An Approach for Low Flow Selection in Water Resource Management

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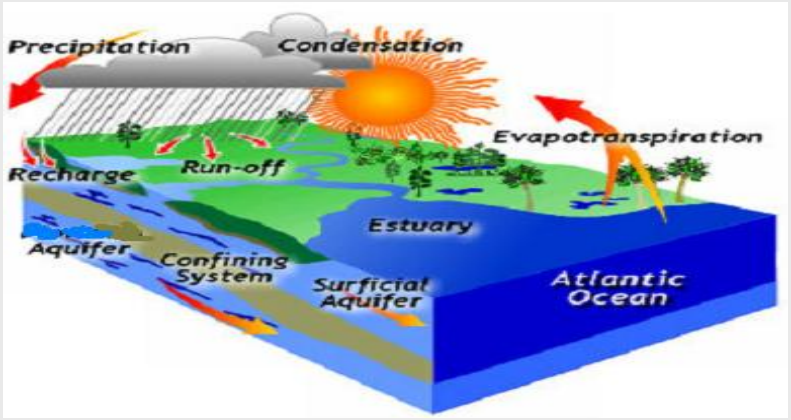


What is Low Flow?

- **A flow of water in a stream during prolonged dry weather (WMO, 1974)**
- **A seasonal phenomenon and an integral component of a flow regime of any river**
- **Affected by climate, topography, geology, soil, and human activities**
- **Estimated by the 7Q10 method (Lowest average flows that occur for a consecutive 7-day period at the recurrence interval of 10 years)**

Rationale

- Central to climate change investigation
- Issue discharge permits and develop water treatment plants
- Determine allowable water transfers and withdrawals in water supply
- Estimate contaminant loading and distributions in surface waters
- Assess stream flow habitats in ecosystem

Objectives

1. Brief overview of low flow selection methods
2. Develop a new approach for low flow selections
3. Compare the new approach with the 7Q10 approach for low flow selections
4. Apply the new approach to analyze low flow characteristics

Low Flow Selection Methods

1. **US-EPA 7Q10 or 7Q2 method**

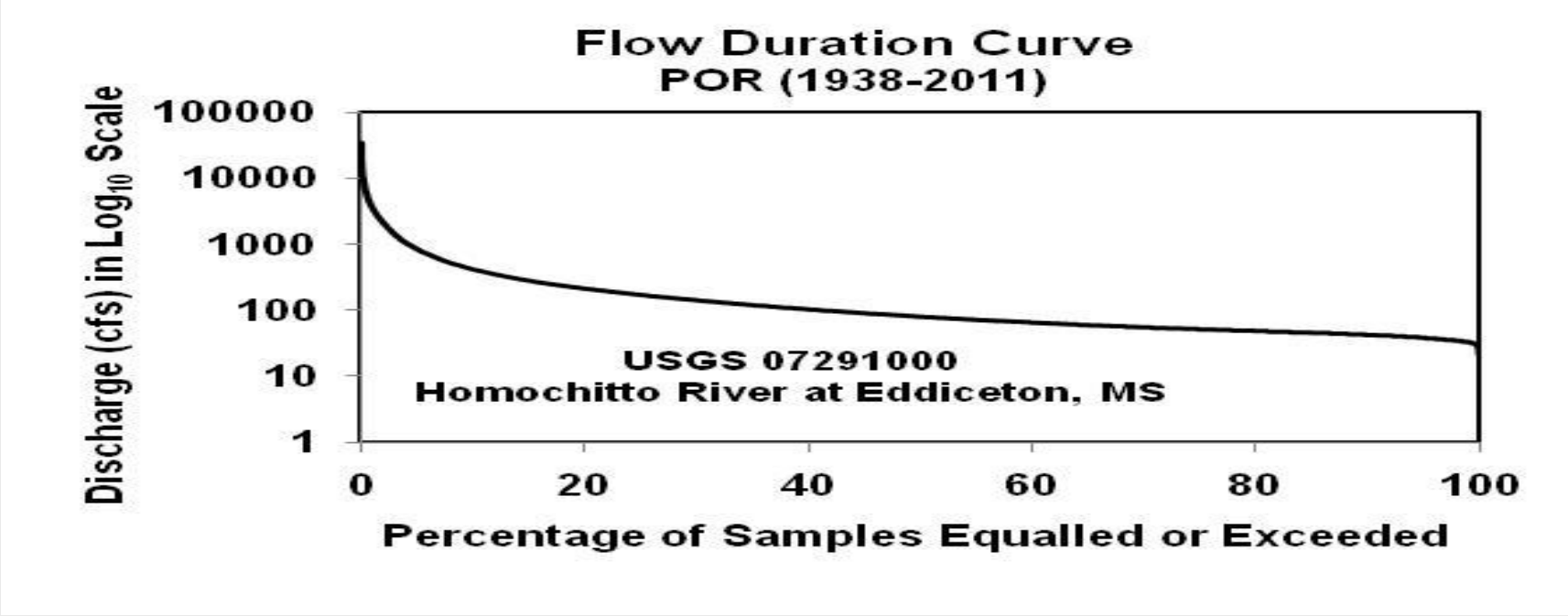
   - **The lowest average flows that occur for a consecutive 7-day period at the recurrence intervals of 10 and 2 years, respectively (USEPA, 1997)**

   - **These flow indices are for most extremely low flow conditions (exceed 95% to 99.5% of the time on the flow duration curve)**

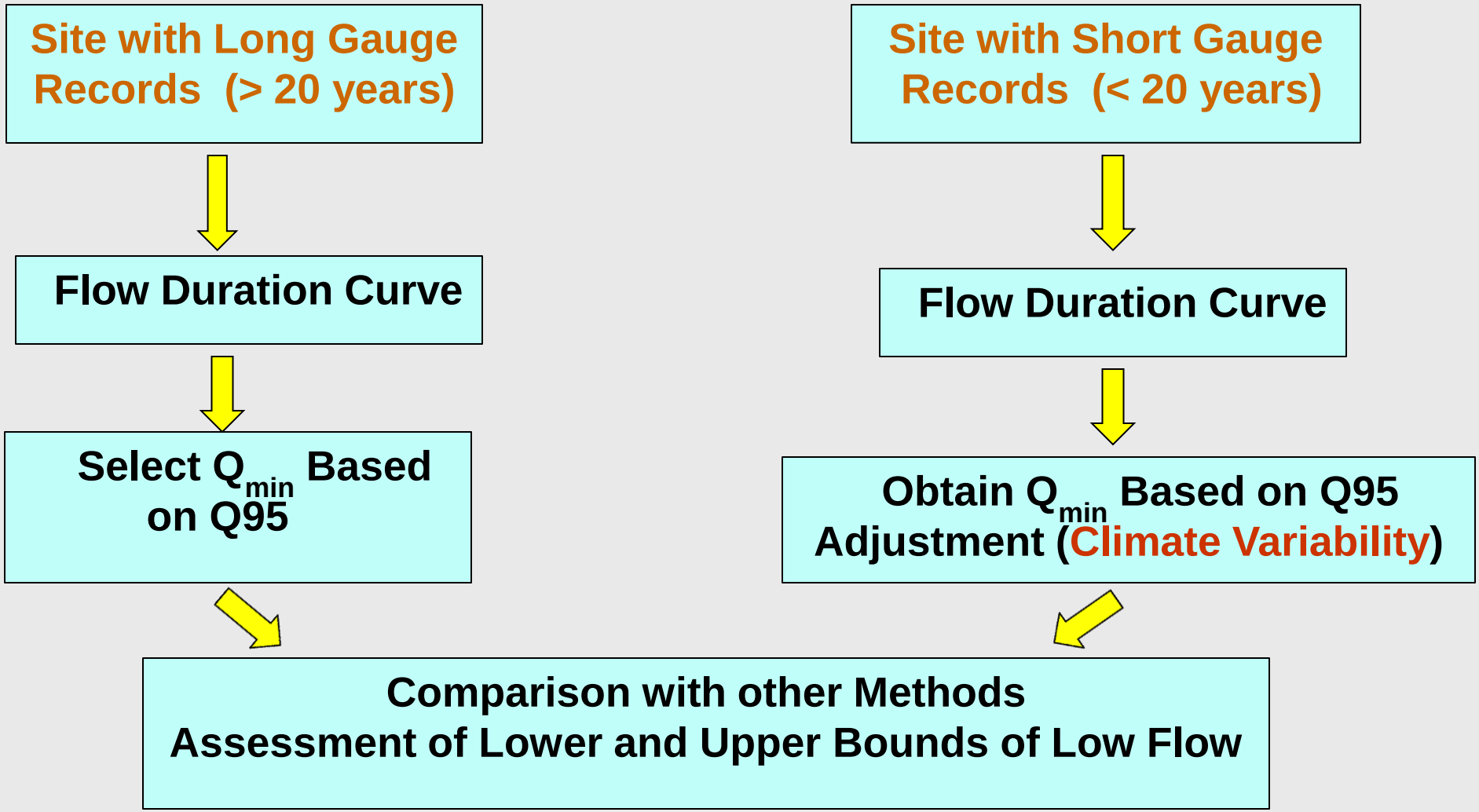
Flow Selection Methods (Continued)

2. Flow Duration Curve Method

- **FDC is a relationship between any given discharge value and the percentage of time that this discharge is equaled or exceeded.**



Flow Duration Curve Method
(Laaha and Bloschl, 2007)



2. New Approach for Low Flow Selection

Based on Minimum Flows and Levels Program implemented by Florida Water Management Districts

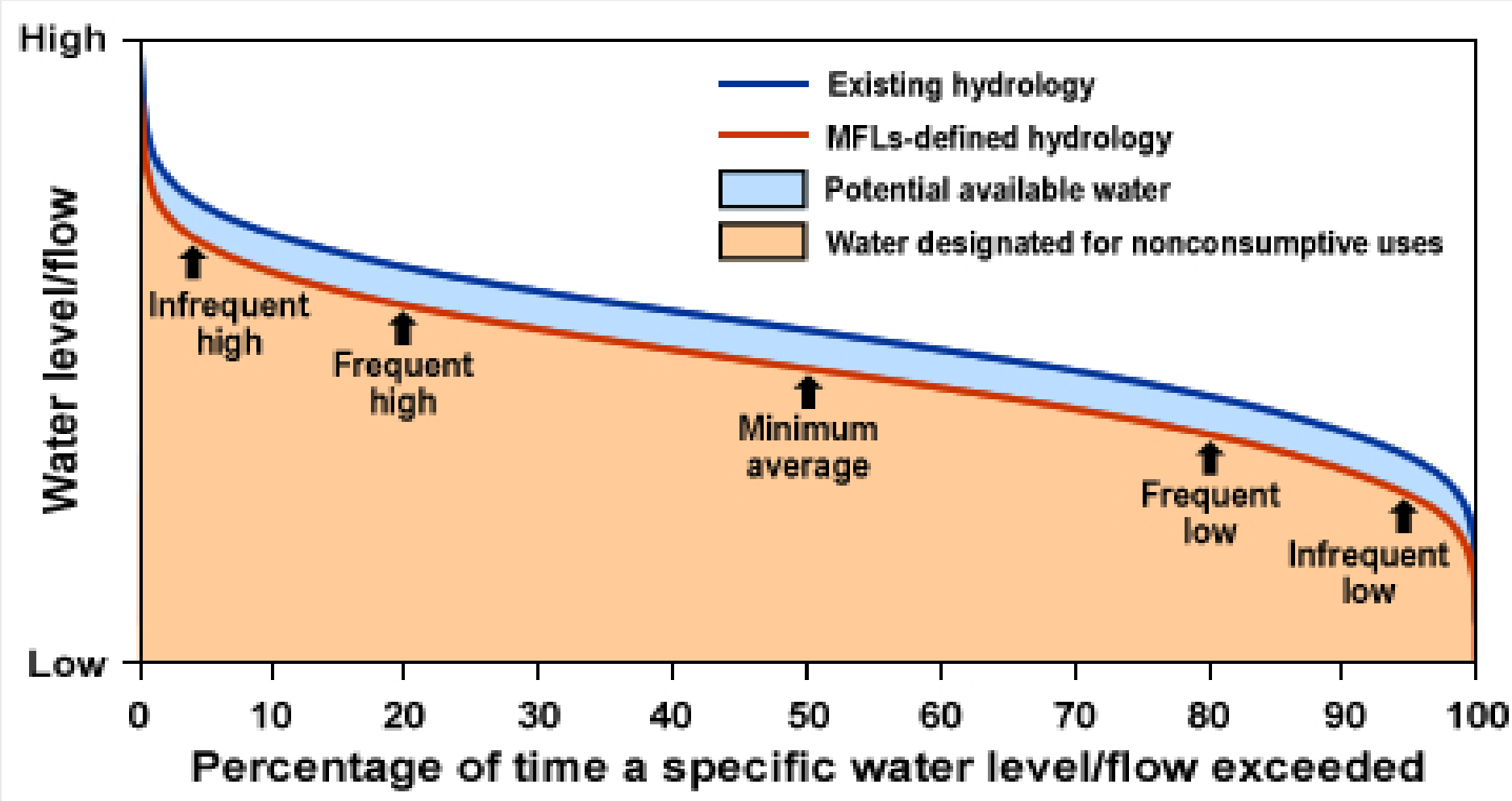
- **MFLs are the minimum water flows and/or levels as necessary to prevent significant harm to water resources or ecology of an area resulting from permitted water withdrawals**
- **MFLs define how often and for how long the high, intermediate and low water flows and/or levels should occur to prevent significant harms**

Significant harm: temporary loss of water resource functions, which result from a change in surface or ground water hydrology that takes more than two years to recover

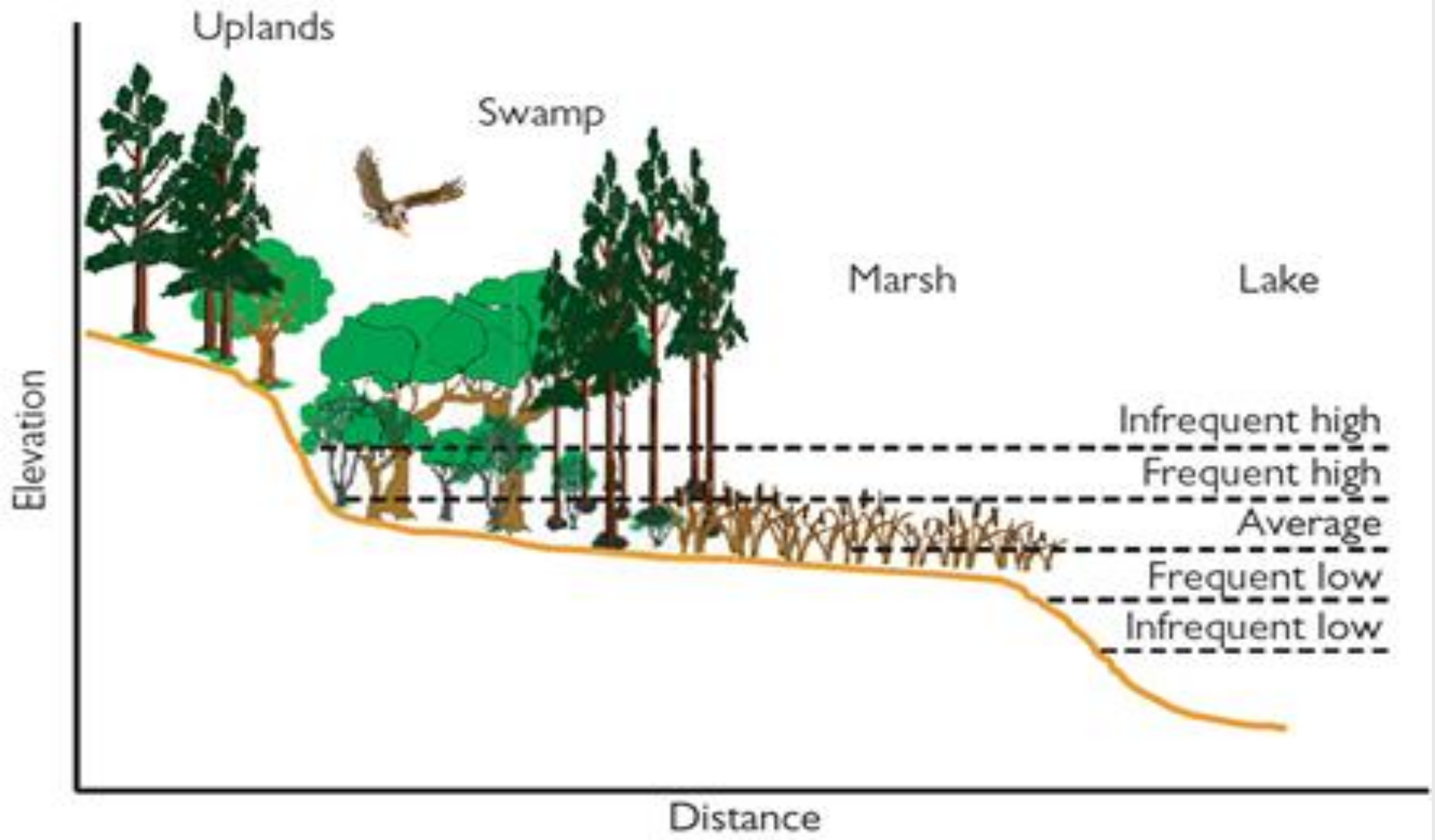
Five Categories of MFLs

1. Minimum infrequent-high (5% on FDC)
2. Minimum frequent-high (20% on FDC)
3. Minimum average (50% on FDC)
4. Minimum frequent-low (80% on FDC): A chronically low surface water level/flow that generally occurs during reduced rainfall. This category is required to prevent harmful impact on floodplain, biota, and ecosystem
5. Minimum infrequent-low (95% on FDC)

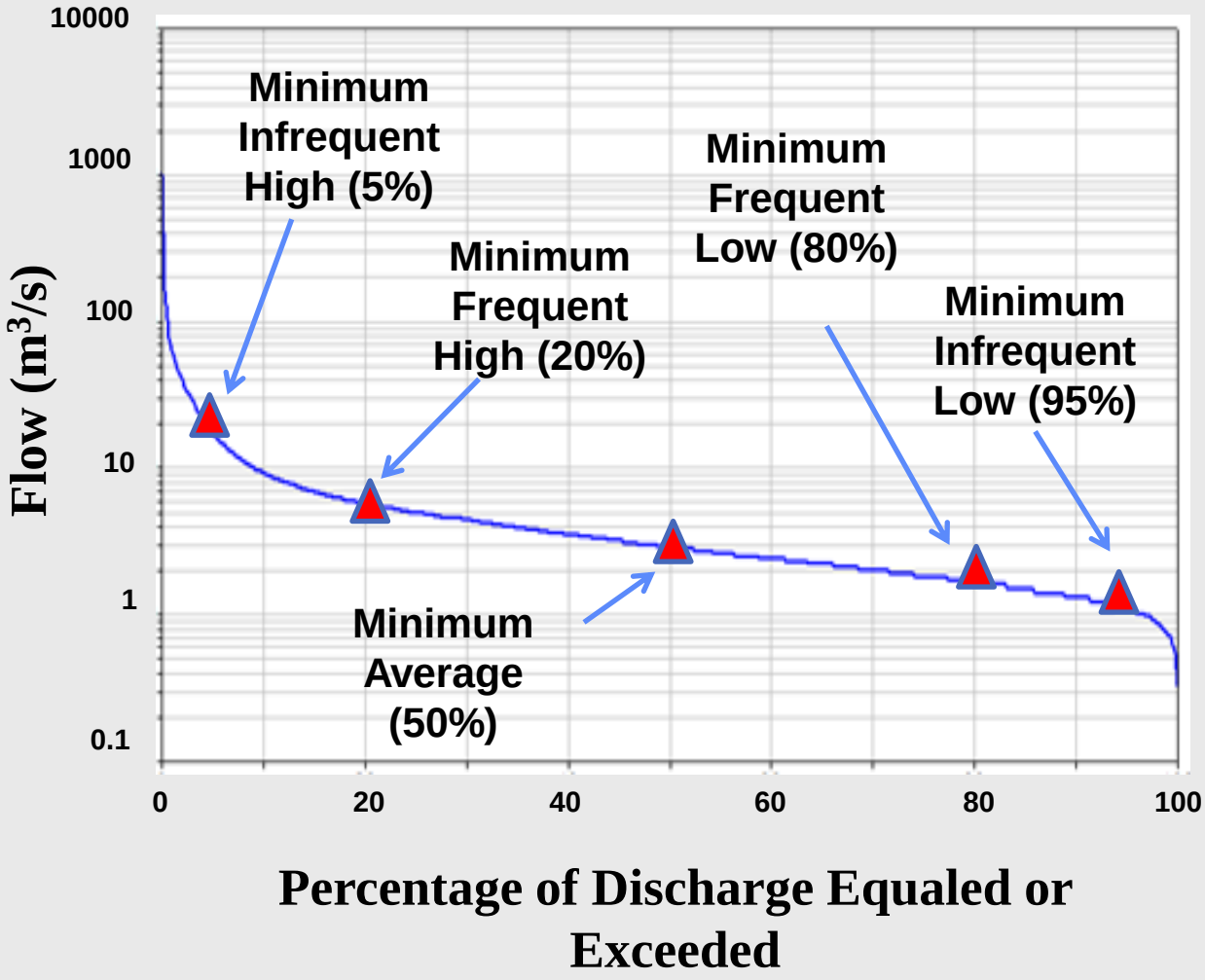
Water Level/Flow Duration Curve Related to MFLs



Water Levels vs. MFLs



New Approach for Low Flow Selection
(continued)



FL Method

Gauge Records (>20 Years)

↓

Flow Duration Curve (FDC)

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Select Low Flow Value Based on MFL's Minimum Frequent Low Category (80%) Using FDC

Rationale

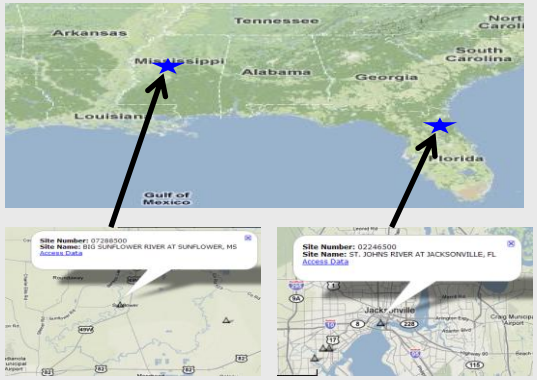
- **MFLs has clearer quantified regarding the impacts of low flow on floodplain, biota, and ecosystem**

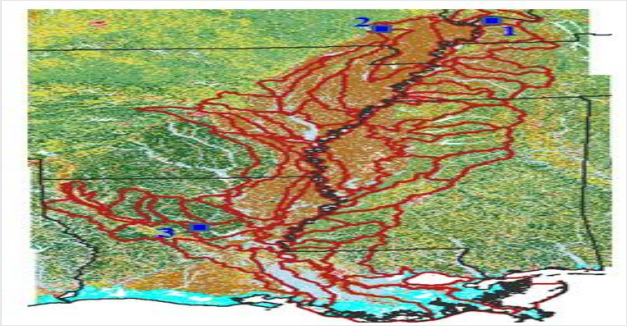
- **7Q10 method is for extremely low flow conditions occurred during severe droughts with short duration and very long return intervals**

Application of Frequent Low (FL) Approach

1. Site selection (USGS stations)

- **Agricultural land with freshwater environment: Big Sunflower River at Sunflower, MS**
- **Residential area with estuarine environment: St. Johns River at Jacksonville, Florida**
- **Pristine forest land in headwater area in Lower Mississippi River Basin. This is an ideal area for estimating low flow response to climate change**

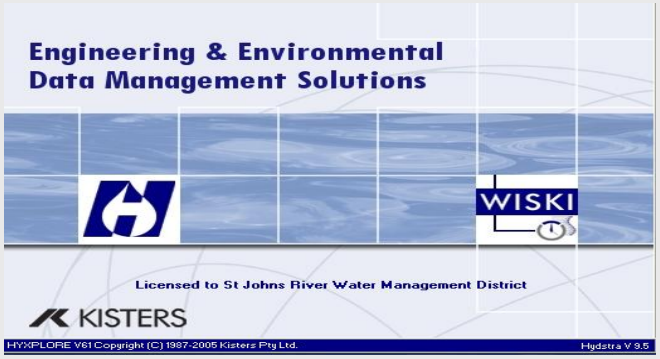




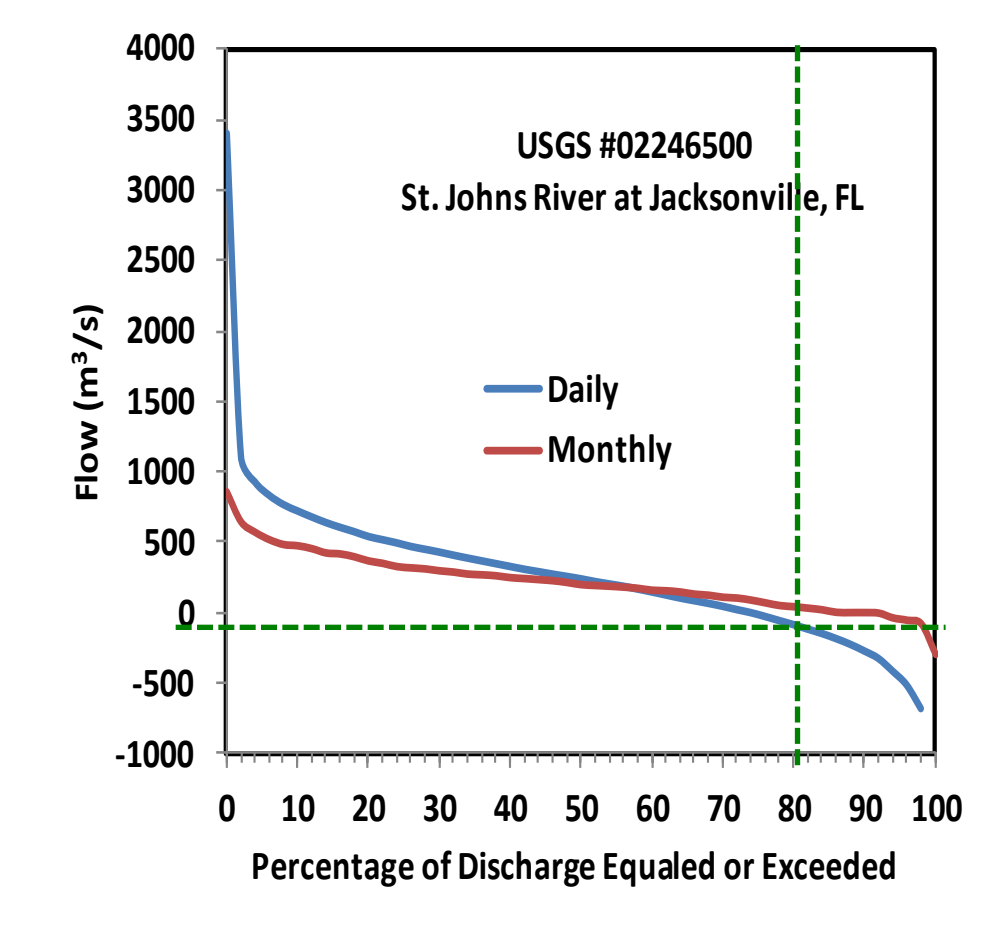
Label	USGS	Land Use	Place	POR
1	3612000	Forest deciduous	Cache River at Forman, IL	1922-2011
2	7039500	Forest deciduous	St. Francis River at Wappaello, MO	1940-2011
3	7373000	Forest evergreen	Big Creek at Pollock, LA	1942-2011

Application of FL Approach

2. Construct flow duration curve using Hydstra Model



3. Select low flows from flow duration curve at 80%

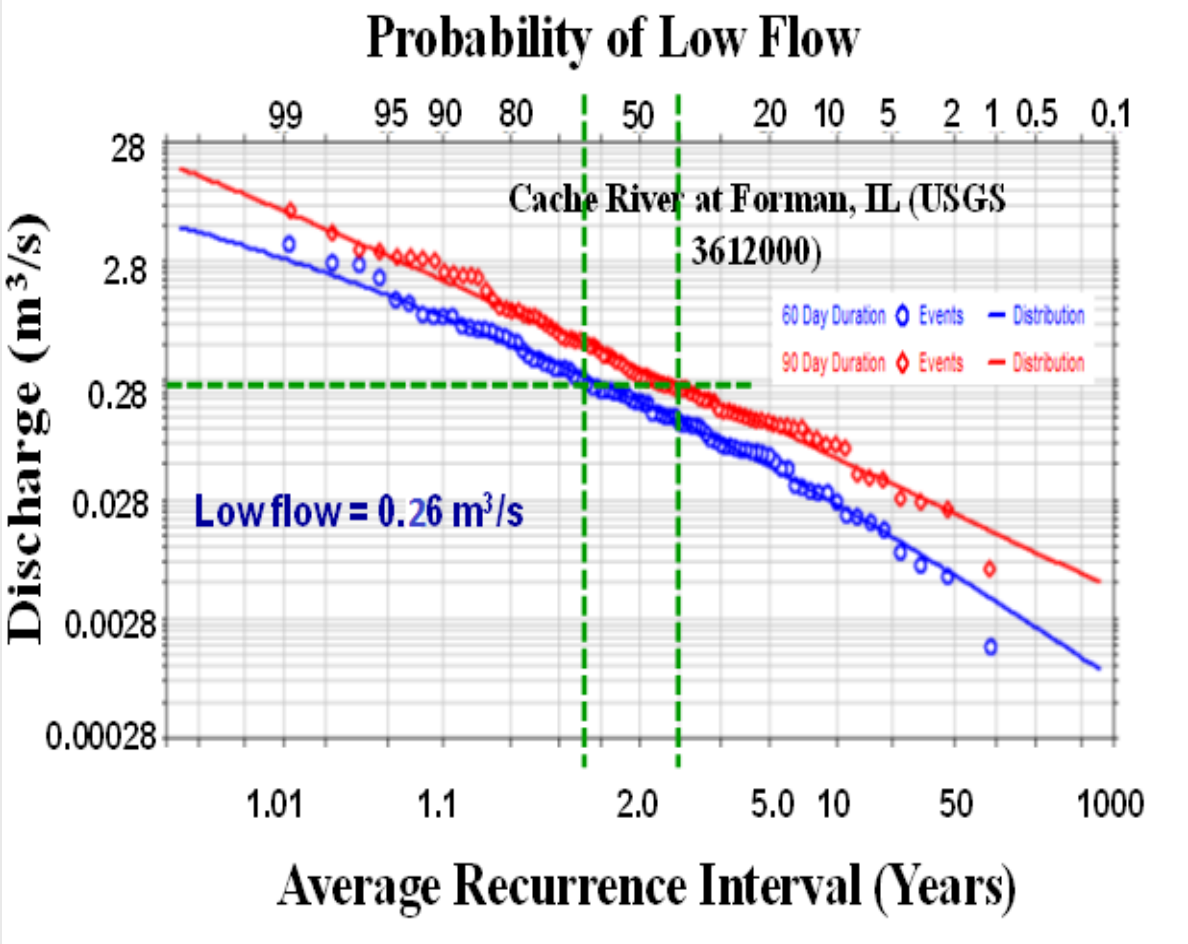


Application of FL Approach

4. Compare the new approach with the 7Q10 approach for low flow selections

5. Perform low flow frequency distribution analysis to determine low flow recurrence period

6. Divided the POR into the 10- or 20-year increments to examine how low flow changes as time elapsed



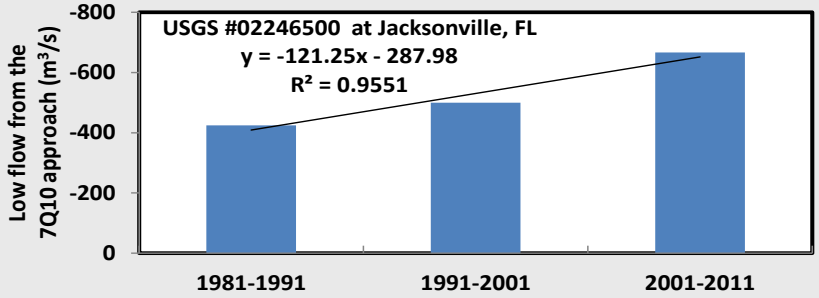
Results

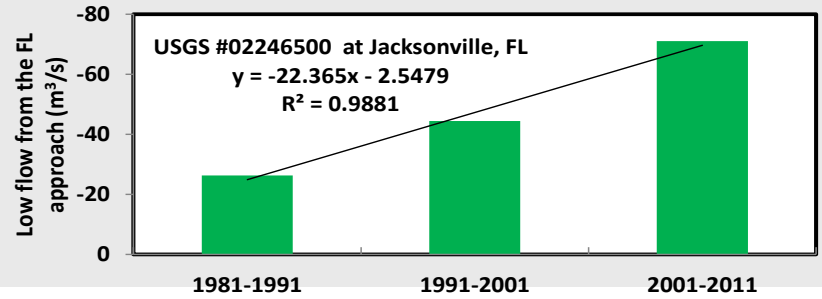
Comparison of 7Q10 and FL methods on low flow selections

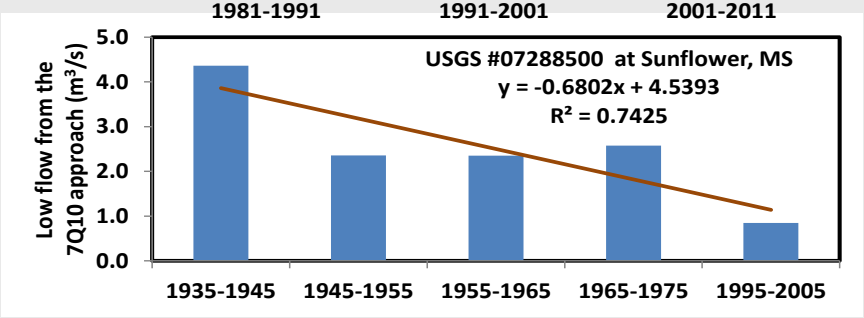
Year	7Q10		FL (Frequent-Low)	
	Low Flow (m^3/s)	% of Time a Low Flow Equaled or Exceeded	Low Flow (m^3/s)	% of Time a Low Flow Equaled or Exceeded
	USGS #02246500 in St. Johns River at Jacksonville, Florida Estuarine Environment			
1981-1991	-424	96	-26	80
1991-2001	-500	96	-44	80
2001-2011	-667	98	-71	80
	USGS #02246500 in Big Sunflower River at Sunflower, Mississippi Freshwater Environment			
1935-1945	4.4	100	5.9	80
1945-1955	2.4	100	5.8	80
1955-1965	2.3	99	4.0	80
1965-1975	2.6	99	4.0	80
1995-2005	0.8	99	3.9	80

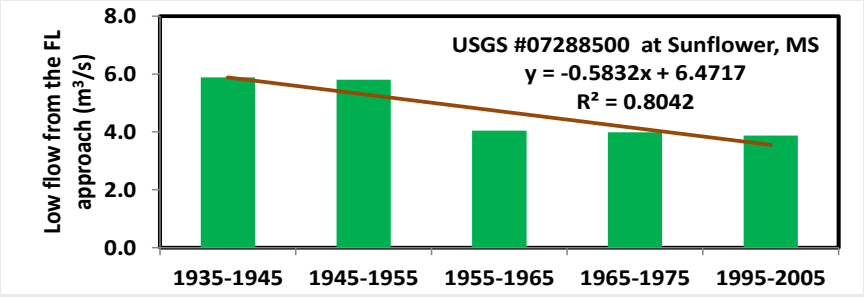
- **7Q10 method could lead to the selection of extremely low flows that may hinder its use for establishing criteria to prevent streams from significant harm to biological and ecological communities**
- **7Q10 method could not be used for data < 10 years by definition**

7Q10 vs. FL Methods on Low Flow Selections



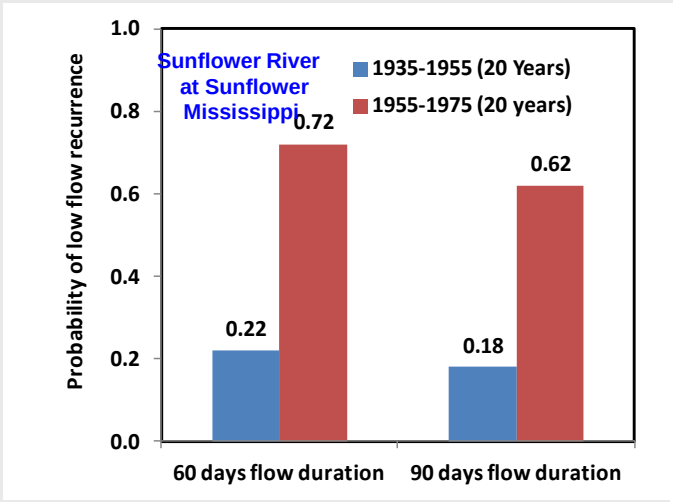


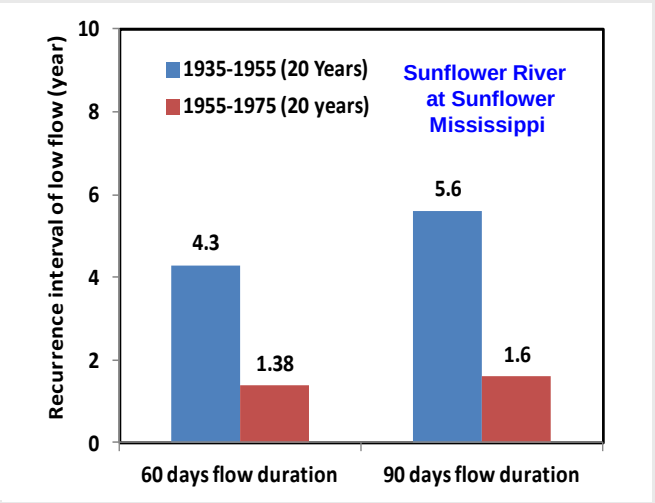


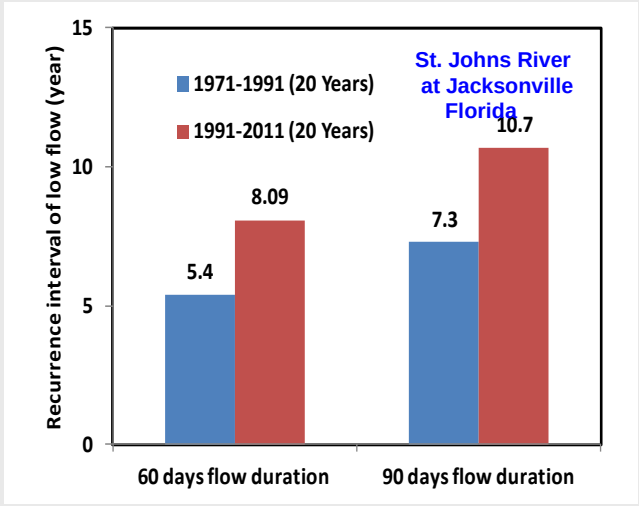


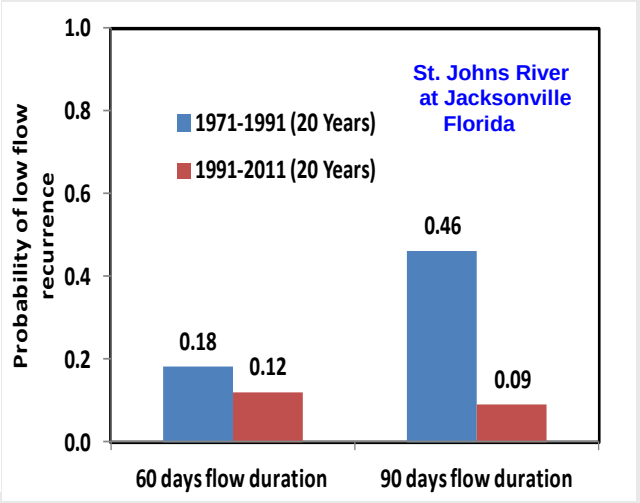
- **Both methods show that low flow decreased as time elapsed in the estuarine and freshwater environments**
- **St. Johns River became drier with a tendency of salted water intrusion during the last two decades**
- **Big Sunflower River became dried during the last seven decades**

Low Flow Recurrence Probability and Recurrence Interval





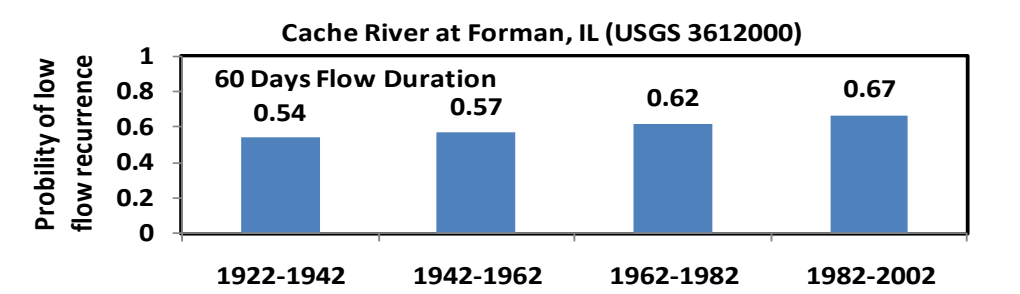


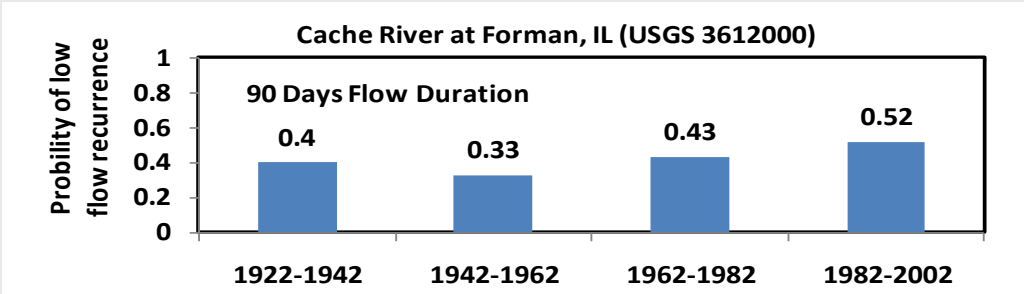


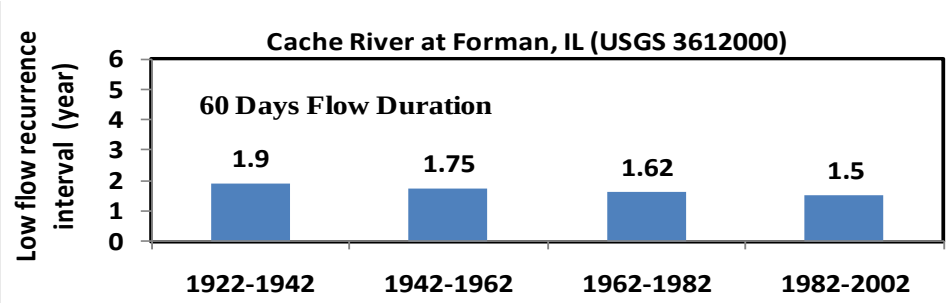
Recurrence probability of low flow increased while the recurrence interval of low flow decreased as time elapsed in both rivers

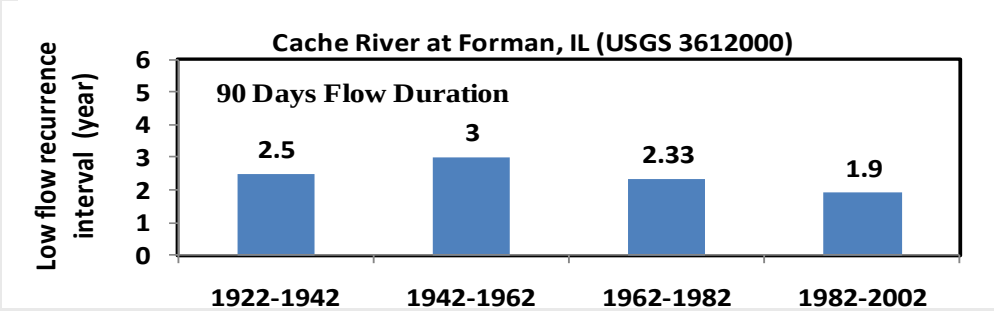
Low flows occurred more frequent in these rivers as time elapsed

Low flows in Pristine Forest Lands









- **Recurrence probability increased and recurrence interval decreased for low flow as time elapsed with a 20-year increment**
- **Low flow occurred more often as time elapsed from 1922 to present**
- **Past climate change has made the headwater areas drier**

Summary

1. Developed a new approach (i.e., frequent low or FL) for low flow selections
2. Compared the FL approach with 7Q10 approach
3. 7Q10 approach could lead to the selection of extremely low flows
4. Low flows occurred more frequent in the rivers as time elapsed, indicating the study areas are becoming drier
5. Past climate change has made the pristine forest lands drier
6. Reduce water use, reclaim wastewater , and enhance GW discharge to mitigate water resource shortage