USGS
science for a changing world

Water Availability Workshop
June 7, 2005

GROUND WATER AVAILABILITY ASSESSMENT FOR FRACTURED ROCK AQUIFERS IN THE DELAWARE RIVER BASIN

Ron Sloto US Geological Survey
PA Water Science Center, Exton Office

U.S. Department of the Interior
U.S. Geological Survey

WHAT IS GROUND WATER AVAILABILITY ?

All water in the ground-water system

All water in the ground-water system "available" for use

Unused water in the ground-water system "available" for use

USGS

SUSTAINABILITY

"Refers to the use of a resource in a manner that meets current needs without compromising the ability to adequately meet the needs of future generations. Sustainability means making choices to use a natural resource base in a manner to ensure that yields in economic prosperity, social improvement, environmental quality and natural beauty will go on – tomorrow and forever – to be passed on to our children and subsequent generations."

Delaware River Basin Commission (2004) Water Resources Plan

USGS

SAFE YIELD

"Safe yield is the amount of naturally occurring ground water that can be withdrawn from an aquifer on a sustained basis, economically and legally, without impairing the native ground-water quality or creating an undesirable effect such as environmental damage." -- Fetter (1980)

USGS

SAFE YIELD

- The amount of water that could be pumped "regularly and permanently without dangerous depletion of the storage reserve." -- Lee (1915)

ALSO CALLED:

- Permissive sustained yield (ASCE, 1961)
- Maximum basin yield (Freeze, 1971)
- Potential sustained yield (Fetter, 1972)

USGS

GROUND-WATER AVAILABILITY CAN BE ESTIMATED USING:

- Median annual base flow
- Mean annual base flow
- Dry year base flow of record
- 25-year annual base-flow recurrence
- $Q_{7\text{-}10}$
- Some percentage of the $Q_{7\text{-}10}$

USGS

GROUND-WATER AVAILABILITY COMPARISON ELK CREEK BASIN

METHOD	GALLONS PER DAY PER ACRE
Mean annual base flow	844
Median annual base flow	797
25-year annual base-flow recurrence	451
Driest year of record base flow (1966)	391
$Q_{7\text{-}10}$	219
One half of the $Q_{7\text{-}10}$	109

USGS - DRBC GROUND-WATER AVAILABILITY PROJECT

OBJECTIVE:

Develop a GIS-based ground-water availability methodology for assessment of water supply and for use in the evaluation of allocation policy for all of the Delaware River Basin's watersheds

Done in cooperation with the Delaware River Basin Commission

USGS

GROUND WATER AVAILABILITY

- Method should be simple and transferable
- GEOLOGY is the major control on ground water
- Annual base flow is related to recharge
- Long-term annual base flow provides a good measure of ground water moving through the system

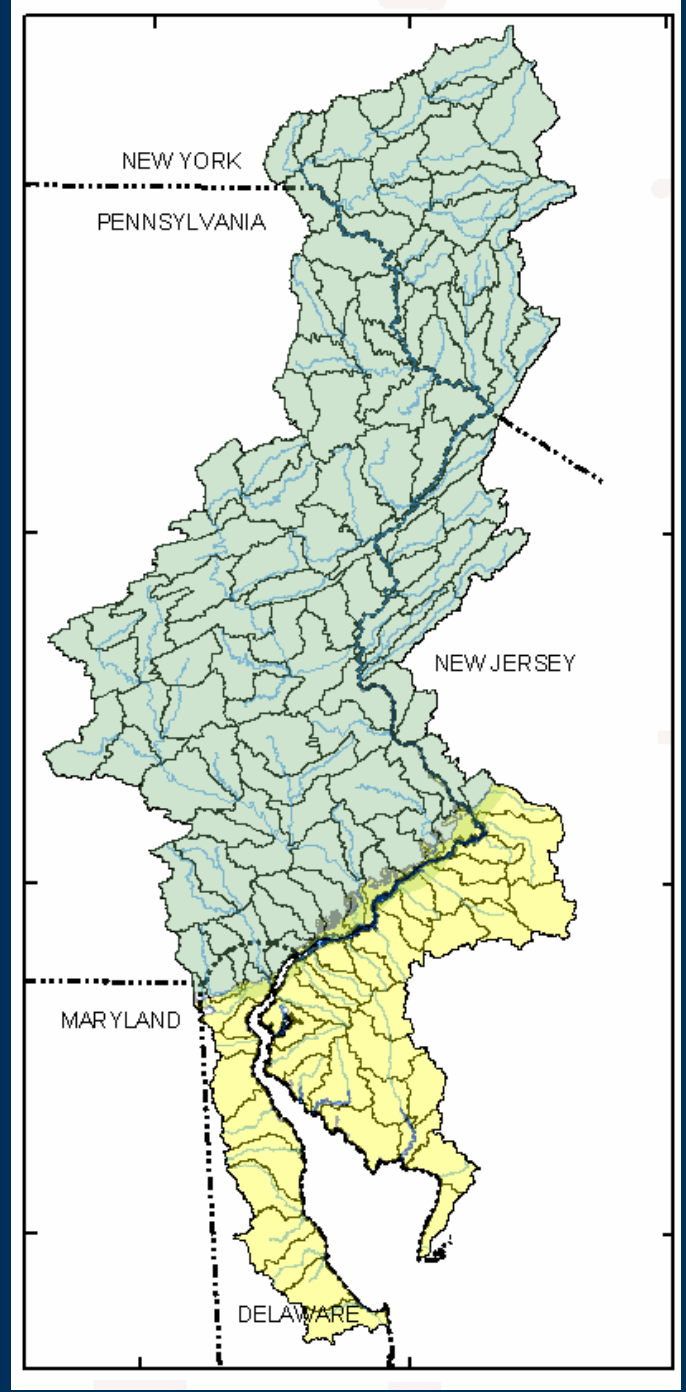
USGS

STEP 1: DEFINE THE WATERSHEDS

FRACTURED ROCK AQUIFERS

COASTAL PLAIN SEDIMENTS

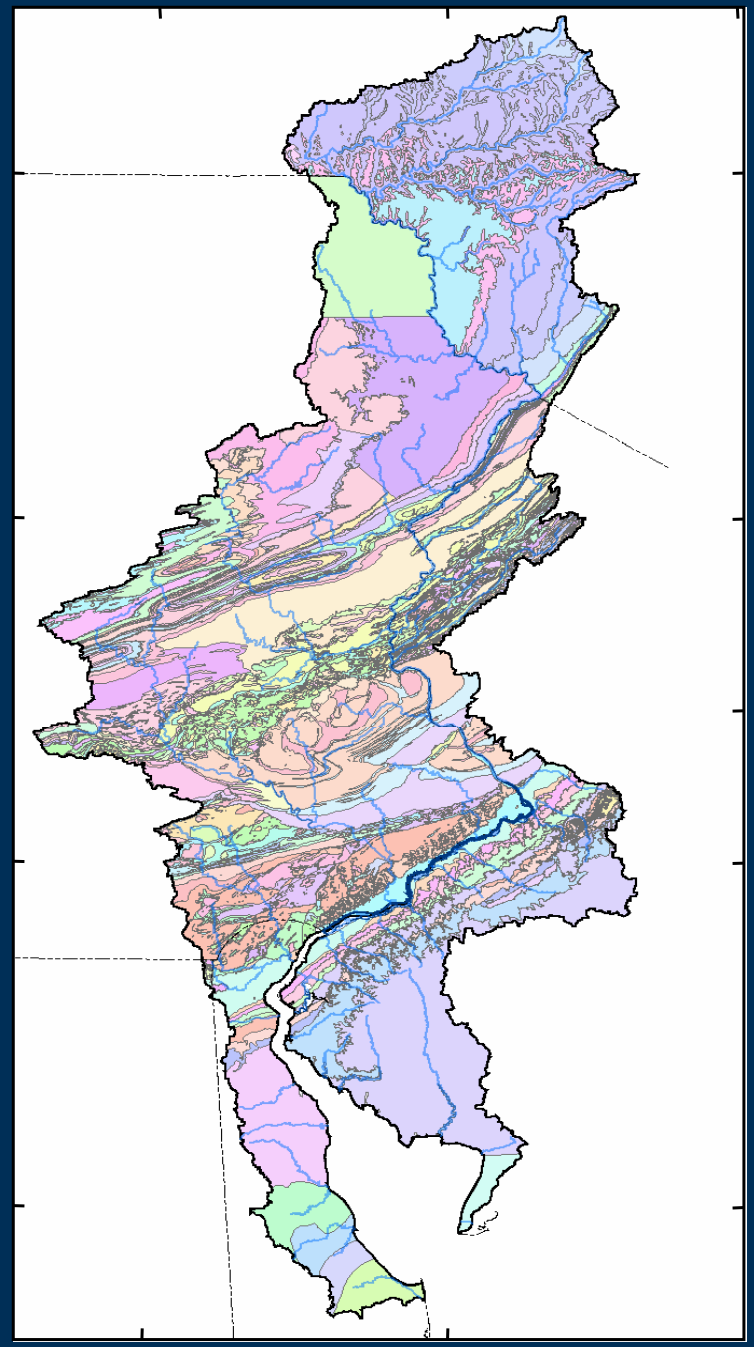
- 147 Watersheds
- Size 17.9 to 210 mi^2
- Average size 87.4 mi^2
- 80% are between 30 and 120 mi^2



DETAILED GEOLOGY IN THE DELAWARE RIVER BASIN

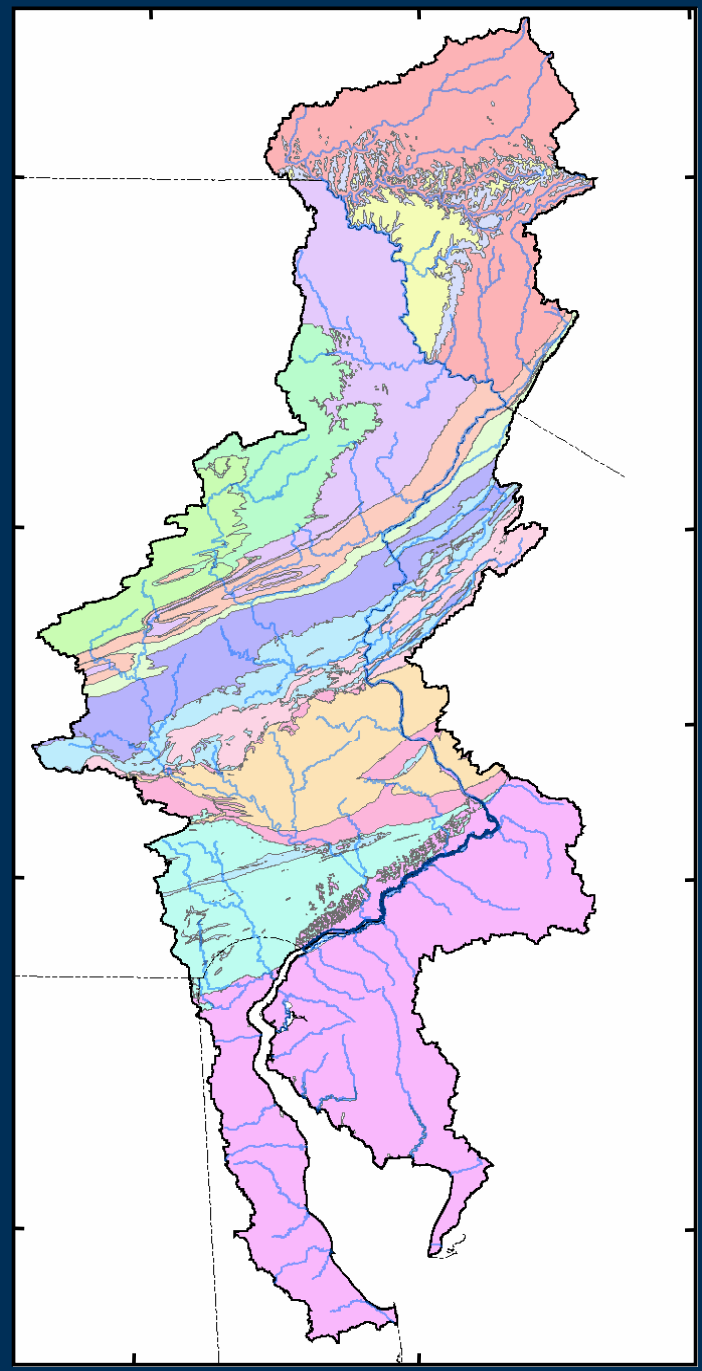
212 MAPPED FRACTURED ROCK GEOLOGIC UNITS

USGS



STEP 2: GENERALIZE GEOLOGY IN THE DELAWARE RIVER BASIN

15 GENERALIZED GEOLOGIC UNITS



USGS

STEP 3: CHOOSE INDEX STREAMFLOW GAGING STATIONS REPRESENTATIVE OF EACH GENERALIZED GEOLOGY

- All current and discontinued USGS gaging stations with more than 20 years of record
- Drainage areas ranged from 0.61 to 6,780 mi^2
- 218 stations

USGS

URBAN WATERSHED
WISSAHICKON CREEK BASE FLOW

	Streamflow (SF)	Direct runoff	Base flow (BF)
12-YEAR AVE	22.24	10.13	12.11

YEAR	Quarry discharge	Sewage treatment plant discharge	Ground-water discharge
12-YEAR AVE	2.91	2.42	6.78
PERCENTAGE OF WATER	24%	20%	56%

USGS

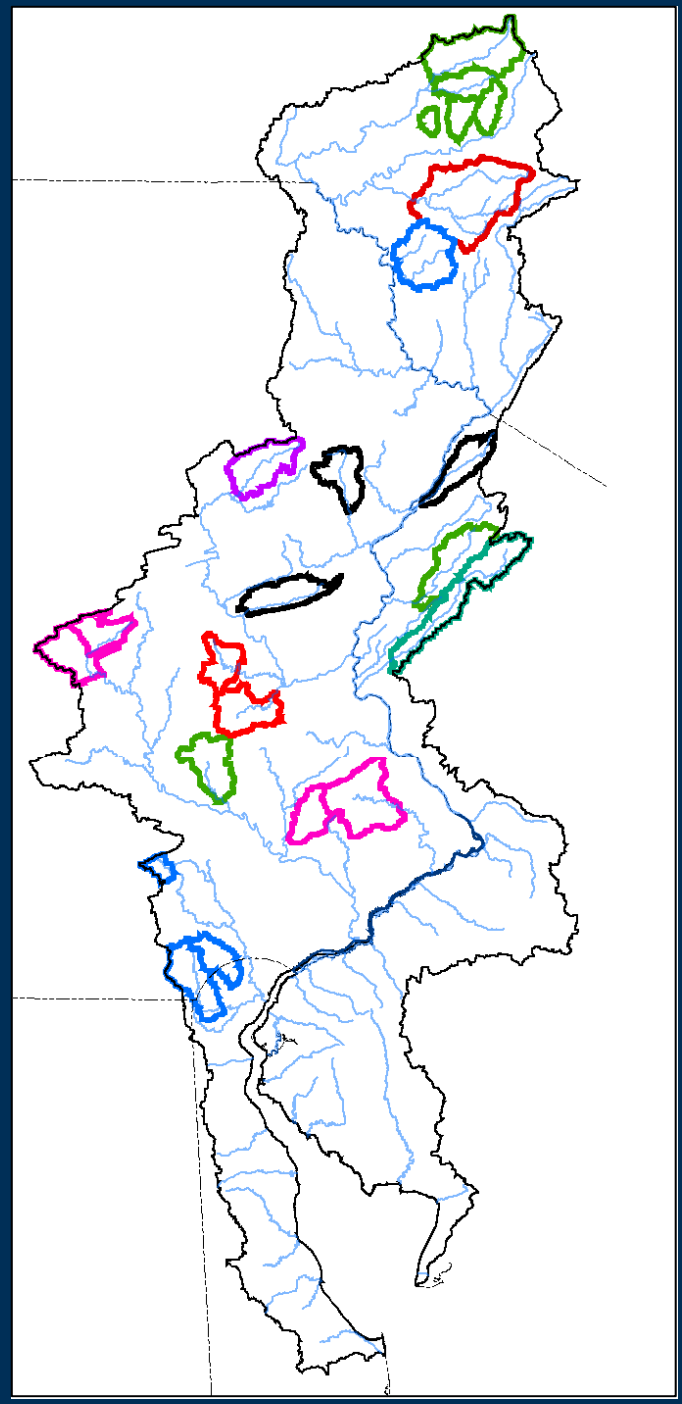
Done in cooperation with the Delaware River Basin Commission

SELECTION OF REPRESENTATIVE INDEX GAGING STATIONS

- Eliminated regulated stations
- Eliminated drainage areas greater than 350 mi^2
- Eliminated drainage areas less than 10 mi^2
- Eliminated urban stations
- 57 suitable gaging stations draining one predominant generalized geologic unit

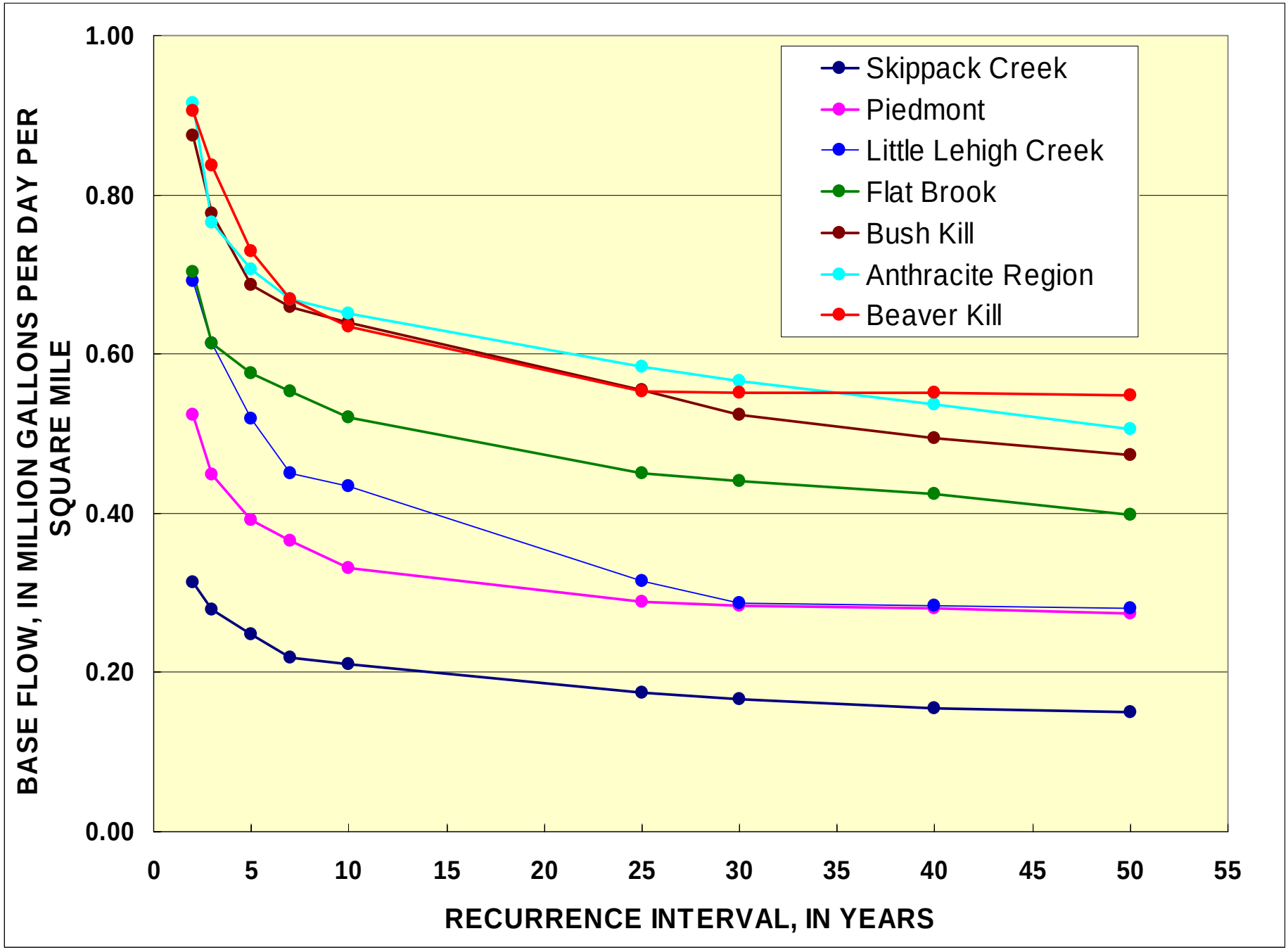
USGS

DISTRIBUTION OF BASINS WITH INDEX STREAMFLOW GAGING STATIONS DRAINING FRACTURED ROCKS

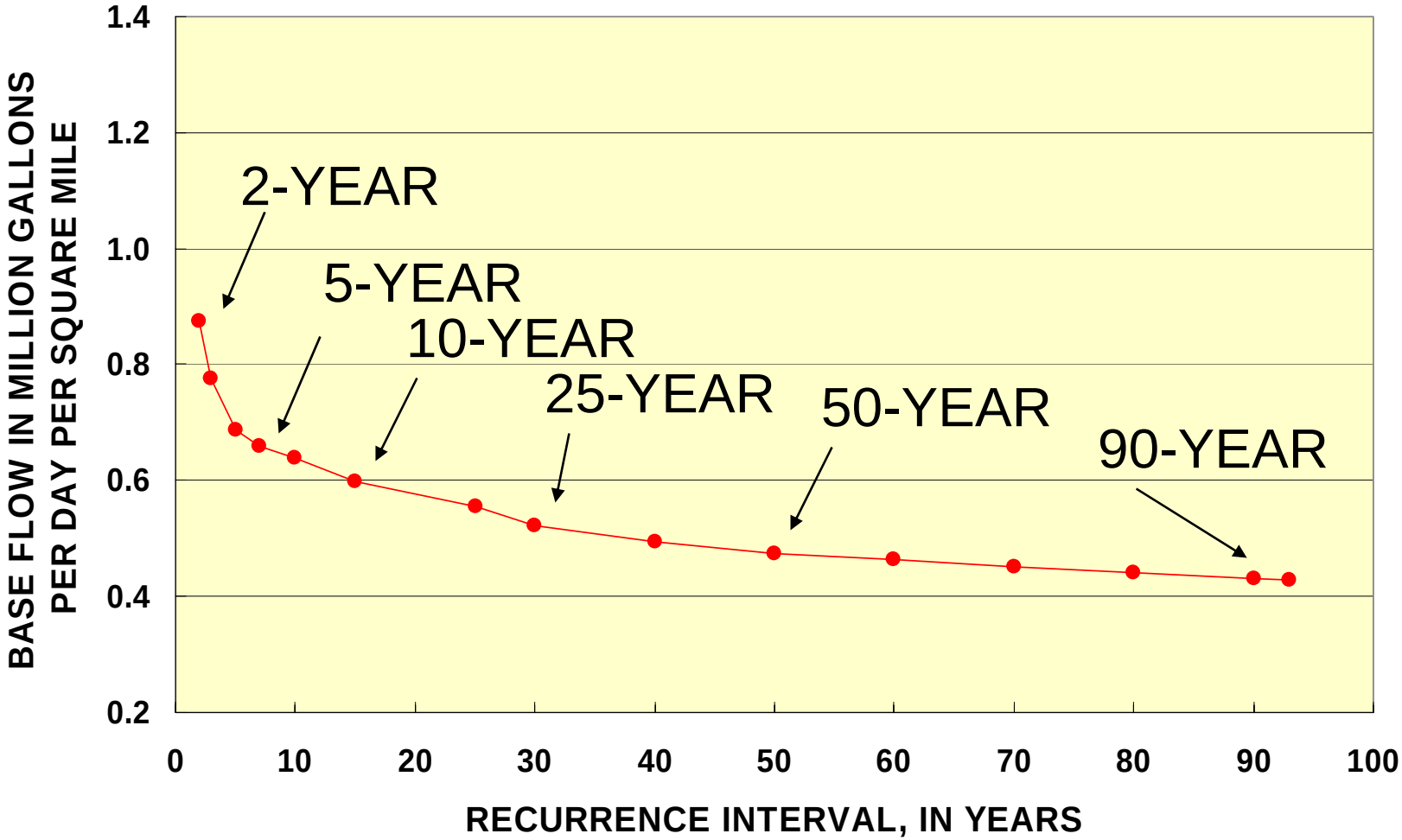


STEP 5: GROUND WATER AVAILABILITY GIS ANALYSIS

- Area of each generalized geologic unit calculated for each watershed
- Hydrograph separation run for period of record on index stations using HYSEP computer program
- Index station base-flow recurrence for each generalized geologic unit
- 2-, 5-, 10-, 25-, and 50-year annual base-flow recurrence calculated for each watershed based on percentage of generalized geologic units


1.00
0.80
0.60
0.40
0.20
0.00
BASE FLOW, IN MILLION GALLONS PER DAY PER SQUARE MILE
0
5
10
15
20
25
30
35
40
45
50
55
RECURRENCE INTERVAL, IN YEARS
Skippack Creek
Piedmont
Little Lehigh Creek
Flat Brook
Bush Kill
Anthracite Region
Beaver Kill

BUSHKILL CREEK BASE FLOW



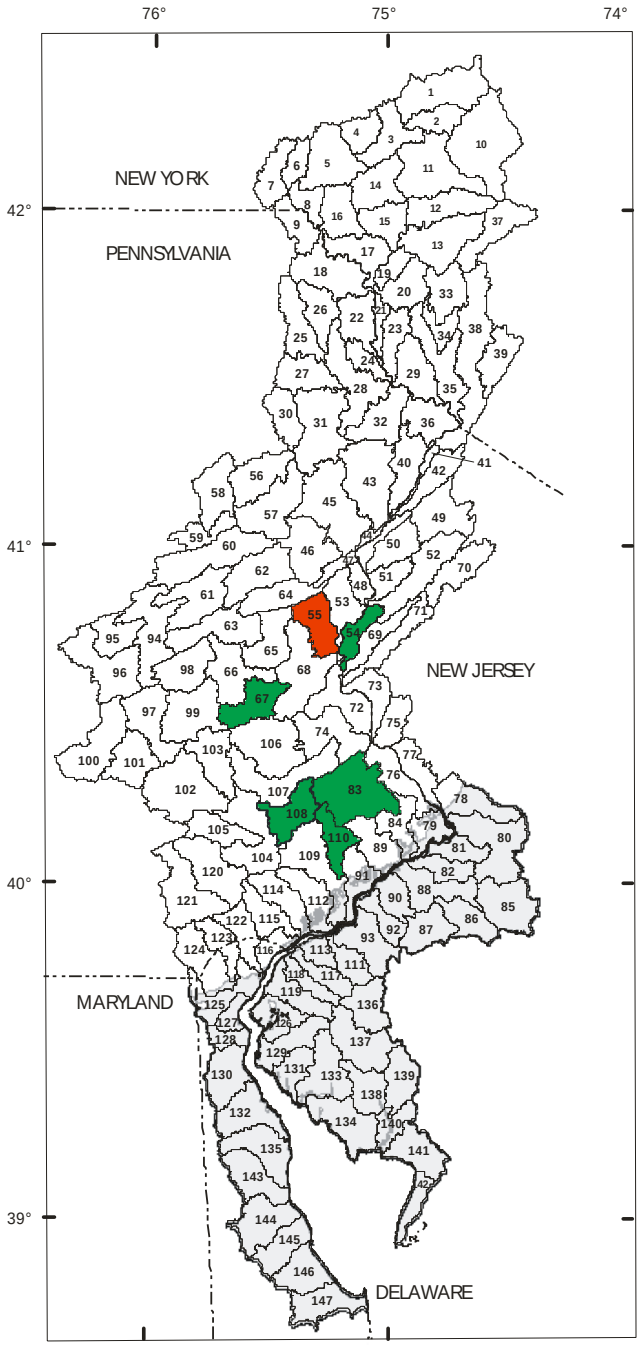
STEP 5: REMAINING AVAILABLE GROUND WATER GIS ANALYSIS

$$GW_{RA} = ABF - GWP - DU + GWR$$

GroundWaterRemainingAvailability =

AnnualBaseFlow – GWPumping – DomesticUse + GWReturns

USGS



AVAILABLE GROUND WATER – 25-YEAR RECURRENCE

- GREATER THAN 100 PERCENT USE OF AVAILABLE GROUND WATER
- GREATER THAN 75 AND LESS THAN 100 PERCENT USE OF AVAILABLE GROUND WATER
- GREATER THAN 50 AND LESS THAN 75 PERCENT USE OF AVAILABLE GROUND WATER
- GREATER THAN 25 AND LESS THAN 50 PERCENT USE OF AVAILABLE GROUND WATER
- LESS THAN 25 PERCENT USE OF AVAILABLE GROUND WATER
- COASTAL PLAIN SEDIMENTS

GROUND WATER AVAILABILITY

What method do we use to determine ground-water availability ?

“The optimal method is one that best meets a set of socioeconomic and/or social and environmental objectives associated with the use of the water.”

Sloto (2002 WRIR 02-4057)

USGS