Environmental Flow Assessment

of

Lower Paung Laung Hydro Power Project

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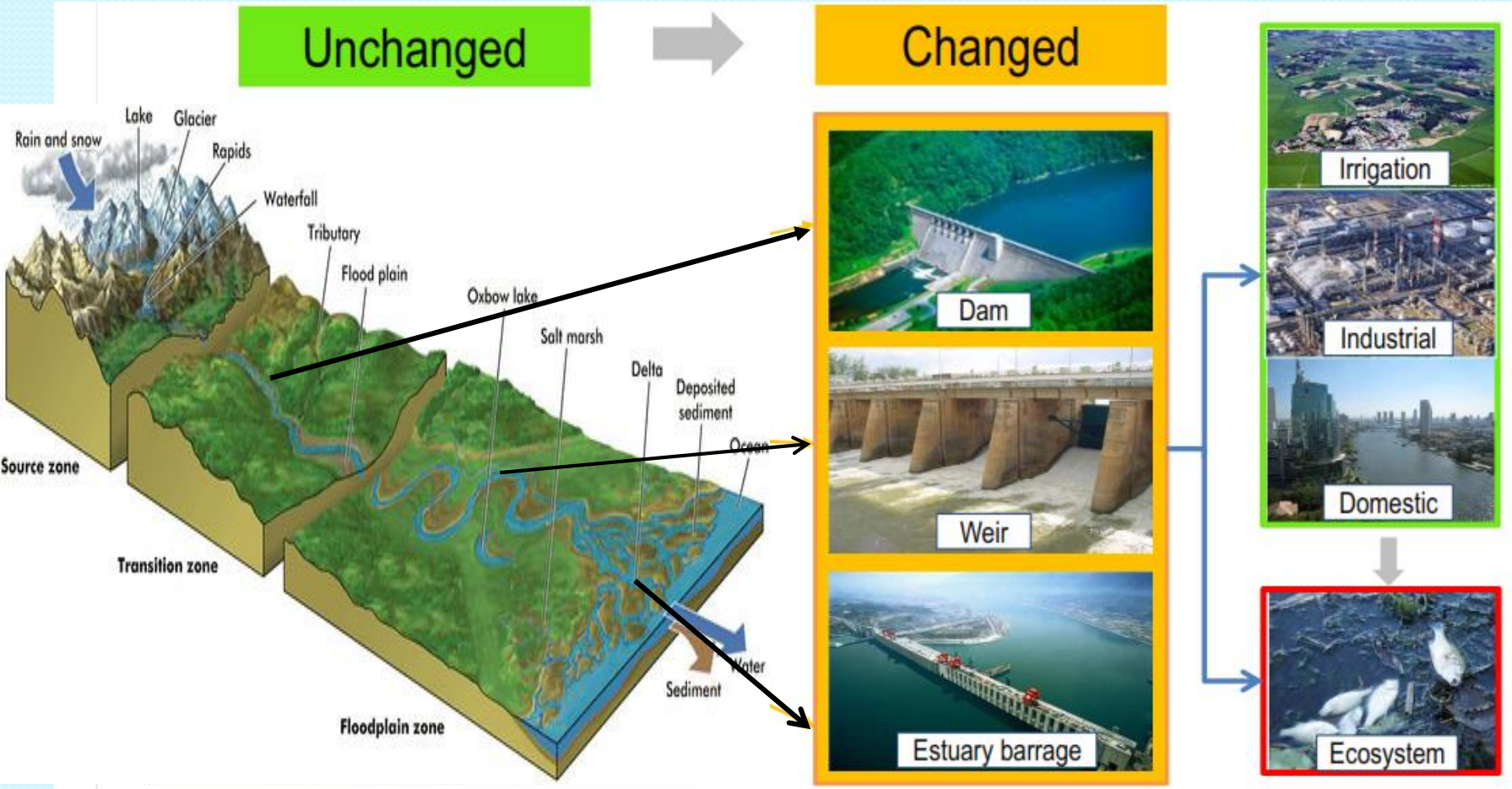
Introduction

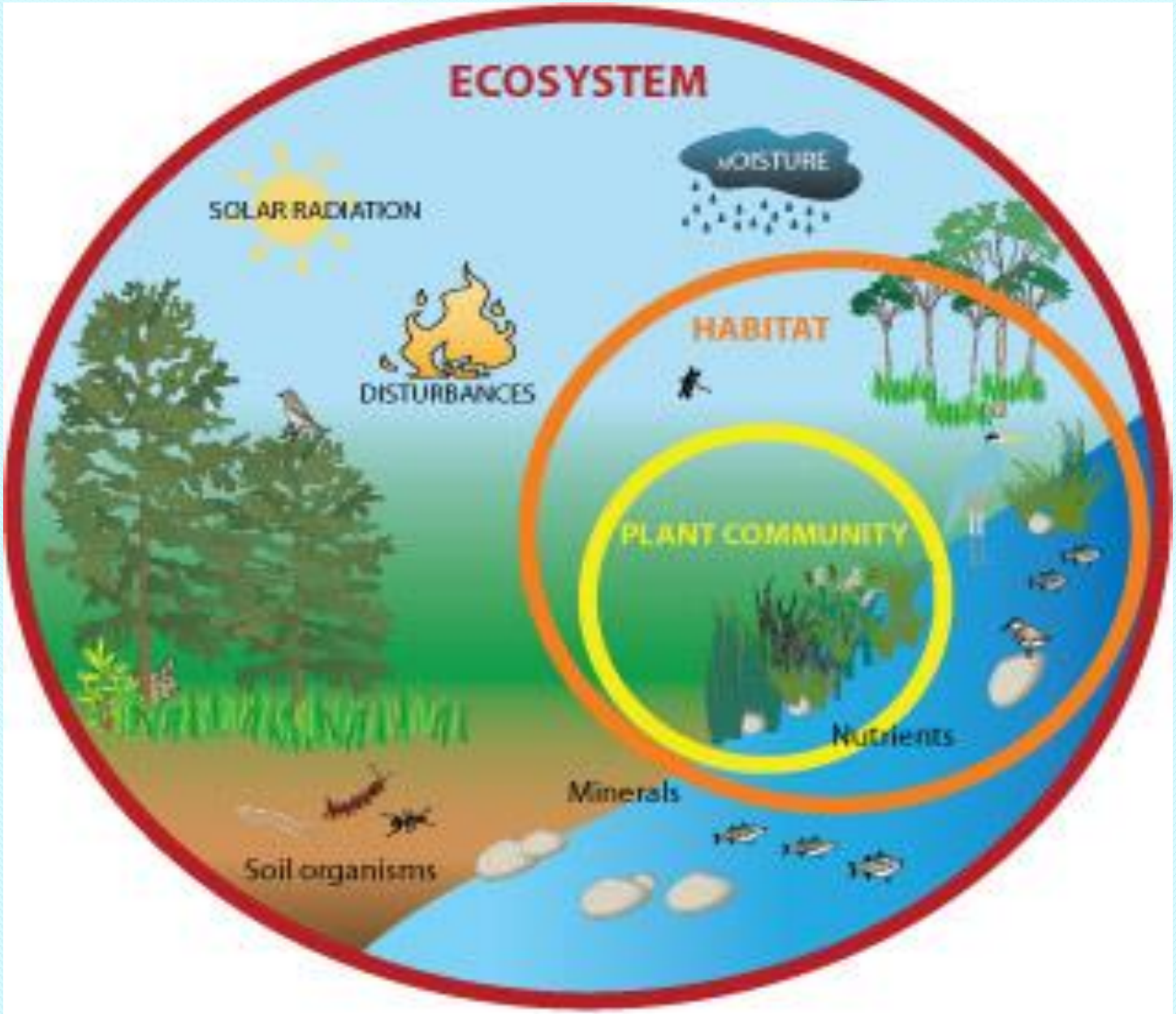
What is Environmental flow?

- Enough water that is left in the river, or release into it to manage downstream environmental, social and economic benefits. (Dyson et al., 2008)

- Quantity, quality and timing of water flows required to sustain freshwater , ecosystem and human livelihoods and well-being that depend on these ecosystem. (Richter et al.,2003)

Why Environmental Flow assessment is important?




ECOSYSTEM
MOISTURE
SOLAR RADIATION
DISTURBANCES
HABITAT
PLANT COMMUNITY
Nutrients
Minerals
Soil organisms

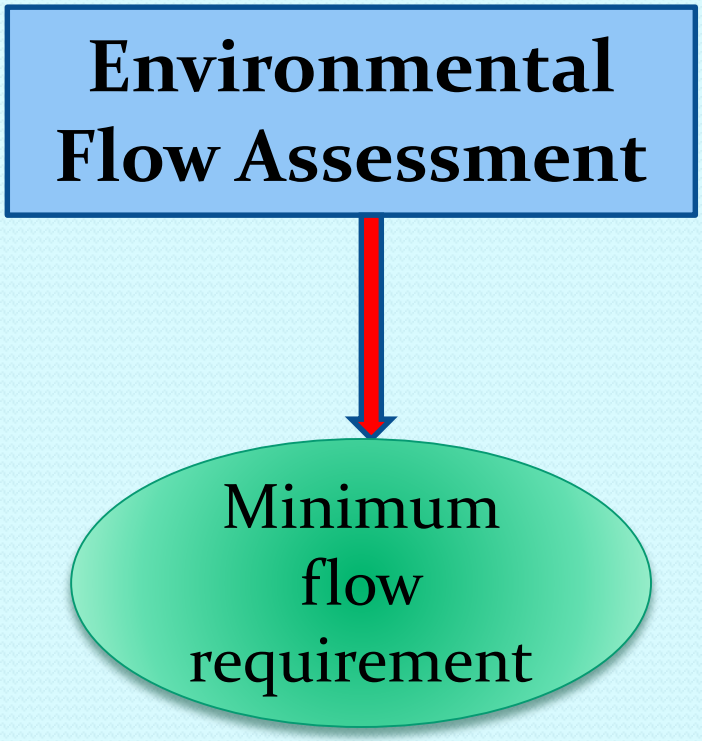
Environmental Assessment Methods

Method Type	Example Methods	Data needs
Hydrological index method	• Tennant • Tessman, • Flow Duration Curve(FDC) • Integrated Hydrologic Alteration(IHA) • Global Environmental Flow Calculator (GEFC)	▪ Historical flow records
Hydraulic rating method	• Wetted Perimeter • R2 cross	▪ Historical flow records ▪ Hydraulic variables-single cross-section
Habitat simulation method	• In-Stream Flow Incremental Methodology (IFIM) • Physical HABitat SIMulation model (PHABSIM)	▪ Historical flow records ▪ Hydraulic variables-multiple cross-section ▪ Biological data
Holistic method	• Building Block Methodology (BBM) • Downstream Response to Imposed Flow Transformation (DRIFT)`	▪ Historical flow records ▪ Hydraulic variables-multiple cross-section ▪ Biological data ▪ Ecological data

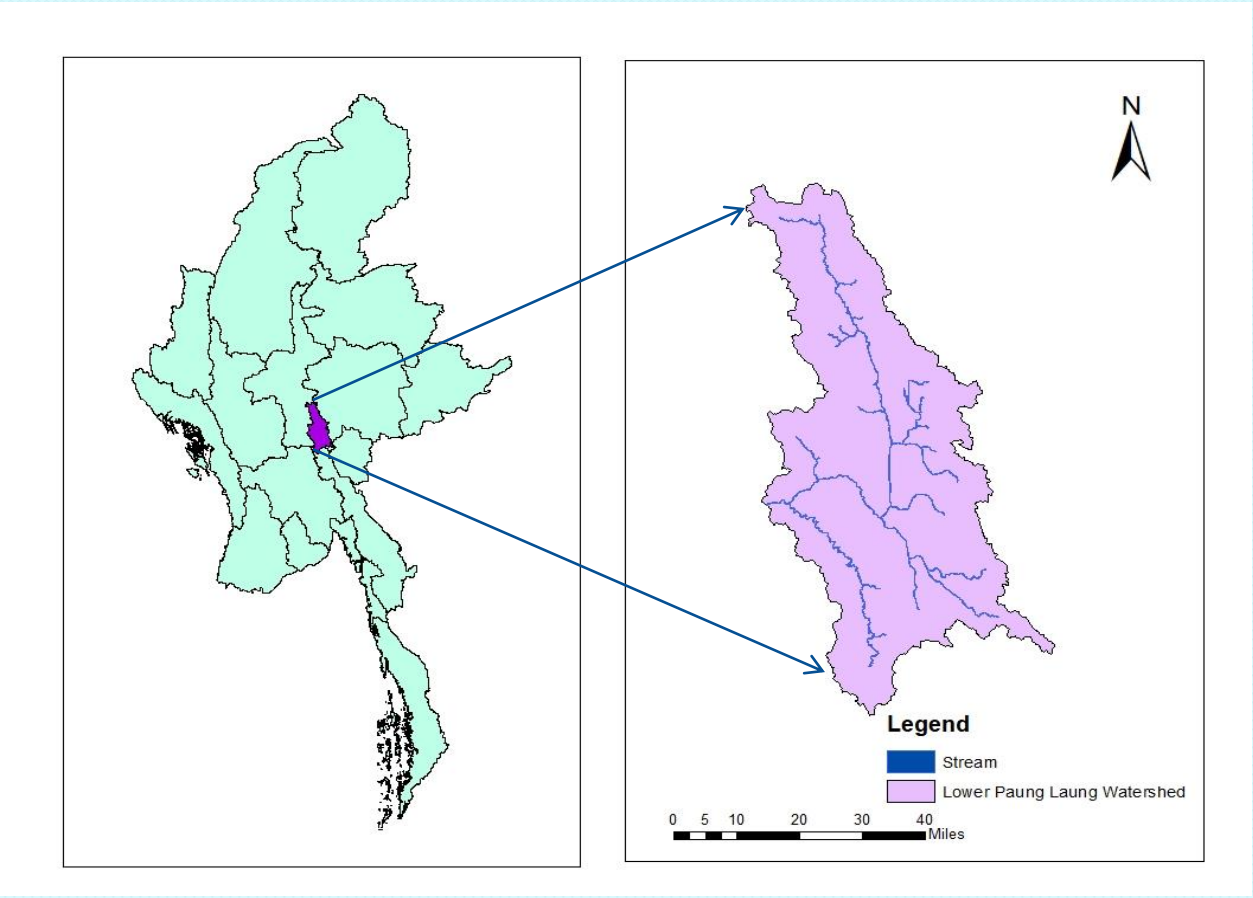
Hydrological index method

- Traditionally engineers have been used hydrologically defined indices for water management rule and compensation of downstream flow.

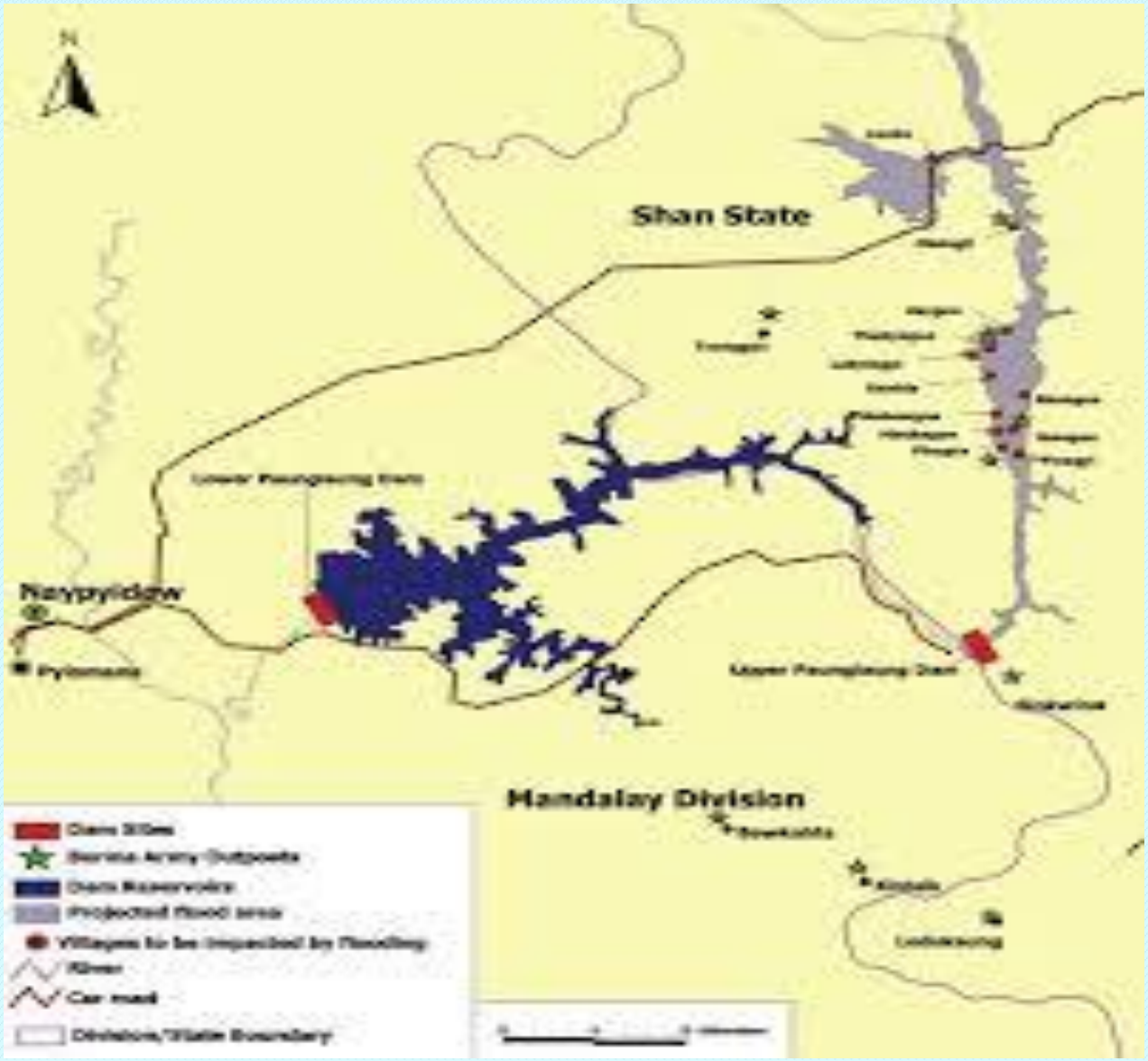
- % MAF or exceedance % of FDC


Environmental Flow Assessment
Minimum flow requirement

Study Area


N
Legend
Stream
Lower Paung Laung Watershed
0 5 10 20 30 40
Miles

Lower Paunglaung Hydropower Project



Selection of EF Assessment Method

- **Data Availability**
- **Technology**
- **Fund**
- **Time**

- Daily Natural Flow 1965-1980
- Daily Release Flow 2004-2014

Tennant Method

Tennant specified percentages of the MAR that provide different quality habitat for fish.

Conditions	Recommended Environmental Flow	
	Dry Season (%) of MAR	Wet Season (%) of MAR
Flushing or Maximum	200	200
Optimum Range	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or Degradation	10	30
Poor or Minimum	10	10
Severe Degradation	0-10	0-10

Environmental Flow Requirement by Tennant Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFR	39.32	39.32	39.32	39.32	39.32	59.52	59.52	59.52	59.52	59.52	39.52	39.52

Tessman Method

- specified by combination of percentages of the MAR and MMF.

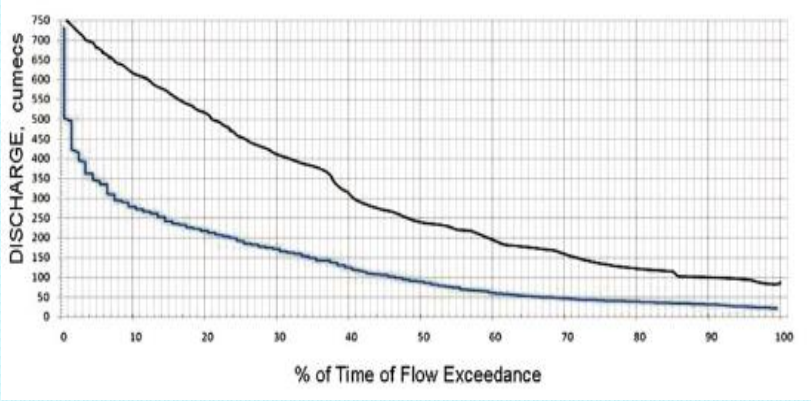
	Condition	Environmental Flow
1	MMF < 40% MAF	MMF
2	40% MAF < MMF < 100% MAF	40% MAF
3	MMF > MAF	40% MMF

Environmental Flow Requirement by Tessman Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFR	52.42	42.83	32.74	32.74	32.74	52.42	84.53	154.41	120.19	82.24	52.42	52.42

Flow Duration Curve Method

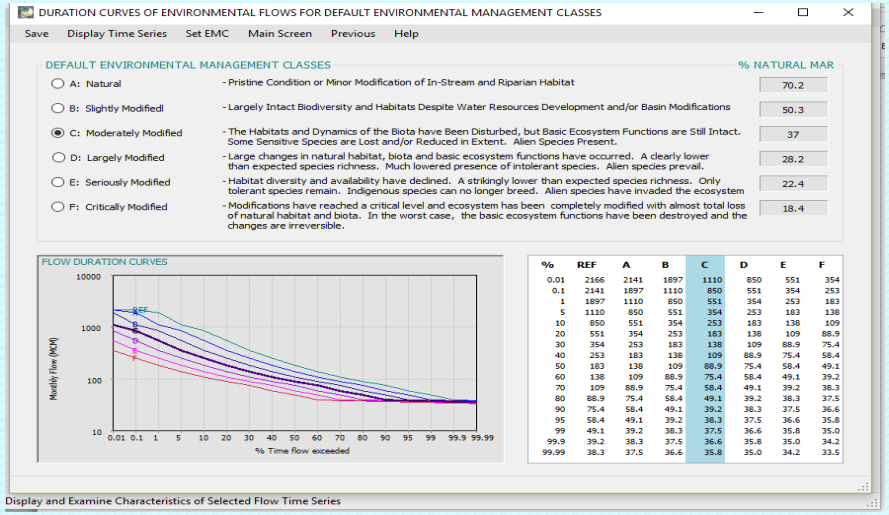
- Q_{50} for wet season
- Q_{90} for dry season



$$P = \frac{m}{(n+1)} \times 100$$

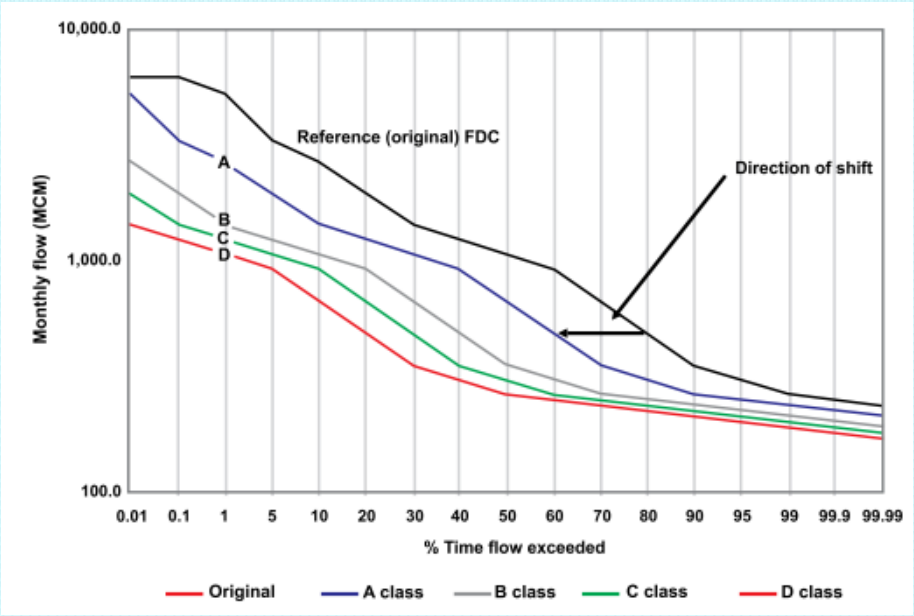
- P = Percentile flow equaled or exceeded
- m = ranked position
- n = number of event

Global Environmental Flow Calculator (GEFC)

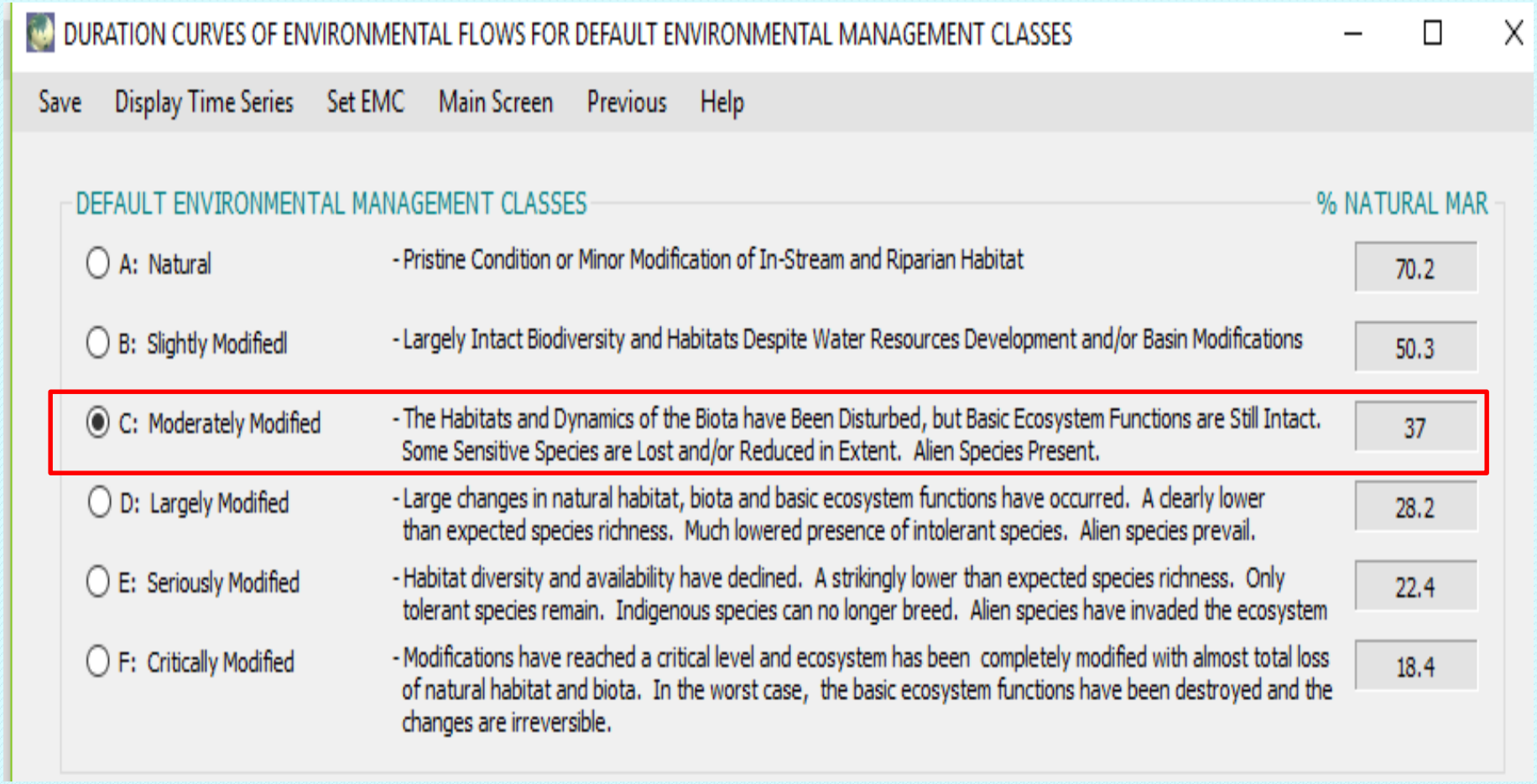


%	REF	A	B	C	D	E	F
0.01	2166	2141	1897	1110	850	551	354
0.1	2141	1897	1110	850	551	354	253
1	1897	1110	850	551	354	253	183
5	1110	850	551	354	253	183	138
10	850	551	354	253	183	138	109
20	551	354	253	183	138	109	88.9
30	354	253	183	138	109	88.9	75.4
40	253	183	138	109	88.9	75.4	58.4
50	183	138	109	88.9	75.4	58.4	49.1
60	138	109	88.9	75.4	58.4	49.1	39.2
70	109	88.9	75.4	58.4	49.1	39.2	38.3
80	88.9	75.4	58.4	49.1	39.2	38.3	37.5
90	75.4	58.4	49.1	39.2	38.3	37.5	36.6
95	58.4	49.1	39.2	38.3	37.5	36.6	35.8
99	49.1	39.2	38.3	37.5	36.6	35.8	35.0
99.9	39.2	38.3	37.5	36.6	35.8	35.0	34.2
99.99	38.3	37.5	36.6	35.8	35.0	34.2	33.5

A. Natural
B. Slightly Modified
C. Moderately Modified
D. Largely Modified
E. Seriously Modified
F. Critically Modified



GEFC


DURATION CURVES OF ENVIRONMENTAL FLOWS FOR DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES
Save
Display Time Series
Set EMC
Main Screen
Previous
Help
DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES
% NATURAL MAR
A: Natural
- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat
70.2
B: Slightly Modifiedl
- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications
50.3
C: Moderately Modified
- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.
37
D: Largely Modified
- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.
28.2
E: Seriously Modified
- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem
22.4
F: Critically Modified
- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.
18.4

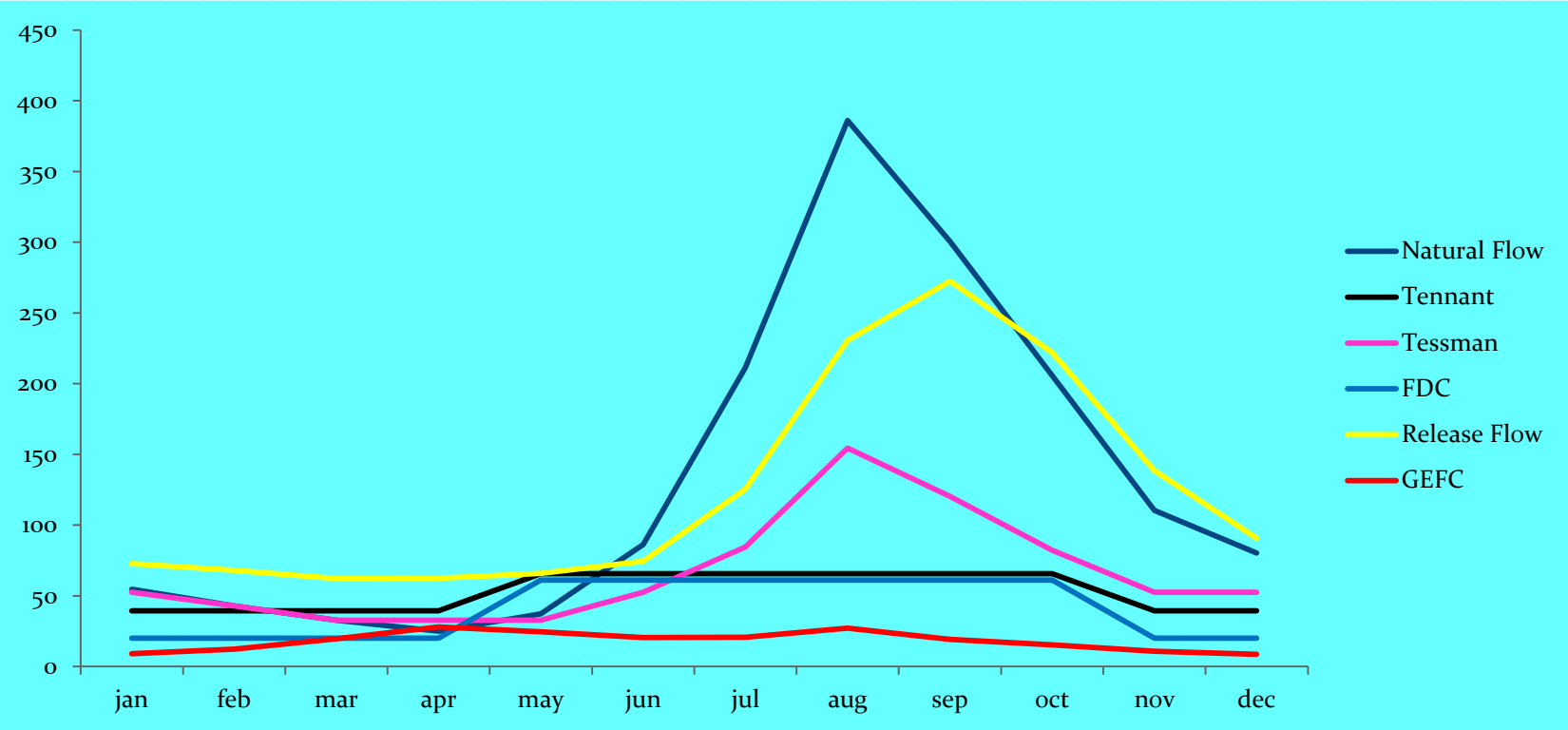
GEFC

Default Environmental Management Classes	% Natural MAF	MAR
A. Natural	70.2	3965 MCM
B. Slightly Modified	50.3	
C. Moderately Modified	37	
D. Largely Modified	28.2	125.73 cumecs
E. Seriously Modified	22.4	
F. Critically Modified	18.4	

Environmental Flow Requirement by GEFC Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFR	24.7	33	52.6	75.4	66.5	55	55.8	73.5	52	41.3	29.3	23.6

Environmental Flow Requirement by Hydrological Index Method

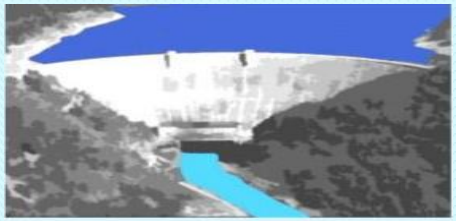


Integrated Hydrologic Alteration Method
(IHA)

Environmental Flow Assessment For Management Level

Indicators of Hydrological Alteration (IHA)

- Total of 67 statistical parameters
- 34 Environmental Flow Component (EFC)
- 33 IHA



IHA

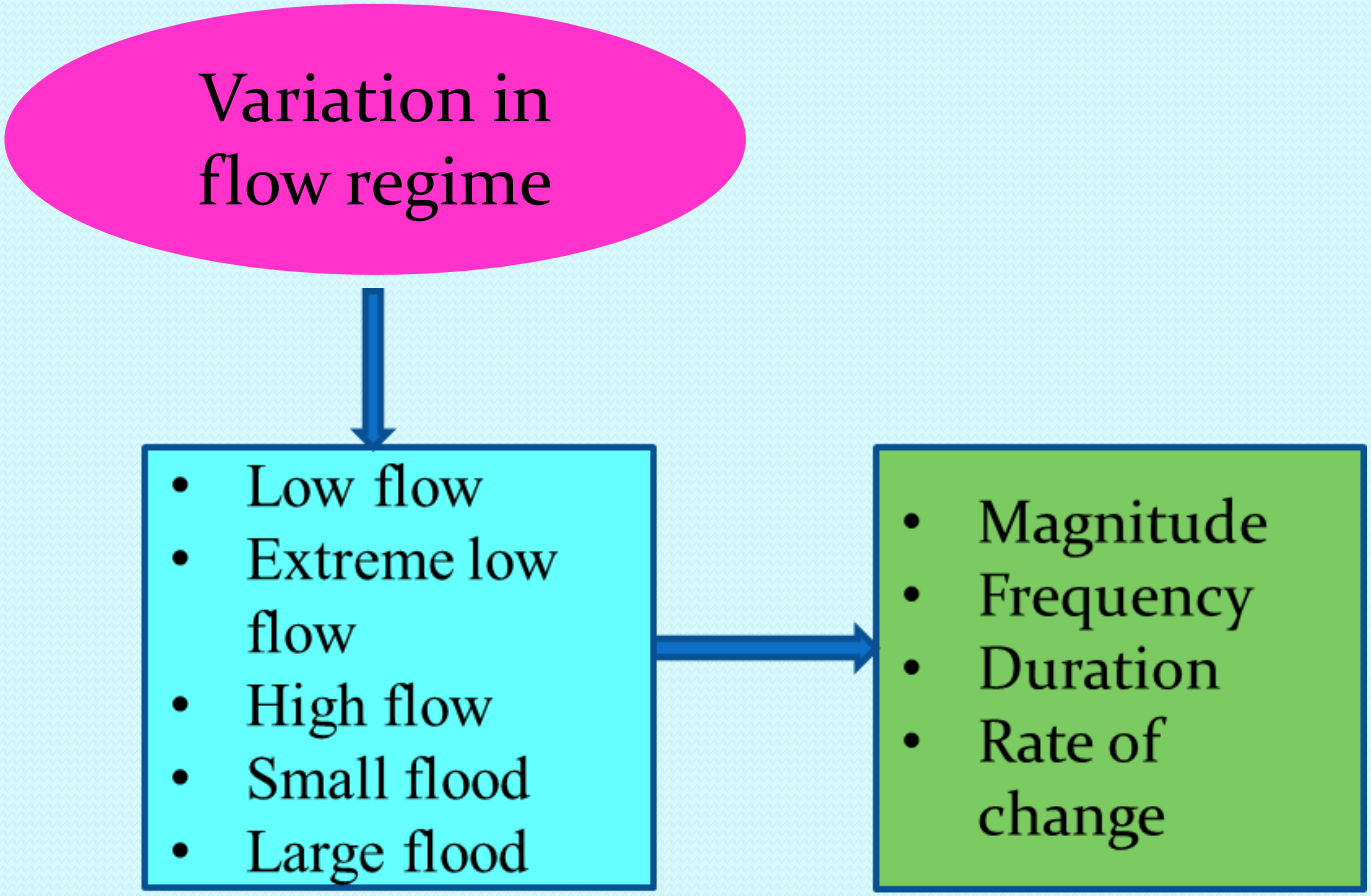
EFC

To assess the EF for various flow condition with quantity, duration, frequency, timing, rate of change

IHA

To quantify the flow alteration degree before and after dam construction

Environmental Flow Component (EFC)



Ecosystem Influences on Environmental Flow Components

1. Low Flows

- Provide adequate habitat for aquatic organisms
- Maintain water table levels in floodplain, soil moisture for plants

2. Extreme Low flows

- Enable recruitment of certain floodplain plant species

3. High flow pulses

- Shape physical character of river channel, including pools, riffles
- Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants

Continued--------

4.Small Floods

- Provide migration and spawning cues for fish
- Enable fish to spawn in floodplain, provide nursery area for juvenile
- Recharge floodplain water table
- Deposit nutrients on floodplain

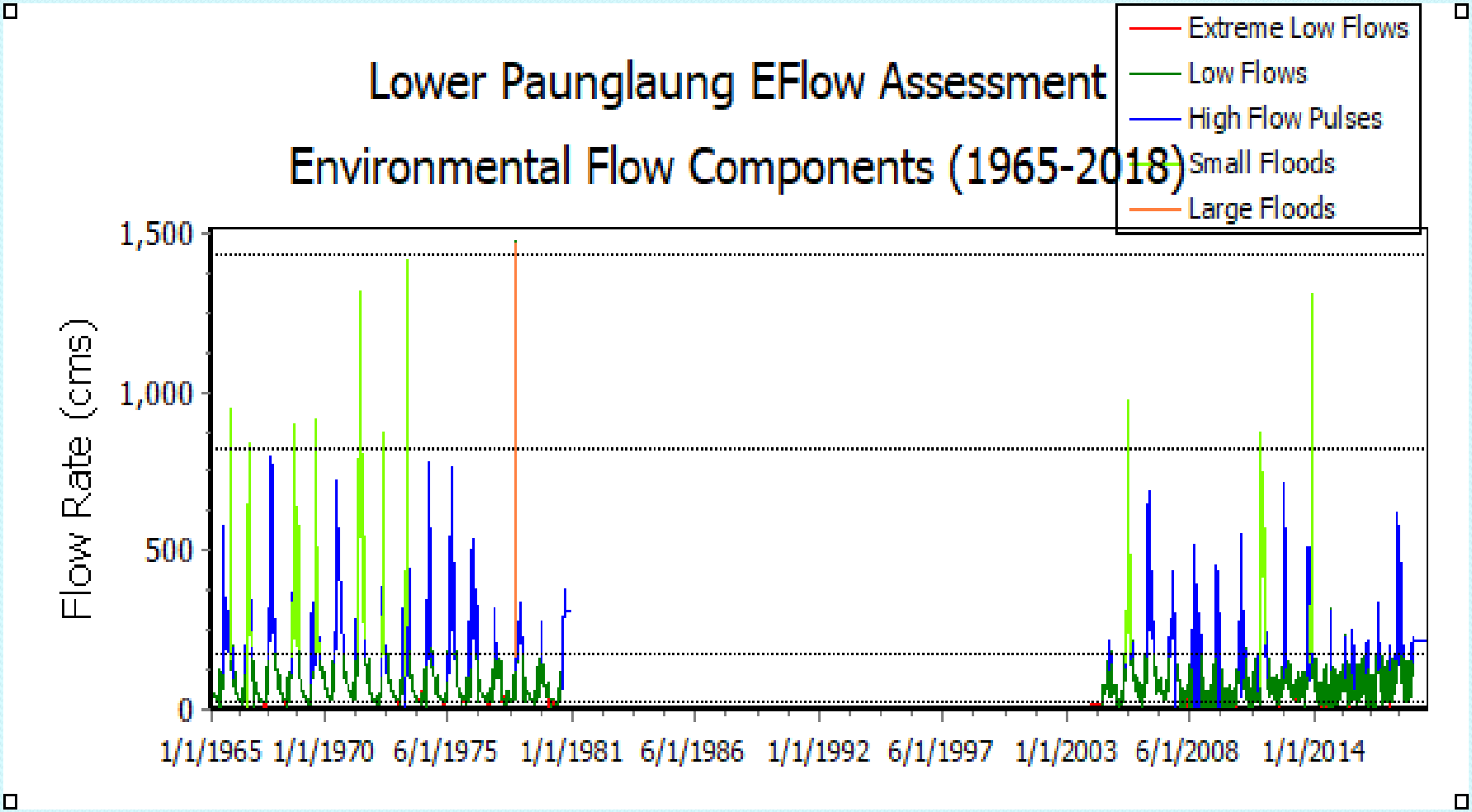
5. Large Floods

- Shape physical habitats of floodplain
- Deposit gravel and cobbles in spawning areas
- Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)

Data Length for Lower Paunglaung River

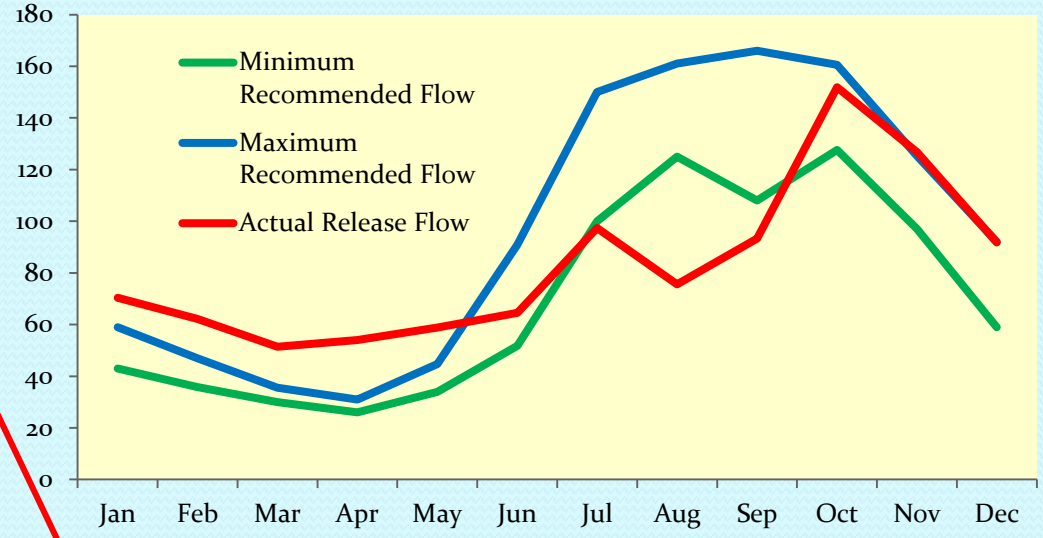
Before Dam	1965-1980	15 yrs
After Dam	2004-2018	14 yrs

Flow Conditions before and after Dam Construction



EF Assessment for Low Flow Condition

	Limitation Boundary		Actual Release
	Minimum	Maximum	
Jan	43	59	70.33
Feb	35.75	47	62.24
Mar	30	35.5	51.36
Apr	26	31	54
May	33.88	44.75	58.83
Jun	51.75	90.88	64.53
Jul	100	150	97.38
Aug	125	161	75.56
Sep	108	166	93.23
Oct	127.6	160.5	151.9
Nov	97	125.2	126.7
Dec	59	92	91.83



Cannot maintain suitable range of

- water temperature
- dissolved oxygen
- water table levels
- soil moisture

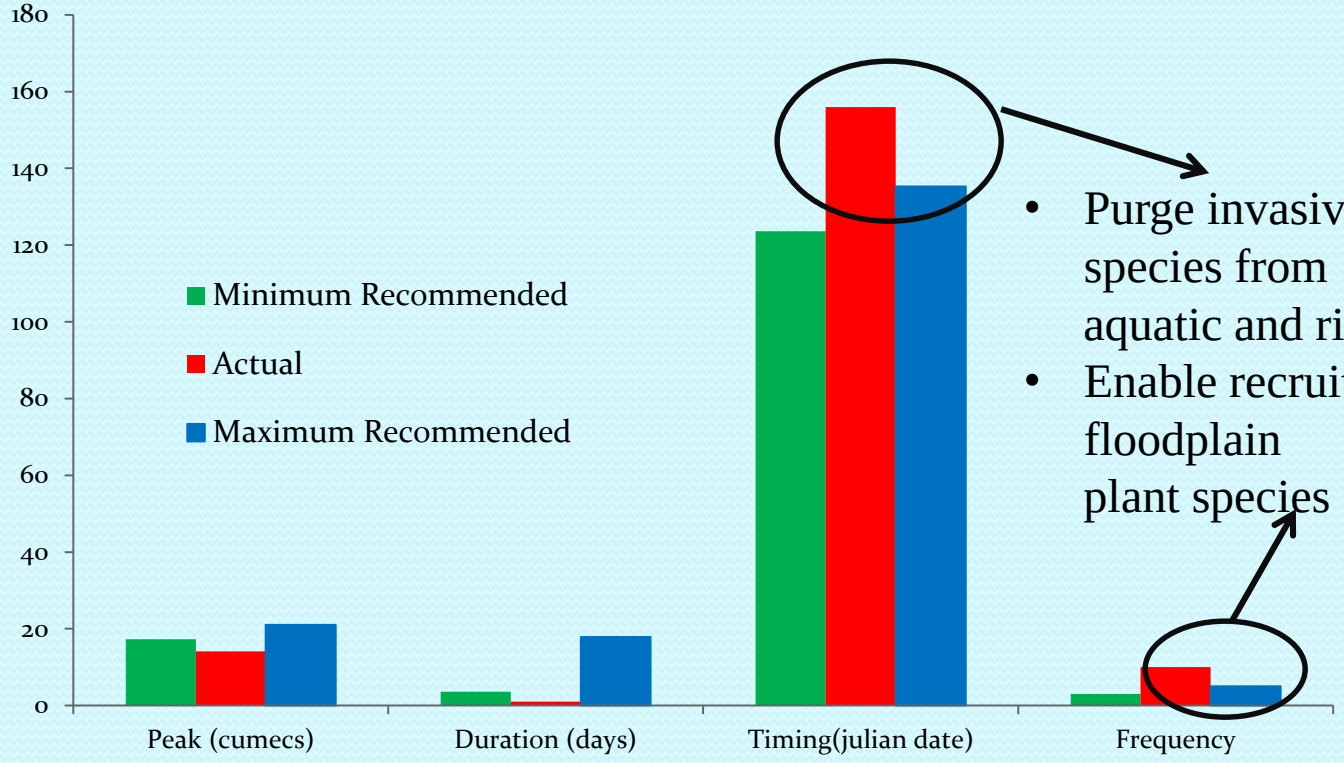
Environmental Flow Assessment for Extreme Flow Condition

Parameter		Extreme Low Flow			High Flow Pulse			Small Flood			Large Flood		
		Min	Max	Actual Release	Min	Max	Actual Release	Min	Max	Actual Release	Min	Max	Actual Release
Peak	cumecs	17.25	21	14.09	213.6	309.5	218.4	868	1318	970.7	-	-	-
Duration	days	3.625	17.88	1	3	7.75	3	45	100	78	-	-	-
Timing	julian date	123.6	135.3	156	200.9	237.3	251	214	242	256	-	-	-
Frequency		3	5	10	2.25	5.75	5	0	1	0	-	-	-
Rise rate					28.04	51.97	34.24	25	105.1	56.88	-	-	-
Fall rate					-30.84	-19.94	-23.51	-43.22	-10.1	-19.85	-	-	-

1. Low flow
2. Extreme low flow
3. High flow
4. Small flood
5. Large flood

- Magnitude
- Duration
- Timing
- Frequency
- Rate of change

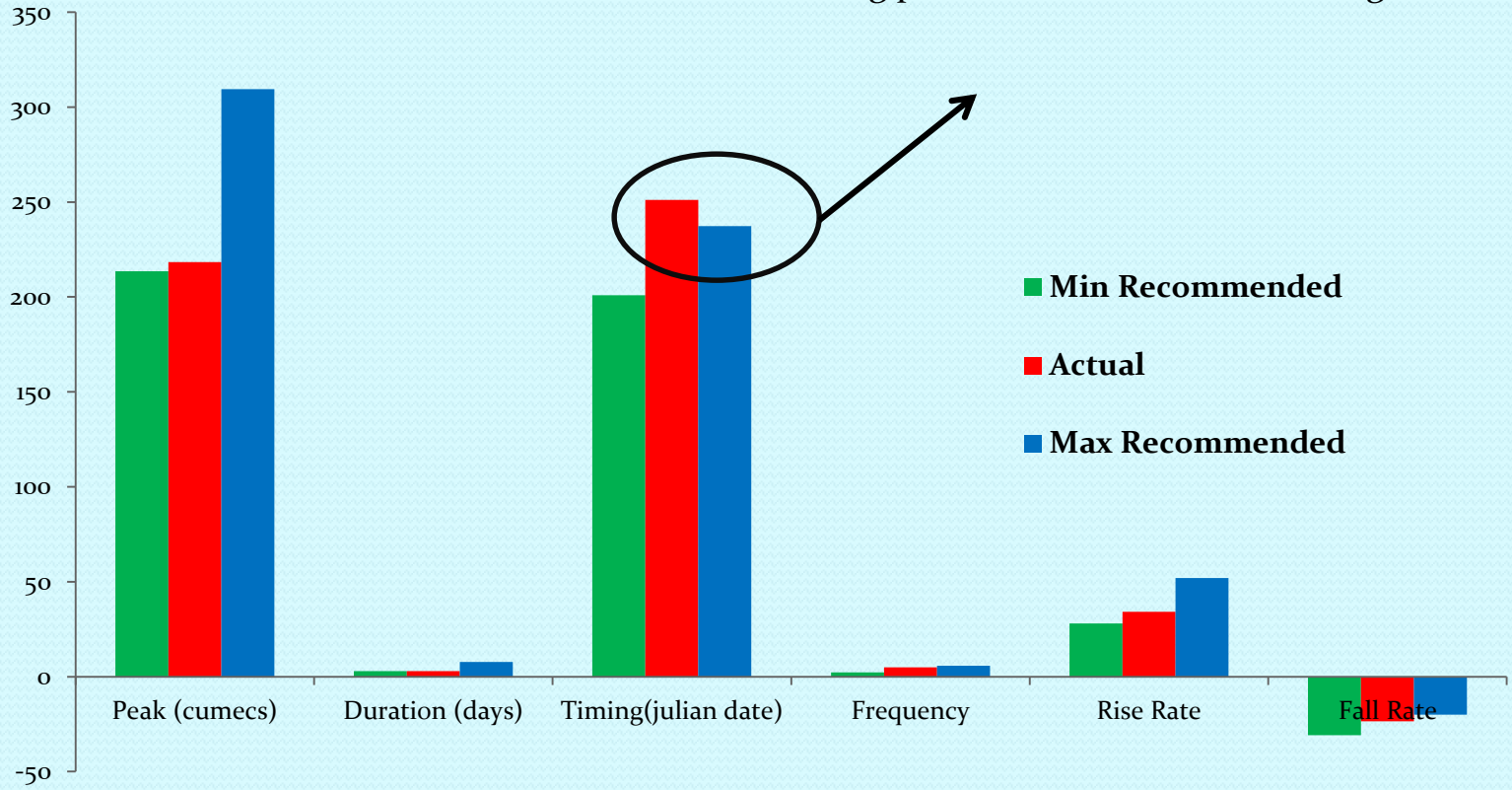
Extreme Low Condition



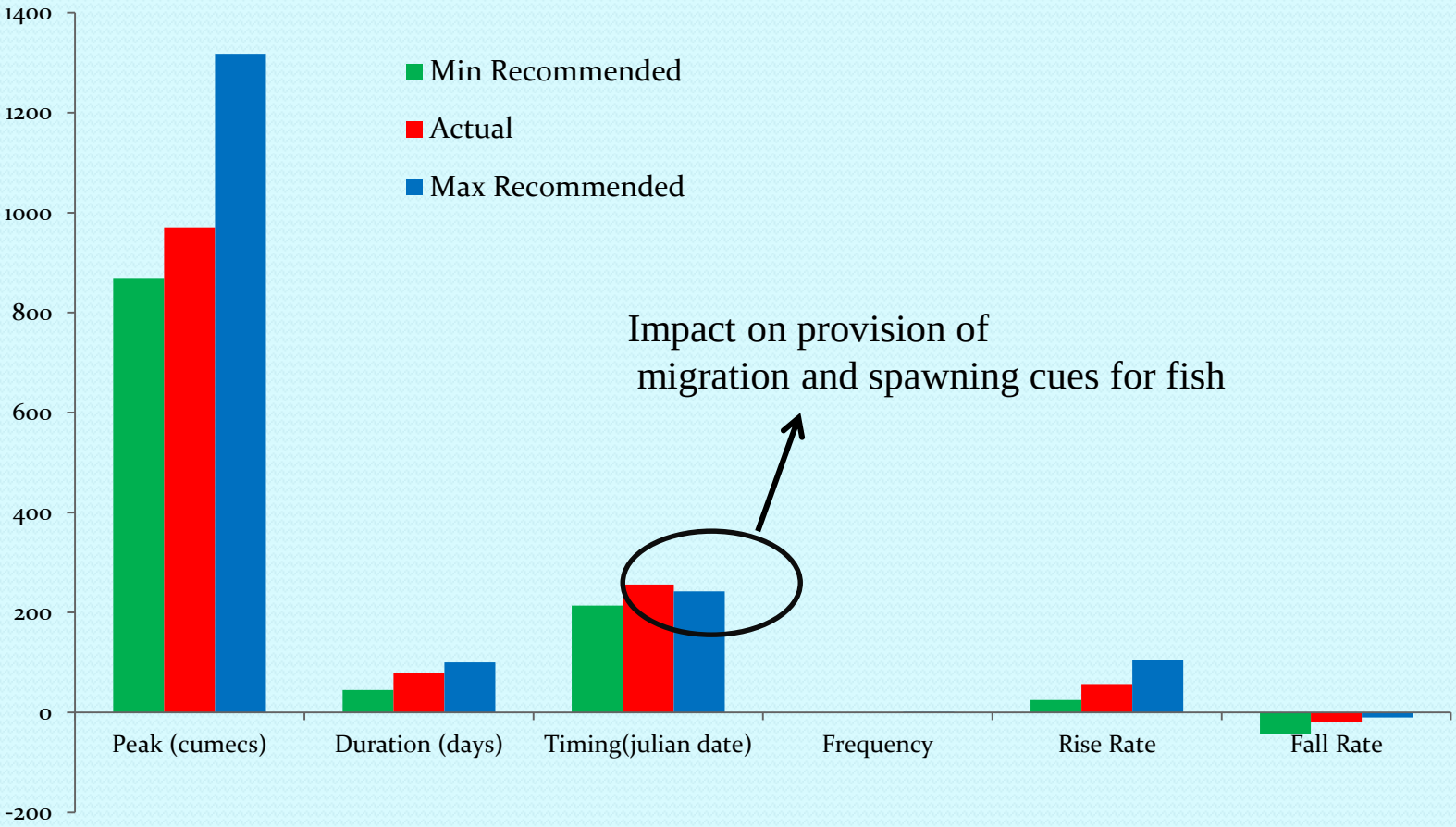
- Purge invasive, introduced species from aquatic and riparian communities
- Enable recruitment of certain floodplain plant species

High Flow Condition

Physical characteristic of river channel, including pools and riffle could be changed.

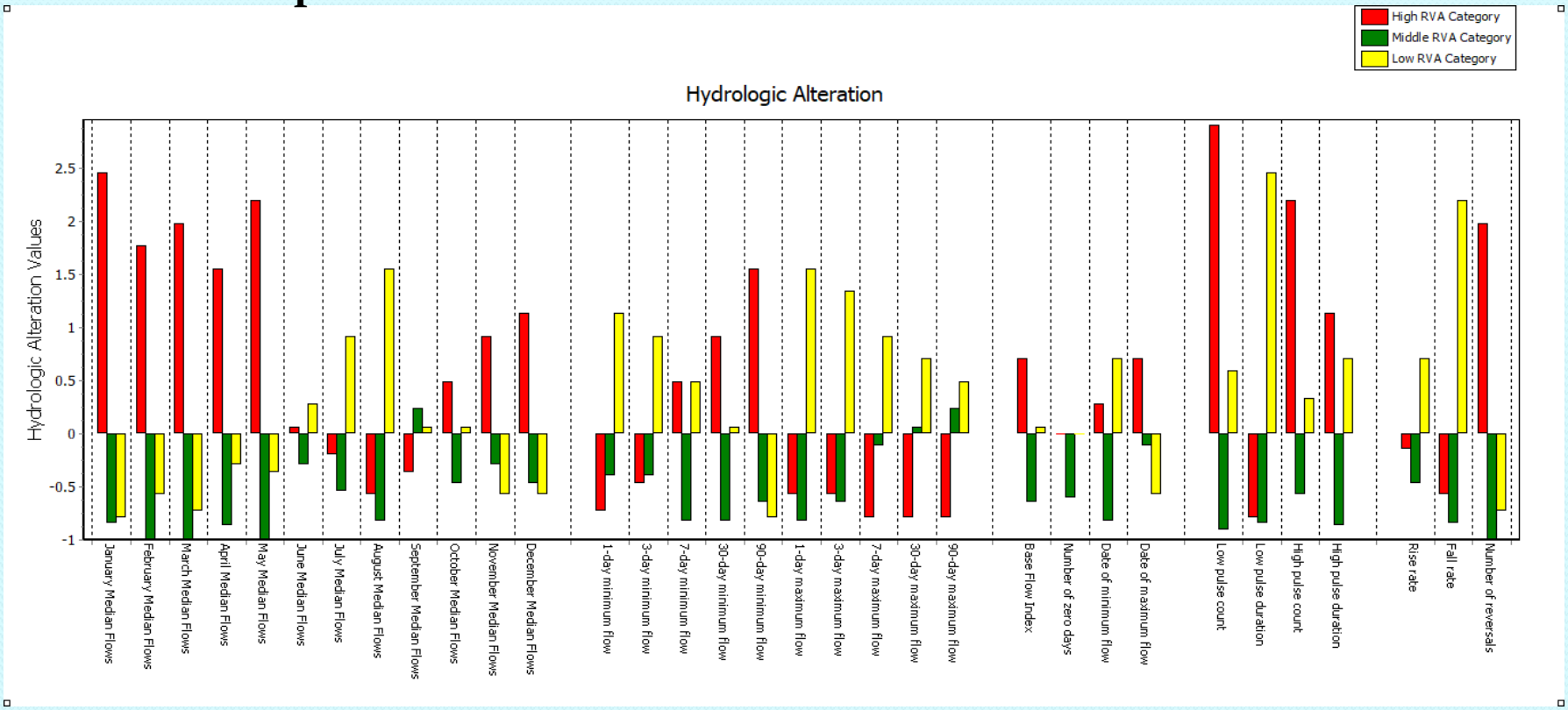


Small Flood Condition



Hydrologic Alteration Assessment before and after Dam Construction

IHA parameters



33 Integrated Hydrologic Alteration parameters

Monthly Water Condition		Extreme Water Condition		Extreme Water Condition	
Jan	H	1-day minimum	M	Date of minimum	H
Feb	H	3-day minimum	M	Date of maximum	L
Mar	H	7-day minimum	H	**High and Low Pulses**	
Apr	H	30-day minimum	H	Low pulse count	H
May	H	90-day minimum	M	Low pulse duration	H
Jun	L	1-day maximum	H	High pulse count	M
Jul	M	3-day maximum	M	High pulse duration	H
Aug	H	7-day maximum	L	**Water Condition Changes**	
Sep	L	30-day maximum	L	Rise rate	M
Oct	M	90-day maximum	L	Fall rate	H
Nov	L	Number of zero day	M	Number of reversals	H
Dec	M	Base flow index	M		

15 High Alteration

11 Middle Alteration

7 Low Alteration

Hydrologic Alteration after dam construction

IHA

The measurement to quantify the deviation of the post-dam flow regime and pre-dam flow regime

$$D_i = \frac{N_o - Ne}{N_e} \text{ x } 100\ \%$$

D_i = Degree of hydrologic alteration for the indicator

N_o = Observed number of post-dam years of the hydrologic parameter falls within RVA target range

N_e = Expected number of post-dam years of the hydrologic parameter falls within RVA target range

- RVA= Range of Variability Approach
- RVA category boundaries median +/- 17 percentile

IHA Class →

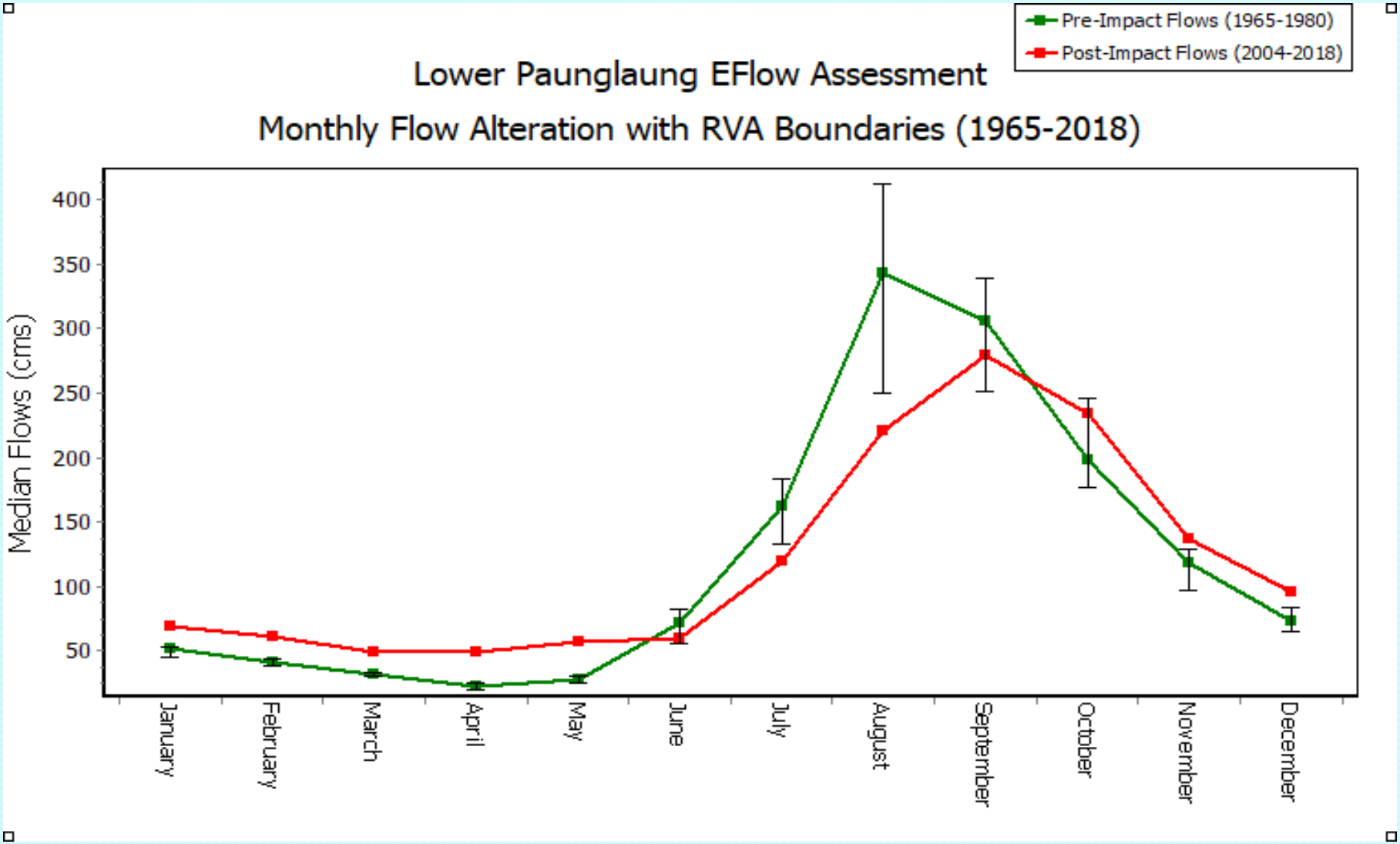
0-33% = low alteration (L)
34-67% = moderate alteration (M)
68-100% = high alteration (H)

A **single** integrated index ,D which is the average value of 32 degree of alteration for the 32 IHA parameters

$$D = \left(\frac{1}{33} \sum_{n=1}^{33} D_i^2\right)^{1/2}$$

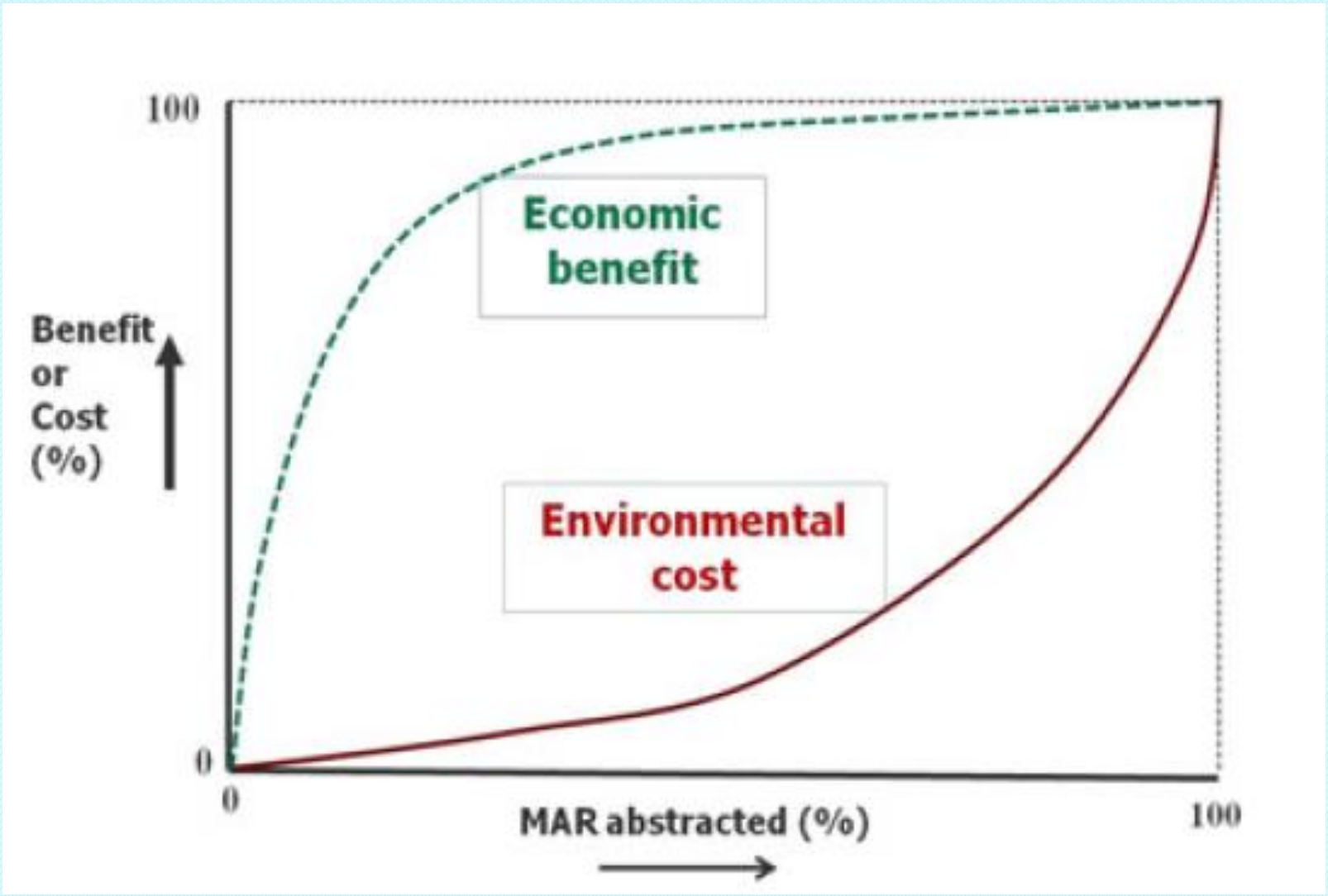
Degree of Hydrologic alteration D = 68.22 % ⟹ High Alteration:

Assessment of Hydrologic Alteration Degree before and after Lower Paunglaung Dam Construction



Conclusions

- (EFR), which is a compromise between water resources development and maintenance of a river in ecologically acceptable or agreed conditions
- IHA method is more reliable than the Hydrlogical methods
- Check and balance based on target development and conservation setting


100
Economic benefit
Benefit or Cost (%)
Environmental cost
0
0
MAR abstracted (%)
100

THANK YOU