Concept of Environmental Flow and Application on Reservoirs Using IHA Software

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Hydroelectic Power Plants in TURKEY

PRESENT STATE OF HYDRAUELECTRIC POWER PLANTS		
IN-SERVICE	**13,700 MW (172 HES)**	**15,660 MW (267 HES)**
DSİ (General Directorate of State Hydraulic Works)	**10,700 MW (57 HES)**	
Others	**3,000 MW (115 HES)**	
UNDER CONSTRUCTION	**8,600 MW (147 HES)**	**8,000 MW (210 HES)**
DSİ (General Directorate of State Hydraulic Works)	**3,600 MW (23 HES)**	
Diğerleri	**5,000 MW (125 HES)**	
DEVELOPING	**22,700 MW (1418 HES)**	**20,000 MW (1050 HES)**
In accordance with the law no. 4628 or 3096, will be constructed by private sector	**18,700 MW (1401 HES)**	
In accordance with the law no. 4628 or 3096, bilateral cooperation projects	**4,000 MW (17 HES)**	
TOTAL POTENTIAL	**45,000 MW (1738 HES)**	**43,660 MW (1527 HES)**

(Karayılan, İ., www.suhakki.org, 2010) (DSİ Web Page, www.dsi.gov.tr, 2012)

Ecological Effects of Damming

- Dams have considerable influence on downstream river ecosystems, in many cases extending for hundreds of kilometers below a dam
- Changes affect water temperature, chemistry, sediment transport, floodplain vegetation communities, nutrient delivery ,etc.
- Dams affect dowstream estuaries, deltas, coastal zones by modifying saltwater intrusion and wedge patterns

Why?

- Heavily modifies the volume of water flowing downstream
- Changes timing, frequency and duration of high and low flows
- Alters the natural rates of water level rise and fall during runoff events.

Main Ecological Effects

Bunn and Arthington (2002) summarize their review of this literature by highlighting four primary ecological impacts associated with flow alteration:

1. Because **river flow shapes physical habitats** such as riffles, pools, and bars in rivers and floodplains, and thereby determines biotic composition, flow alteration can lead to severely modified channel and floodplain habitats;
2. **Aquatic species have evolved life history strategies**, such as their timing of reproduction, in direct response to natural flow regimes, which **can be desynchronized through flow alteration**;
3. Many species are highly dependent upon **lateral and longitudinal hydraulic connectivity,** which can be **broken through flow alteration**; and
4. **The invasion of exotic and introduced species in river systems** can be facilitated by flow alteration.

Bunn, S. E., and Arthington, A. H. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.

ENVIRONMENTAL FLOW POLICY OF TURKEY

- According to regulation*, for the sustainment of the natural life downstream the flow must be at least **10 percent of the average of the last ten years flow**.
- The flows released can be increased when ecological needs arise in the process of the Environmental Impact Assessment
- The released flows (the 10%fraction) can be inadequate to sustain the flora and fauna downstream.
- The environmental flow amount must be determined by taking the living conditions in the stream into consideration.

*Elektrik Piyasasında Üretim Faaliyetinde Bulunmak Üzere Su Kullanım Hakkı Anlaşması İmzalanmasına İlişkin Usul ve Esaslar Hakkında Yönetmelik

(Regulation on methods and guidelines for water use rights agreeements about production activities at the electricity market)

IHA Software

(Indicators of Hydrologic Alterations)

- Version 7.1
- The Nature Conservancy
- An easy-to-use tool for calculating the characteristics of natural and altered hydrologic regimes.
- http://conserveonline.org/workspaces/iha
- The method and software will work on any type of **daily hydrologic data**, such as streamflows, river stages, ground water levels, or lake levels.
- The power of the IHA method is that it can be used to summarize long periods of daily hydrologic data into a much more manageable series of ecologically relevant hydrologic parameters.

Five environmental flow components (EFCs) used in the IHA, and their ecosystem influences (IHA ver 7.1 Manual)

1. Monthly low flows

- Provide adequate habitat for aquatic Organisms
- Maintain suitable water temperatures, dissolved oxygen, and water chemistry
- Maintain water table levels in floodplain, soil moisture for plants
- Provide drinking water for terrestrial animals
- Keep fish and amphibian eggs suspended
- Enable fish to move to feeding and spawning areas
- Support hyporheic organisms living in saturated sediments

2. Extreme low flows

- Enable recruitment of certain floodplain plant species
- Purge invasive, introduced species from aquatic and riparian communities
- Concentrate prey into limited areas to benefit predators

3. High flow pulses

- Shape physical character of river channel, including pools, riffles
- Determine size of streambed substrates, e.g., sand, gravel, cobble
- Prevent riparian vegetation from encroaching into channel
- Restore normal water quality conditions after prolonged low flows, flushing away waste products, and pollutants
- Aerate eggs in spawning gravels, prevent siltation
- Maintain suitable salinity conditions in estuaries

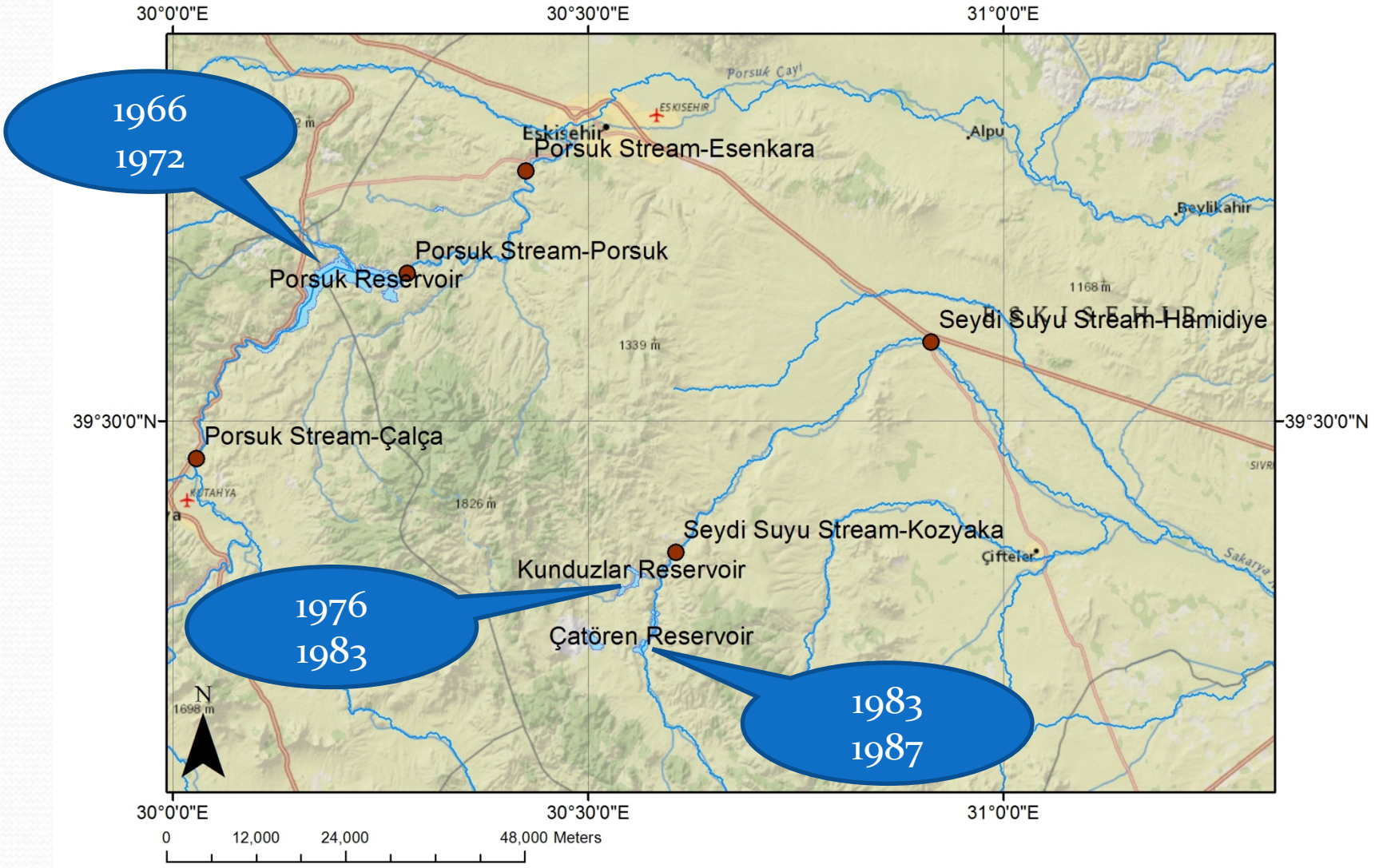
4. Small floods, i.e., 2-10 yr events

- May apply to small or large floods:
- Provide migration and spawning cues for fish
- Trigger new phase in life cycle, i.e., insects
- Enable fish to spawn in floodplain, provide nursery area for juvenile fish
- Provide new feeding opportunities for fish, waterfowl
- Recharge floodplain water table
- Maintain diversity in floodplain forest types through prolonged inundation, i.e., different plant species have different tolerances
- Control distribution and abundance of plants on floodplain
- Deposit nutrients on floodplain

5. Large floods, i.e., >10-yr events

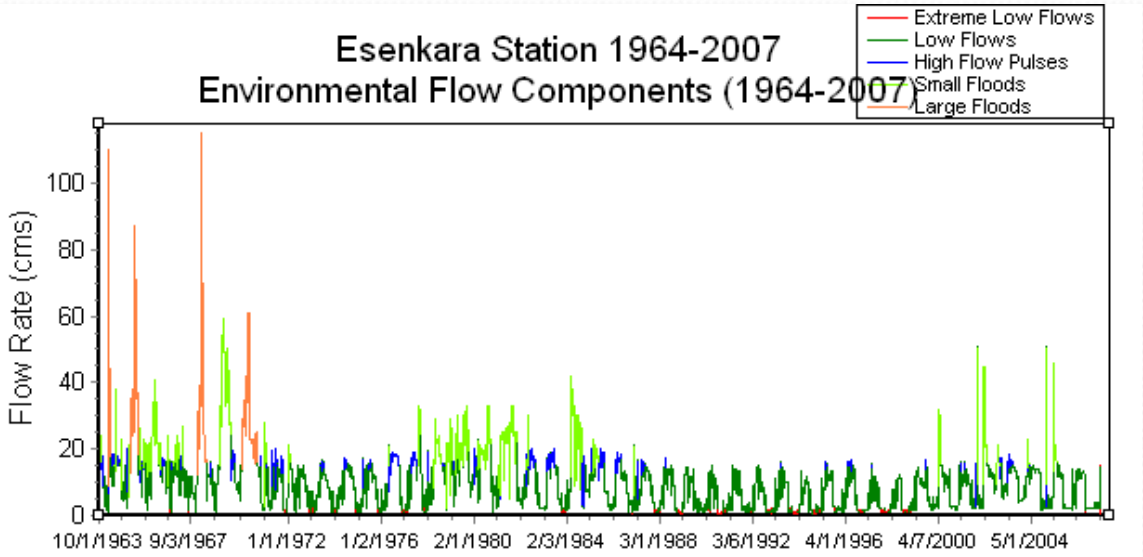
- May apply to small or large floods:
- Maintain balance of species in aquatic and riparian communities
- Create sites for recruitment of colonizing plants
- Shape physical habitats of floodplain
- Deposit gravel and cobbles in spawning areas
- Flush organic materials such as food and woody debris such as habitat structures into channel
- Purge invasive, introduced species from aquatic and riparian communities
- Disburse seeds and fruits of riparian plants
- Drive lateral movement of river channel, forming new habitats, e.g., secondary channels, oxbow lakes
- Provide plant seedlings with prolonged access to soil moisture

FLOW STATIONS USED

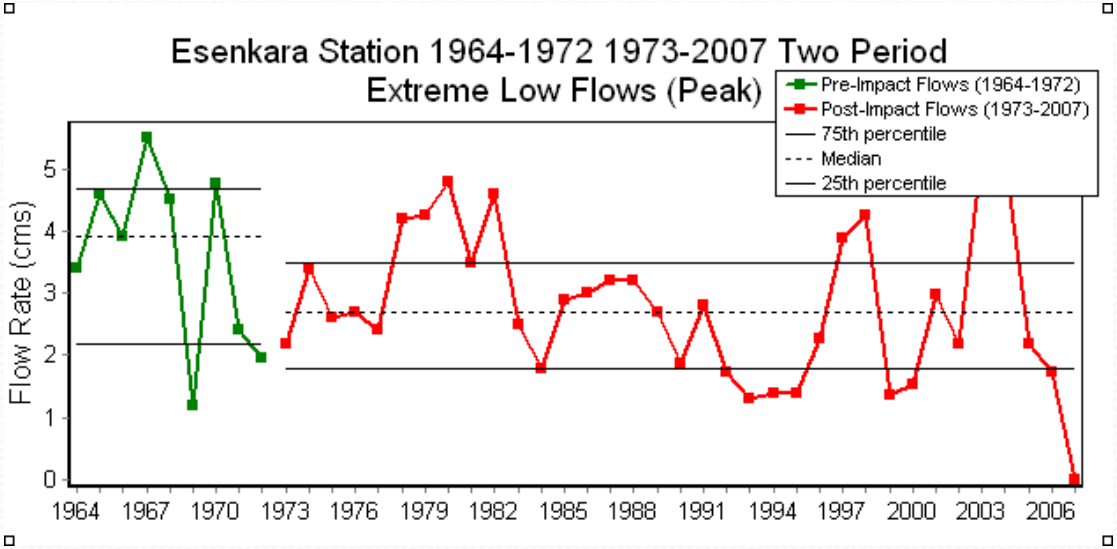


ANALYSIS TYPES

Single Time Period Analysis

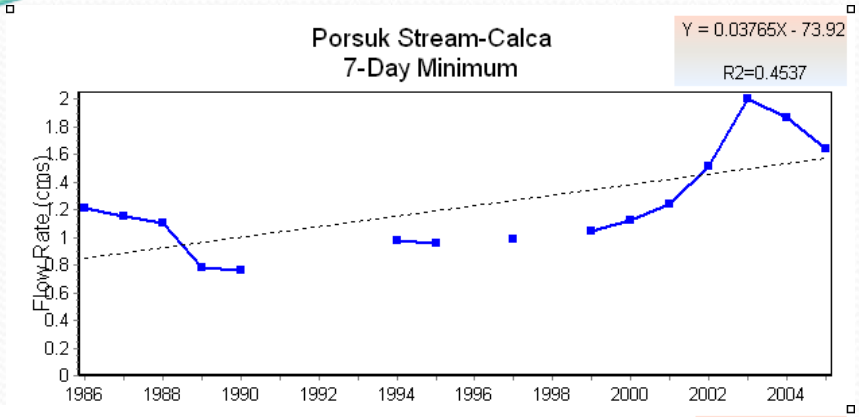


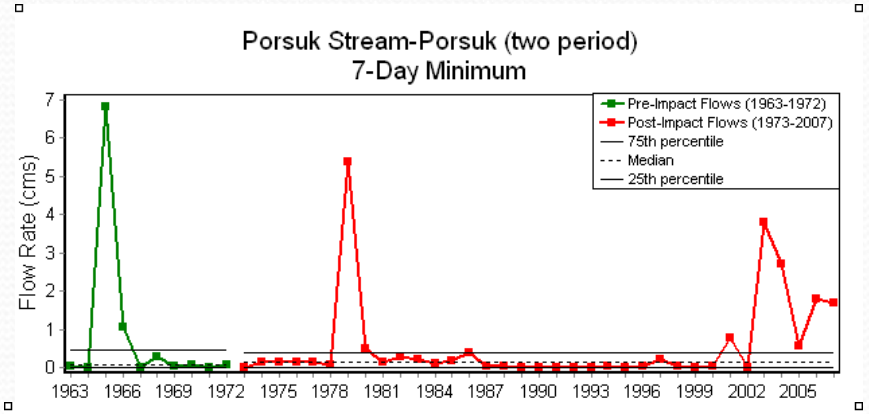
Two Distinct Time Period Analysis

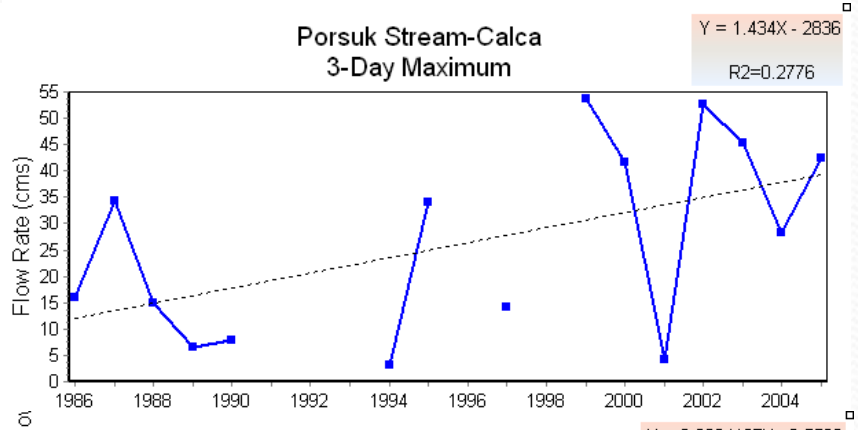


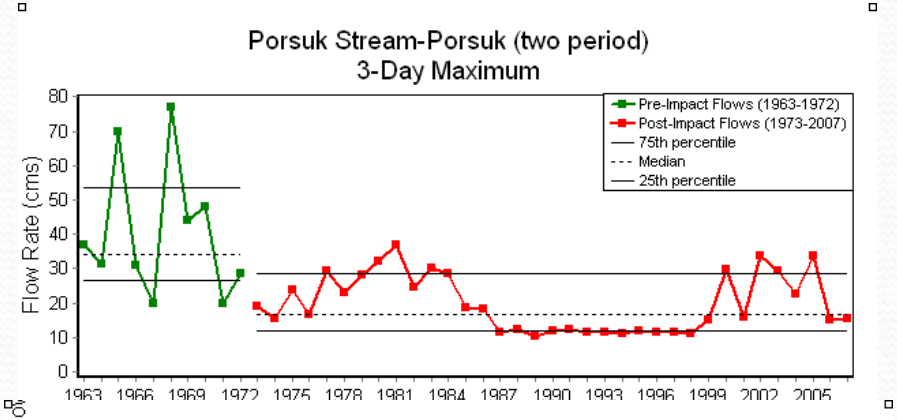
IHA RESULTS

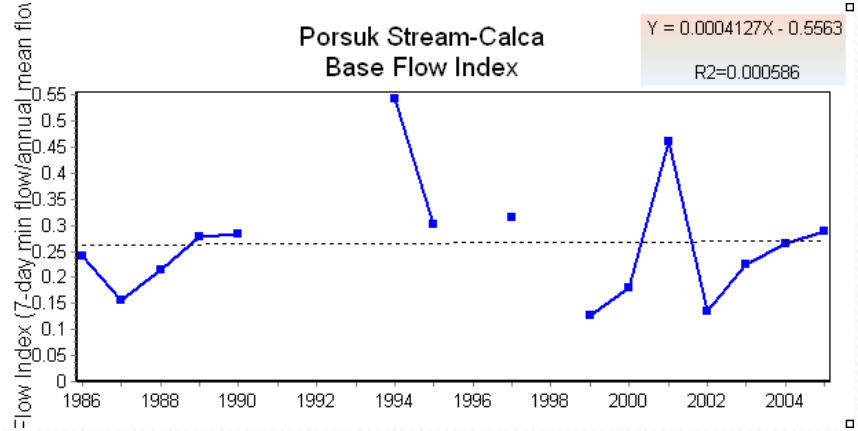
- Monthly flows
- Zero-flow days
- 1-3-7-30-90 day minimum
- 1-3-7-30-90 day maximum
- Date of min, max flows
- Low-High pulse counts-durations
- Rise-Fall Rates
- Base flow index
- Flow duration curves
- Environmental flow components
- Monthly low flows
- Extreme low flows
- High flow pulses
- Small floods
- Large floods

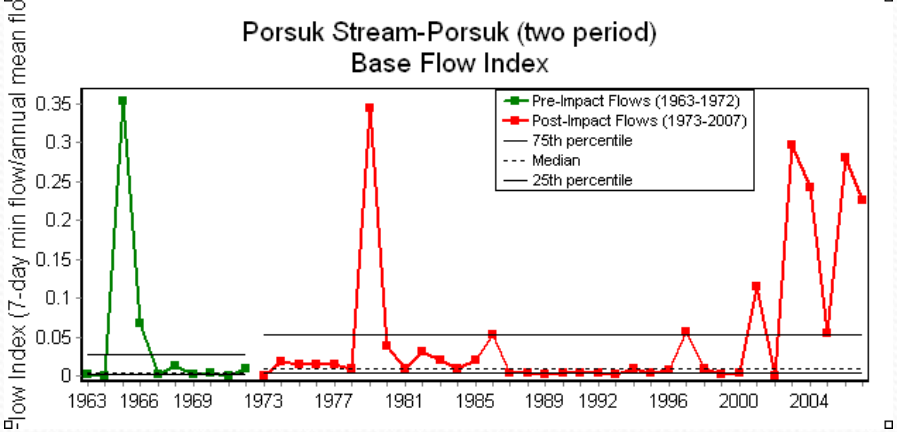

Porsuk Stream-Calca
7-Day Minimum
Y = 0.03765X - 73.92
R2=0.4537
Flow Rate (cms)


Porsuk Stream-Porsuk (two period)
7-Day Minimum
Pre-Impact Flows (1963-1972)
Post-Impact Flows (1973-2007)
75th percentile
Median
25th percentile
Flow Rate (cms)


Porsuk Stream-Calca
3-Day Maximum
Y = 1.434X - 2836
R2=0.2776
Flow Rate (cms)


Porsuk Stream-Porsuk (two period)
3-Day Maximum
Pre-Impact Flows (1963-1972)
Post-Impact Flows (1973-2007)
75th percentile
Median
25th percentile
Flow Rate (cms)


Porsuk Stream-Calca
Base Flow Index
Y = 0.0004127X - 0.5563
R2=0.000586
Flow Index (7-day min flow/annual mean flo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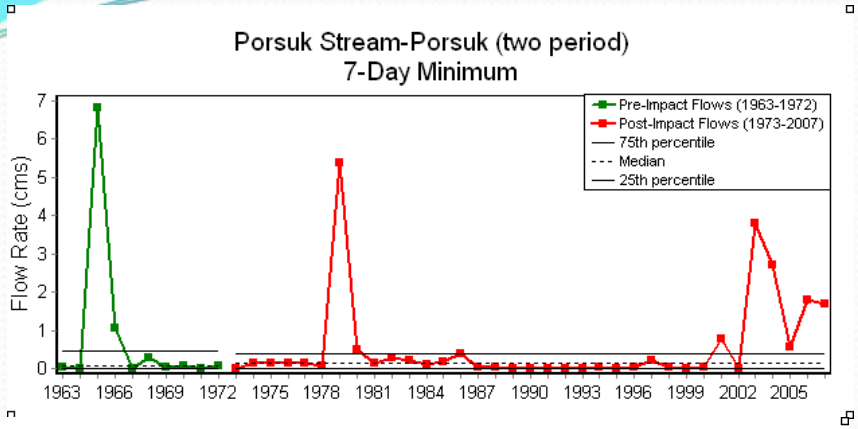
Base Flow Index
Pre-Impact Flows (1963-1972)
Post-Impact Flows (1973-2007)
75th percentile
Median
25th percentile
Flow Index (7-day min flow/annual mean flow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Flow Rate (cms)
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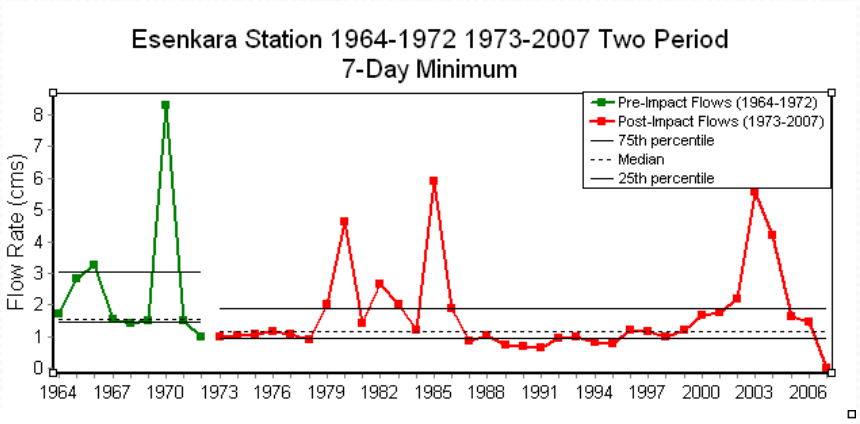
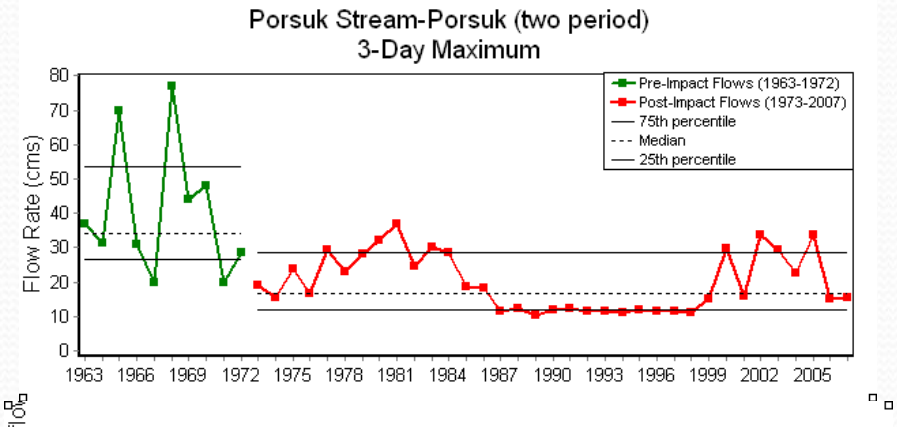
25th percentile


Esenkara Station 1964-1972 1973-2007 Two Period
7-Day Minimum
Flow Rate (cms)
Pre-Impact Flows (1964-1972)
Post-Impact Flows (1973-2007)
75th percentile
Median
25th percentile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Flow Rate (cms)
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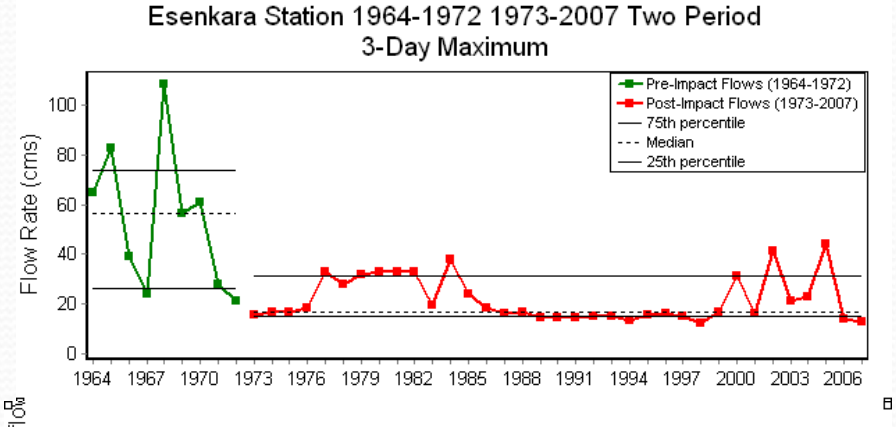
Median
25th percentile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3-Day Maximum
Flow Rate (cms)
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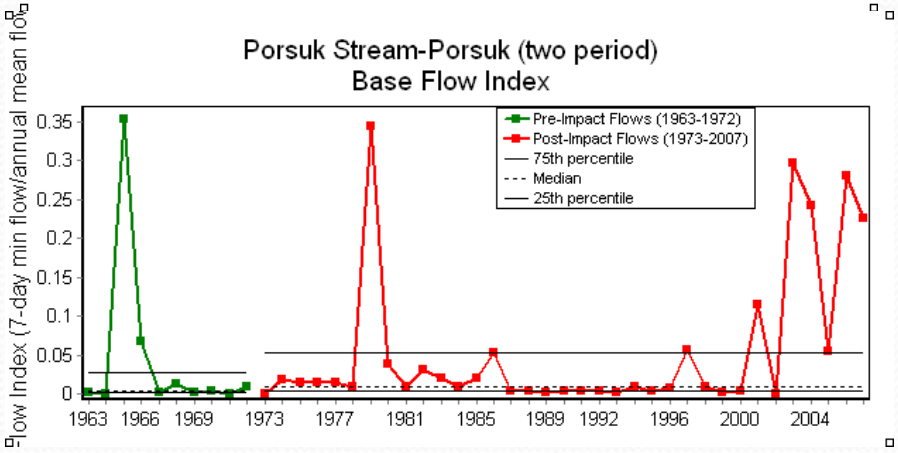
Post-Impact Flows (1973-2007)
75th percentile
Median
25th percentile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Base Flow Index
low Index (7-day min flow/annual mean flow
Pre-Impact Flows (1963-1972)
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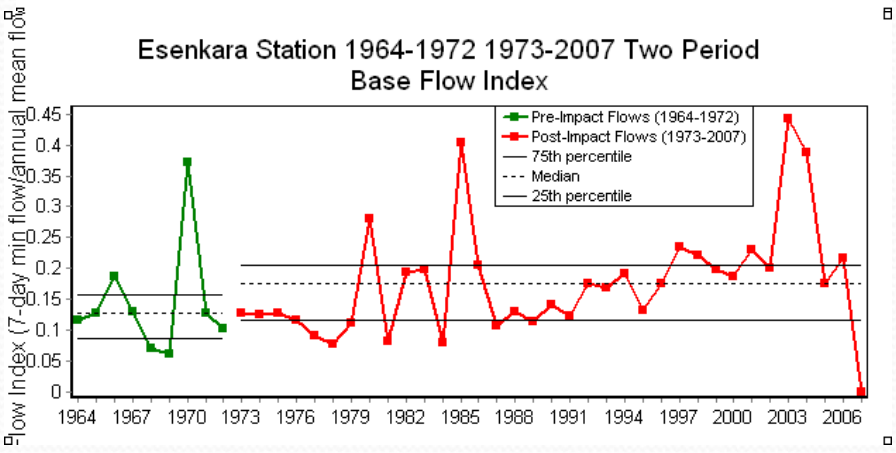
75th percentile
Median
25th percentile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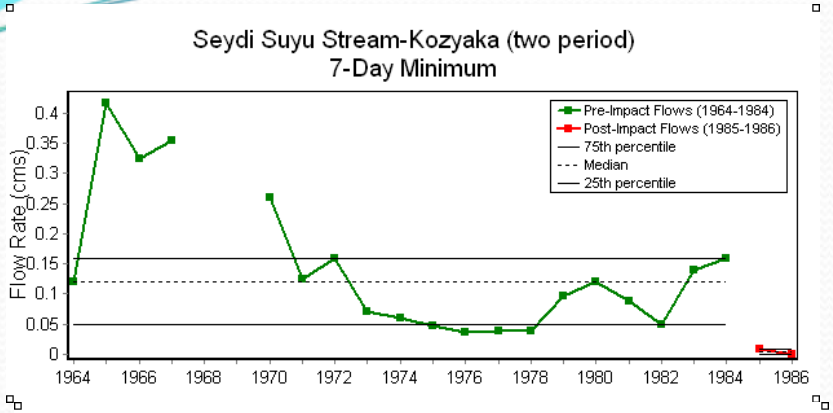
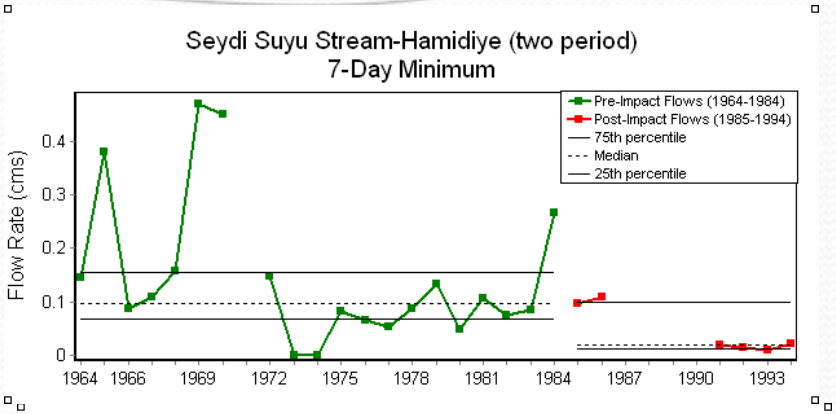
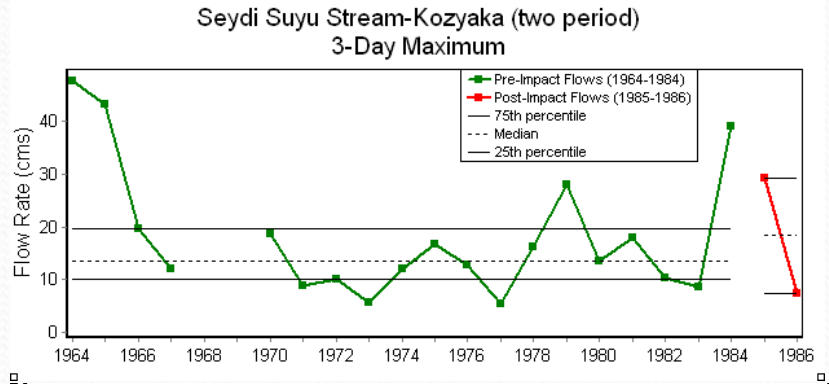
75th percentile
Median
25th percentile


Seydi Suyu Stream-Kozyaka (two period)
7-Day Minimum
Flow Rate (cms)
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1986)
75th percentile
Median
25th percentile
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986


Seydi Suyu Stream-Hamidiye (two period)
7-Day Minimum
Flow Rate (cms)
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1994)
75th percentile
Median
25th percentile
0
0.1
0.2
0.3
0.4
1964
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993


Seydi Suyu Stream-Kozyaka (two period)
3-Day Maximum
Flow Rate (cms)
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1986)
75th percentile
Median
25th percentile
0
10
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1964
1966
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1976
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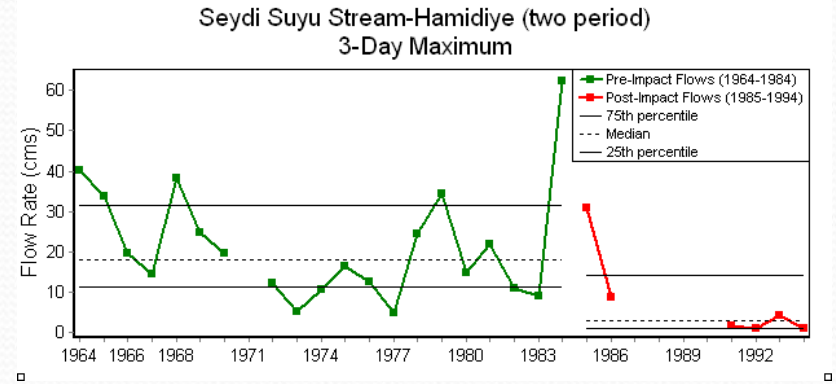
1980
1982
1984
1986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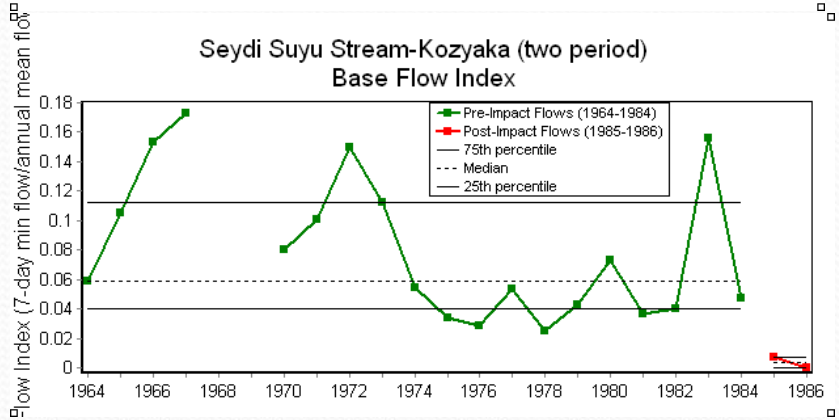
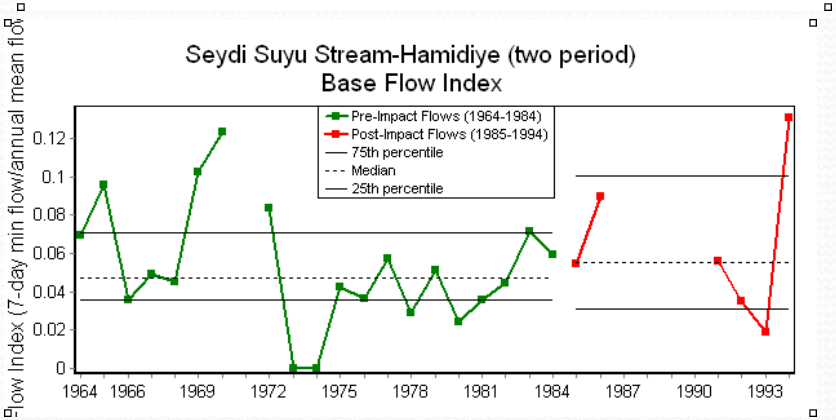
3-Day Maximum
Flow Rate (cms)
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1994)
75th percentile
Median
25th percentile
0
10
20
30
40
50
60
1964
1966
1968
1971
1974
1977
1980
1983
1986
1989
1992


Seydi Suyu Stream-Kozyaka (two period)
Base Flow Index
low Index (7-day min flow/annual mean flo
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1986)
75th percentile
Median
25th percentile
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986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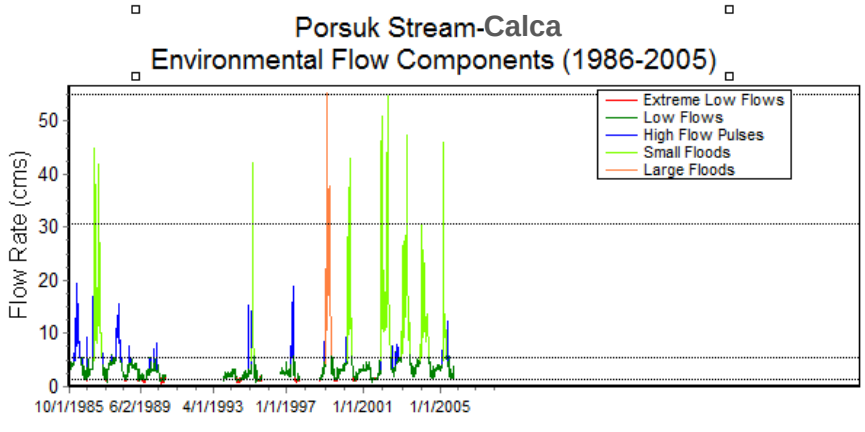
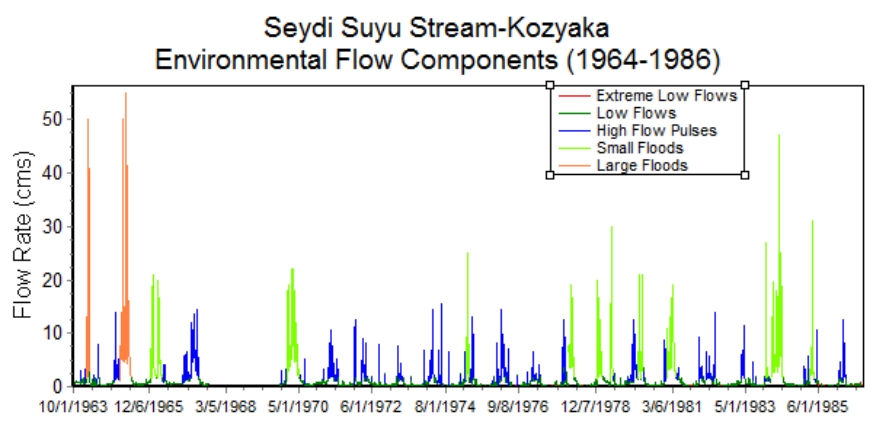
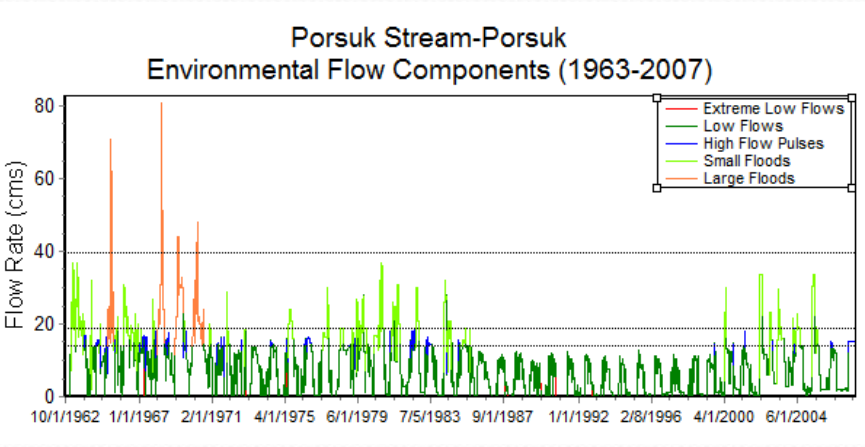
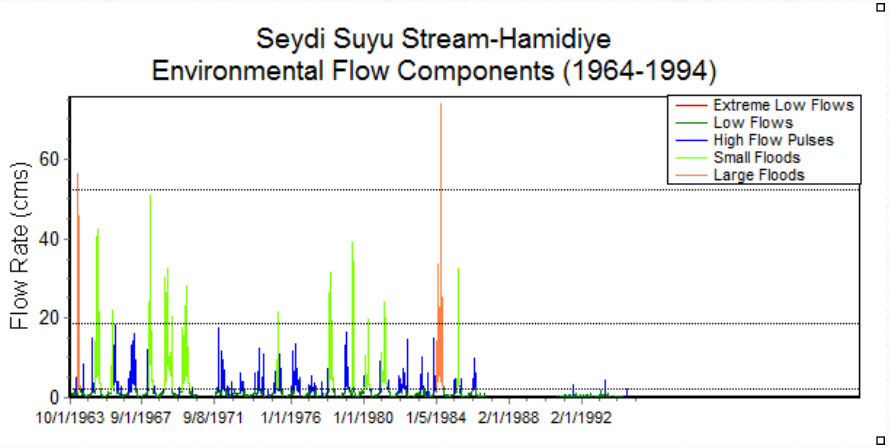
Base Flow Index
low Index (7-day min flow/annual mean flo
Pre-Impact Flows (1964-1984)
Post-Impact Flows (1985-1994)
75th percentile
Median
25th percentile
0
0.02
0.04
0.06
0.08
0.1
0.12
1964
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993

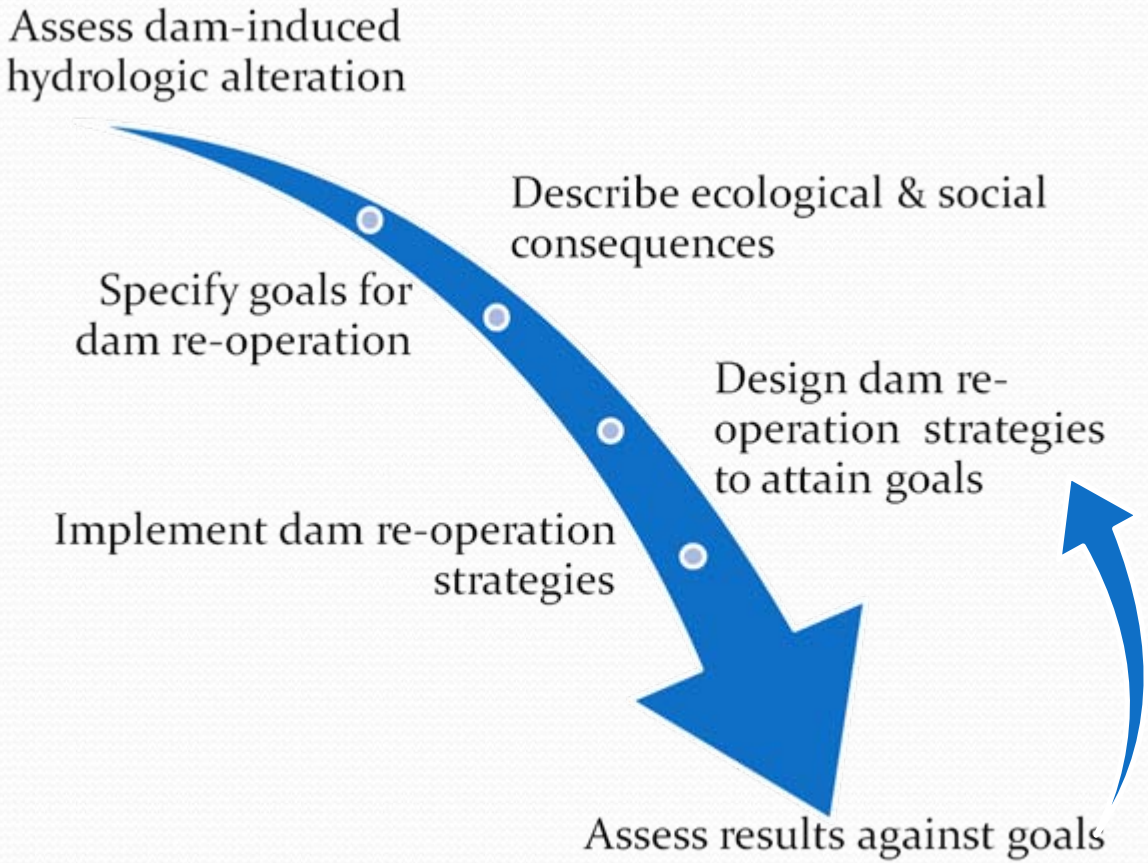

Porsuk Stream-Calca
Environmental Flow Components (1986-2005)
Flow Rate (cms)
0
10
20
30
40
50
10/1/1985
6/2/1989
4/1/1993
1/1/1997
1/1/2001
1/1/2005
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods


Seydi Suyu Stream-Kozyaka
Environmental Flow Components (1964-1986)
Flow Rate (cms)
0
10
20
30
40
50
10/1/1963
12/6/1965
3/5/1968
5/1/1970
6/1/1972
8/1/1974
9/8/1976
12/7/1978
3/6/1981
5/1/1983
6/1/1985
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods


Porsuk Stream-Porsuk
Environmental Flow Components (1963-2007)
Flow Rate (cms)
0
20
40
60
80
10/1/1962
1/1/1967
2/1/1971
4/1/1975
6/1/1979
7/5/1983
9/1/1987
1/1/1992
2/8/1996
4/1/2000
6/1/2004
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods


Seydi Suyu Stream-Hamidiye
Environmental Flow Components (1964-1994)
Flow Rate (cms)
0
20
40
60
10/1/1963
9/1/1967
9/8/1971
1/1/1976
1/1/1980
1/5/1984
2/1/1988
2/1/1992
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods

Dam Re-Operation Process



Problems !!!

- IHA needs daily flow data
- Insufficient monitoring station amount
- Insufficient data intervals (<30 years)
- Missing data, gaps
- Data QA/QC
- To be need change at the Legal regulations

THANKS !

WATER
WILL
NOT
FLOW
FOR
NOTHING !