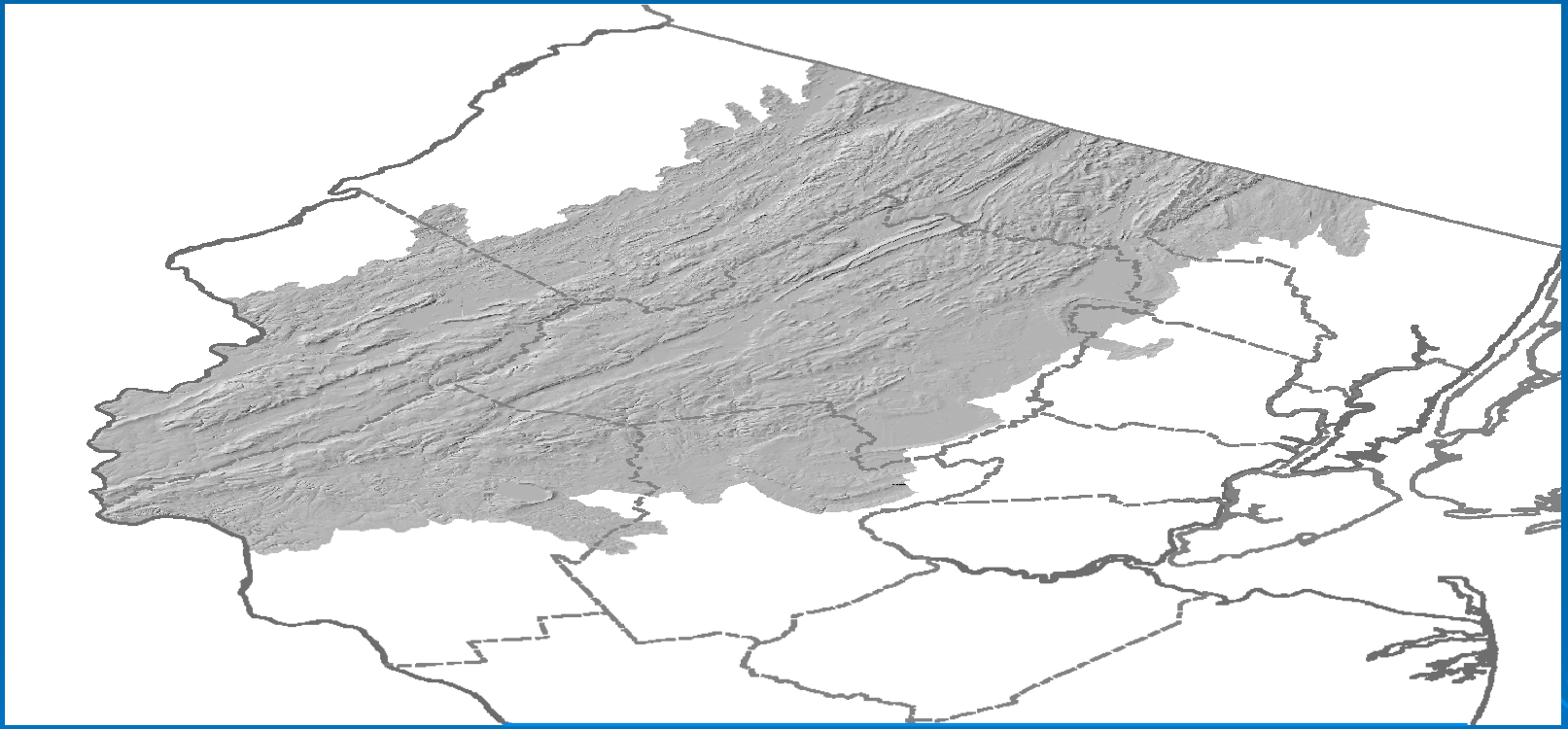
Water Capacity Analytical Methods New Jersey Highlands



New Jersey Highlands Council

USGS science for a changing world

Ultimate Goal

- Identify the capacity of Highlands watersheds to meet current and future water supply demands

- Public Supply Needs
- Stream Habitat
- Ecological Health

What do we need to know?

- How much water is continually being supplied to the ground-water system
- How much is discharging to streams
- How much water is and will be used for human use

Why focus on ground water?

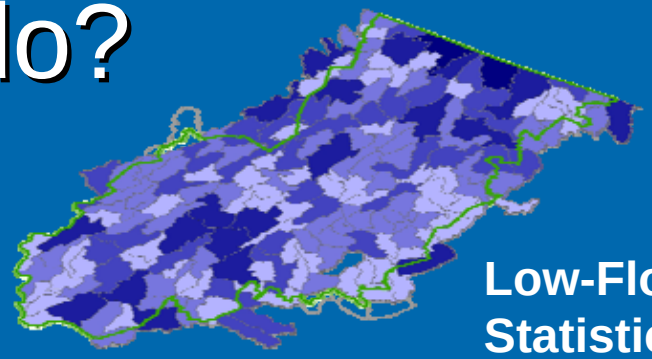
- Primary drinking water source for Highlands Communities
- Ground water is the critical component of streamflow

What do we need to do?

- Evaluate on a regional basis the amount of water per watershed under a set of climatic and ecological conditions

- Take into account existing and projected withdrawals

- Identify watershed capacity



Low-Flow Statistics

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Water Use

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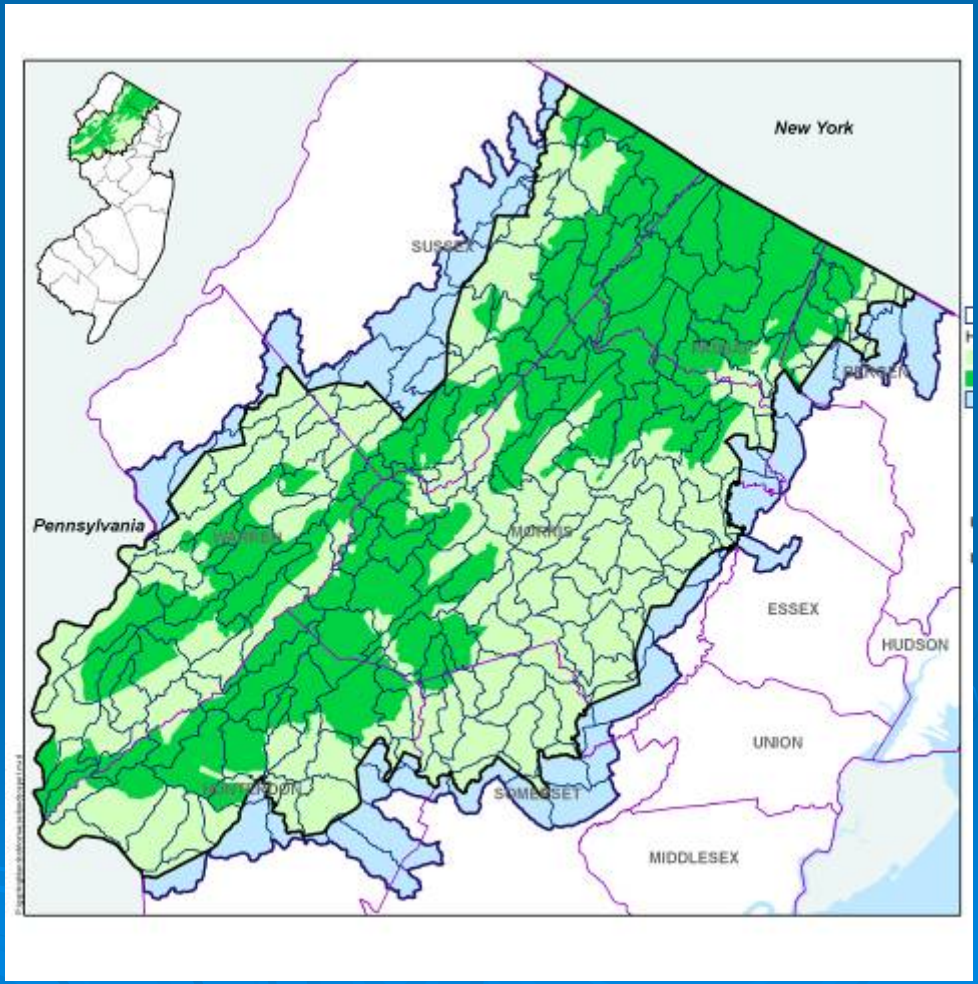
Watershed Capacity

Watershed Analysis

183 HUC14 drainage basins

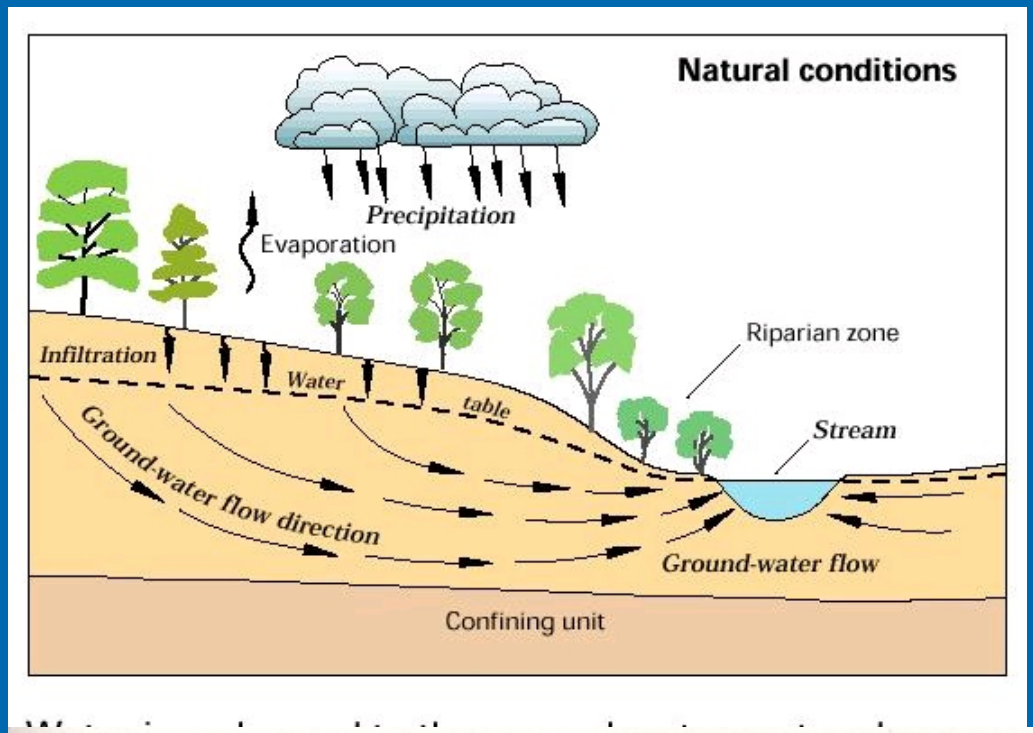
3 to 27 mi^2 range in area

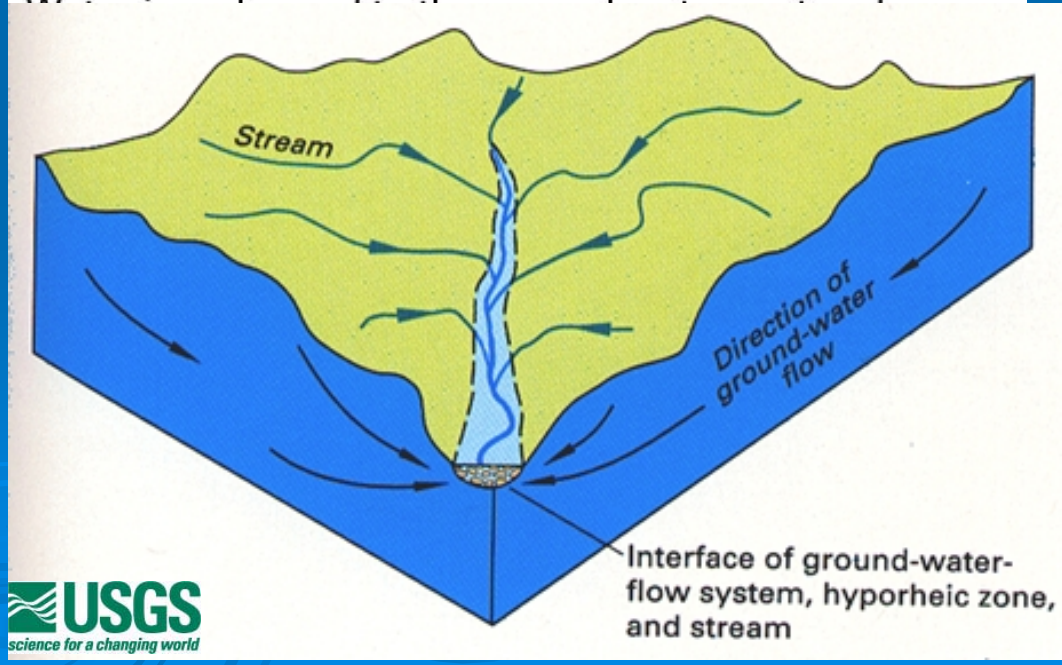
- Low-flow statistics of Highlands streams
  - Baseflow Recurrence Intervals
  - Low-Flow Margin approach
- Physical characteristics of the regions HUC14 watersheds
- Water Use Data



Stream Baseflow

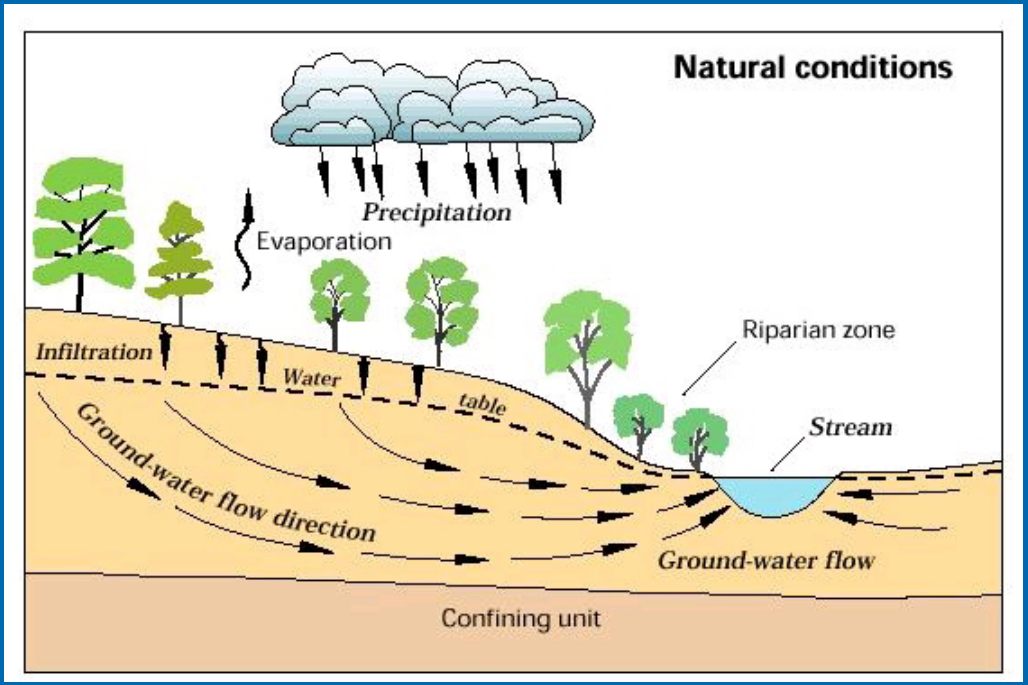
- Stream baseflow is ground-water discharge
- 75% of HIGHLANDS streamflow is ground-water discharge
- Amount of baseflow in a stream is a measure of the yield of the underlying aquifer and a measure of the streams ability to sustain flow.

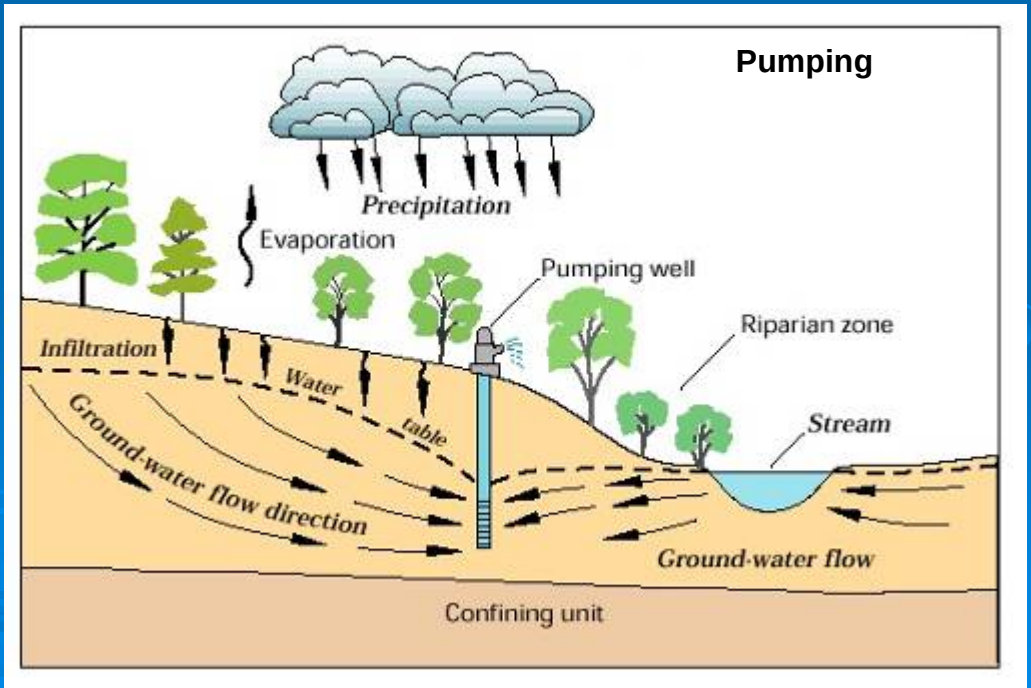




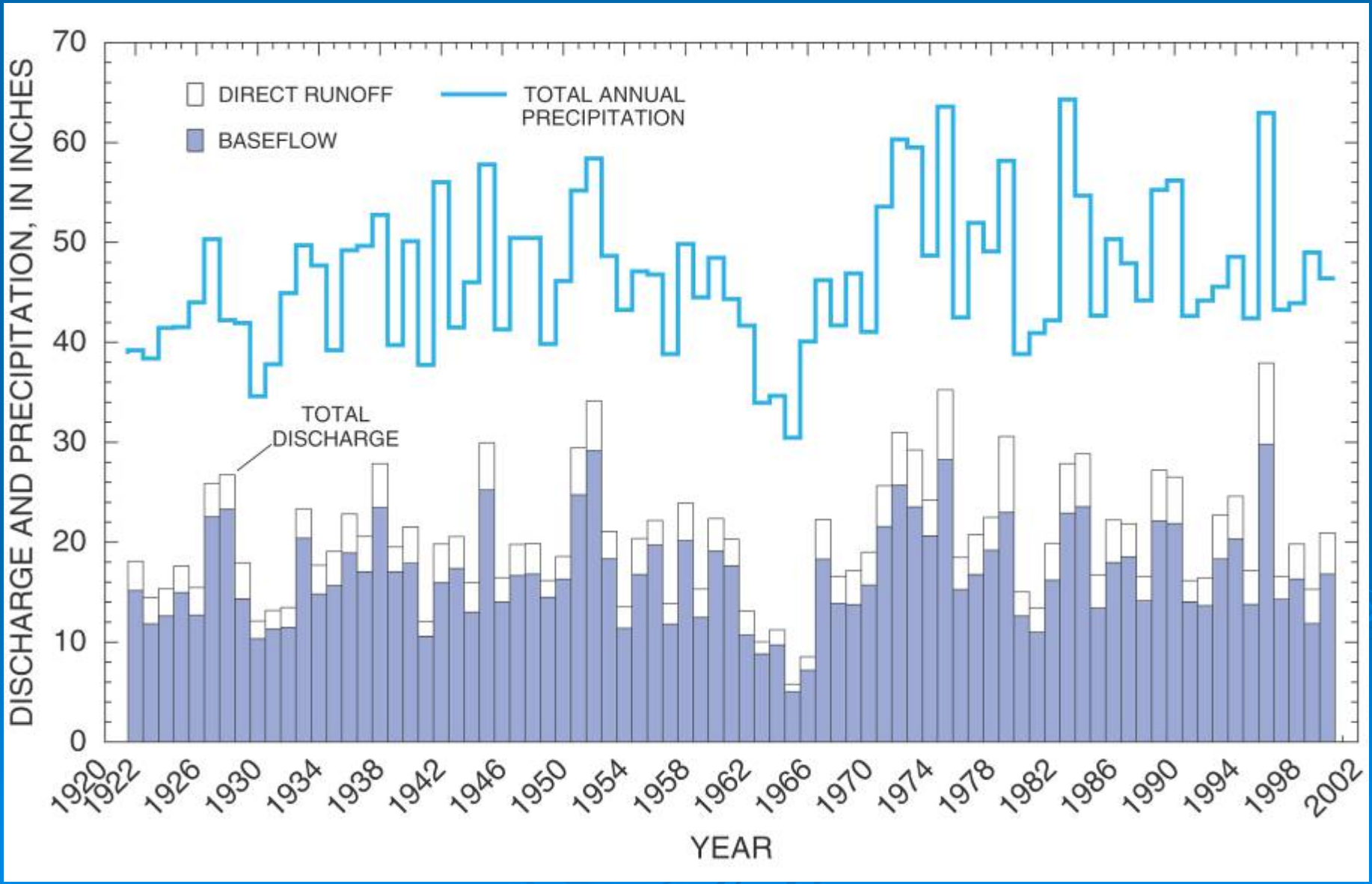
Streamflow Depletion

- Stream baseflow is ground-water discharge
- Well withdrawals intercept part of baseflow to streams
- Pumping will divert discharge to, or induce flow from streams





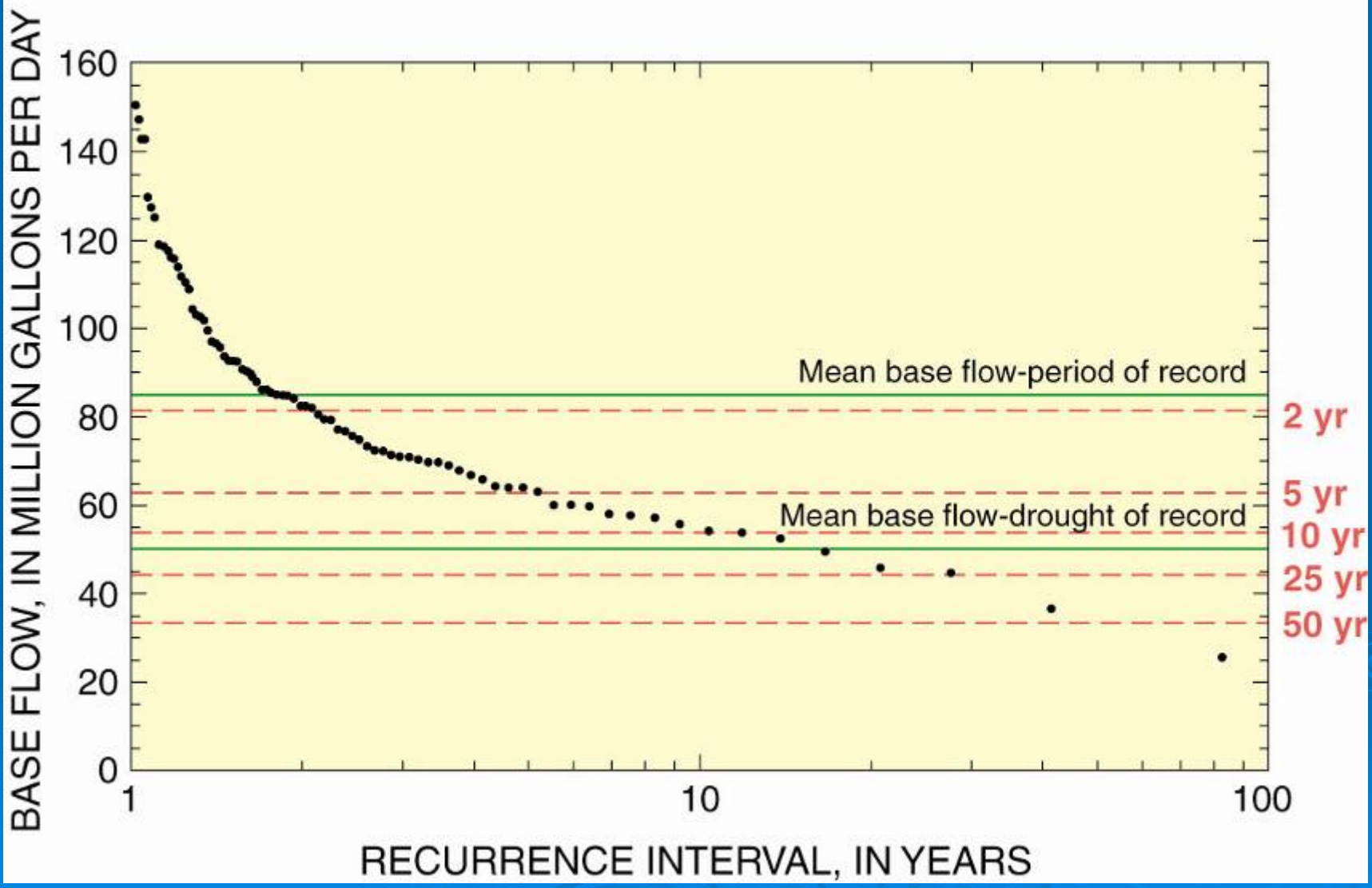
Baseflow Variability



Baseflow Recurrence Interval Method

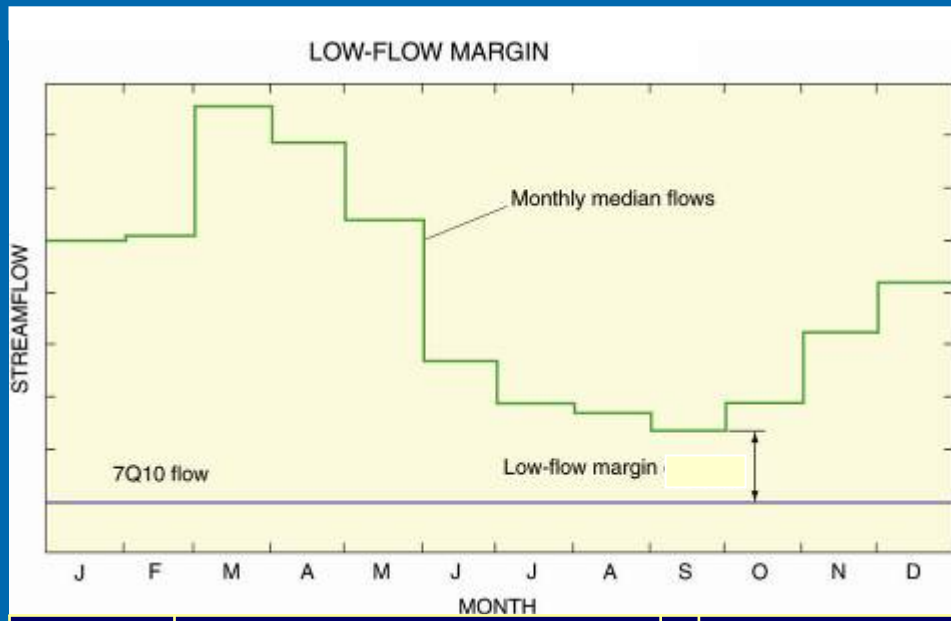
- 2, 5, 10, 25, and 50 year annual intervals
- Represent range of climatic conditions from wet (2yr) to dry (50yr)
- Represent an average time and probability between occurrence
- The 2, 5, 10, 25, and 50 year baseflows have a 50, 20, 10, 4, and 2% probability of occurring every year

Distribution of flow statistics at a typical gaging station



Low-Flow Margin Method

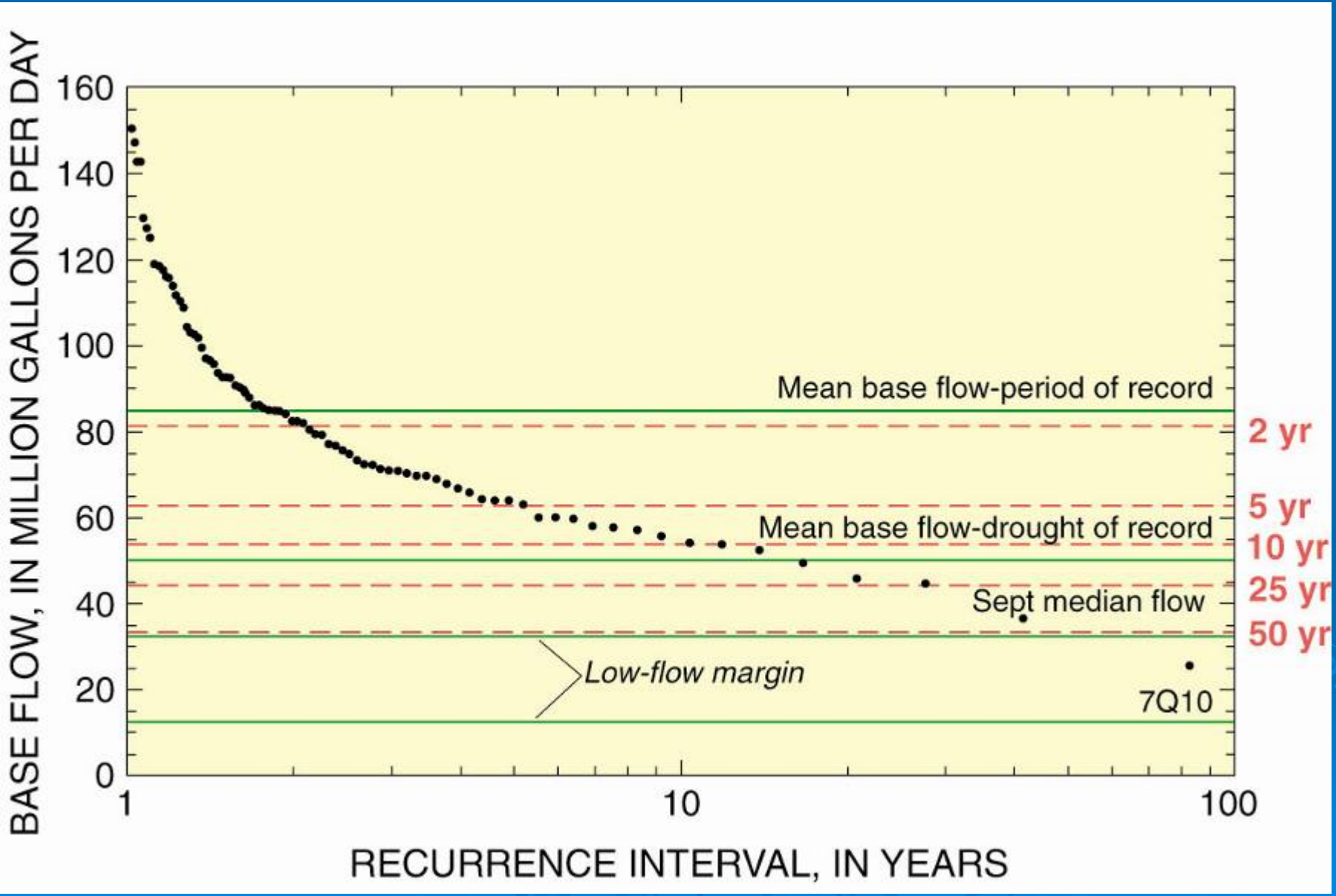
- Ecologically-based approach that protects stream low flows; uses margin between stream low-flow statistics
- Critical flow regime for aquatic ecology is the lowest monthly flow (September)
- Traditional low-flow condition is the lowest flow over 7 consecutive days during a 10 year period (7Q10)
- The low-flow margin is the September median flow minus the 7Q10
- The low-flow margin of "Safety" is a % of the margin less basin water use



Statistic	Sept median flow		37.3 mgd
	7Q10		12.5 mgd
Low-flow margin	100%		24.8 mgd
	50%		12.4 mgd
	10%		2.5 mgd
Monthly max.	Consumptive Withdrawal		6.3 mgd

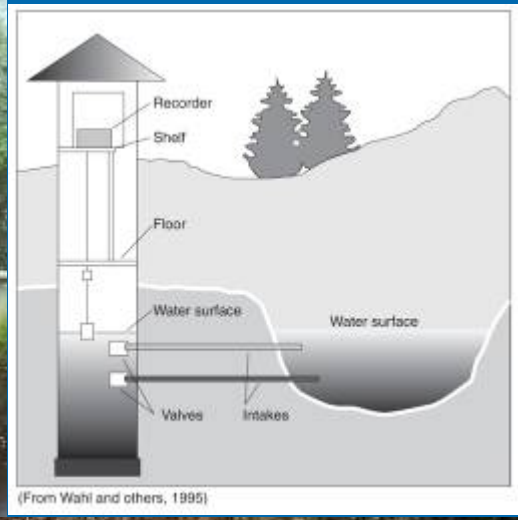
Using 50 %, LFM of Safety = 6.1 mgd

Low-Flow Margin versus Base Flow Recurrence Interval



Surface Water Gaging Stations

25 continuous record stations

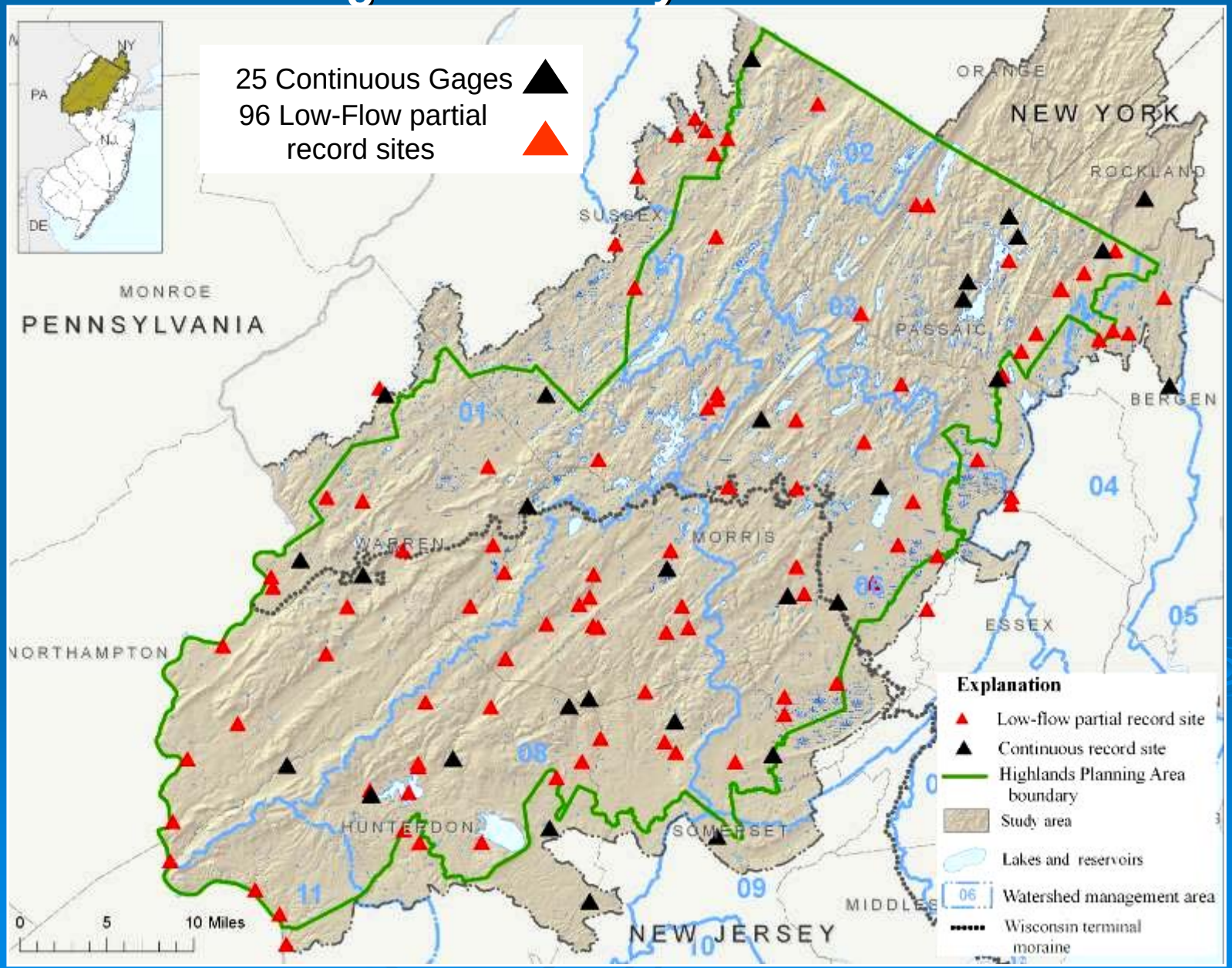


(From Wahl and others, 1995)

96 low-flow partial record stations

USGS

Location of streamflow gaging stations in the Highlands study area



USGS

Site selection

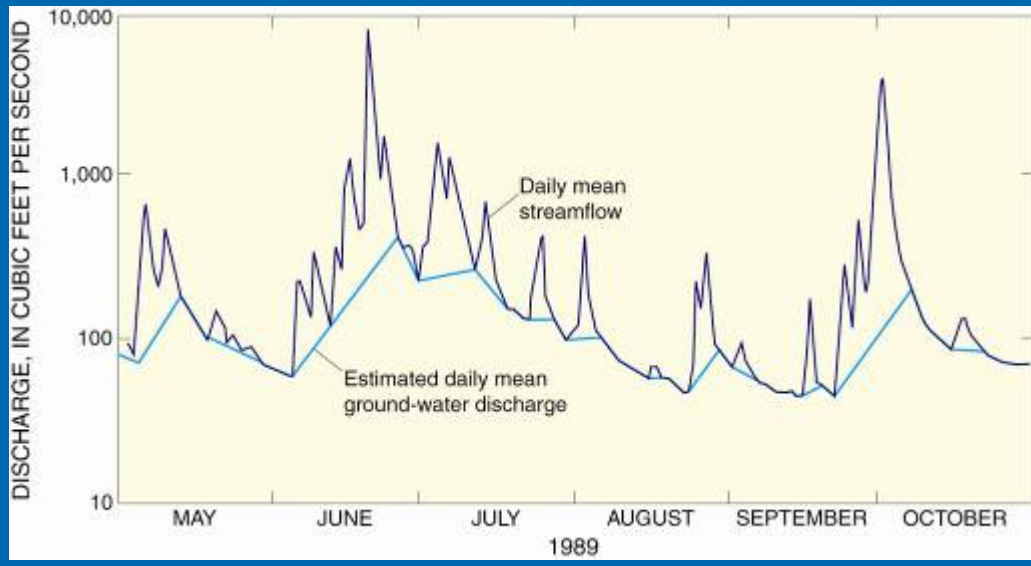
- Unregulated (no dams or reservoirs)
- Minimal withdrawals/sewerage returns
- Continuous gage – a minimum of 20 years of quality record
- Low-flow station – a minimum of 8 measurements over a period of 4 years
  - Average 22 measurements over 30 years

USGS

Low-Flow Statistics Computed for **Gaged Basins**

USGS PART Computer Program

- Streamflow Partitioning used to determine mean annual baseflow

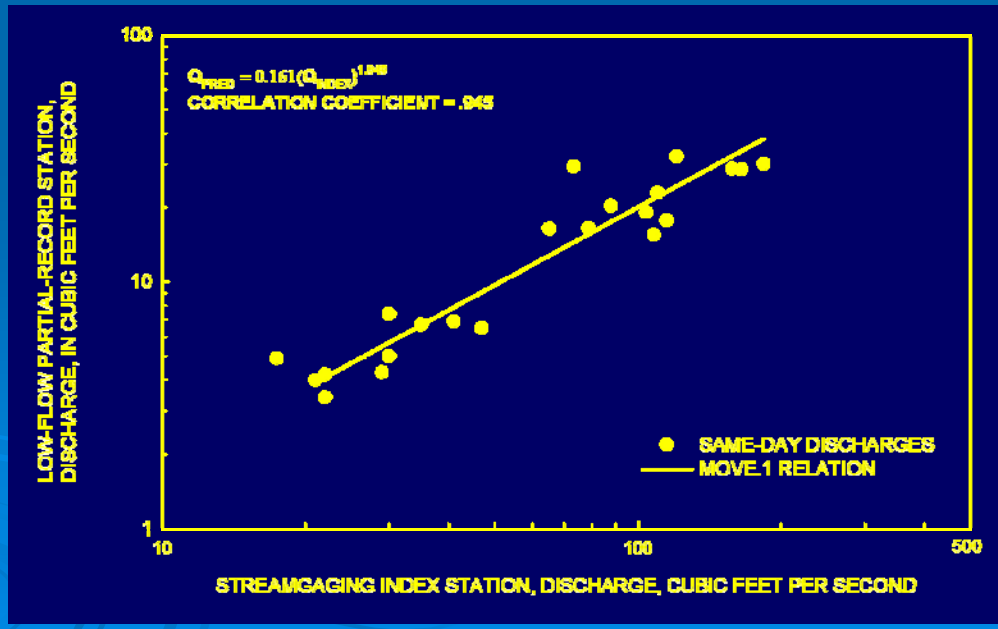


USGS SWSTAT computer program

- 7Q10 computed from lowest mean annual flows for 7 days over a 10 year interval
- September Median streamflows are the median of daily mean flows for all complete Septembers for period of record

USGS MOVE1 computer program

- Relates low-flow statistics from partial record stations to index station



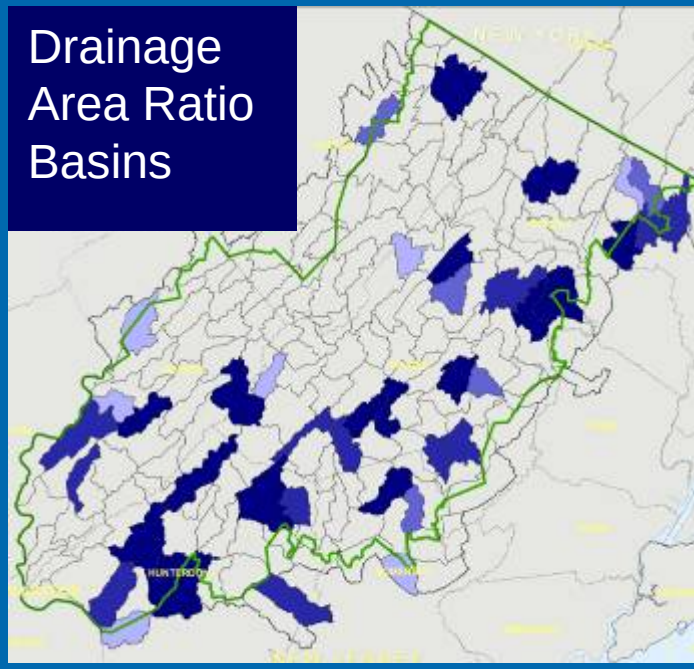
Estimating Low-Flow Statistics for **Ungaged Basins**

Drainage Area Ratio Method

Assumes streamflow in an ungaged basin is the same per unit area as nearby gaged basin.

Requirements

- Must be on the same stream.
- Ratio of ungaged basin area/gaged basin area must be within the range of 0.3 to 1.5



Estimating Low-Flow Statistics for **Ungaged Basins**

Basin Characteristics and Low-Flow Regression Analysis

- Basin characteristics determined for continuous- and partial-record stations as well as HUC14 watersheds

- Relate low-flow statistics to basin characteristics
  - Drainage area
  - Land use / land cover
  - Impervious surface
  - Geology
  - Area/percent storage (lakes, wetlands, reservoirs)
  - Channel slope (10/85 ratio)
  - Channel length
  - Mean basin slope
  - Climate and Recharge

USGS

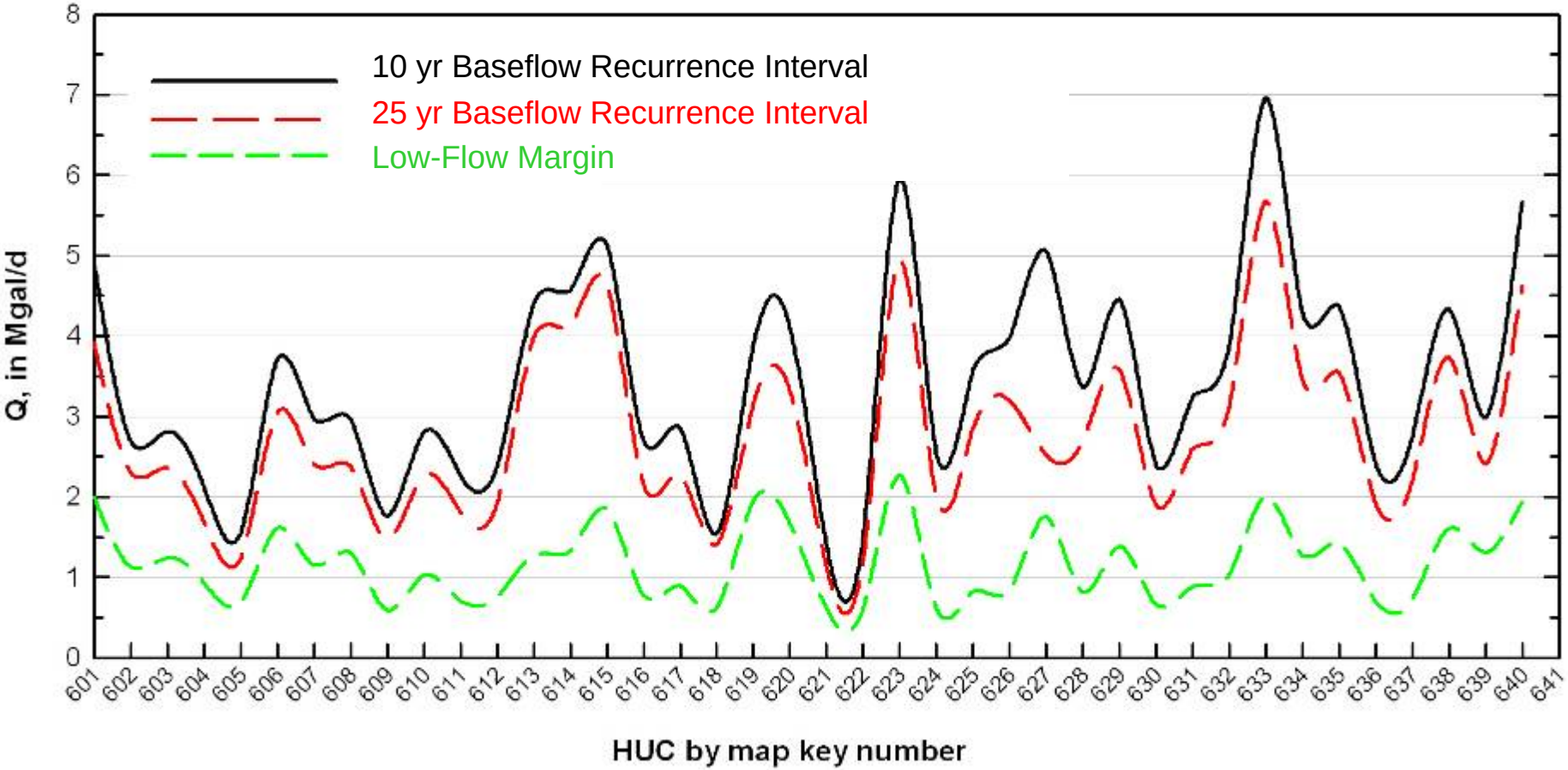
Regression Equations

- Each low-flow statistic is determined by a multiple linear-regression analysis
- A low-flow statistic for a group of gaged stations is related to one or more physical or climatic characteristics of the drainage area of the stations
- This results in an equation that can be used to estimate the low-flow statistic for sites where no streamflow data are available
- Regression equations take the form:
  $Q_{pred} = 0.371A^{0.615}R^{0.821}B^{0.472}$
- where:

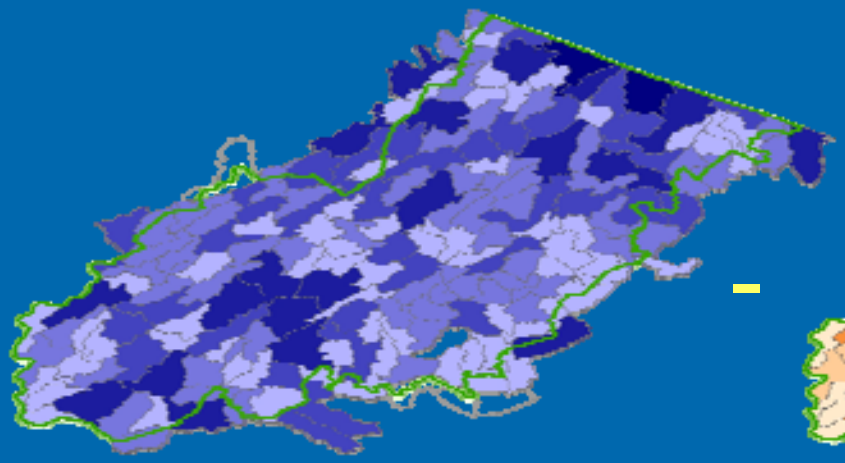
A	is drainage area, in square miles
R	is recharge,
B	is basin slope

Distribution of low-flow statistics in HUC 14 watersheds

Water Management Area 6



Determination of Ground-Water Availability



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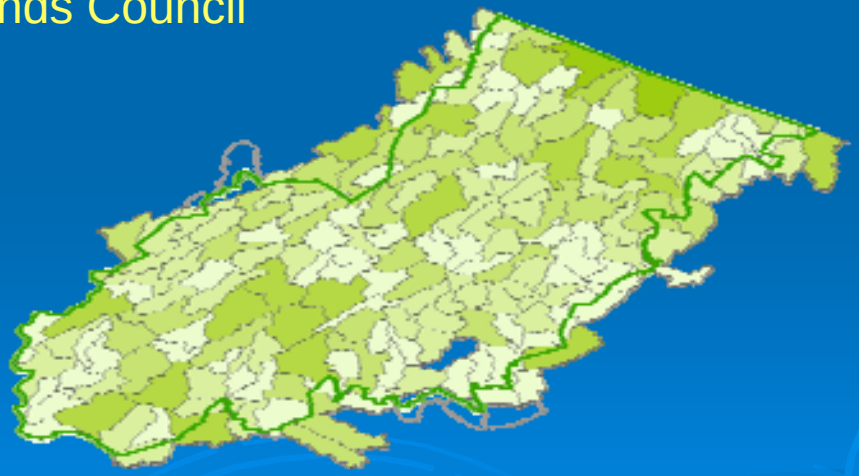
Percentage of baseflow statistic
Determined by Highlands Council

Basin consumptive water use



Ground-water availability

Hydro-ecological Integrity Assessment
"ECO FLOW GOALS"

- Quantifies the amount of water needed to protect the ecological integrity of the stream.
- Characterizes streamflow variability using the **full range** of flow statistics, and examines the impact on streamflow of depletive and consumptive water-use.
- For low, high and average flows: magnitude, frequency, duration, timing, and rate of change are examined
- Flow regimes: baseline (predevelopment), current, and impacted (future change) can be examined.

Defining Streamflow Indices and Thresholds

Ten Flow Components

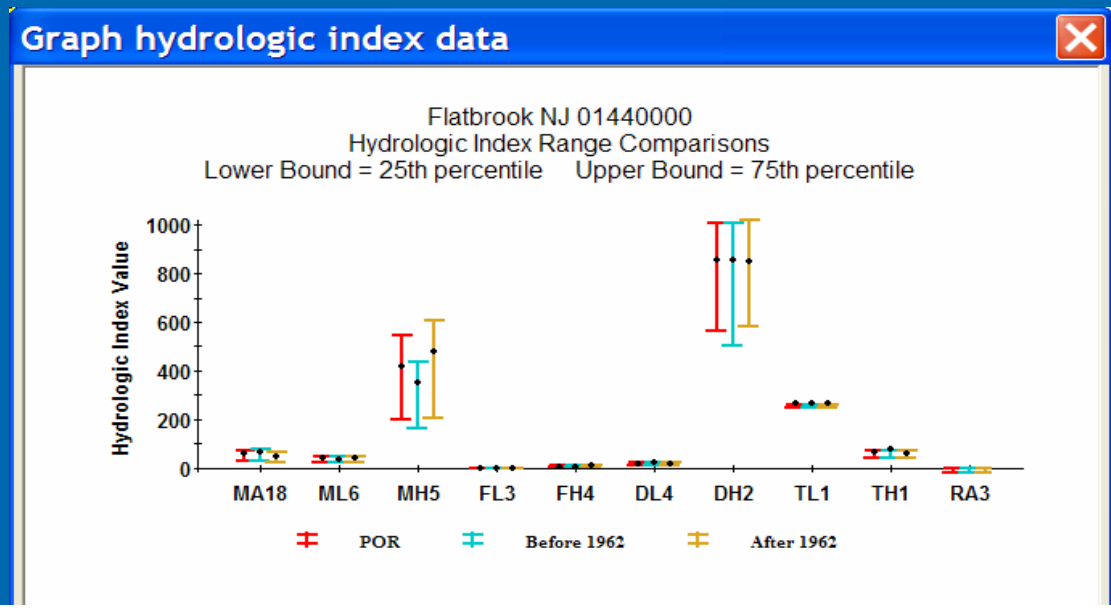
MAGNITUDE
- Average
- High
- Low

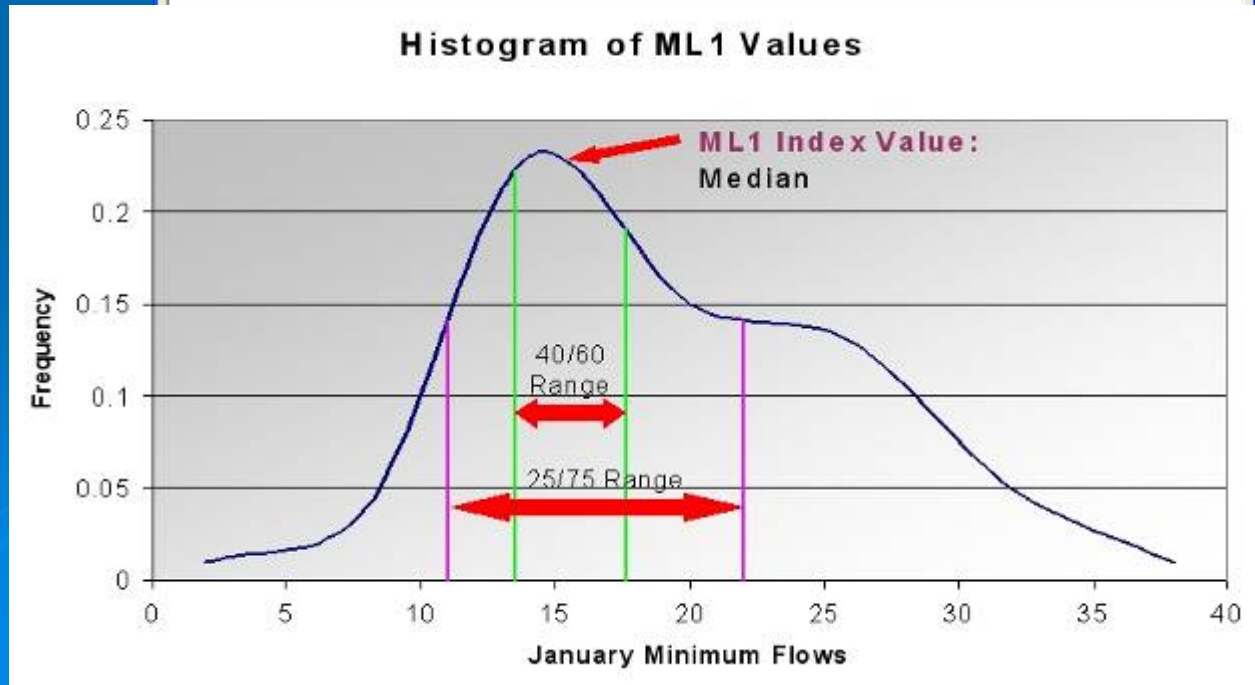
FREQUENCY
- Low
- High

DURATION
- Low
- High

TIMING
- Low
- High

RATE OF CHANGE





Threshold ranges to be determined by the Highlands Council

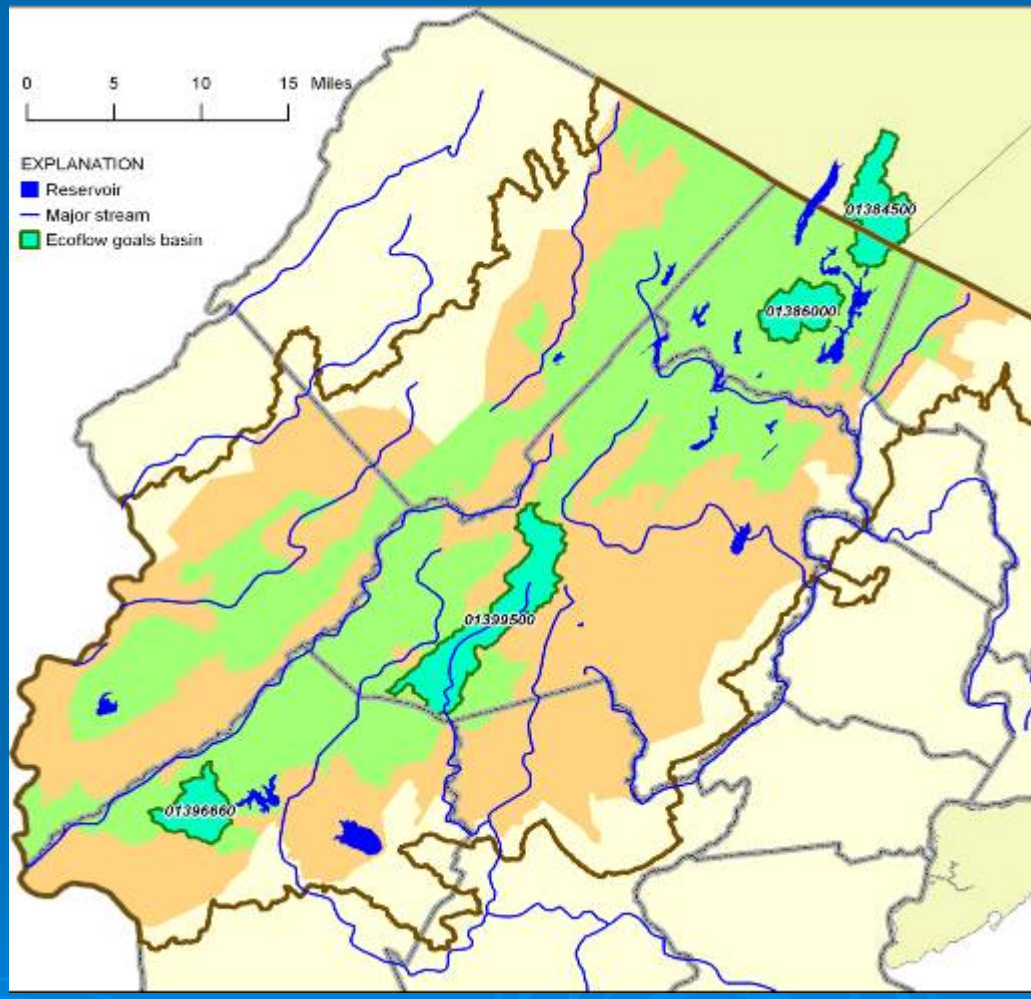
ECO-FLOW GOALS Pilot Study

- Four study basins selected:
  - Ringwood Creek near Ringwood (1934-2004)
  - West Brook near Wanaque (1935-1978)
  - Mulhockaway Creek at Van Syckel, NJ (1976-2004)
  - Lamington (Black) River near Pottersville, NJ (1921-2004)

- How does withdrawal affect 10 flow indicies for each basin?
  - "Bend" indices until they "break" – as withdrawal percent increases, the index values will change until they break the selected percentage threshold
  - What is the maximum withdrawal that a stream system can take before altering index beyond the threshold?

Basin Locations and Criteria

- **Small Headwater Basins (less than 35 mi^2)**
- **Gaged basins are unregulated**
- **At least 20 years continuous daily discharge data**



Comparison with 100% of Low-Flow Margin