Seasonal Water Budget Approach for Assessing Ground Water Availability

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Objective

Evaluate whether a seasonal water budget (SWB) can provide a reliable basis for assessment of ground water availability in the fractured bedrock aquifers of the Potomac River basin

- –Assessments of availability via ground water modeling can be prohibitively expensive on large scale
- –Annual water budgets (annual recharge ~ annual baseflow) neglect seasonality and storage
- –Seasonal water budgets are viewed as difficult to compute/unreliable (?)

Approach

- **Compute 42-year time series of SWB components (1960 – 2002)**
- **Use storage estimates from streamflow recession analyses to obtain seasonal recharge estimates**
  - Use of method has long history (Meyboom 1961; Bevans 1986; Rutledge and Daniels 1994 …)
  - Compare results with RORA and with well data
- **Construct indicator of summer availability:**
  - V_{Q3} = beginning-of-summer storage + summer recharge
  - Plot frequency curves to estimate dry year availability

Study Area:
Monocacy River and Catoctin Creek Drainages

Four Gaged Sub-basins

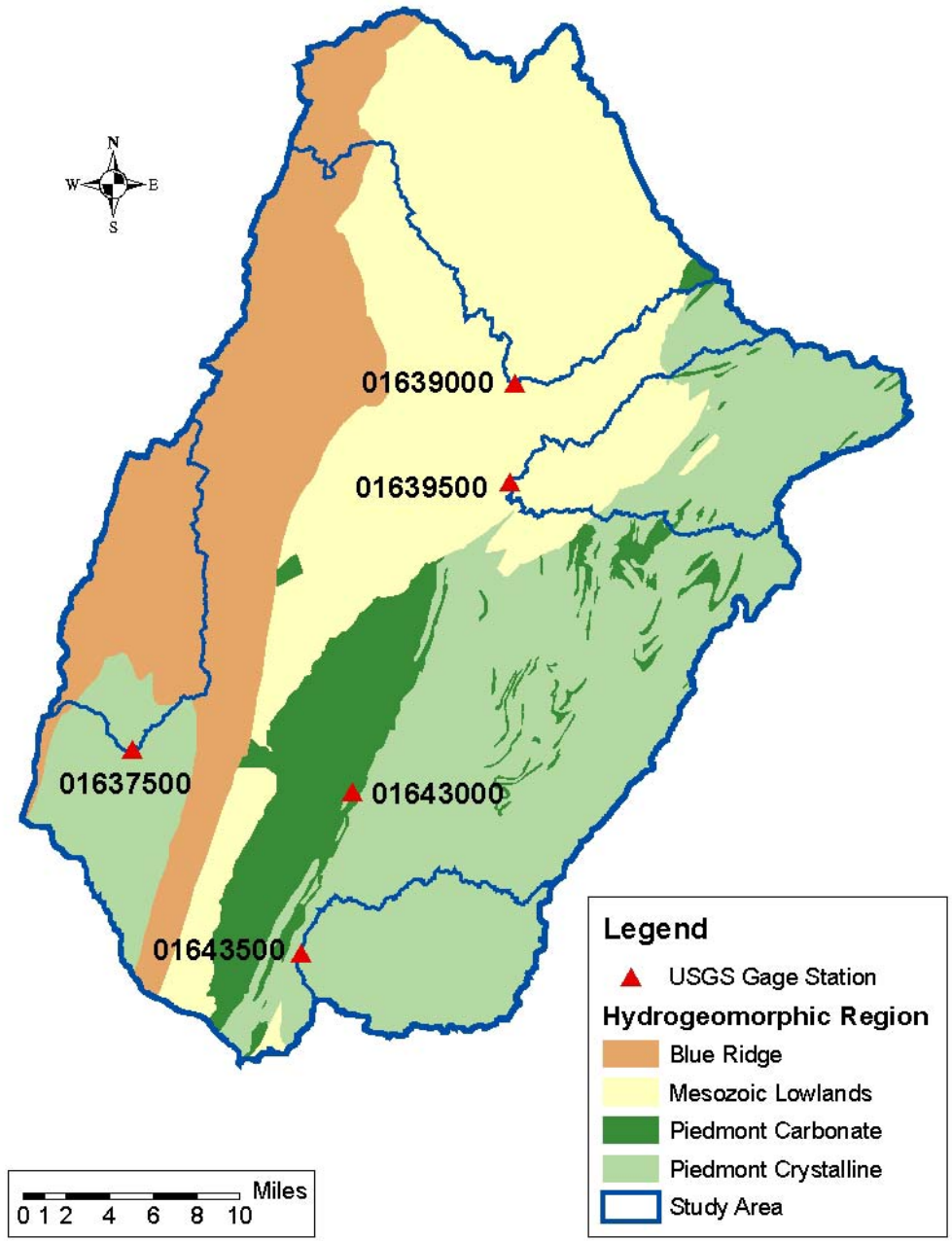
– (periods of record from 1960 – 2002)

Catoctin Cr: 01637500

Upper Monocacy: 01639000

Big Pipe Cr: 01639500

Bennett Cr: 01643500



Seasonal Water Budget for Sub-basin Aquifers

$$\Delta S_i = S_{i+1} - S_i = \text{inflows} - \text{outflows}$$

$$= R_i - (q_{BF\,i} + RET_i + W_i)$$

$$= R_{Net\,i} - (q_{BF\,i} + W_i)$$

ΔS_i	=	change in aquifer storage in time interval, $\Delta t = t_{i+1} - t_i$
S_i	=	volume stored in aquifer at time t_i
R_i	=	ground water recharge
$R_{Net\,i}$	=	net recharge, $R_i - RET_i$
$q_{BF\,i}$	=	aquifer discharge to stream base flow
RET_i	=	riparian evapotranspiration
W_i	=	ground water withdrawals

Storage and Recharge Estimates

Water budget equation can be solved for net recharge:

$$R_{Net\ i} = \Delta S_i + (q_{BF\ i} + W_i)$$

Aquifer storage estimate from base flow recession analyses:

$$S_i = (q_{0,\ i}\ K) / \ln 10$$

where

$q_{0,\ i}$ = initial (beginning-of-quarter baseflow) value

K = recession index

Storage estimate is based on simple approximation for baseflow recession:

$$q(t) \sim q_0 \, e^{-k(t - t0)}$$

where q(t) = stream discharge = baseflow, during period of recession

$$\Rightarrow \quad S = q_0 \, K / \ln 10$$

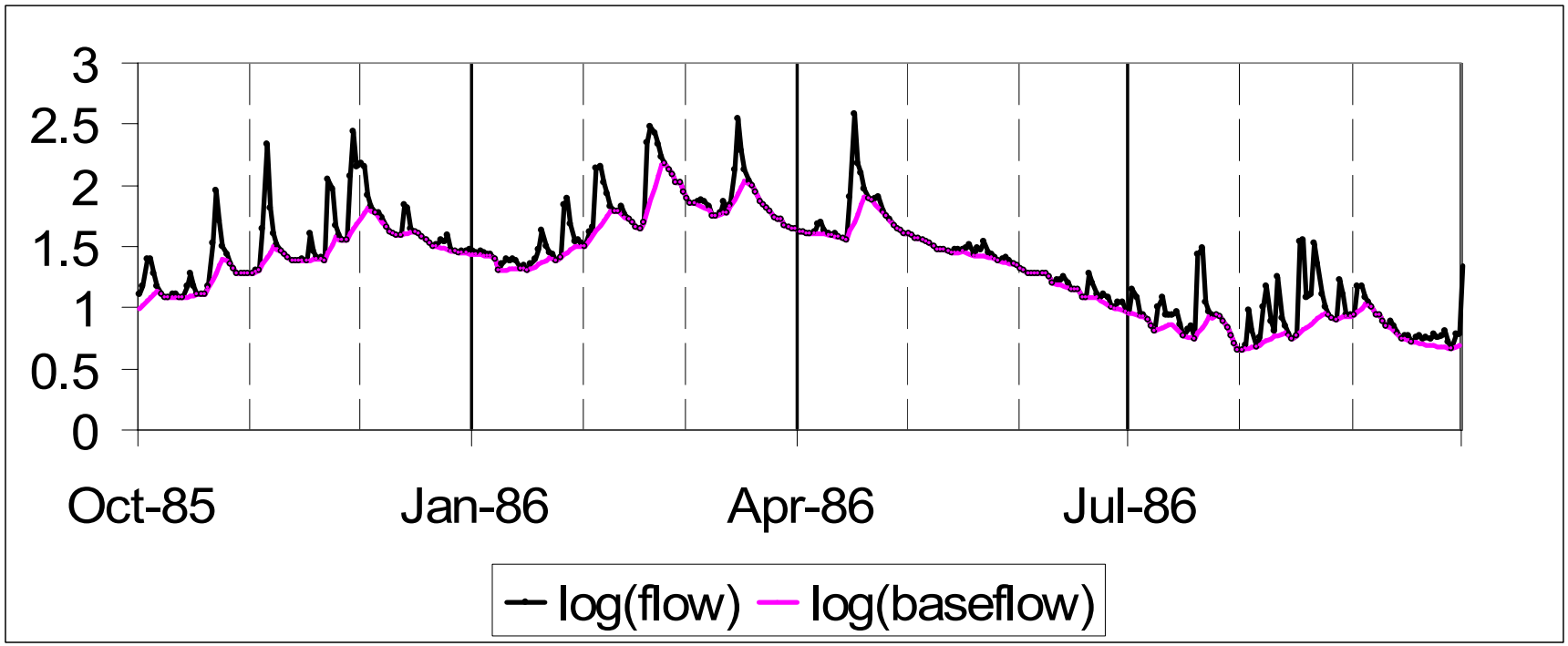
S = volume stored in aquifer above zero-flow level

q_0 = baseflow at initial time

K = recession index (days) = ln 10/k

Estimates of "Beginning of Quarter" Baseflow Values

$q_{0,i}$ estimated from 60-day means of log (daily baseflows):



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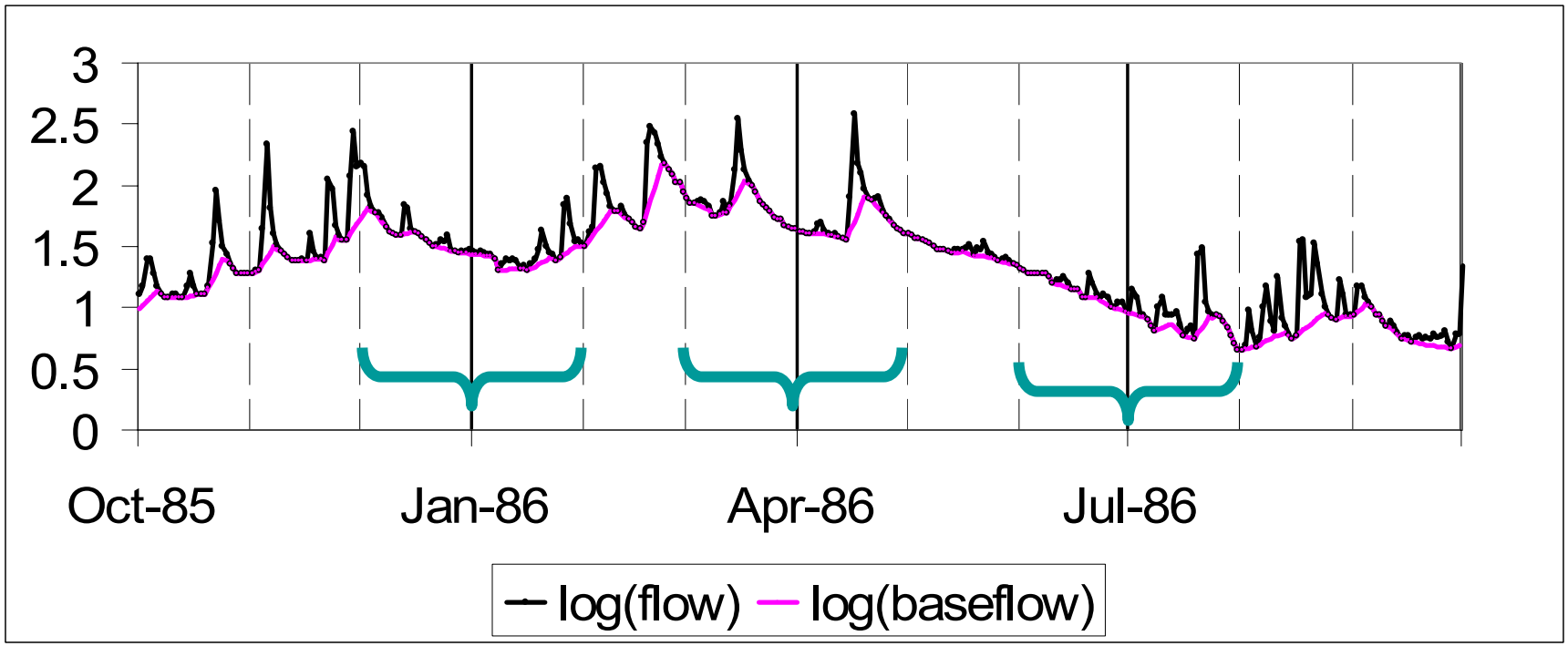


Recession Index Results

(for Oct-Mar, using USGS program, RECESS)

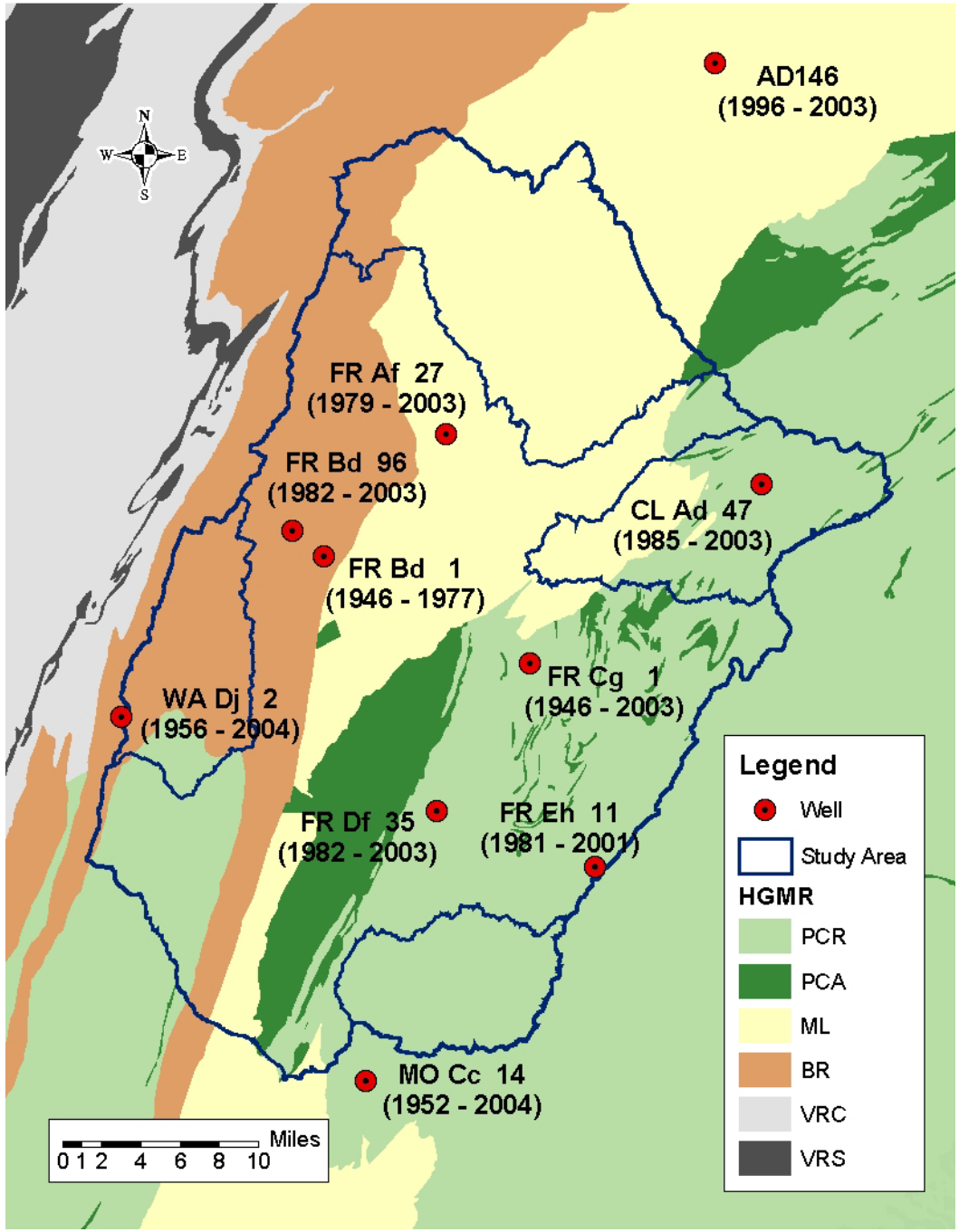
Recession Index, K (days)

	Bennett Creek	Big Pipe Creek	Upper Monocacy	Catoctin Creek
Count	16	14	16	30
90th Percentile	128	104	45	111
75th Percentile	105	94	37	59
Median	80	71	33	45
25th Percentile	57	66	32	35
10th Percentile	56	64	26	31

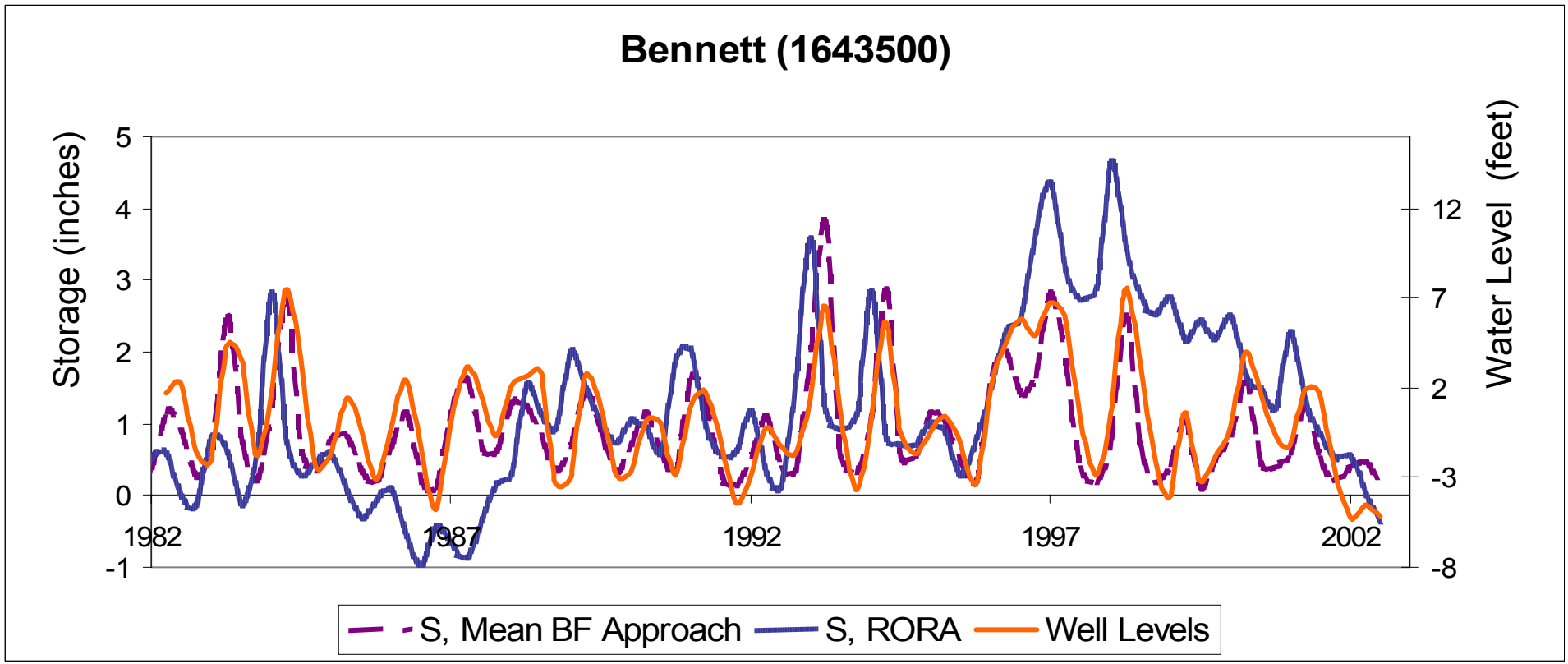
Comparisons of Predicted Storages, S_i, with Other Results

- **RORA: alternative storage-based approach (USGS automated program)**
- **Monocacy/Catoctin well data**
  - Wells were identified with > 3 years of continuous periods of record with ~ monthly observations
  - Well data was temporally smoothed: took 3 month means, centered around beginning of quarters
  - Well data was spatially smoothed: took means of available wells within or near sub-basin of interest
  - Average well levels were plotted for time period in which periods of record overlapped

Wells Used for Comparisons



S_i Comparisons



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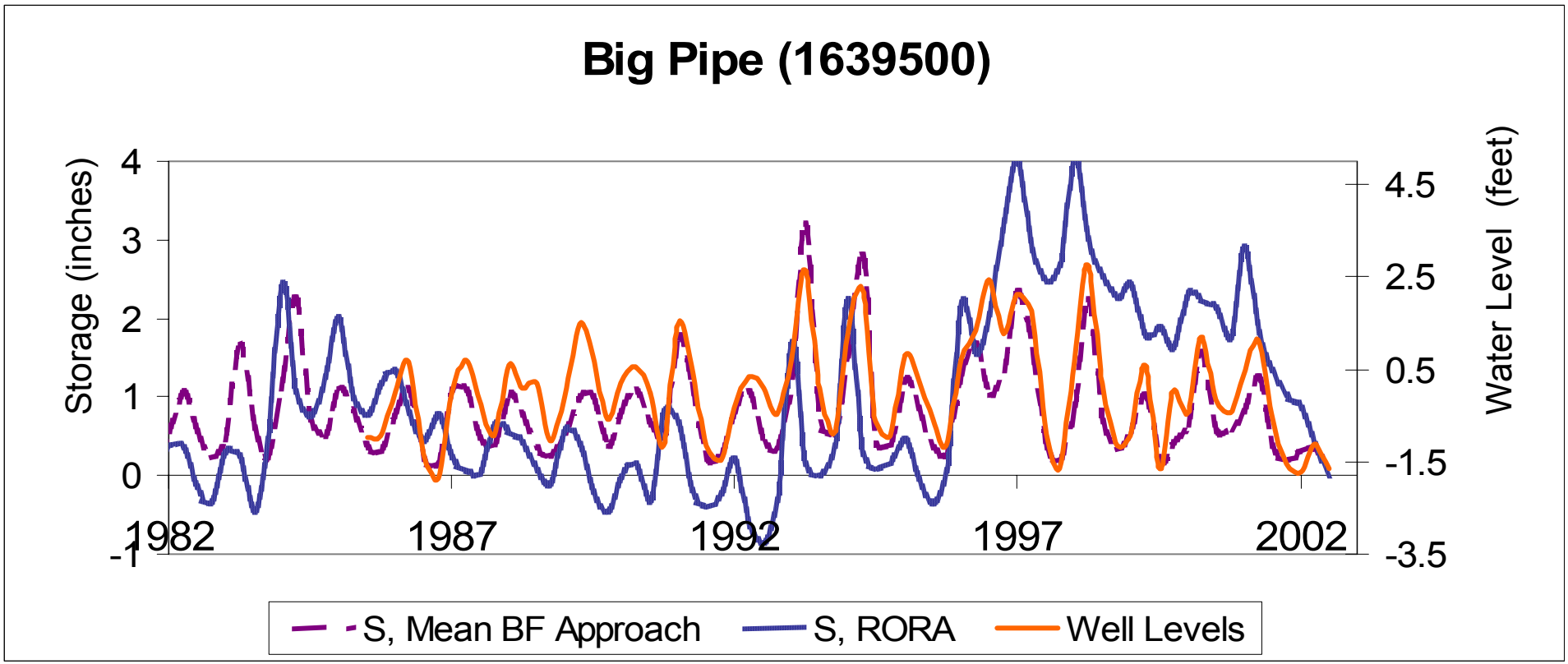

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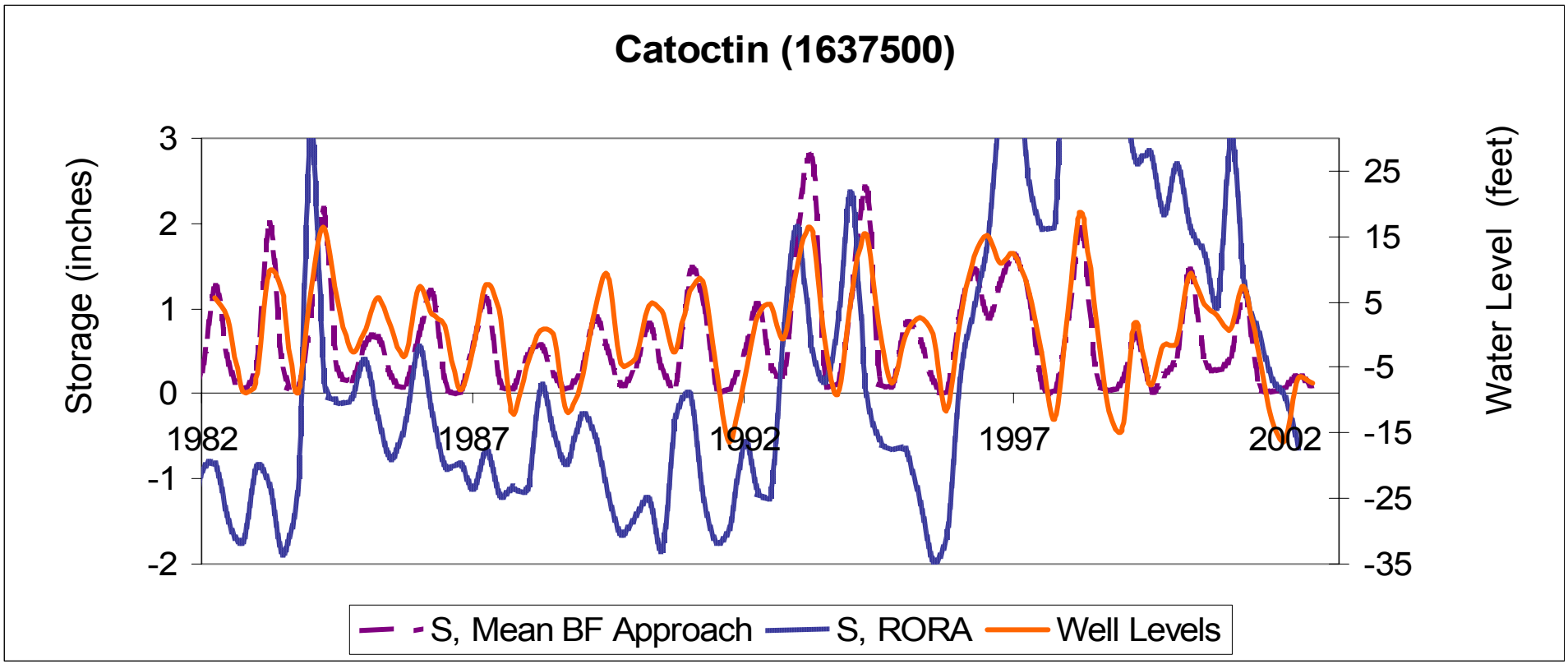

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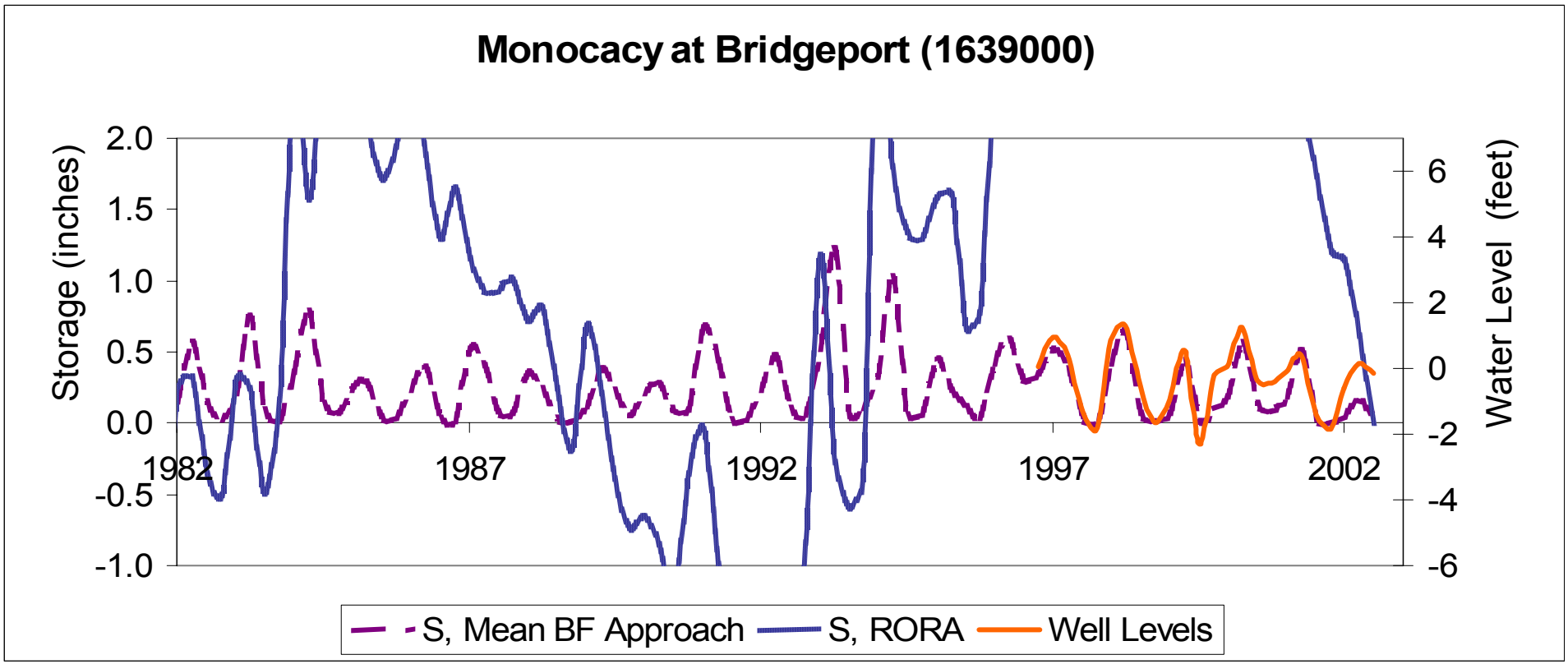


Summer Water Availability

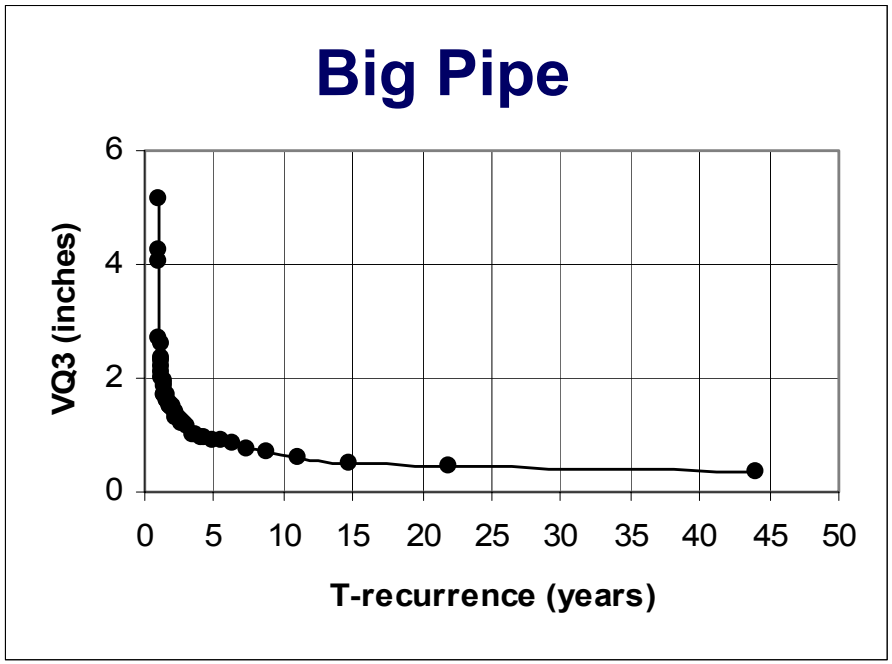
(using SWB time series from mean BF storage-based approach)

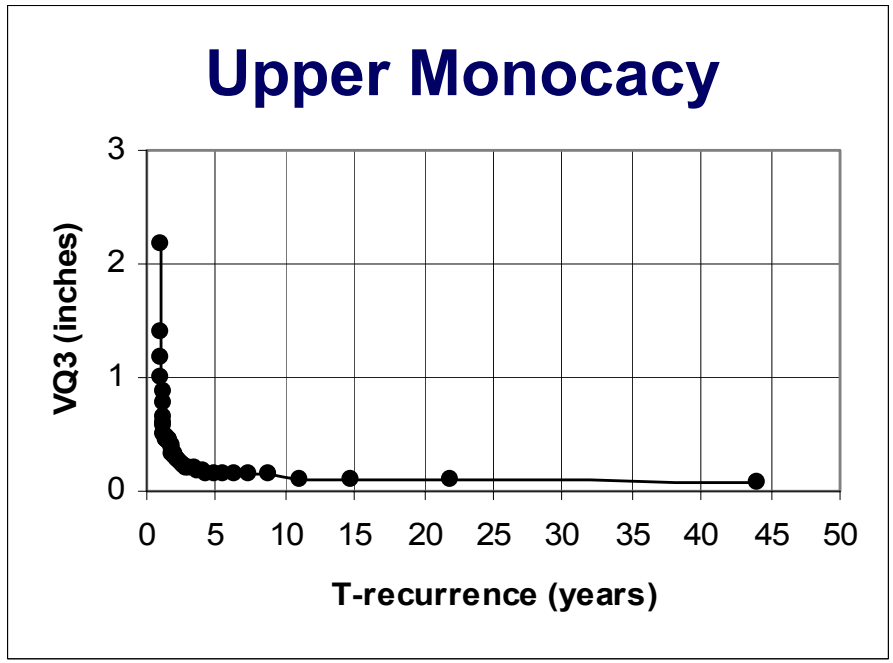
A simple indicator

summer availability ~ sum of beginning-of-summer storage and summer recharge:

$$V_{Q3} = S_{Q3} + R_{Q3}$$

Frequency Curves for V_{Q3}





Annual vs. SWB Summer Availability Predictions

Recurrence Intervals for Annual Baseflow (gpd/acre)

	2-year	10-year	20-year
Bennett (1643500)	640	435	389
Big Pipe (1639500)	624	398	345
Catoctin (1637500)	630	400	346
Upper Monocacy (1639000)	410	270	234

Recurrence Intervals for V_{Q3} (gpd/acre)

	2-year	10-year	20-year	2001 GW Withdraw.
Bennett (1643500)	408	223	149	6
Big Pipe (1639500)	446	190	141	12
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Conclusions

- SWBs may provide useful tool for estimating water availability in Potomac sub-basins underlain by fractured bedrock aquifers
- For sub-basins with short baseflow recession indices, SWBs indicate much lower summer availability than annual recharge estimates