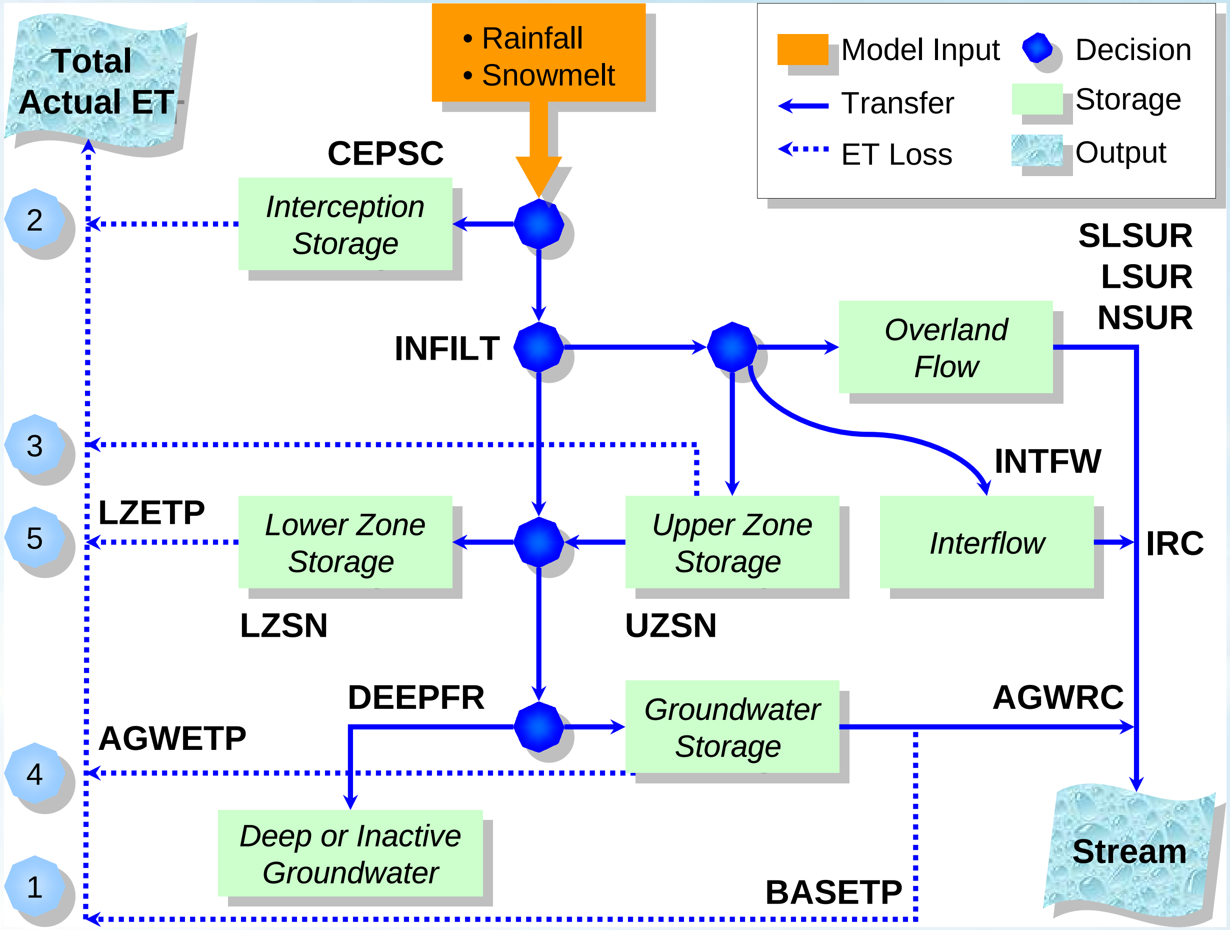


THE HYDROLOGIC CYCLE



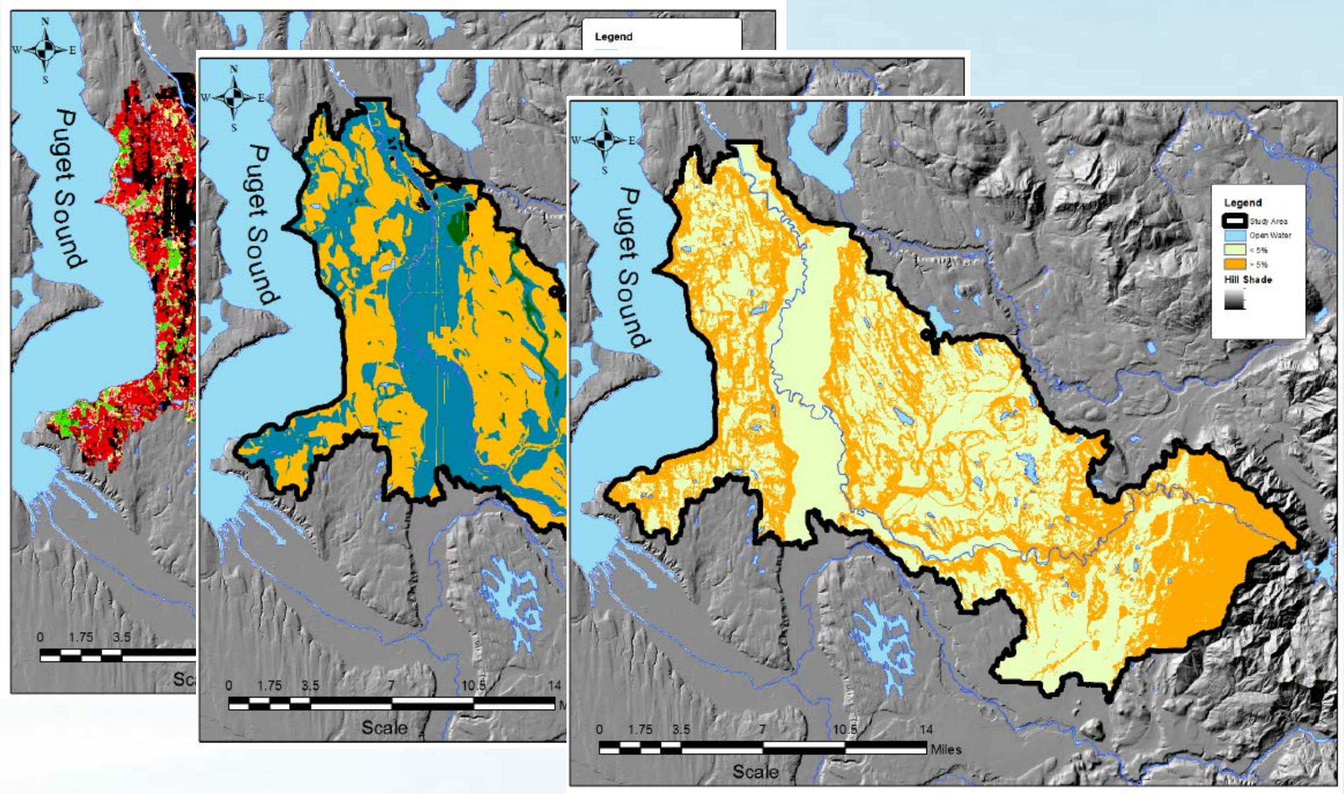
LSPC Hydrology Model

- Hydrologic Components:
  - Precipitation
  - Interception
  - Evapotrans-piration
  - Overland flow
  - Infiltration
  - Interflow
  - Subsurface storage
  - Groundwater flow
  - Groundwater loss



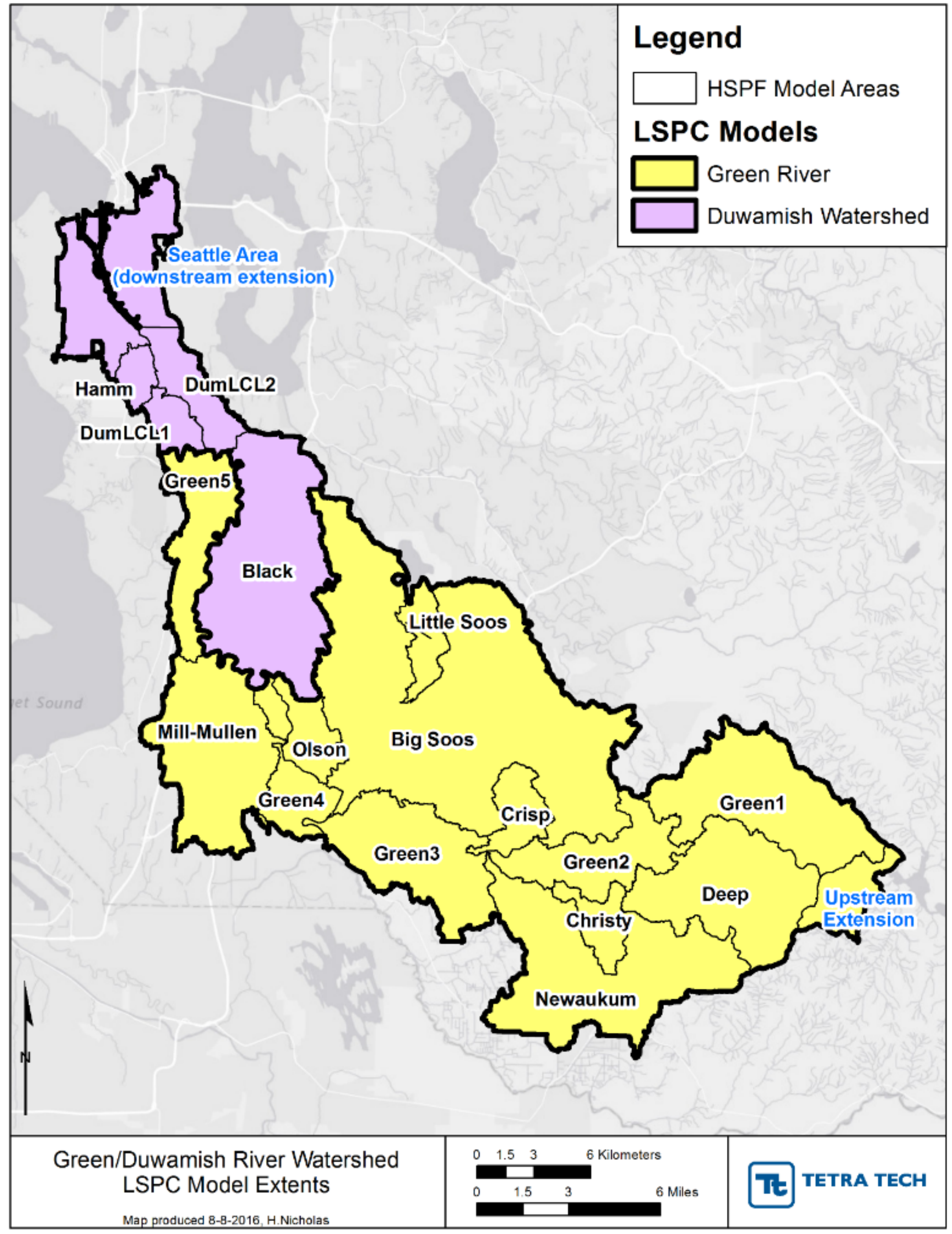
Source: Stanford Watershed Model

Overlay of Land Use, Geology, Slope



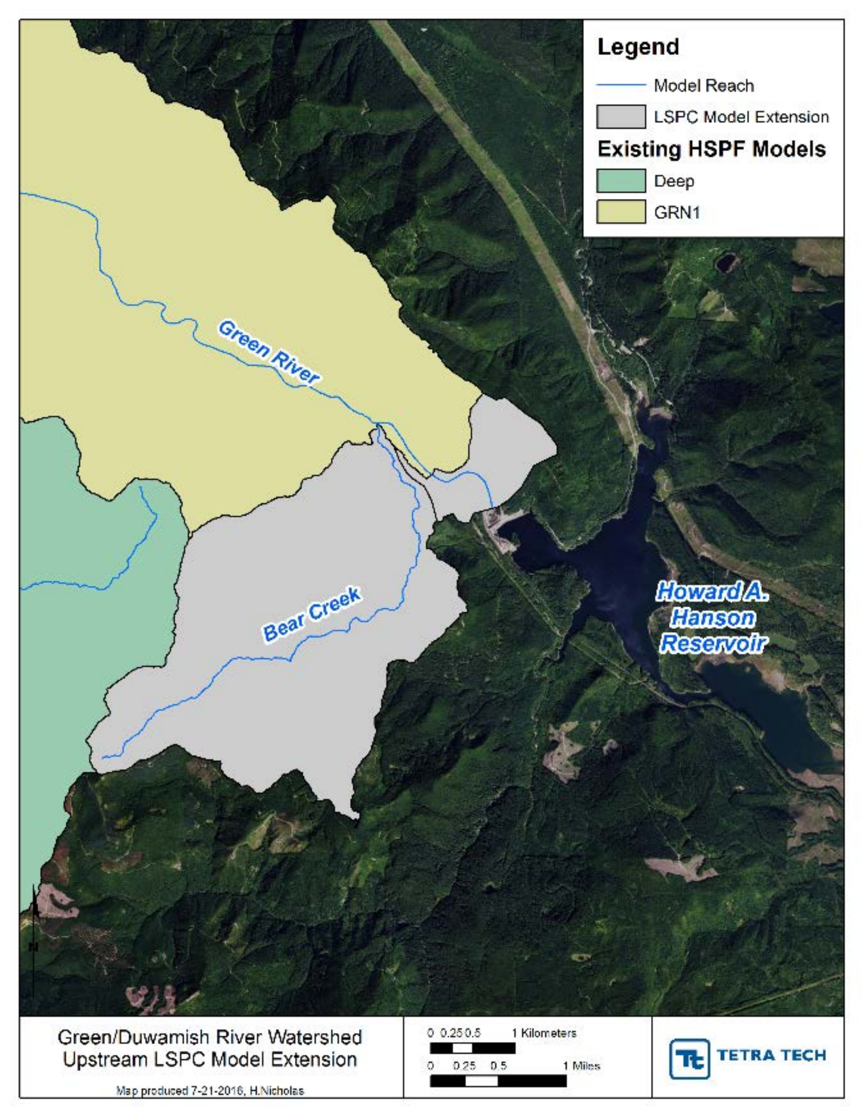
Model Extent

- ► Start with existing HSPF models
- ► Extend to full area draining to LDW
- ► Create two LSPC models
  - Green River Model – area draining to head of EFDC model
  - Duwamish Model (direct downstream drainages)



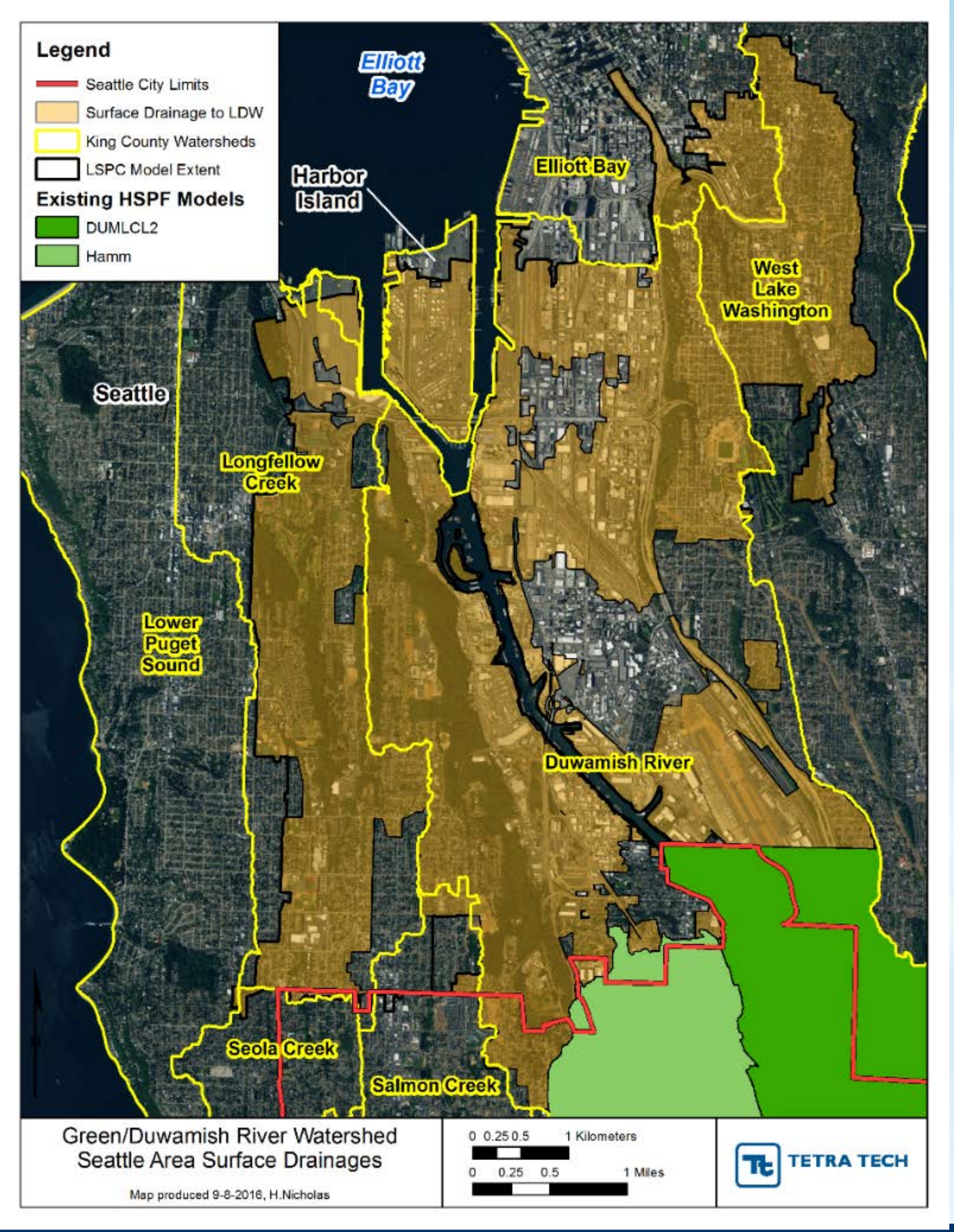
Upstream Extension to Howard A. Hanson Dam Spillway

Bear Creek enters below Dam and above the Tacoma Diversion



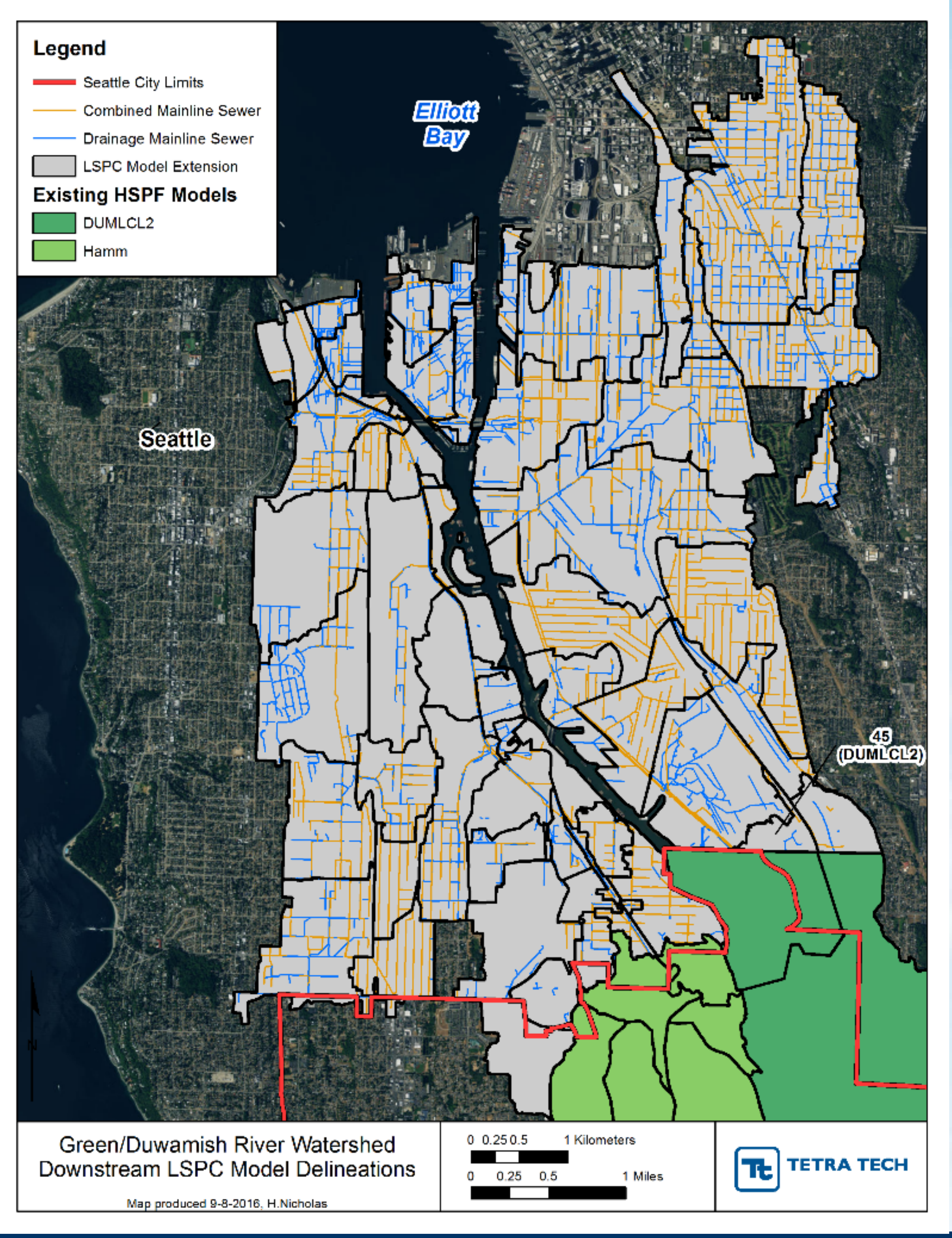
Downstream Extension: Seattle Area

- Take to boundary of LDW and Elliott Bay
- Substantial alterations to natural watersheds
- Includes combined, partially separated, and fully separated SW drainages

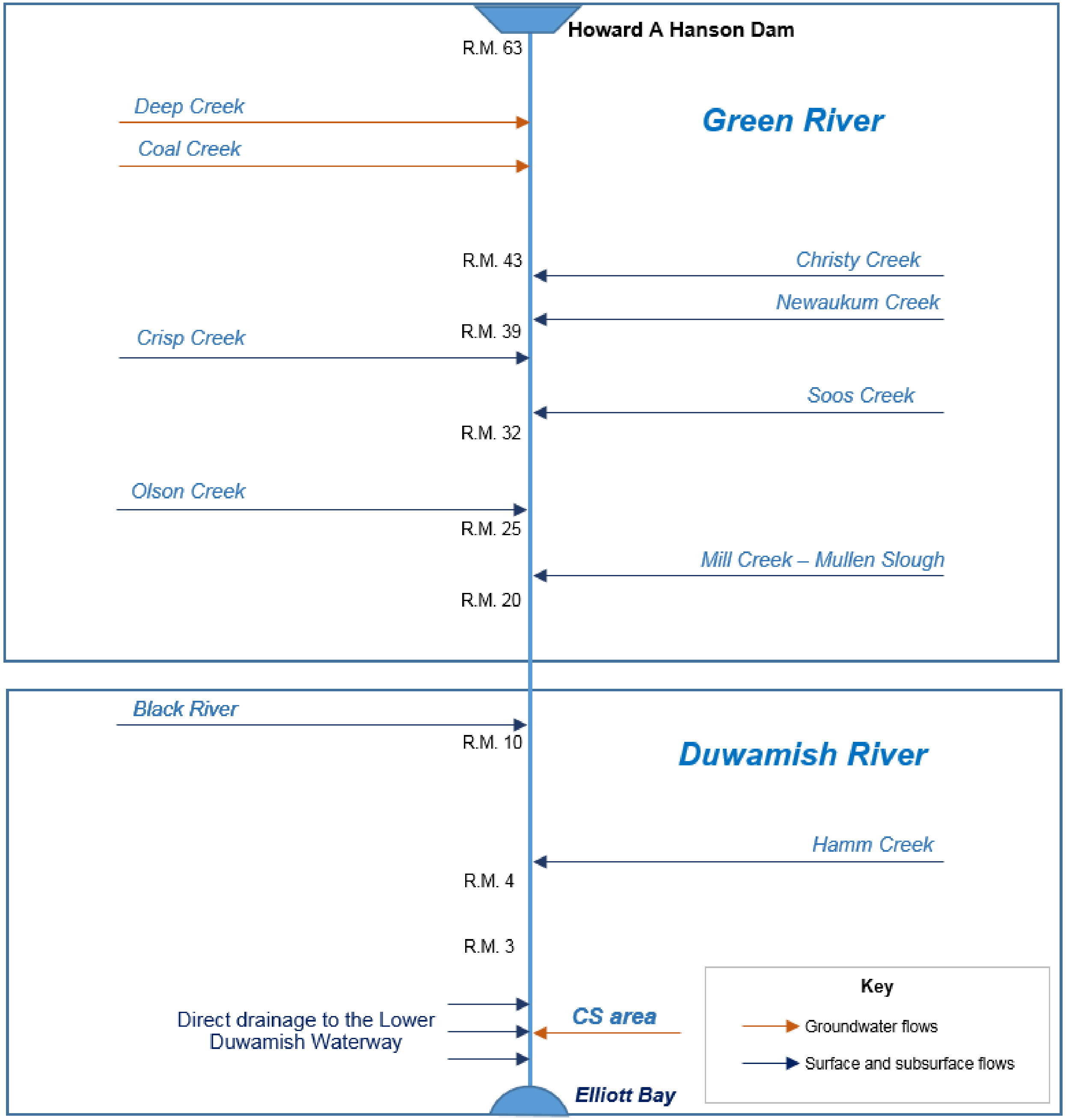


Delineating Seattle Area

- Use SPU drainage basins, sewer lines and SWMM models
- Include combined sewer areas, as they may contribute groundwater flow to LDW
- Surface runoff in combined area only contributes to LDW during CSO events



Linked Models

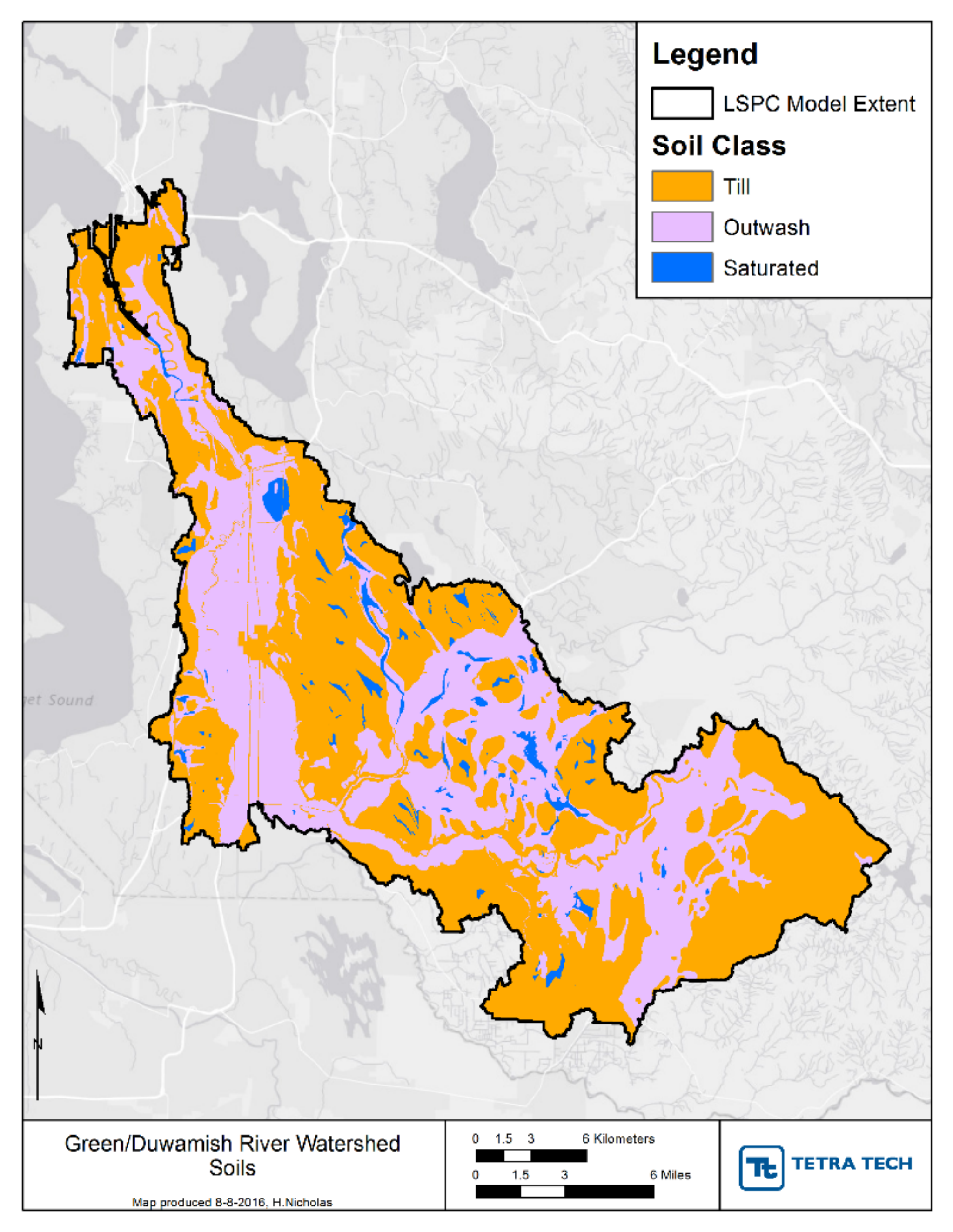


Notes: Not to scale. River Mile zero is defined at the southern tip of Harbor Island

Upland Representation

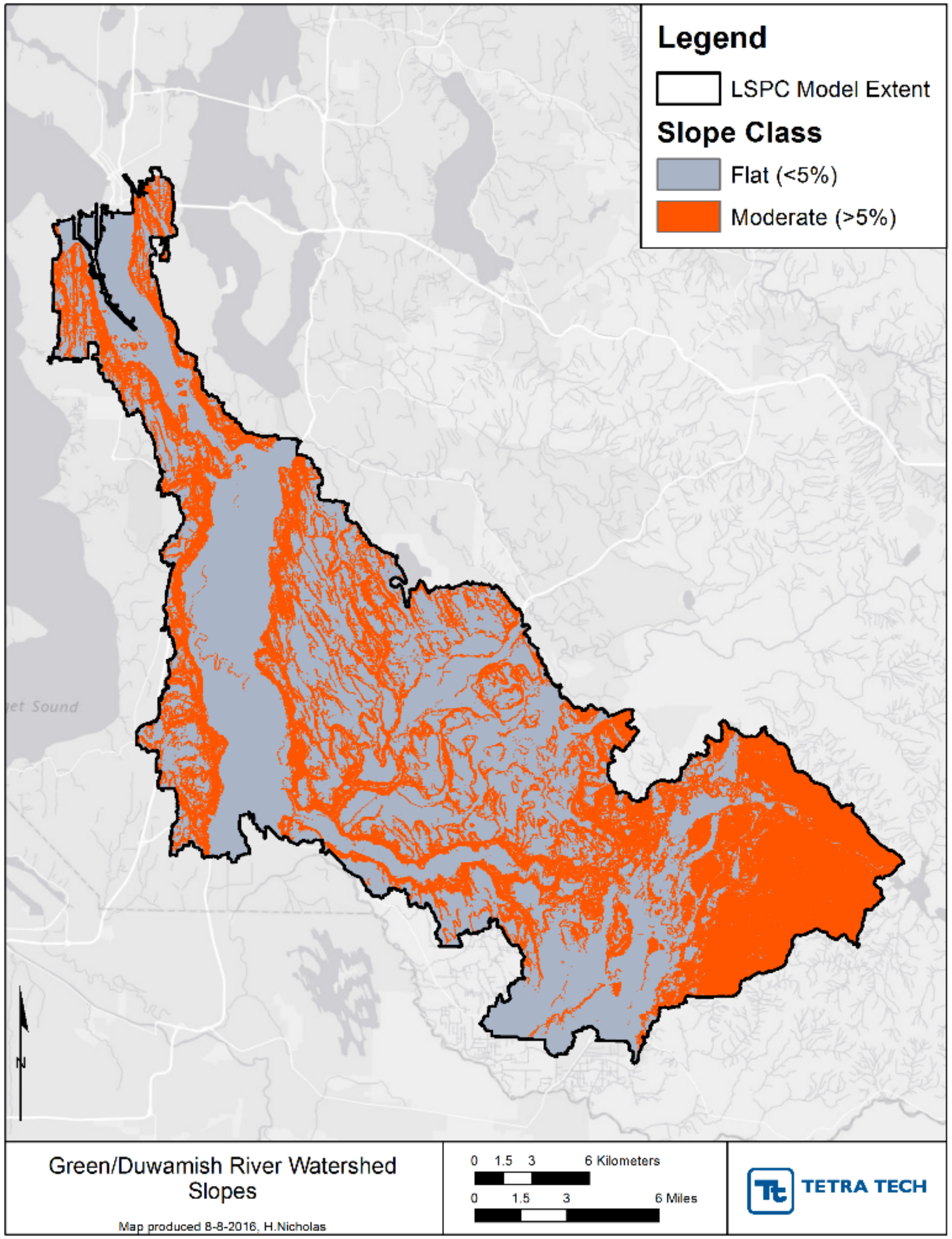
- Define Hydrologic Response Units (HRUs) consistent with existing HSPF models based on intersection of:
  - Land Use/Land Cover
  - Effective Impervious Area
  - Soil type
  - Slope characteristics
- Add additional characteristics to represent drainage type
  - Separate storm sewers
  - Combined sewers
  - Partially separated areas

Soil Classes



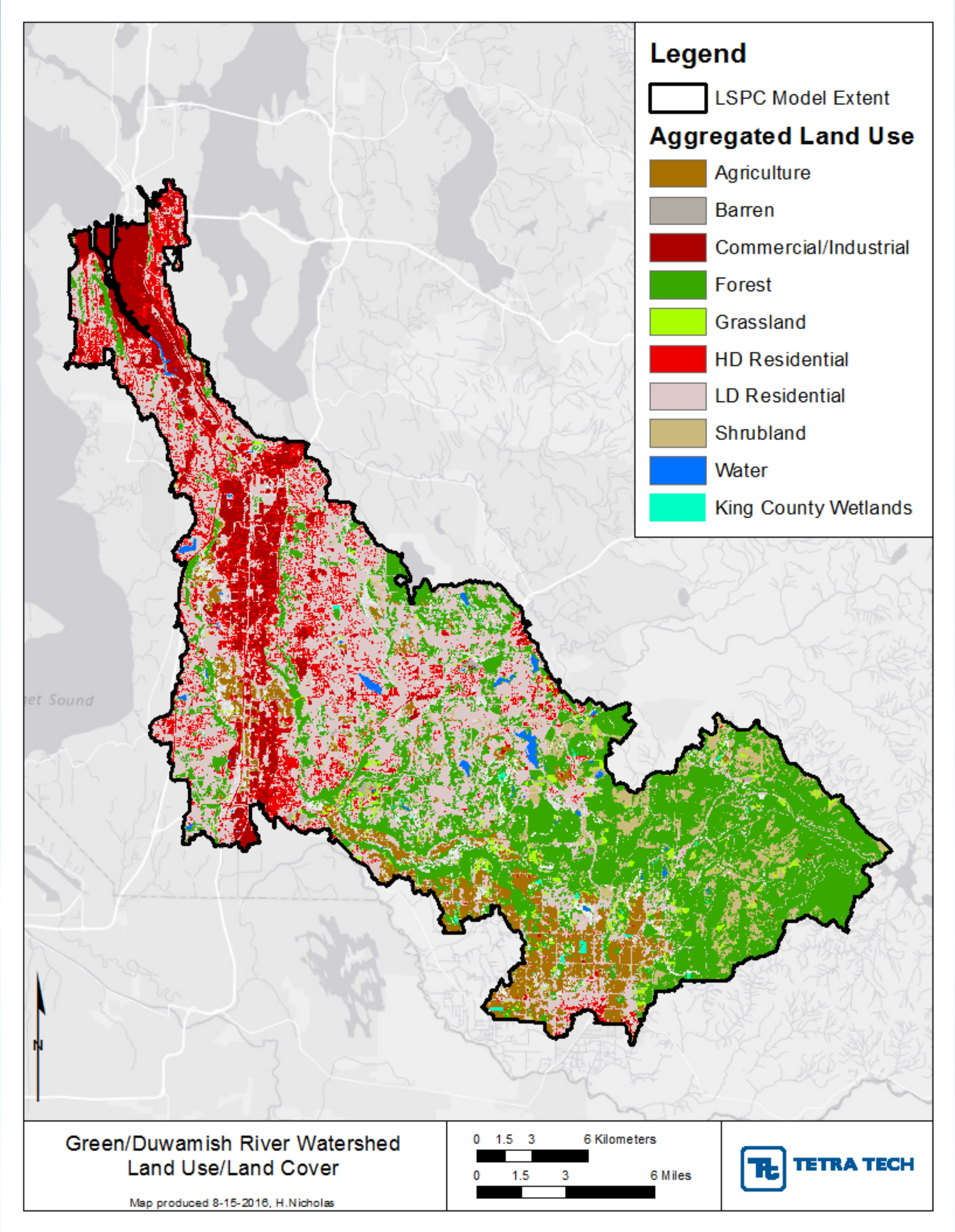
Slope Classes

King Co. 10m DEM developed from LiDAR



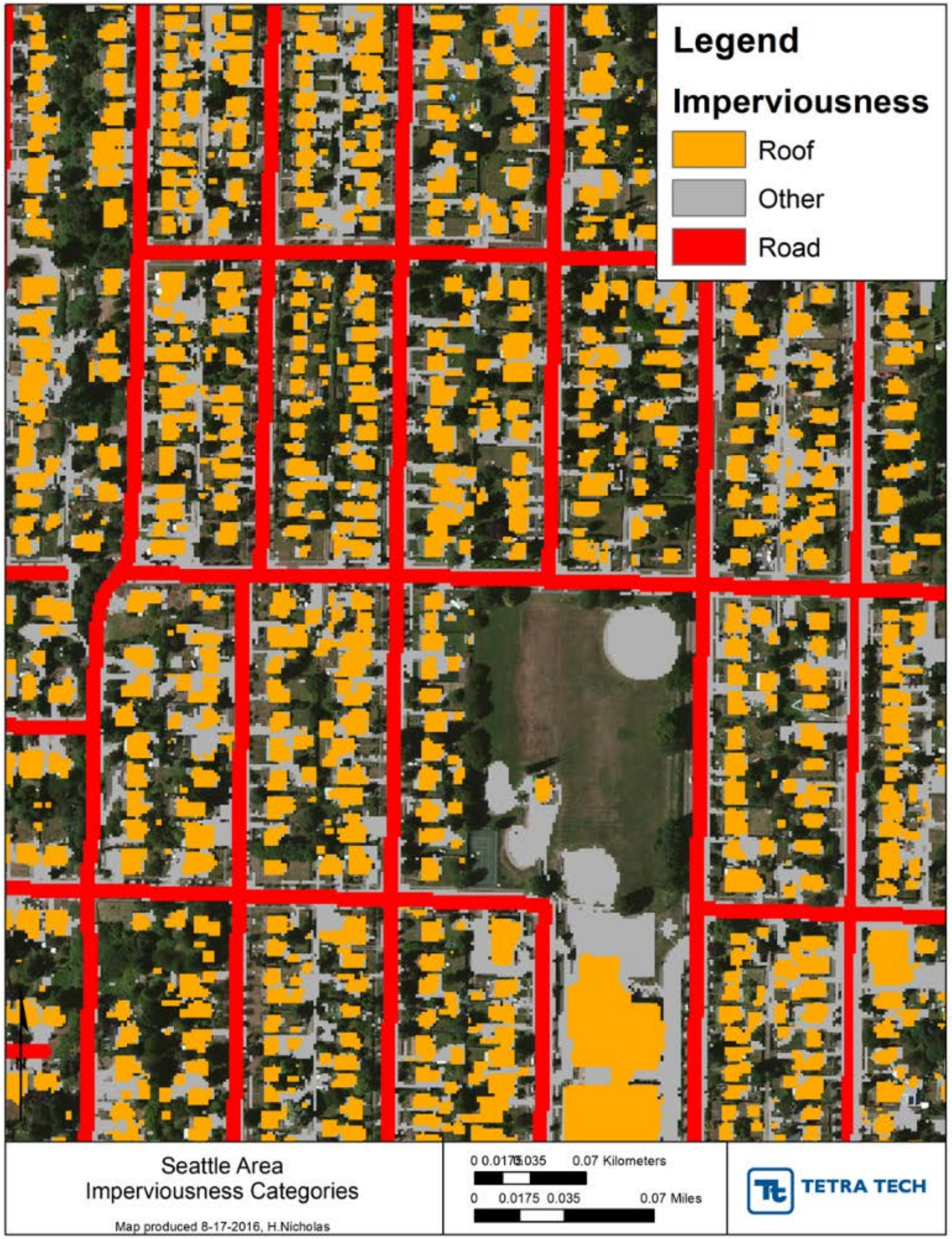
Base Land Use

- ► 2006 NLCD satellite coverage
- ► Wetlands area redefined based on King Co. wetlands
- ► Explicitly simulated lakes and streams are represented as reaches and removed from upland coverage



Impervious Area

- New high resolution LiDAR coverages include height
- Distinguish roof, road, and other ground-level impervious areas
- Analyze for "effective" impervious fraction that connects to drainageways

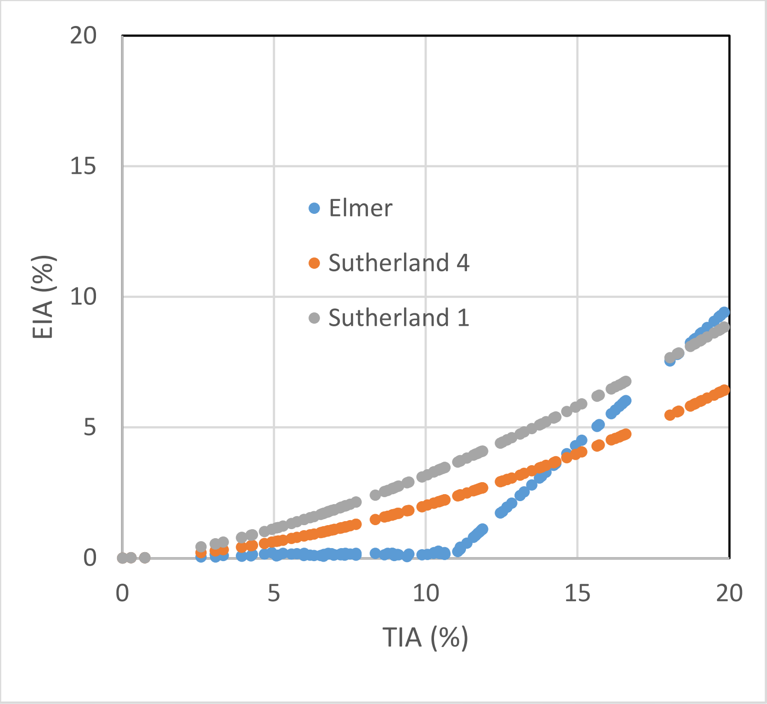


Effective Impervious Area (EIA) Fraction

- ► Use Elmer (2001) for densely developed areas:

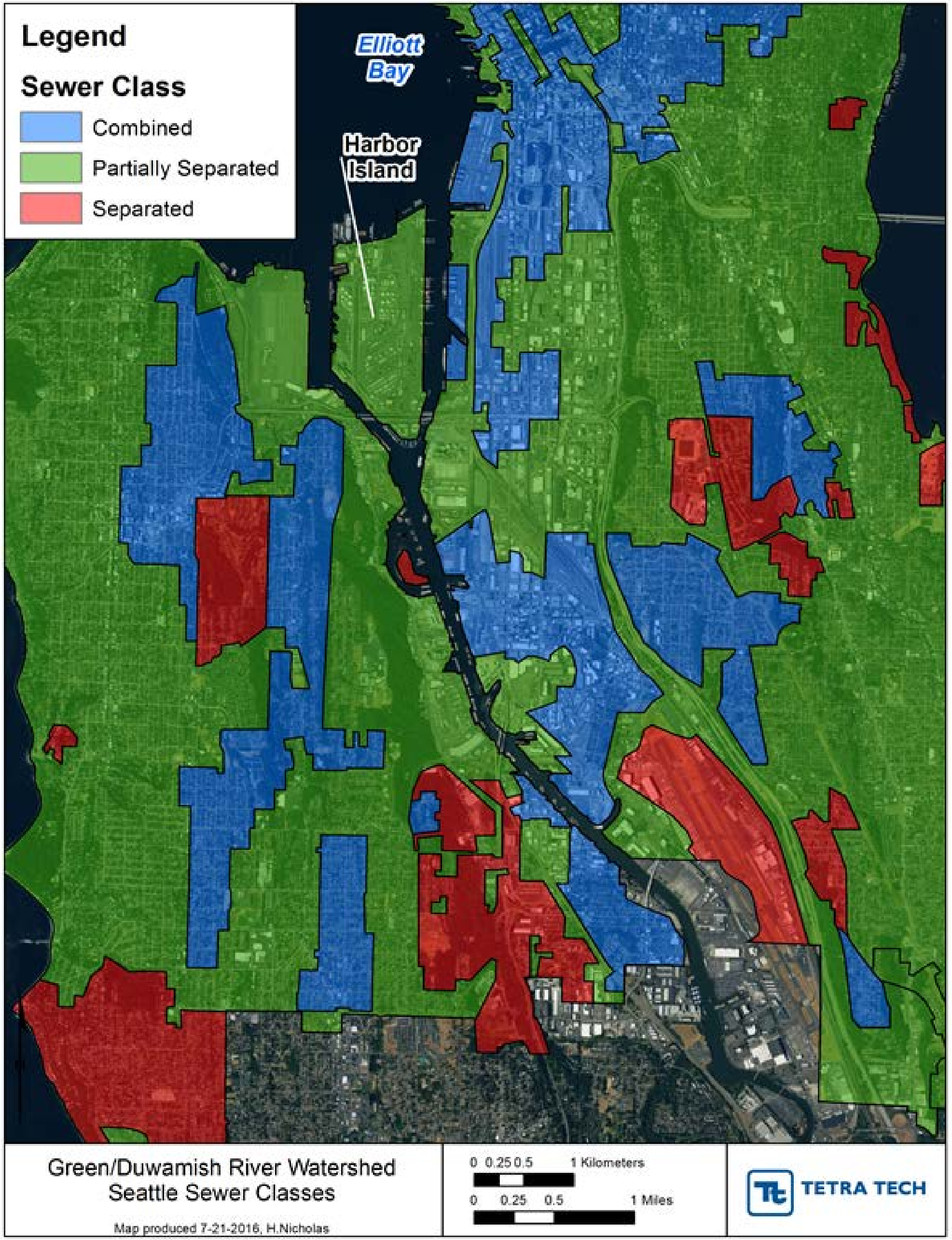
$$EIA = 1.0428\ TIA - 11.28\%$$

- ► Not applicable below TIA of 10.82%; should not go to zero – apply Sutherland (1995) equations
- ► May need to adjust for SW BMP extent that changes EIA in specific drainage areas



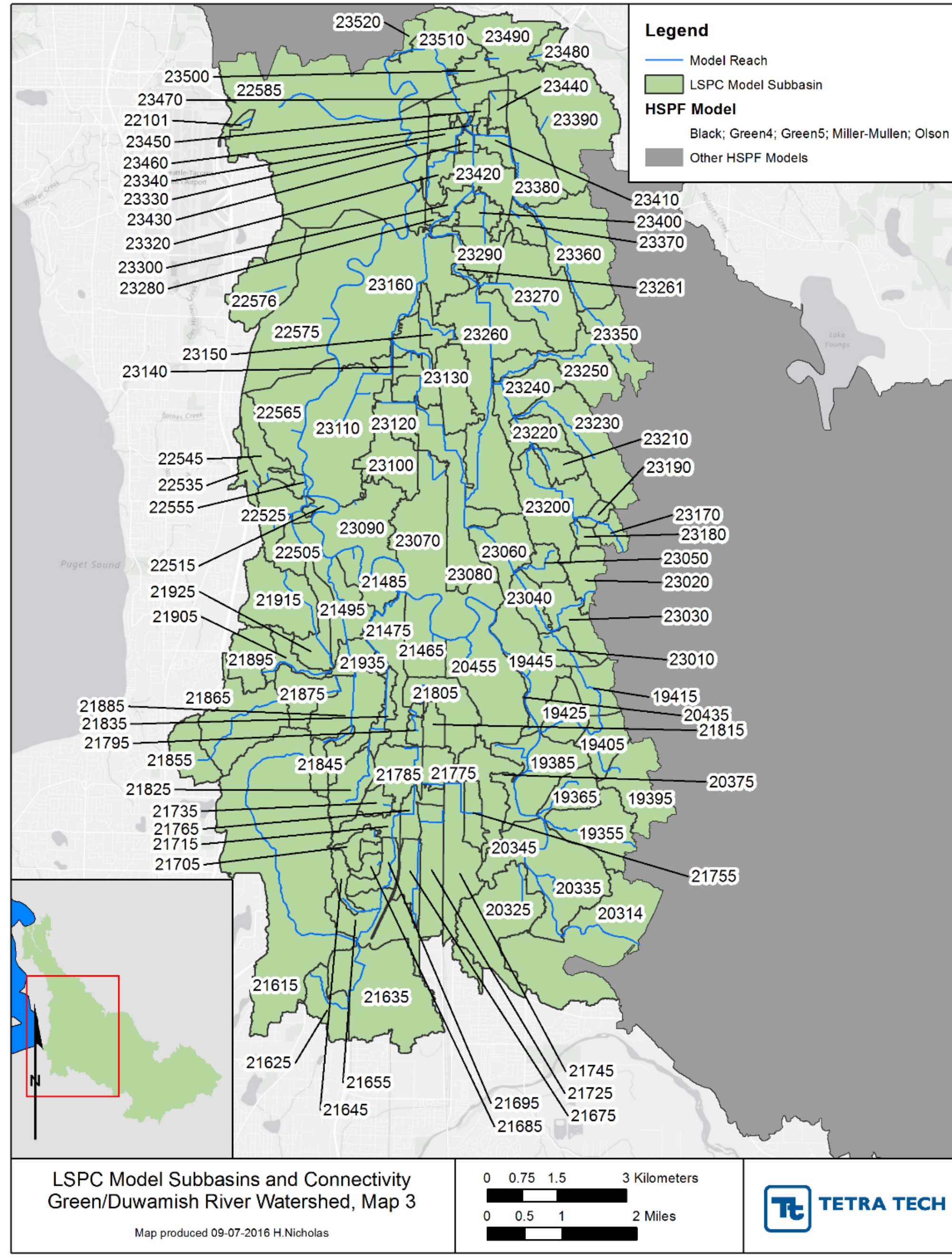
Drainage Classes from SPU

- ► Stormwater from combined sewers enters LDW only during CSO events
- ► Note areas outside Seattle contribute sanitary sewage to CSOs but storm drainage is separated



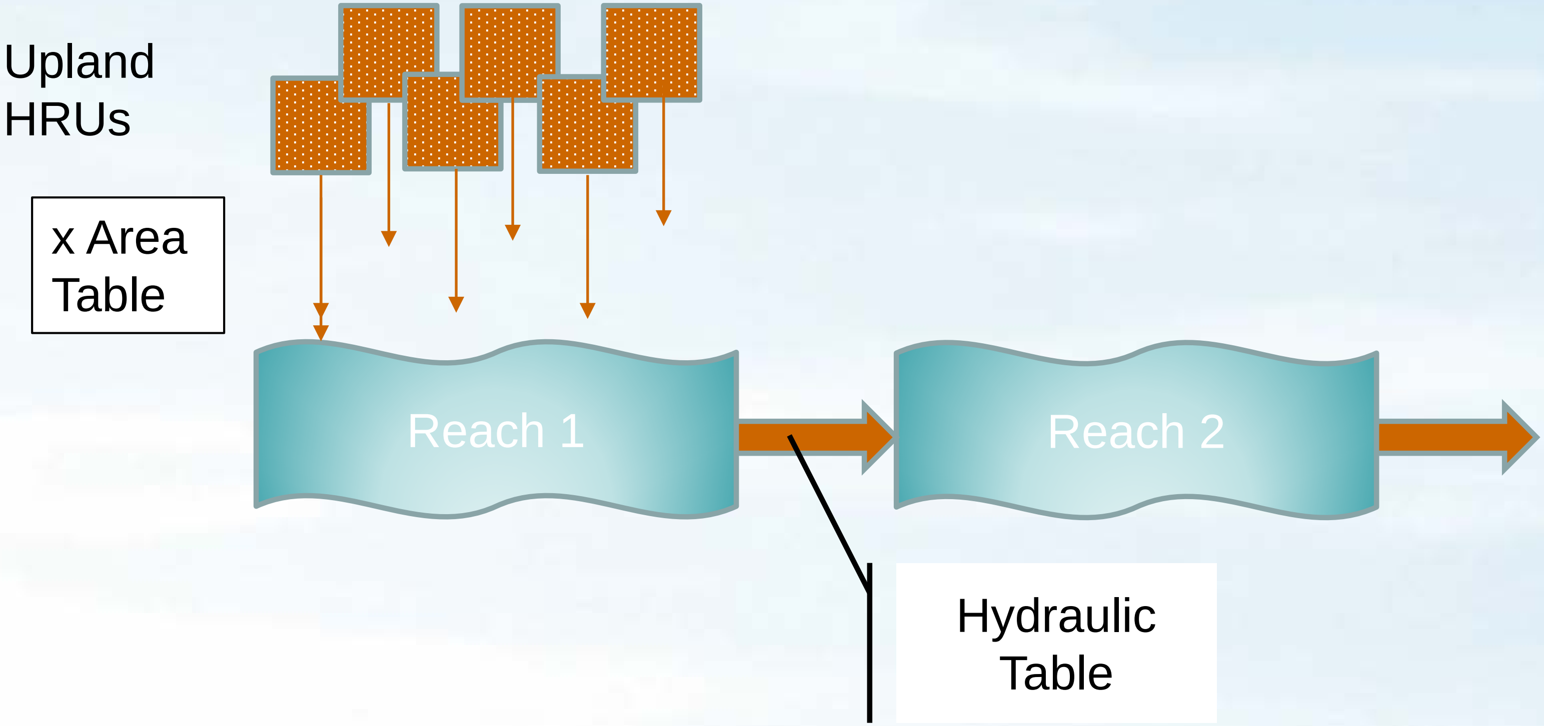
Reach Network

- Upland land units are connected to reaches (streams, lakes)
- Each subbasin has an accompanying reach
- Characteristics of these reaches control movement of water and pollutants to the LDW



Flow through reaches

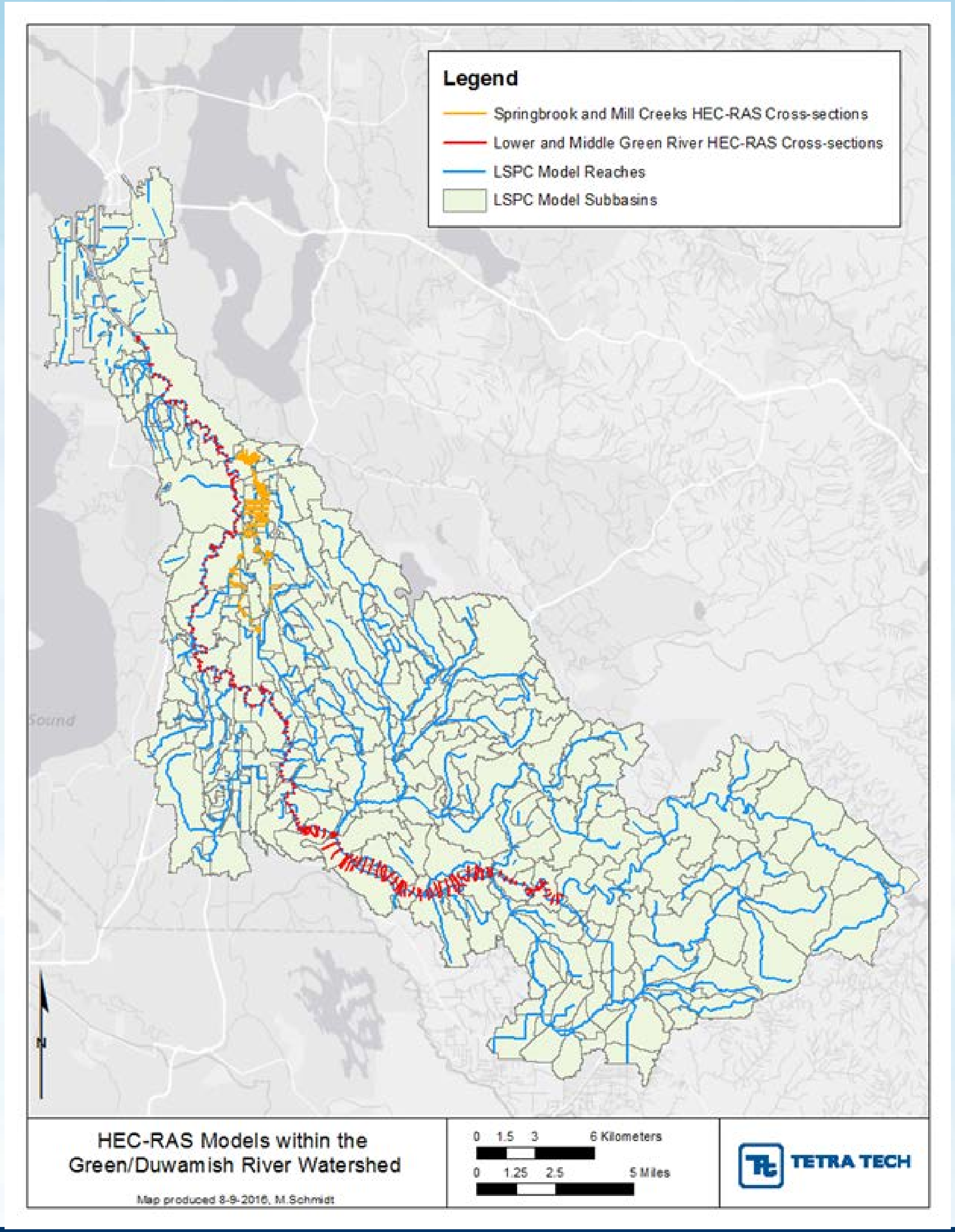
- ▶ Each stream reach or conveyance is represented in the model as a 1-D, fully mixed segment
- ▶ Additional information is used to represent hydraulic response and details of bed – water column interactions



Reach Geometry and Hydraulics

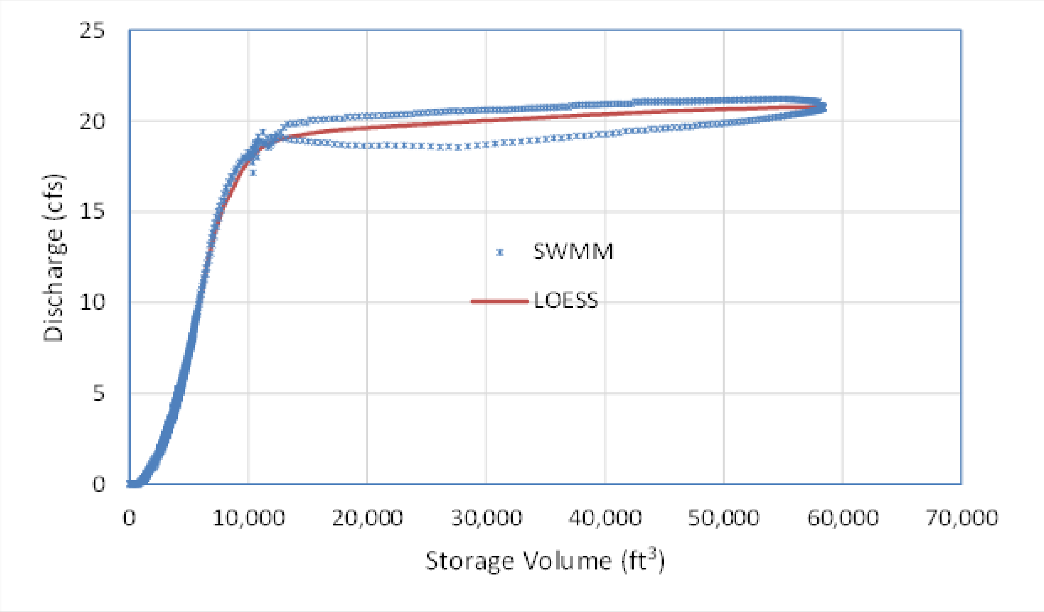
- Key for sediment transport
  - Determines storm hydrograph shape and associated energy to erode and move channel sediment
- Data sources
  - HEC-RAS flood elevation models
  - SWMM stormwater models
    - Received from SPU
    - Still seeking availability of additional city stormwater conveyance models
  - Stream gage rating curves
  - Regional hydraulic geometry equations
- Process fine-scale model output to define volume-discharge-depth-area relationships for LSPC reaches

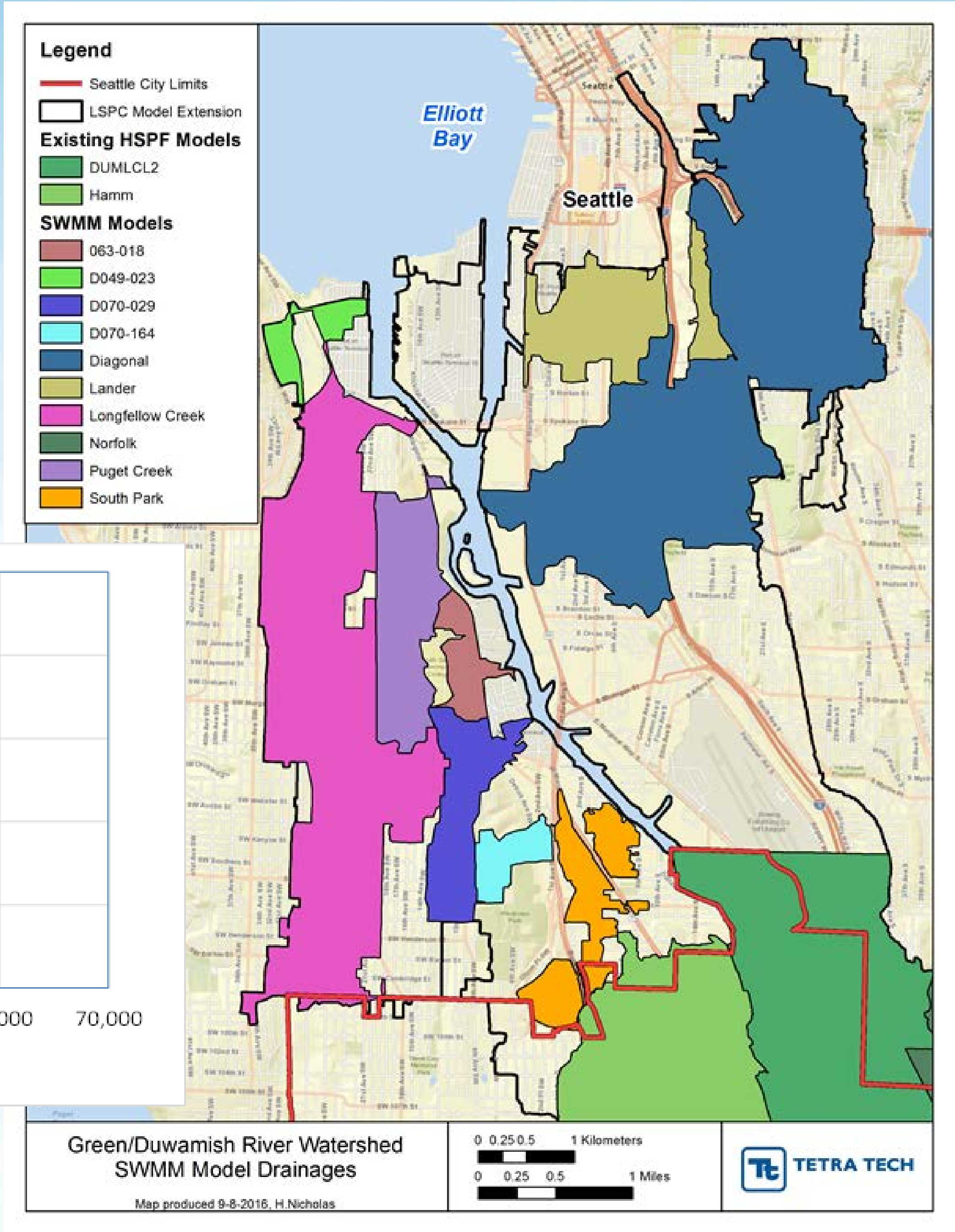
HEC-RAS Models



SPU SWMM Models

Use LOESS fit to approximate hysteresis of rising and falling limbs of hydrograph in dynamic SWMM model simulations





Hydraulics – Other Methods

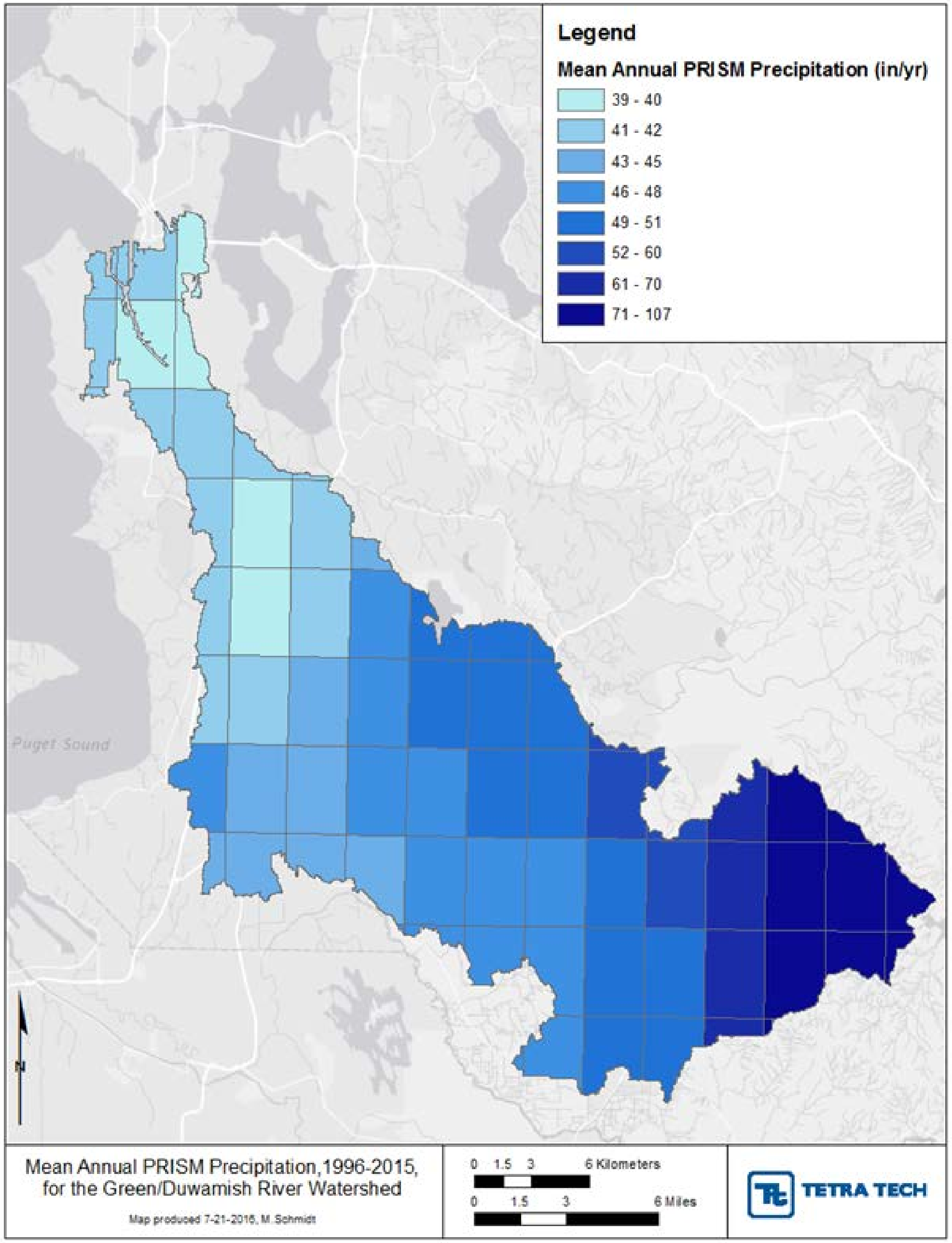
- Where detailed hydraulic models are lacking can resort to other methods
- Cross-section available: solve Manning's equation
- Pipe/culvert dimensions available: solve pipe flow equations
- Gage rating curves: Combine with cross-section information to directly generate relevant table
- Regional hydraulic geometry (Castro and Jackson, 2001):
  - Predict X-section area, bankfull width, depth from flow
  - Solve Manning's equation

Weather Data - Precipitation

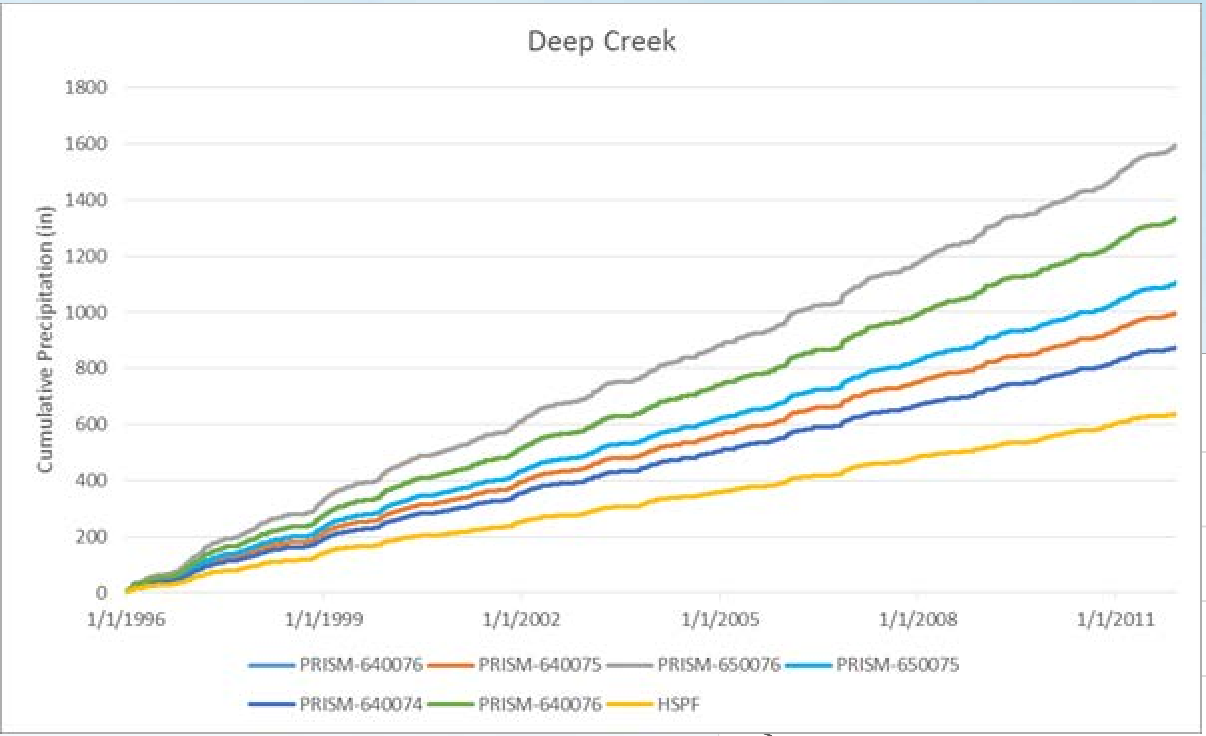
- Existing HSPF models used precipitation data from available stations, with multiple processing steps to combine information from various time periods and adjust for PRISM average annual precipitation
- Method not easily replicated for other time periods and introduces inaccuracies
- For the new model, use newly available daily PRISM
  - Automated distribution of station-based data using climate-elevation regression function at ~4 km resolution
  - Disaggregate sub-daily patterns using NLDAS-2 information from Doppler radar and satellite data
- NLDAS-2 also provides a full suite of other weather variables at 1/8 degree resolution

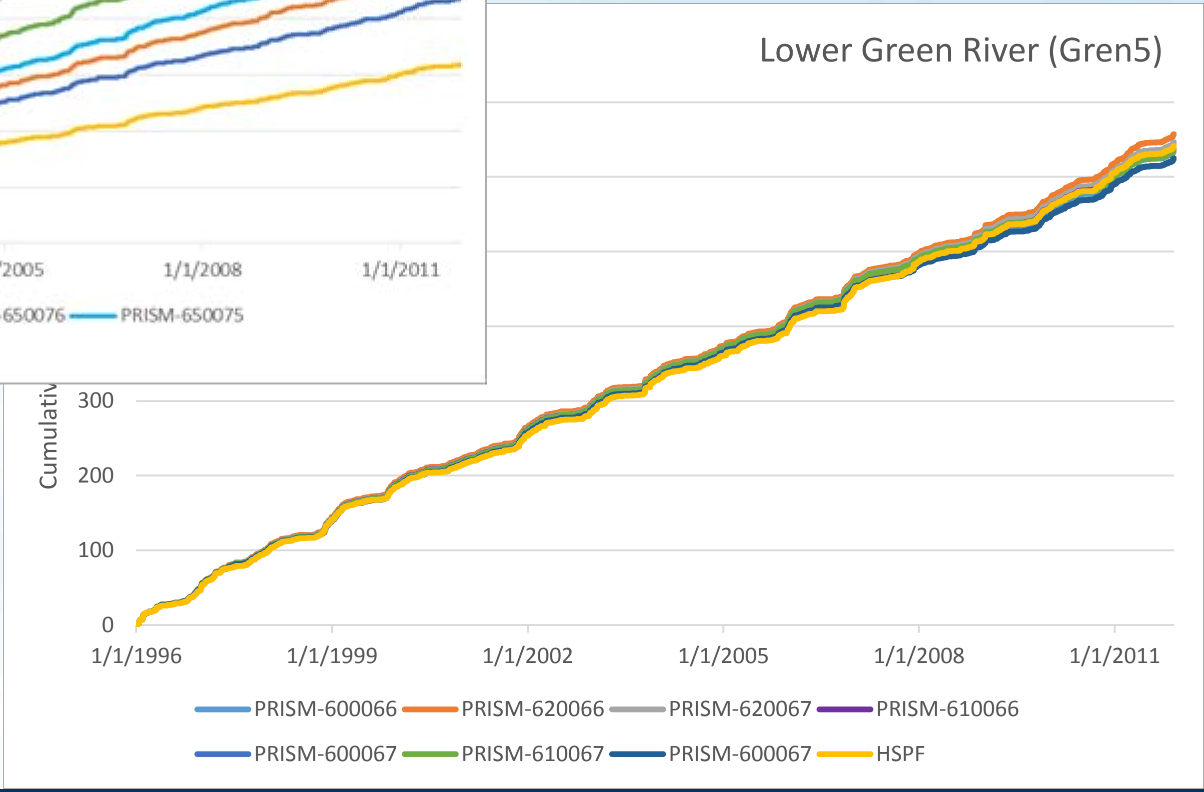
Mean Annual Precipitation from PRISM, 1996-2015

Range from 39 to 107 in/yr



Substantial Changes in Poorly Gauged Areas



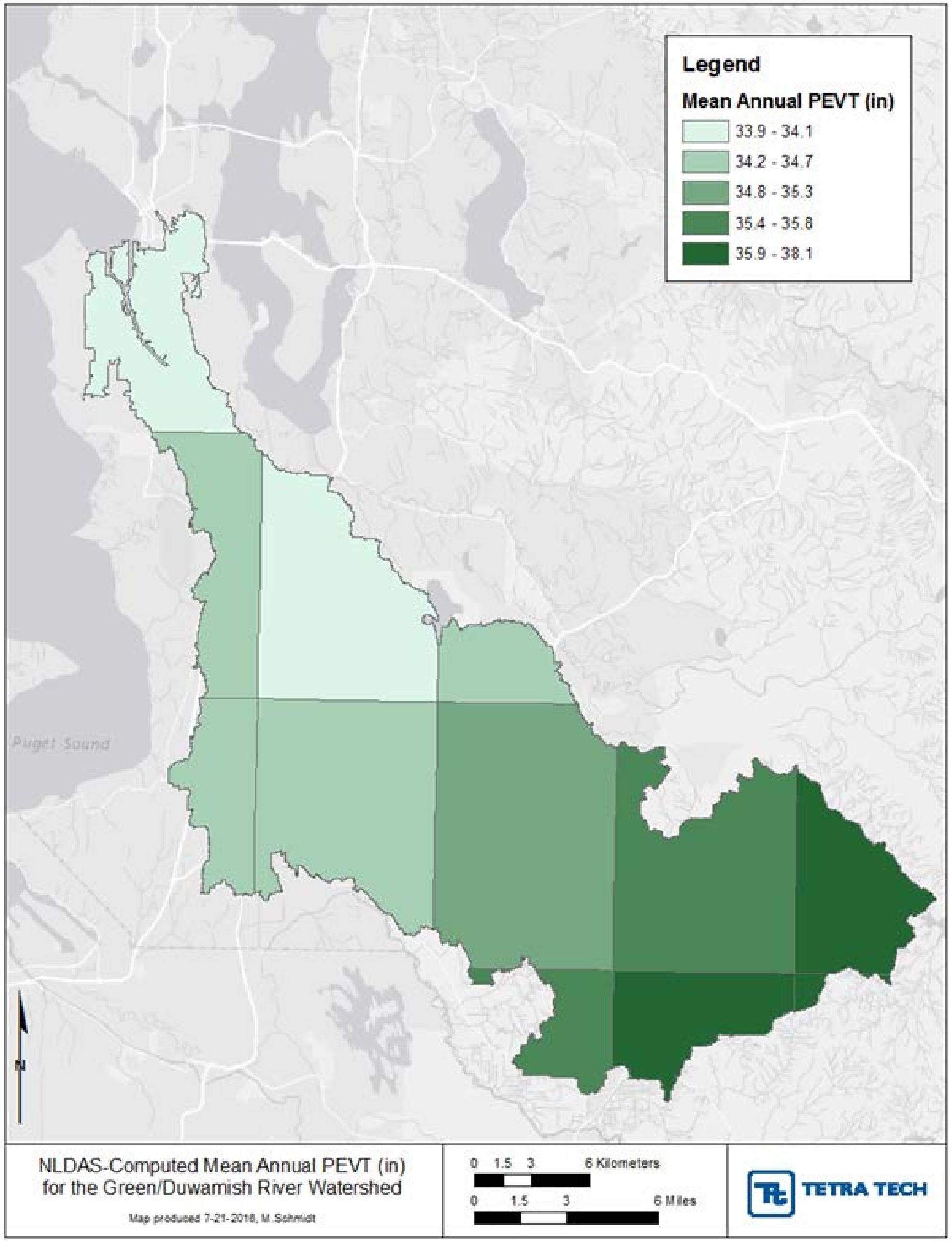


Potential Evapotranspiration (PEVT)

- Largest outgoing component of water balance
- HSPF used WSU Puyallup data (outside watershed)
  - Does not reflect spatial variability
  - Input as constant daily rate, not capturing diel patterns
  - Not matched to local rainfall pattern
- We recalculate Penman-Monteith energy balance reference PEVT (FAO 56) using variables available in NLDAS gridded coverage

PEVT Calculated from NLDAS

- Centered near Puyallup average (~35.7 in/yr), but has distinct spatial variability

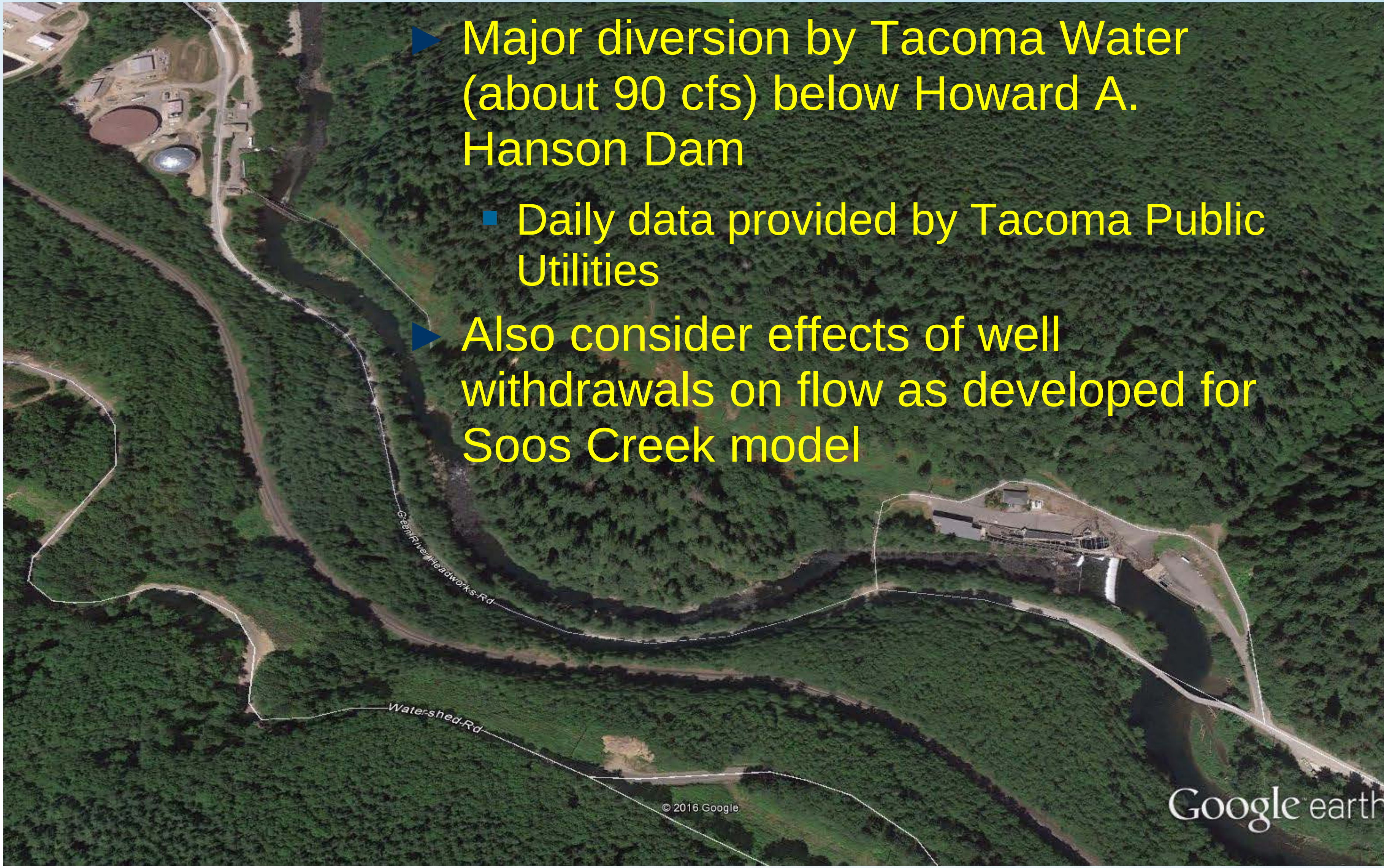


Boundary Conditions

- Upstream boundary: Gaged releases from Howard A. Hanson Dam
- Other minor boundaries follow HSPF methods
  - Lake Youngs piped outflow to Little Soos Creek
  - Groundwater routing from closed depressions (Deep Creek, Coal Creek, Horseshoe Lake) and Green River Natural Resource Area
  - External groundwater inflows and routing between subbasins as developed for Black River, Crisp Creek, and Soos Creek HSPF models

Water Appropriations

- Major diversion by Tacoma Water (about 90 cfs) below Howard A. Hanson Dam
  - Daily data provided by Tacoma Public Utilities
- Also consider effects of well withdrawals on flow as developed for Soos Creek model



Green/Duwamish River Watershed

Pollutant Loading Assessment: Current Status of LSPC Model for Hydrology

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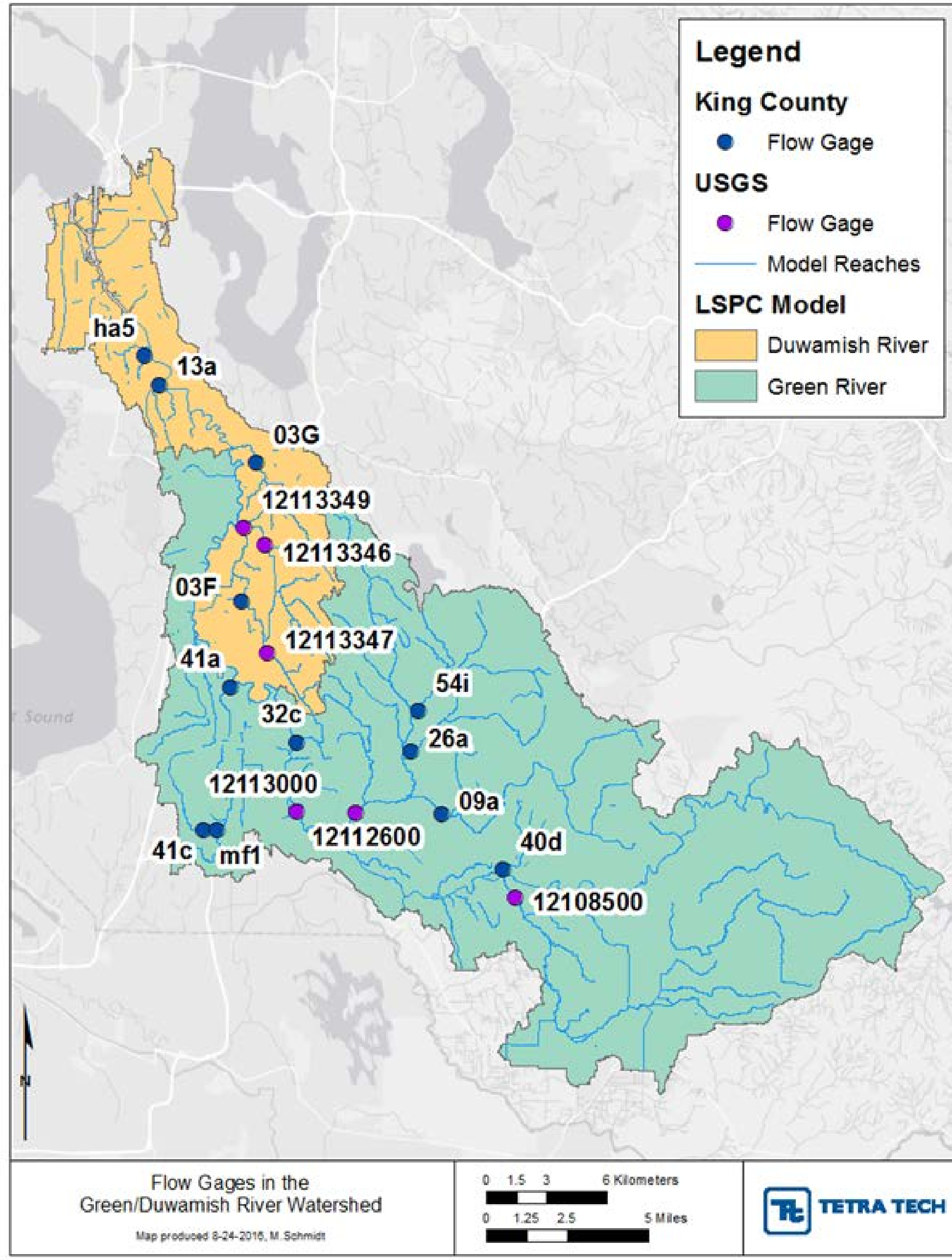
Flow Gaging

- 17 gages with 2+ years data in 1997-2015 period (excluding headwater boundary)
- Also use 32c on Olson Creek, although a bit less than 2 years available

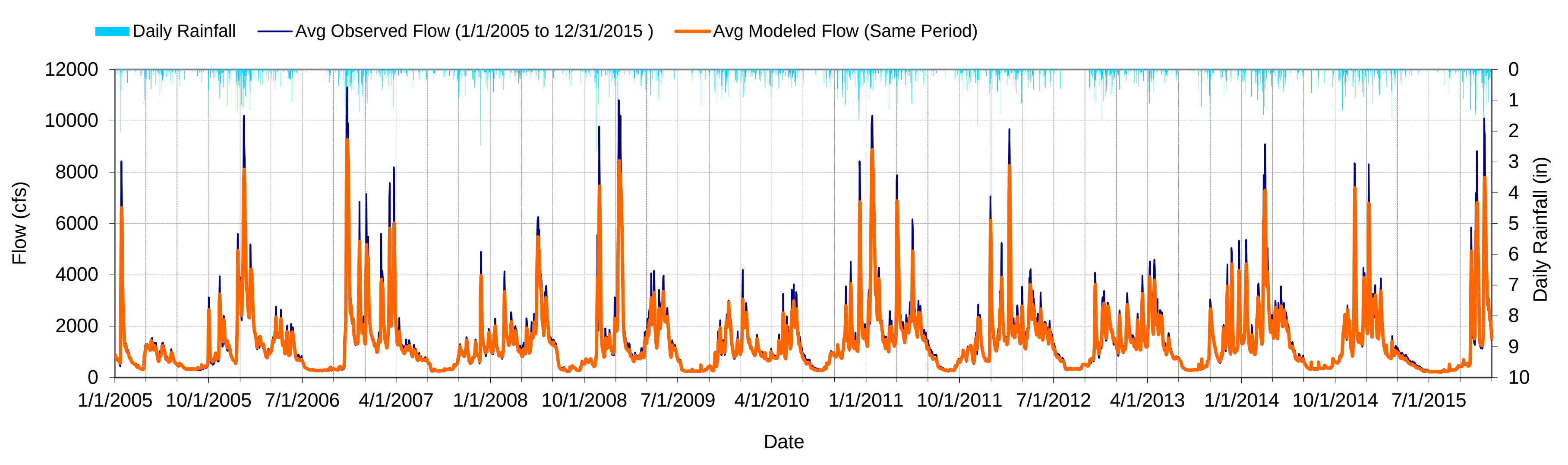


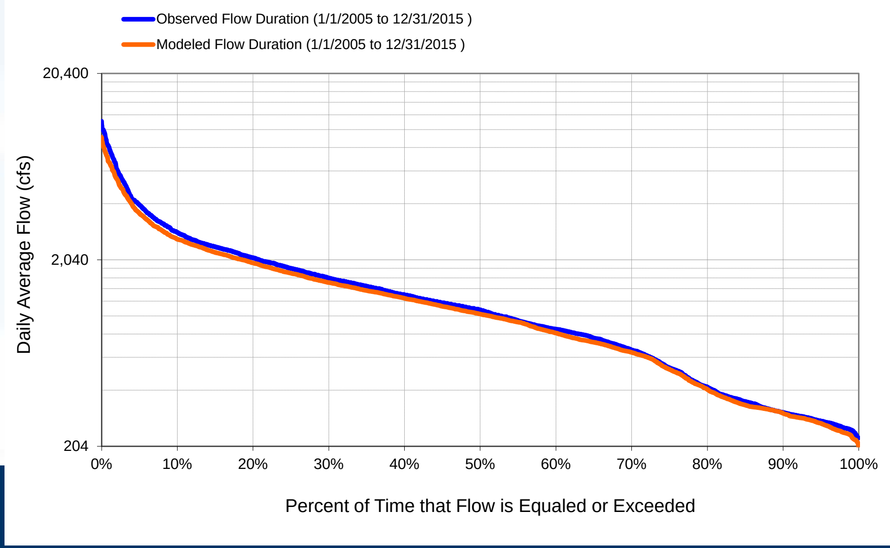
Uncalibrated Hydrology (first look)

- Use existing parameters imported from HSPF models
- Significant changes to model weather data, land use, and simulation period
- Unadjusted fit is already good at some stations; others will require calibration adjustments (e.g., Little Soos Creek, Mill Creek)
- Potential sources of discrepancies
  - Parameter values that compensated for uncertainty in weather data
  - Representation of stormwater BMPs and EIA (local SWMM models may help)
  - Uncertainty in representation of groundwater transfers
  - Uncertainty in gage rating curves

Overall System Flow is Good

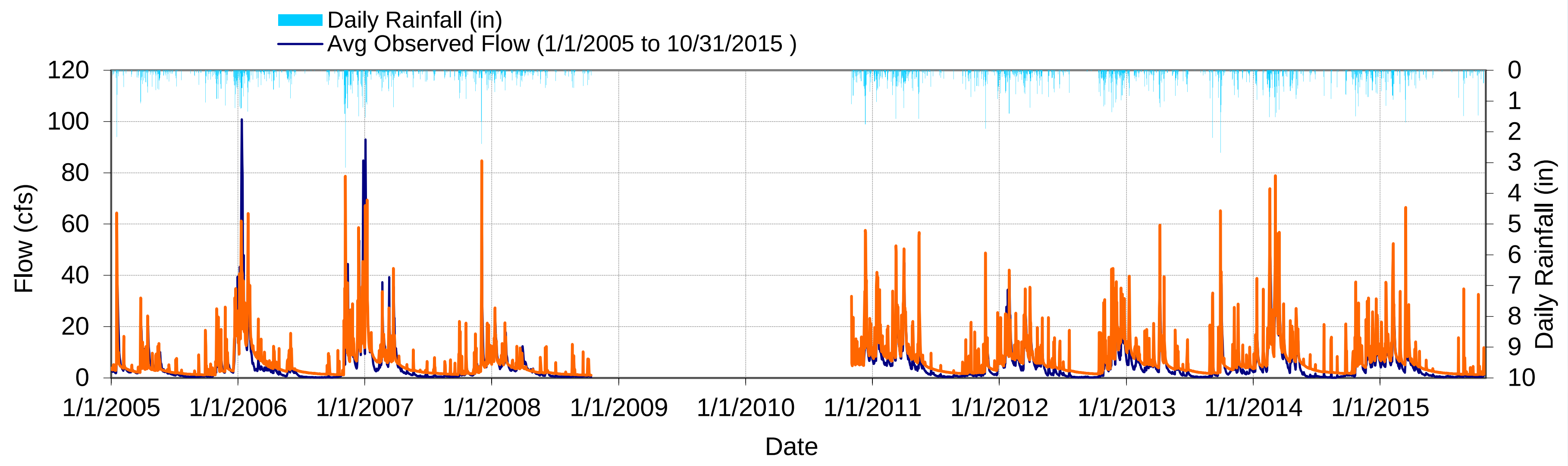
- Green River nr Auburn (USGS 12113000) has percent volume error of -7%, Daily Nash-Sutcliffe coefficient of model fit efficiency of 0.958.

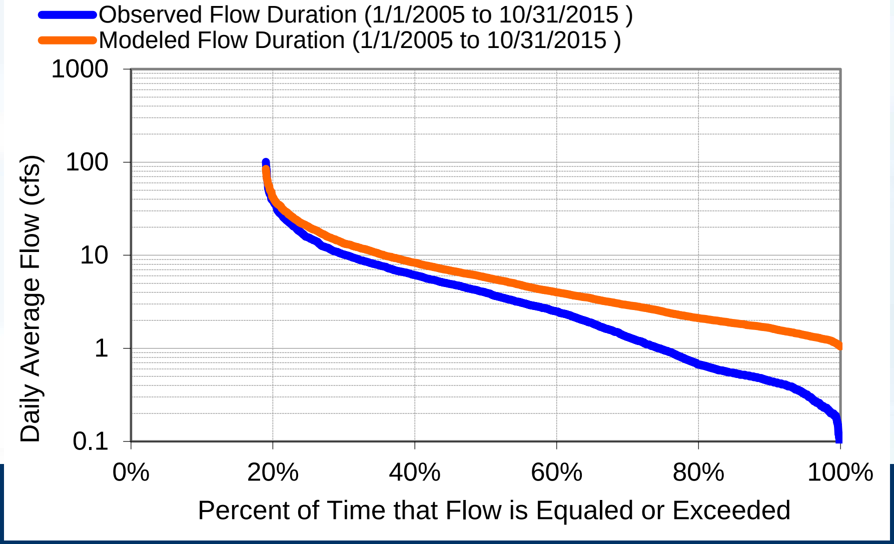




Additional work is needed elsewhere…

- Mill Creek at Peasley Canyon Rd (King Co. 41c) has percent volume error of +38%, Daily Nash-Sutcliffe coefficient of model fit efficiency of 0.460.





Data Gaps for Hydrology

- Stream profiles, cross-sections, and conveyance models
  - Improve hydraulic and sediment scour representation
  - Currently pursuing local stormwater models from MS4 cities
  - Other studies for unincorporated areas?
- Incorporating stormwater BMPs
  - Have significant SW BMPs been included in HSPF, what can be added?
  - HSPF approach was to adjust EIA as calibration step
    - We hope to avoid this through use of more detailed impervious area and stormwater BMP information
  - Municipal stormwater conveyance (SWMM) models should help clarify

Data Gaps for Hydrology (Continued)

- Some outstanding requests for well withdrawal records from utilities
- Need detailed information on rating curve development, adjustment, and reliability for King Co. stream gages
  - Potential refinement of volume-discharge relationships
  - Interpretation of discrepancies in fit
- Need to think about benefit vs. cost of pursuing details: Where will it matter for toxics simulation?
  - Low flow less important than high flow
  - Sediment transport processes in areas of contaminated stream sediments are of high interest
  - Runoff (and runoff controls) from concentrated source areas are of greatest importance to PLA

Summary of Data Requests from TAC

1. MS4s provide detailed stormwater conveyance models where available
   - Tt use to improve hydraulic tables
   - Tt consult with MS4s on extent of additional reductions in EIA associated with BMP installations
2. King Co.: provide information gage rating curve calibration
3. Water utilities: requested additional information on well withdrawals that are included in the HSPF models

Next Steps

- Finish watershed hydrology model
  - Additional data requests and TAC input
  - Initial calibration refinements and reporting
    - Review model status with Project Team
    - Adjustments to model based on comments/review
  - Final calibration adjustments
  - Model documentation report for review
  - Response to comments and final model report for hydrology

Questions and Discussion