Developing ICPRB's Potomac Watershed Model using Soil & Water Assessment Tool

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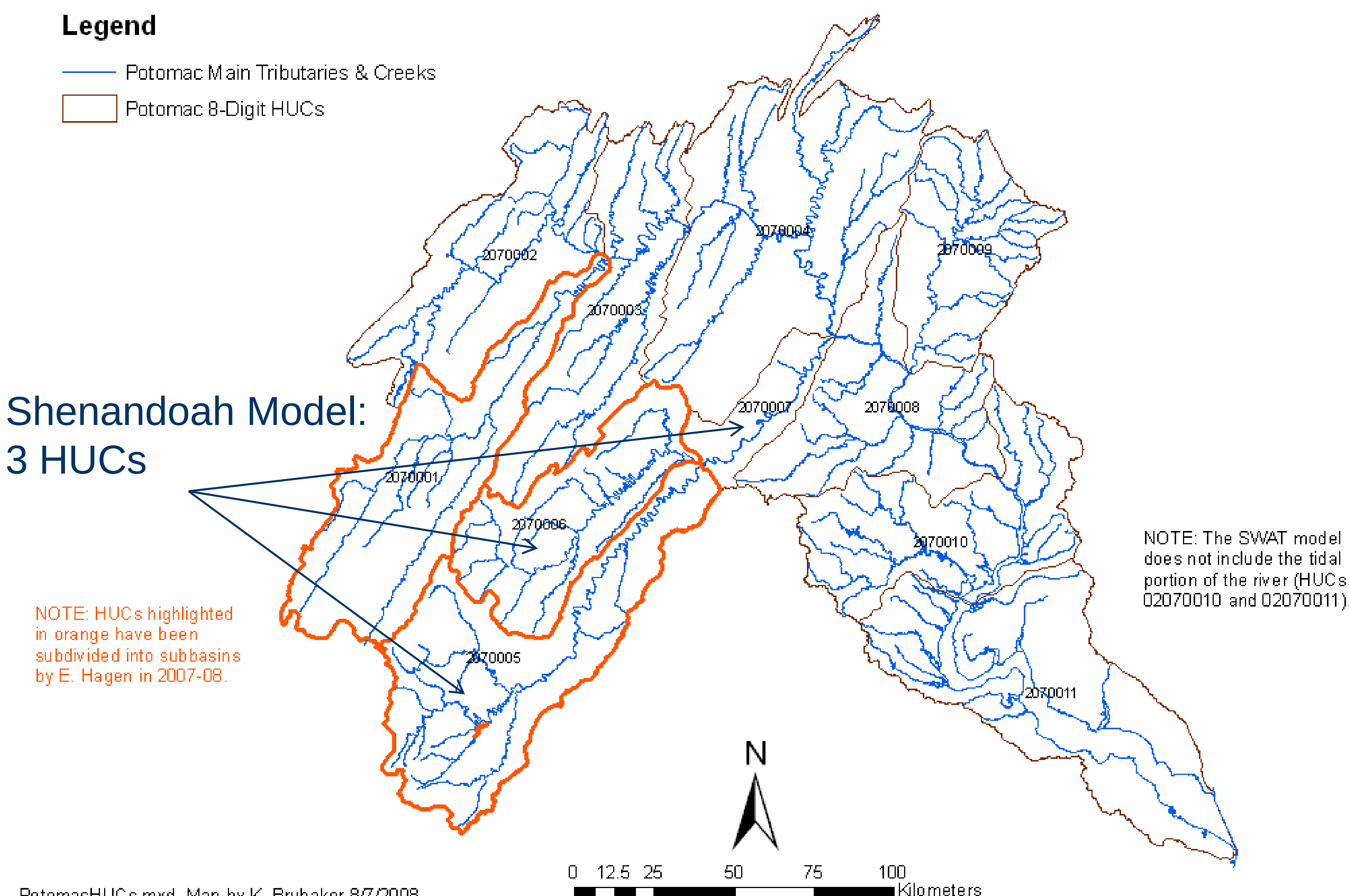
Why a Potomac Watershed Model?

- Understand the physical processes associated with variability in water supply
- Understand the effects of human activities on water supply
- Predict potential effects of future climatic and land use changes
- Allow more accurate assessments of
  - drought risk
  - need for resource development
  - Implications for management

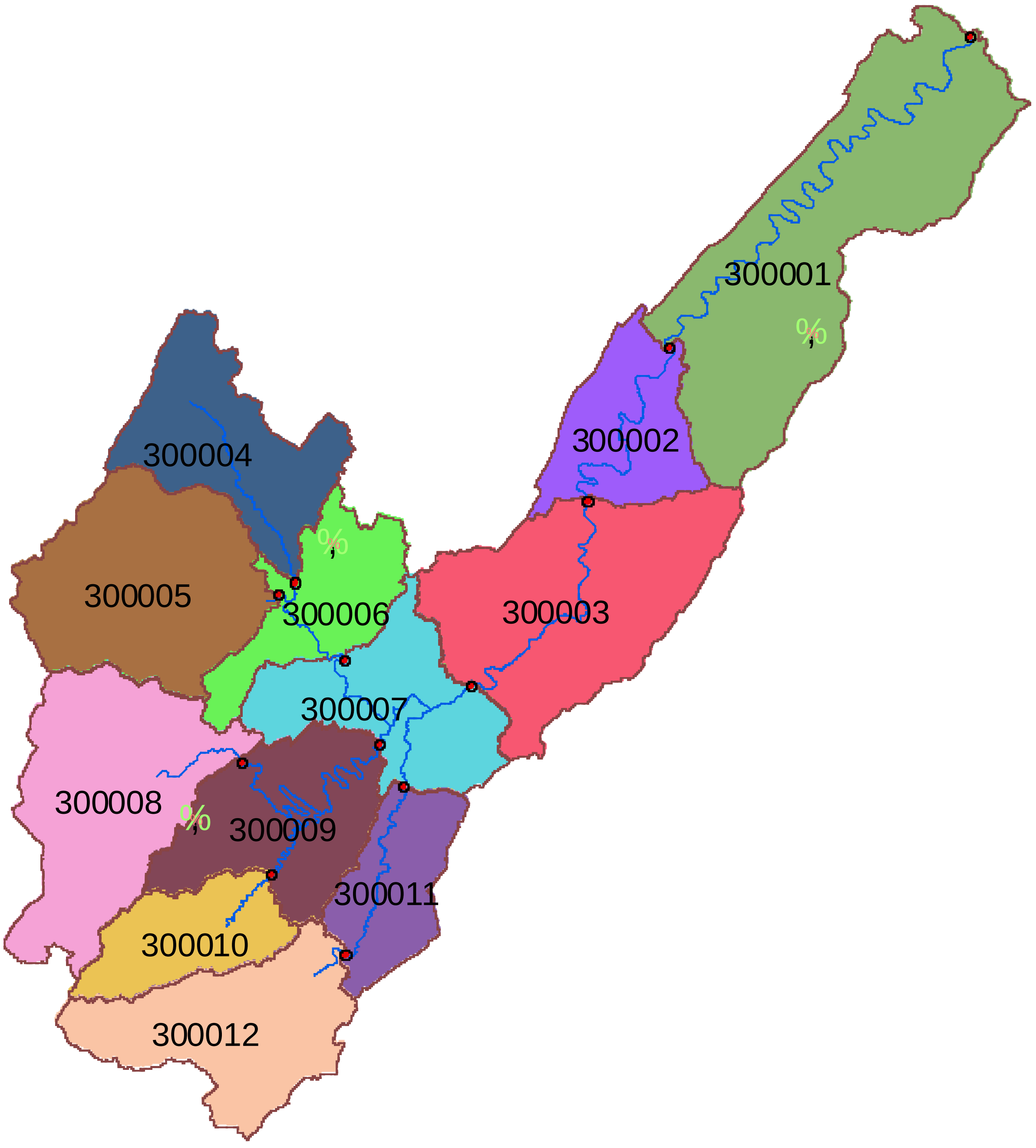
Why SWAT? (Soil & Water Assessment Tool)

- Ease of use, Portability
  - Free of charge (USDA Agricultural Research Service)
  - Model set-up – GIS interface (ArcSWAT)
  - Changes to land use easy to implement
  - Once built, model runs at “Command” prompt
- Longevity
  - Future investigators can learn the model and keep it updated
  - Modeling system has a long history & should be supported in the future
- Spatio-temporal formulation
  - Considers spatial pattern on the landscape
  - Can simulate long periods using continuous time

Potomac Watershed Subdivision by 8-digit HUC



PotomacHUCs.mxd Map by K. Brubaker 8/7/2008



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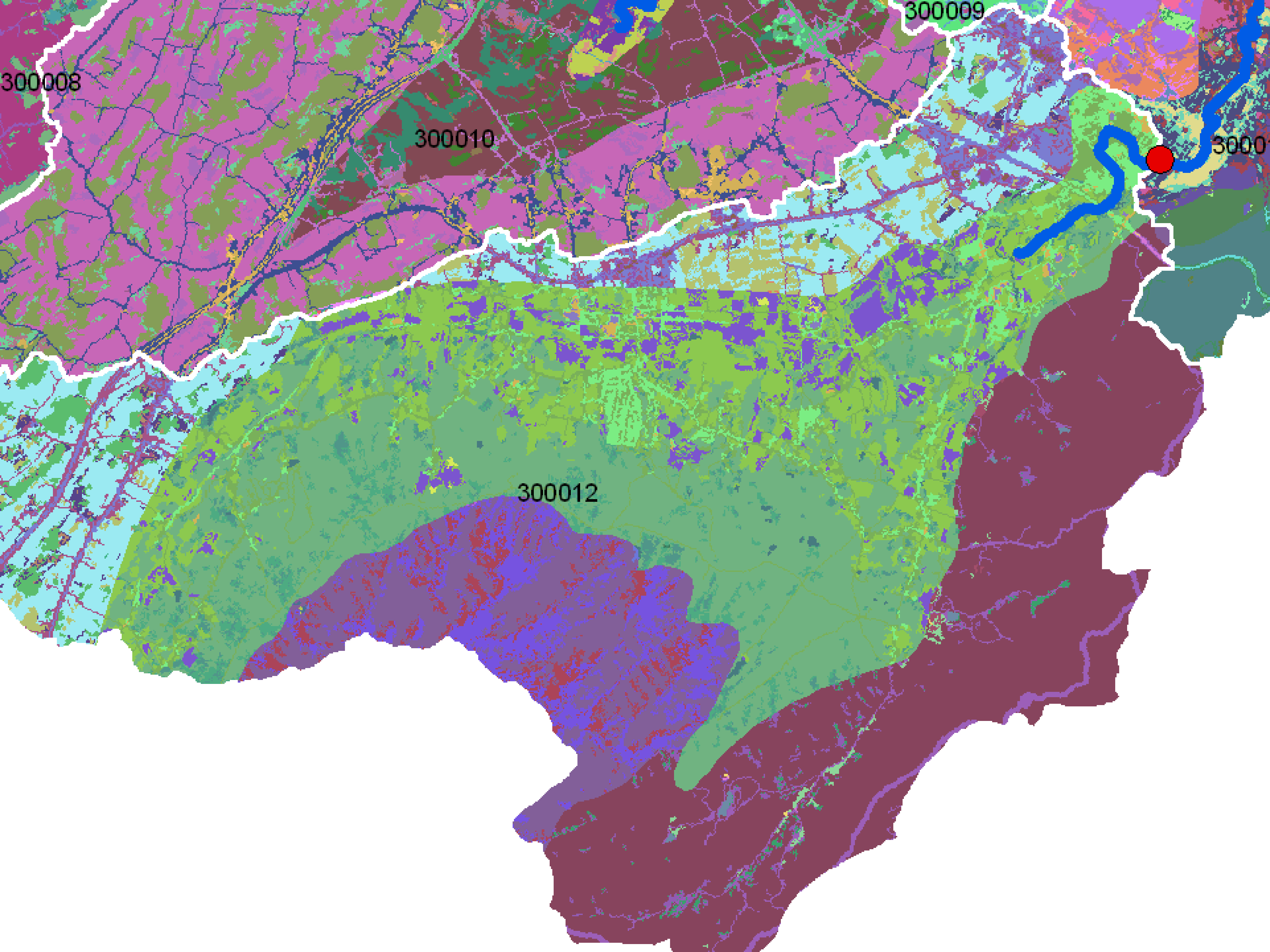
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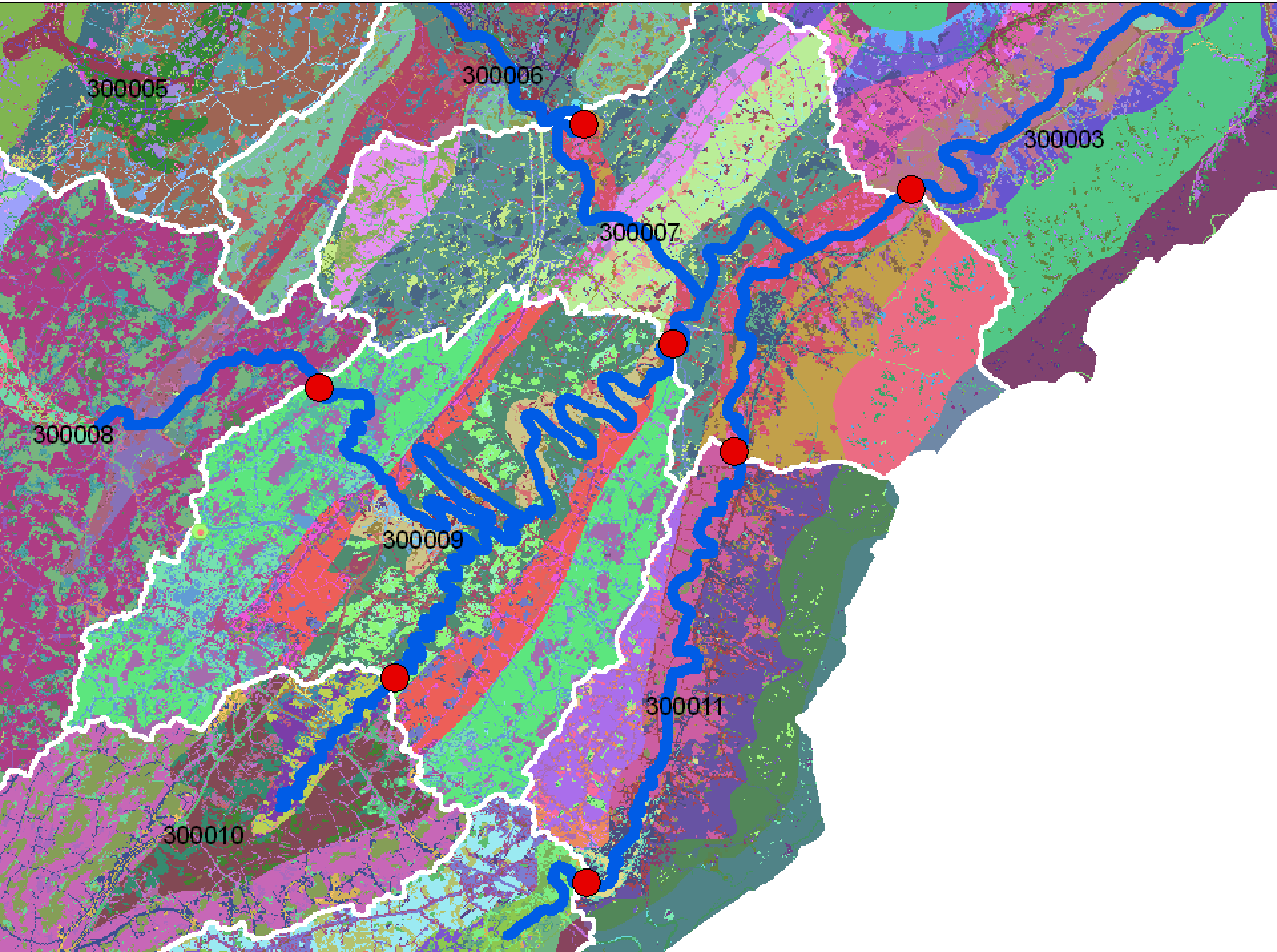
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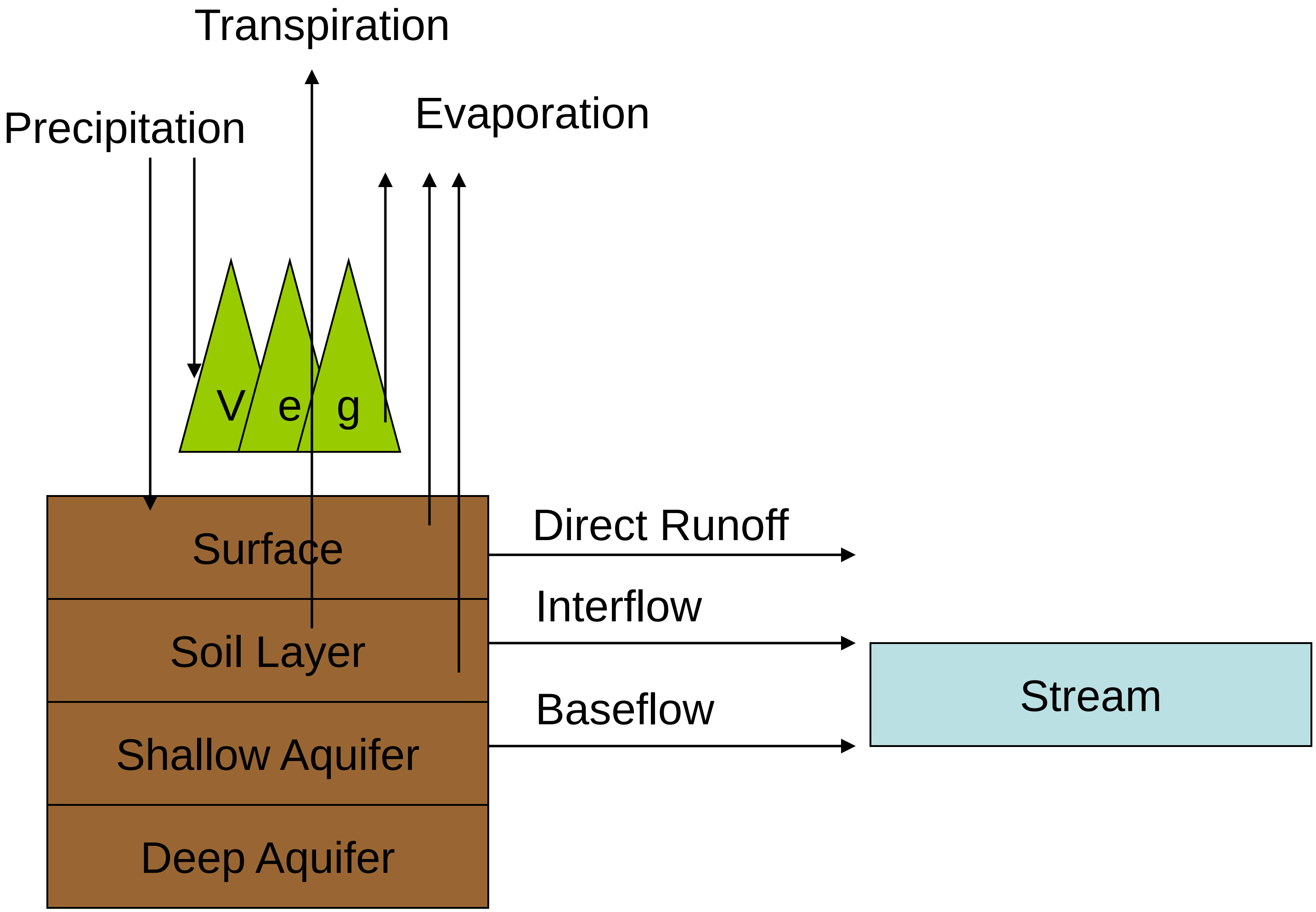

Transpiration
Precipitation
Evaporation
V e g
Surface
Direct Runoff
Interflow
Soil Layer
Baseflow
Stream
Shallow Aquifer
Deep Aquifer

```
ptf #
 .gw file Subbasin:12 HRU:5 Luse:FRSD Soil: VA005 Slope: 0-10 12/21/2007 12:00:00 AM
      1000.0000    | SHALLST : Initial depth of water in the shallow aquifer [mm]
      1000.0000    | DEEPST : Initial depth of water in the deep aquifer [mm]
      #gdva005#    | GW_DELAY : Groundwater delay [days]
       #ava005#    | ALPHA_BF : BAseflow alpha factor [days]
      1000.0000    | GWQMN : Threshold depth of water in the shallow aquifer requir
      #rvva005#    | GW_REVAP : Groundwater "revap" coefficient
      #revapmn#    | REVAPMN: Threshold depth of water in the shallow aquifer for "
         0.0000    | RCHRG_DP : Deep aquifer percolation fraction
         1.0000    | GWHT : Initial groundwater height [m]
         0.0030    | GW_SPYLD : Specific yield of the shallow aquifer [m3/m3]
         0.0000    | SHALLST_N : Initial concentration of nitrate in shallow aquife
         0.0000    | GWSOLP : Concentration of soluble phosphorus in groundwater co
         0.0000    | HLIFE_NGW : Half-life of nitrate in the shallow aquifer [days]
       #bva005#    | B_BF: Baseflow "b" exponent
```

```
ptf #
 .mgt file Subbasin:12 HRU:5 Luse:FRSD Soil: VA005 Slope: 0-10 11/30/2007 12:00:00 AM ARCG
               0    | NMGT:Management code
Initial Plant Growth Parameters
               0    | IGRO: Land cover status: 0-none growing; 1-growing
               0    | PLANT_ID: Land cover ID number (IGRO = 1)
            0.00    | LAI_INIT: Initial leaf are index (IGRO = 1)
            0.00    | BIO_INIT: Initial biomass (kg/ha) (IGRO = 1)
            0.00    | PHU_PLT: Number of heat units to bring plant to maturity (IGRO = 1)
General Management Parameters
            0.20    | BIOMIX: Biological mixing efficiency
           72.00    | CN2: Initial SCS CN II value
            1.00    | USLE_P: USLE support practice factor
            0.00    | BIO_MIN: Minimum biomass for grazing (kg/ha)
           0.000    | FILTERW: width of edge of field filter strip (m)
Urban Management Parameters
               0    | IURBAN: urban simulation code, 0-none, 1-USGS, 2-buildup/washoff
               0    | URBLU: urban land type
Irrigation Management Parameters
               0    | IRRSC: irrigation code
               0    | IRRNO: irrigation source location
           0.000    | FLOWMIN: min in-stream flow for irr diversions (m^3/s)
           0.000    | DIVMAX: max irrigation diversion from reach (+mm/-10^4m^3)
           0.000    | FLOWFR: : fraction of flow allowed to be pulled for irr
Tile Drain Management Parameters
           0.000    | DDRAIN: depth to subsurface tile drain (mm)
           0.000    | TDRAIN: time to drain soil to field capacity (hr)
           0.000    | GDRAIN: drain tile lag time (hr)
Management Operations:
               1    | NROT: number of years of rotation
Operation Schedule:
          0.150  1    7          3600.00000   0.00     0.00000 0.00     0.00 #c5d#
          0.200  6  108            #c5g#
          1.200  5                 #c5d#
                 0
```

Linear Reservoir Model

$$S = KQ$$

Where

S = Storage

Q = Discharge (volume/day)

K = Recession coefficient (days)

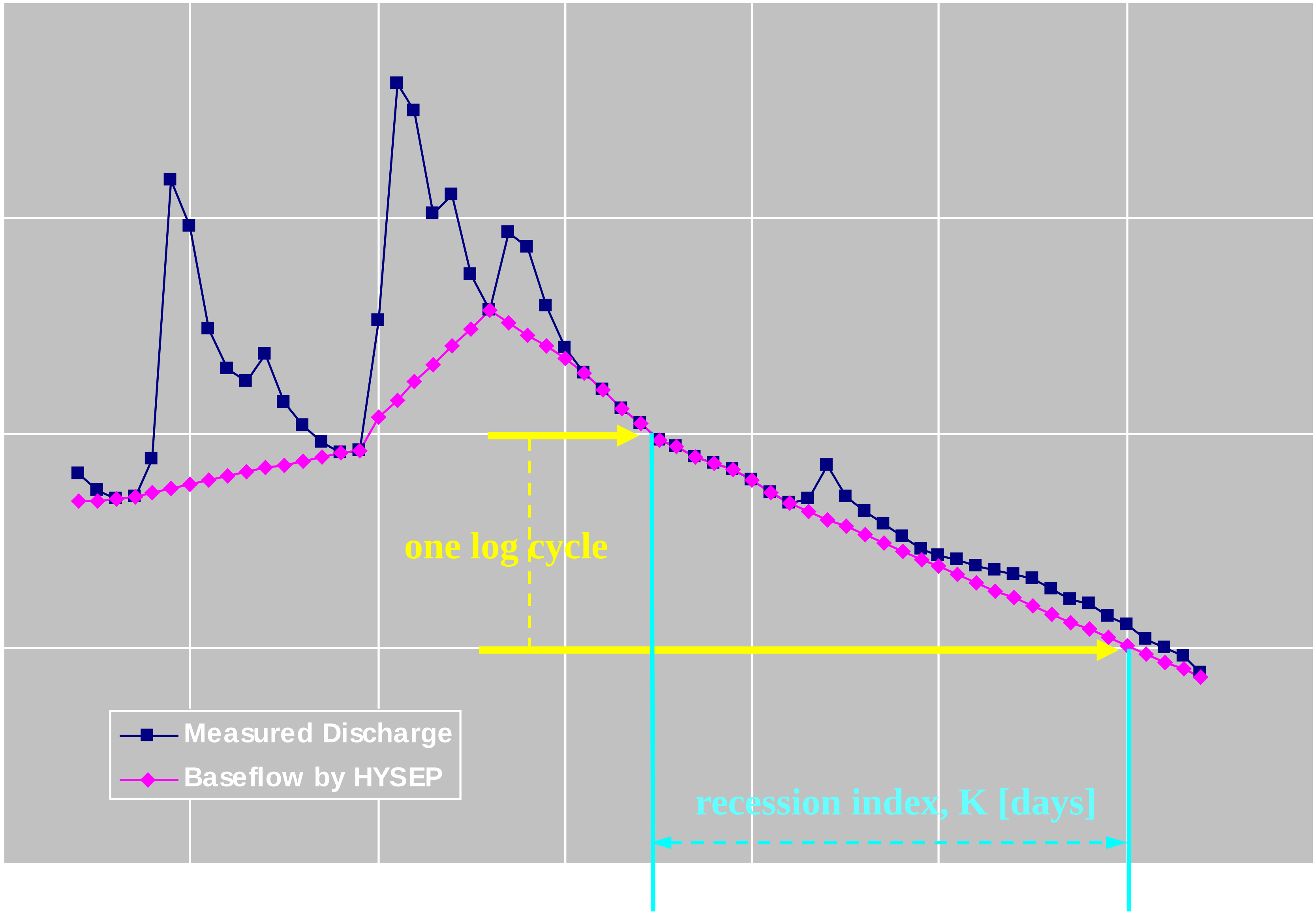
Note that, for pure recession,

$$\frac{dS}{dt} = -Q = -\frac{1}{K}S$$

This has the solution

$$S(t) = S_0 \exp(-\frac{1}{K}t)$$

Which plots as a straight line on a semi-log graph



one log cycle
Measured Discharge
Baseflow by HYSEP
recession index, K [days]

Advantages of Linear Model

- Reasonable physical concept – outflow is greatest when reservoir is full
- Closed-form solution
- A parameter with dimension of time – easy to understand

But is it realistic for GW flow?

- Observations indicate that real baseflow aquifers (e.g., in the Shenandoah Valley) don't behave as we would like!
- Can show with physical arguments (Wittenberg 1999) that, with typical assumptions for unconfined aquifers, a better assumption would be

$$Q \propto S^2$$

$$S = aQ^{1/2}$$

Wittenberg (1999) Model

- Analyzed rivers in Germany and found a more general result

$$S = aQ^{b}$$

Found values of *b* between 0 and 1.1, with a mean value of 0.49.

(Set b = 1 to get the linear model.)

Incorporation into SWAT

- Wrote new groundwater module for SWAT
- Calculates groundwater flow as an explicit function of state variable for GW storage

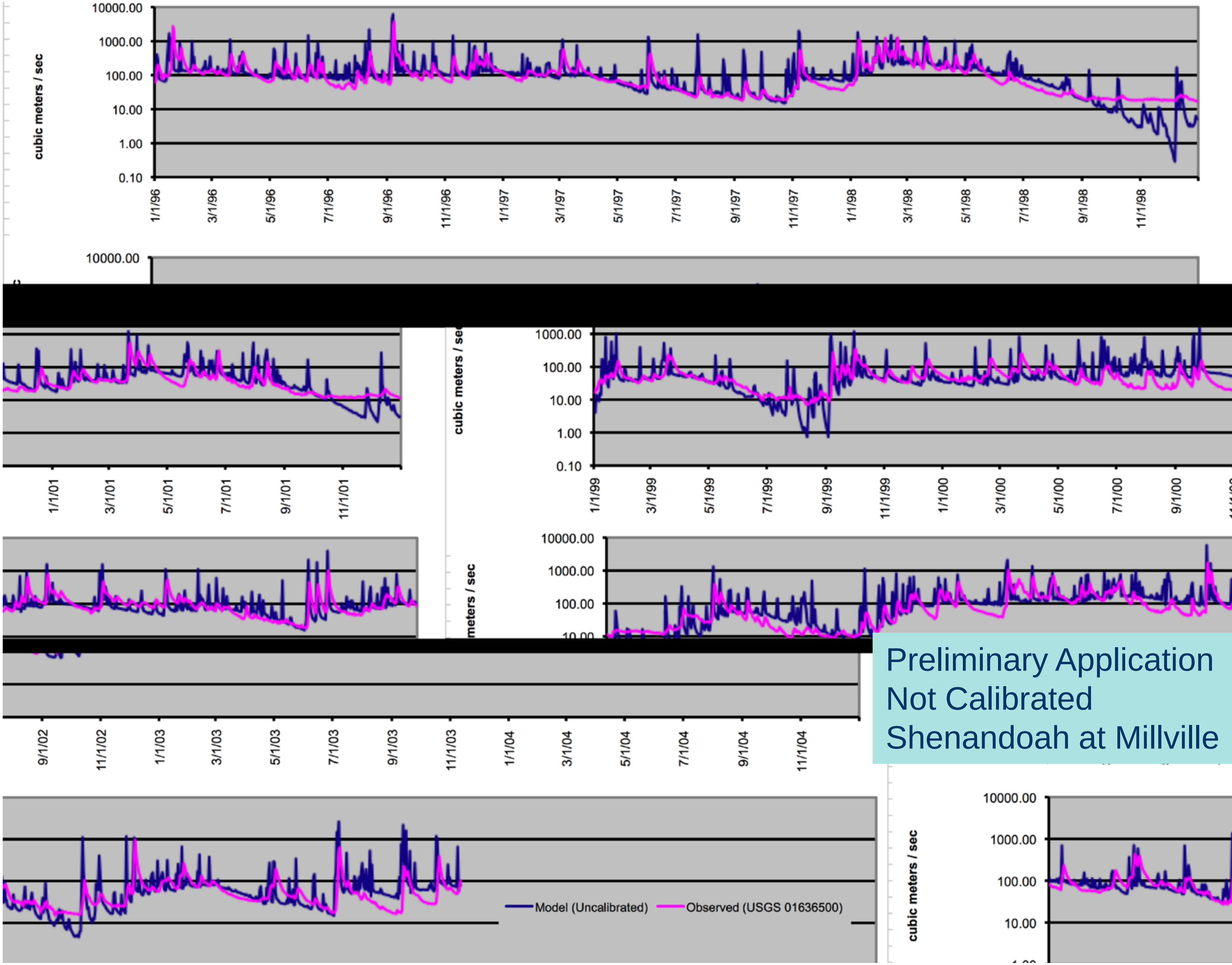
$$Q_{bf} = \left(\frac{S - S_{\min}}{a} \right)^{1/b}$$

where

S is shallow aquifer storage [L]
$S_{\min}$ is the minimum storage for GW flow [L]
a is a scale parameter [weird dimensions]
b is a coefficient [dimensionless]

Shenandoah Model

- 3 HUCs
- 28 Subbasins
- 489 HRUs



Preliminary Application
Not Calibrated
Shenandoah at Millville

Calibration Principles

- physical fidelity
- parsimony
- sensitivity, and
- repeatability.

Parameters for Calibration

In HRU files	ESCO	Adjustment factor for evaporation from soil	Vary by soil type
	EPCO	Adjustment factor for plant uptake of water by evapotranspiration	two values – crop and forest
	SLSOIL	Subsurface flow length (interflow)	Vary by soil type
	CANMX	Maximum canopy interception	two values – crop and forest
In GW files	GW_DELAY	Time lag for appearance of groundwater flow in stream	Assigned on the basis of parent geology as inferred from soil type
	ALPHA_BF	Coefficient in groundwater recession	
	BETA_BF	Exponent in groundwater recession	
In BASINS file	SURLAG		Applies to entire model domain
In SUB files	CH_N1	Manning's “n” for the tributary channels	Vary by dominant geology of subbasin
In RTE files	CH_N2	Manning's “n” for the main channel	Vary by geology corresponding to main channel

Calibration: Soil-Rock Associations

Soil Name	Soil ID(s) in Shenandoah Model	Parent rock*	Parameter code for ESCO and SLSOIL	Parameter code for ALPHA_BF and Beta_BF
BERKS	VA066	shale, siltstone and fine grained sandstone	_va066	_sss
CARBO	VA002	limestone bedrock	_va002	_lim
EDGEMONT	WV114	quartzitic rocks	_wv114	_qua
FREDERICK	VA003	dolomitic limestone with interbeds of sandstone, siltstone, and shale	_va003	_lss
HAGERSTOWN	VA069, WV010	hard gray limestone	_va069	_lim
LAIDIG	VA016	colluvium from sandstone, siltstone, and some shale… benches and foot slopes	_va016	_col
LILY	VA005, WV119	sandstone	_va005	_san
MOOMAW	VA004	alluvium derived from acid sandstone, quartzites, and shales	_va004	_col
MYERSVILLE	VA006	basic crystalline rocks, including greenstone	_va006	_cry
WEIKERT	VA001	interbedded gray and brown acid shale, siltstone, and fine-grained sandstone	_va001	_sss