Environmental Flows (EFlows): Concepts and methods

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southern waters

Contents

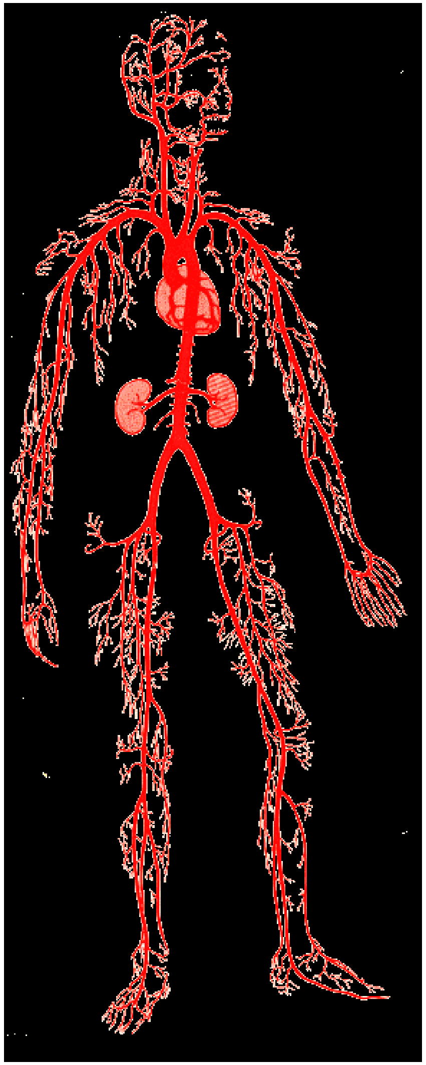
- River ecosystems
- EFlows
- EFlows methods of assessment
- Summary

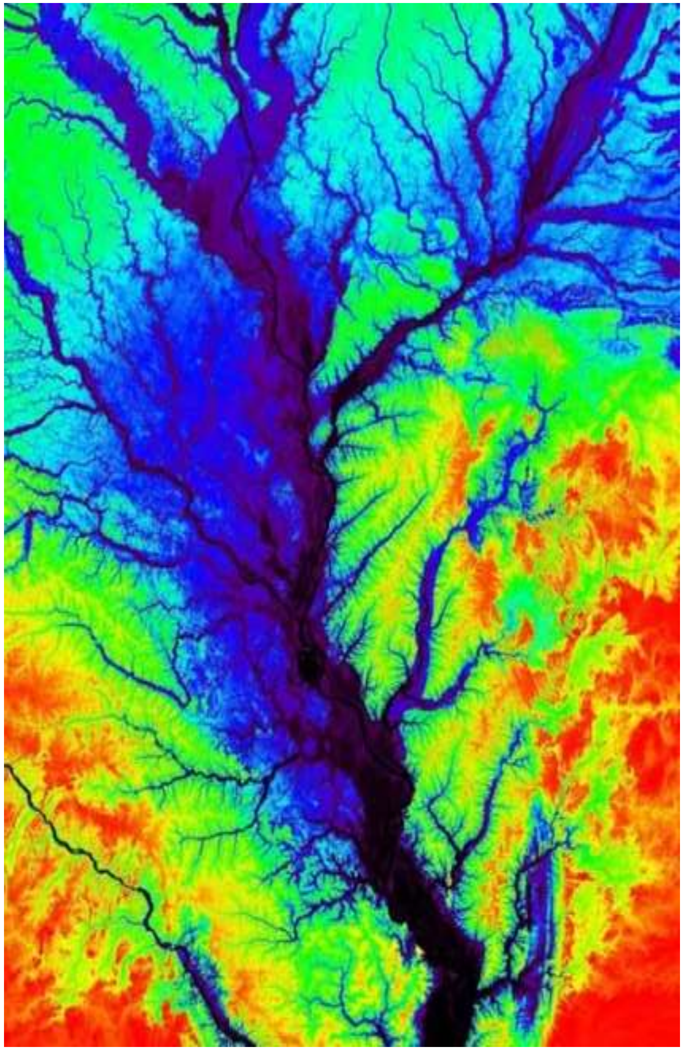
ADB Environment Operational Directions

- Promoting a shift to sustainable infrastructure;
- Investing in natural capital;
- Strengthening environmental governance and management capacity; and
- Responding to the climate change imperative.

RIVER ECOSYSTEMS

Rivers are like the venous system of Planet Earth



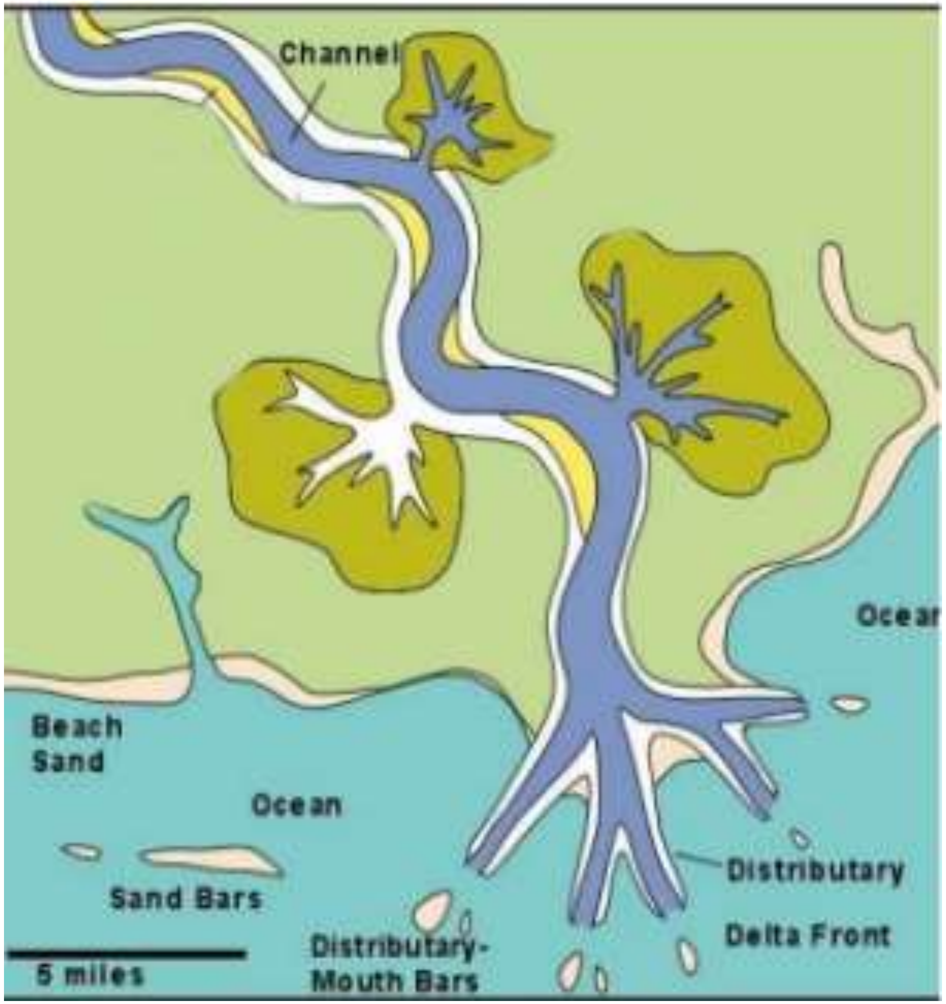


Our bodies and Planet Earth

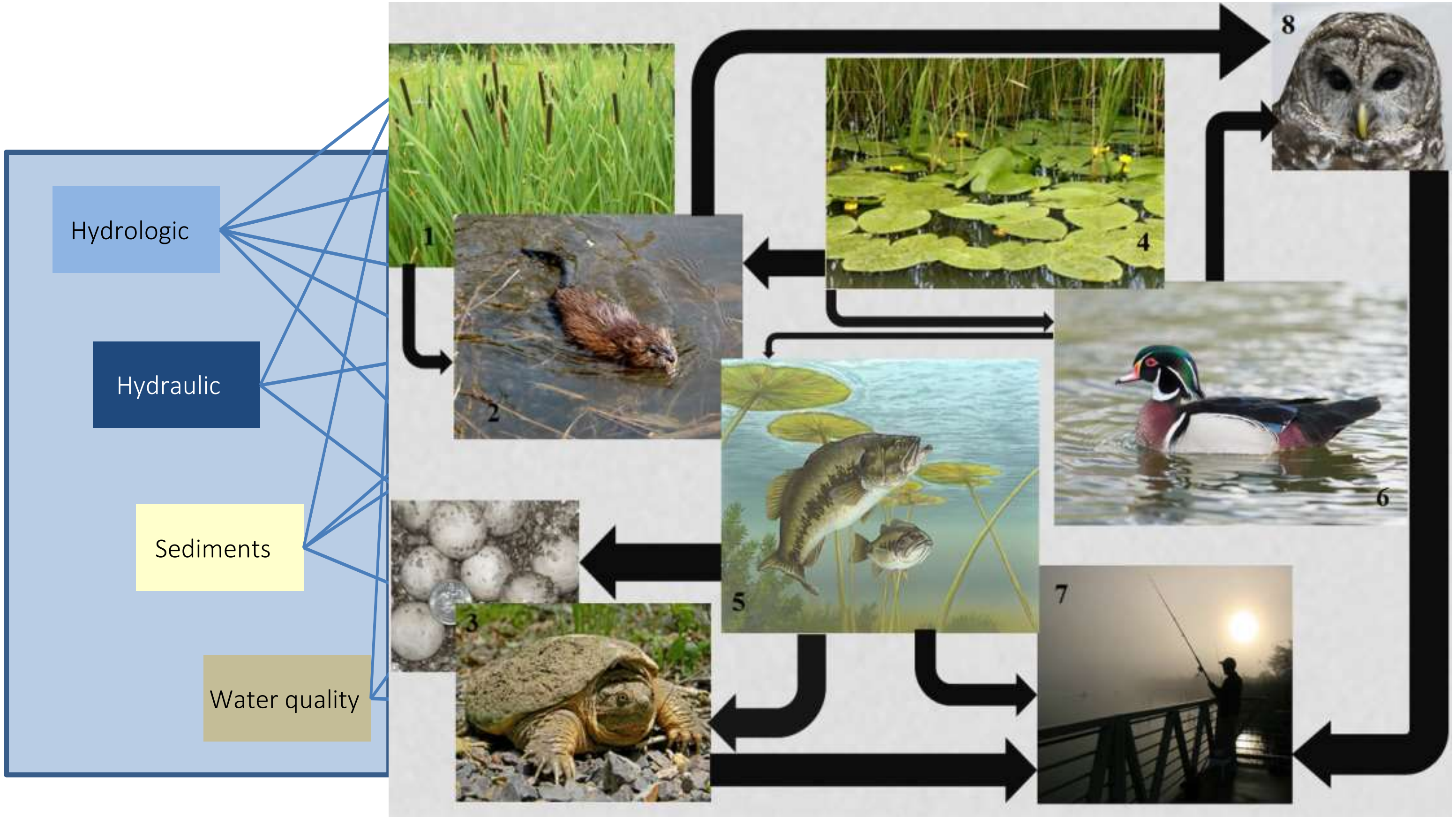
- Veins are part of the lifeline of the human body
- Transport blood – essential for life
- Connect vital organs
- Blood carries life supporting elements
- Transport it to organs that clean and protect the blood
- Veins, arteries and organs inter-connected and inter-dependent
- Complex multi-dimensional
- Different elements, velocities and flow for different functions

- Rivers are the lifelines of the landscape
- Transport water – essential for life
- Rivers connect vital ecosystems
- Water carries life supporting elements
- Transport it to systems that clean and protect the water
- Rivers, aquifers and oceans inter-connected and inter-dependent
- Complex multi-dimensional
- Different elements, velocities and flow for different functions

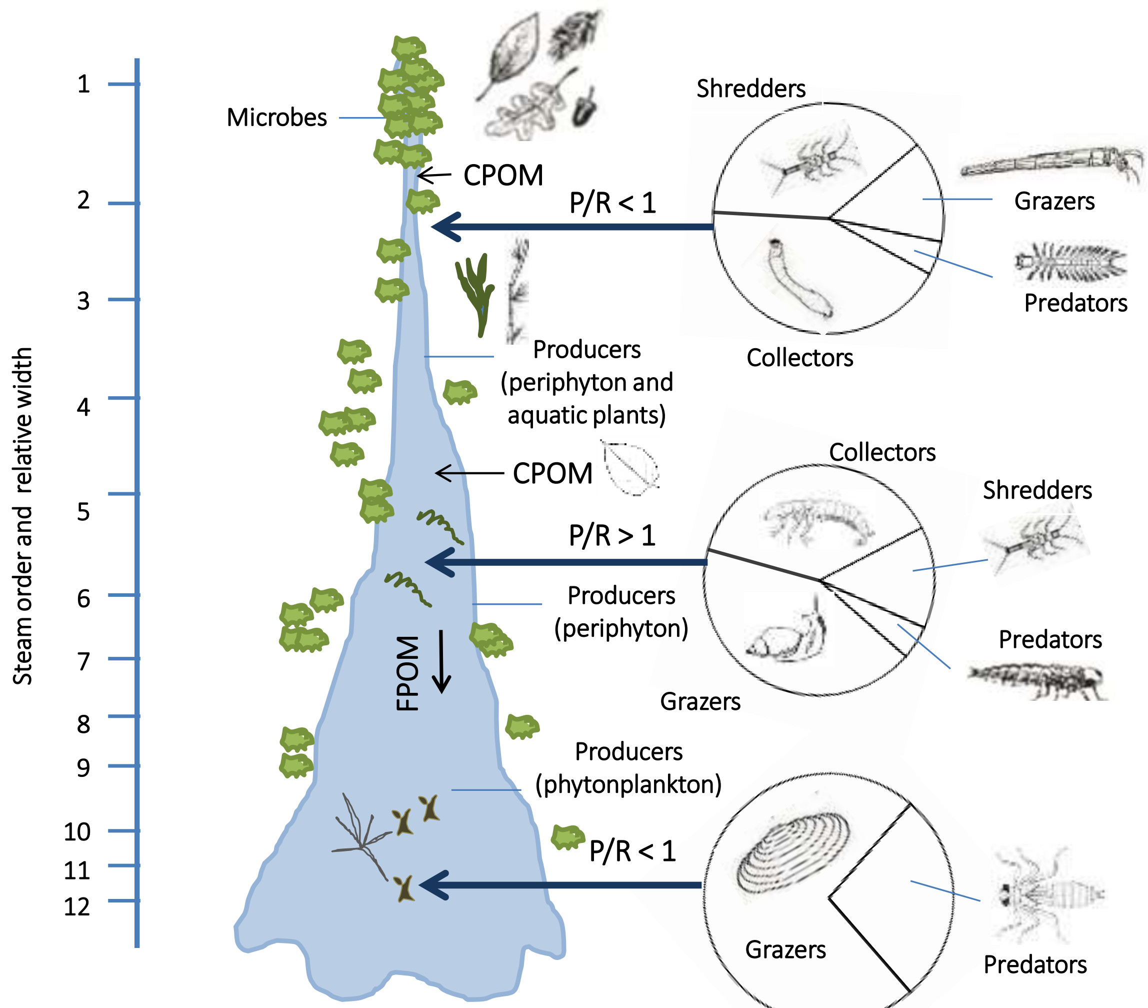
Rivers are living systems



Inter-connected and inter-dependent



River continuum concept (Vannote et al. 1980)



EFLOWS

What are EFlows?

Patterns of flows

Sediments

Water quality

Water quantity

Movement of animals and plants

The quantity, timing and quality of the flow of *water, sediment and biota* necessary to sustain freshwater and estuarine ecosystems, and the human livelihoods and well-being that depend on these ecosystems

Amended from Brisbane Declaration (2007)

Sustainability

Biodiversity

Reliable water supply

Viable businesses

Livelihoods

Resilience

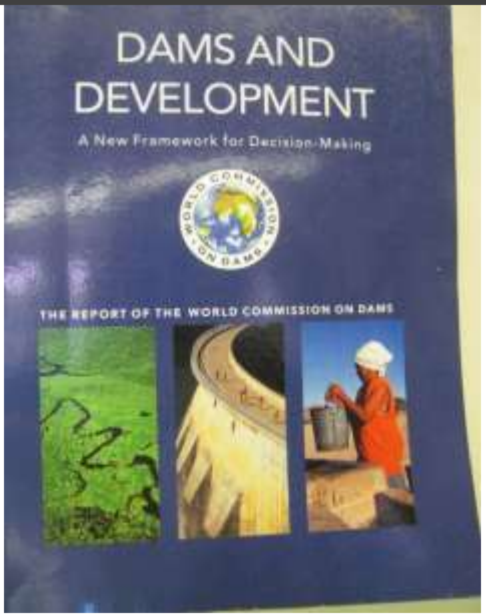
Equity

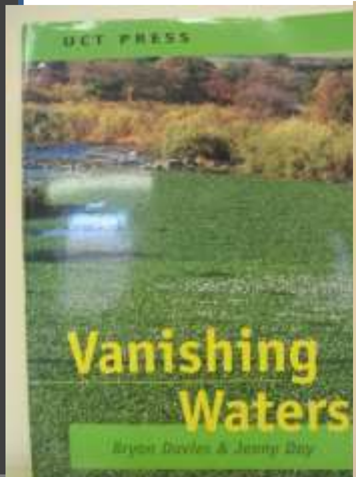
Sustain and protect the systems that support us

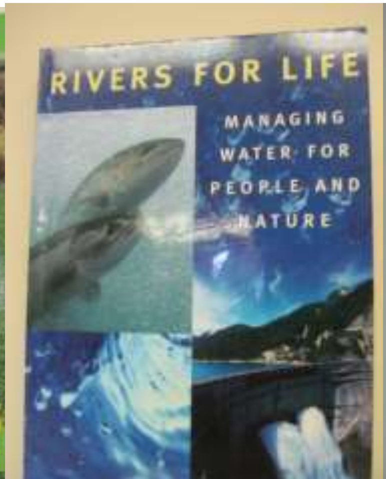
Last century was the great era of dam building:

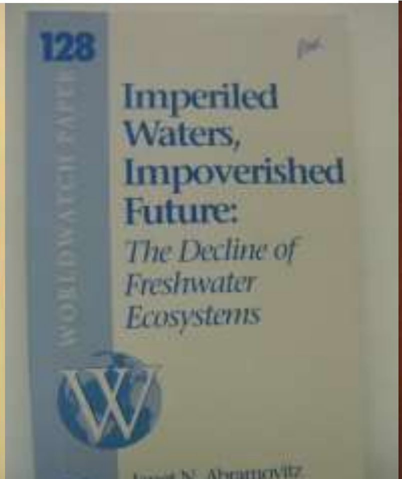
- Many benefits
- Downside (costs) starting to become apparent by 1970s
- Global concern over failing rivers

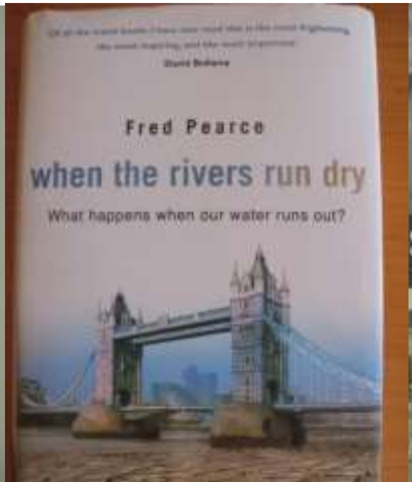
EFlows responded to need to spell out the **ecological and social** costs and benefits of water-resource development at the same level of detail as the **engineering and macroeconomic** costs and benefits to provide information on options to enhance overall benefits and avoid/mitigate costs

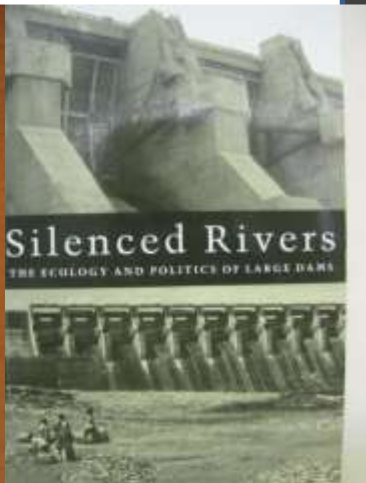








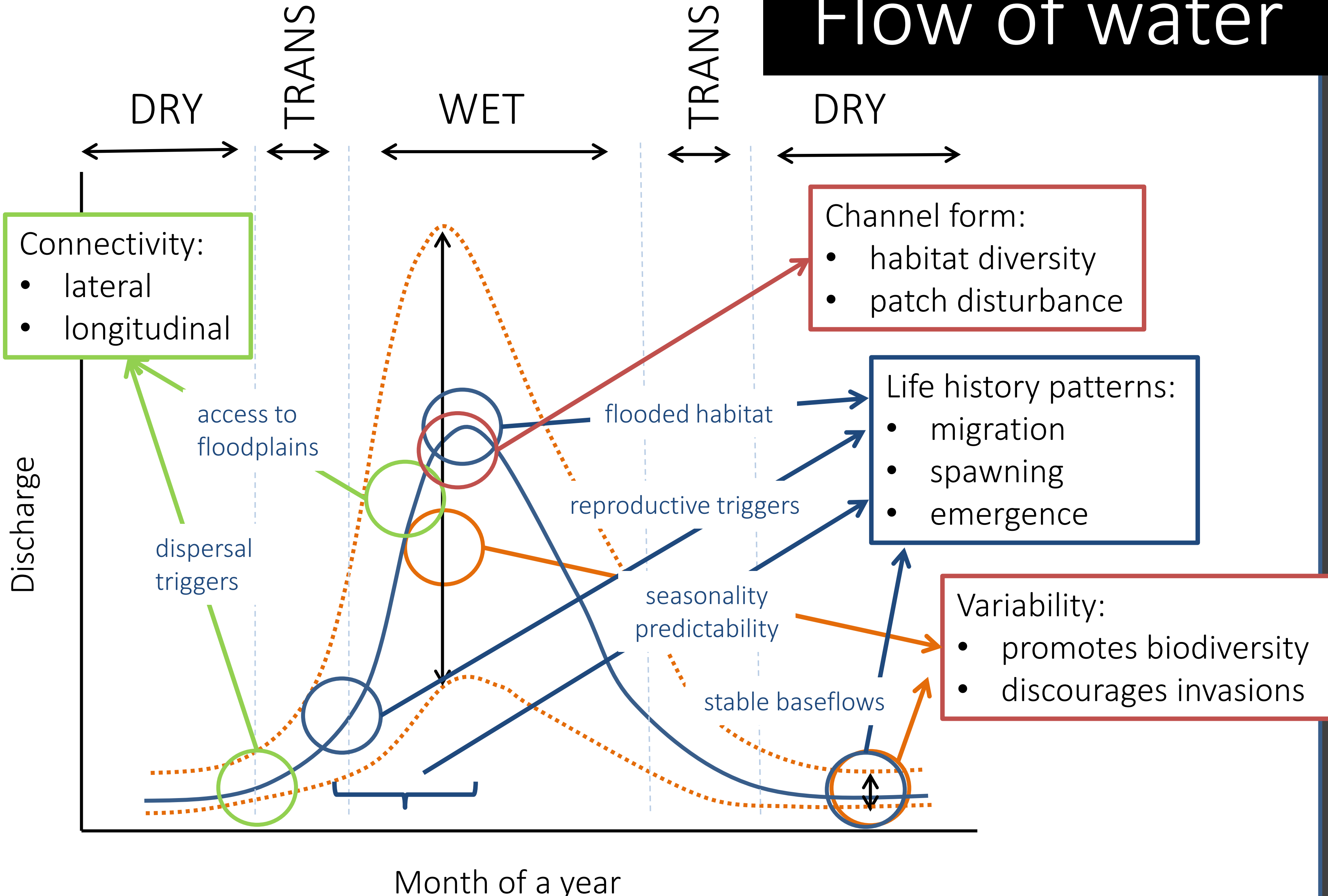




Main aspects of EFlows

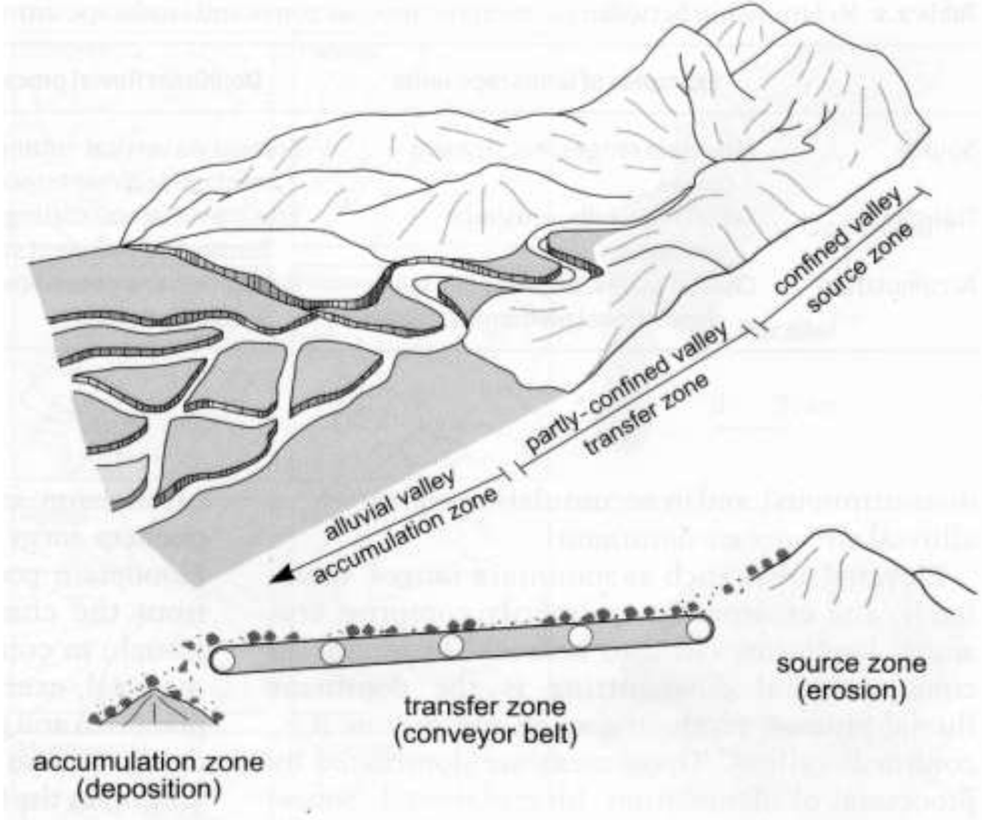
- Hydrology (flow of water)
- Sedimentology/geomorphology (flow of sediments)
- Connectivity (flow of biota):
  - lateral
  - longitudinal

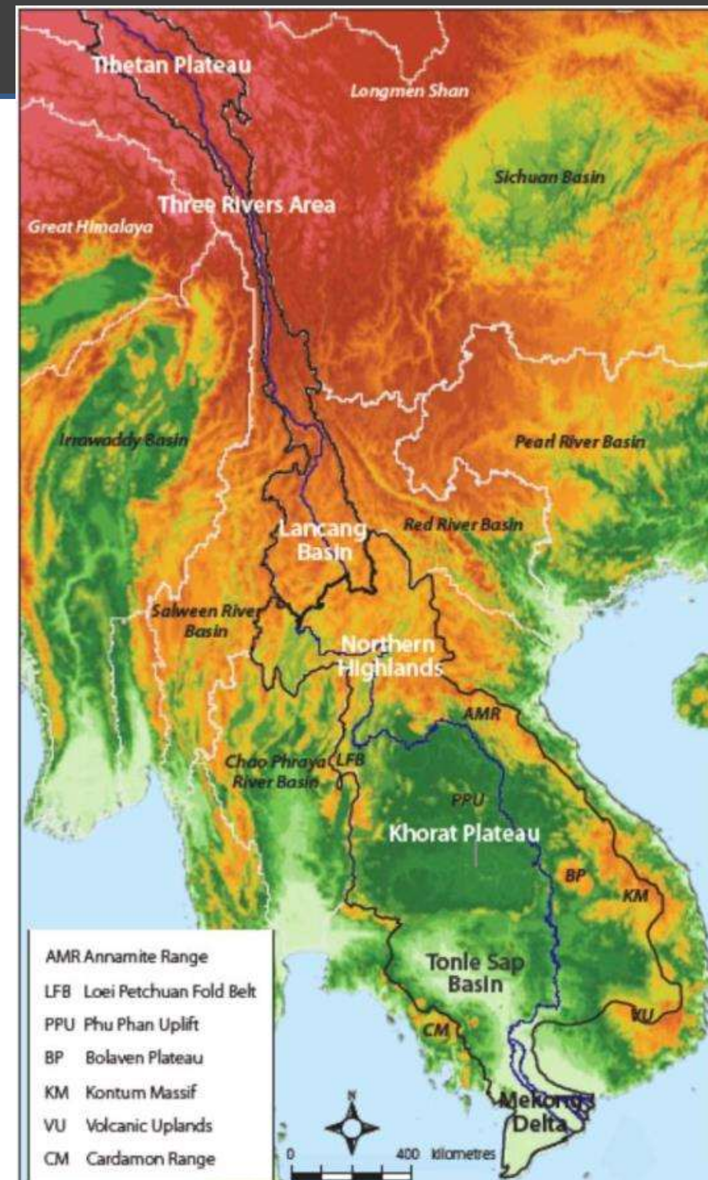
Flow of water

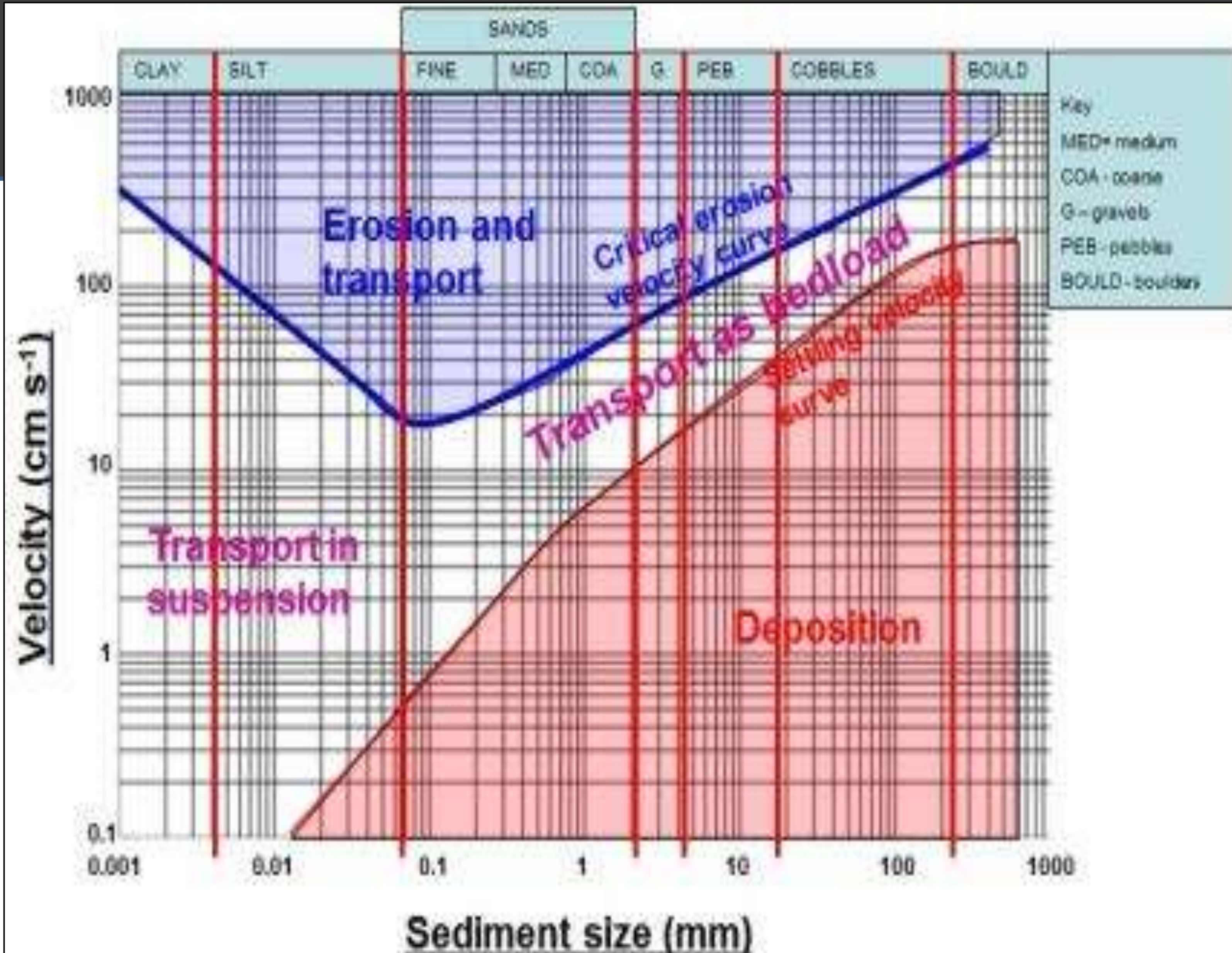


Flow of sediment

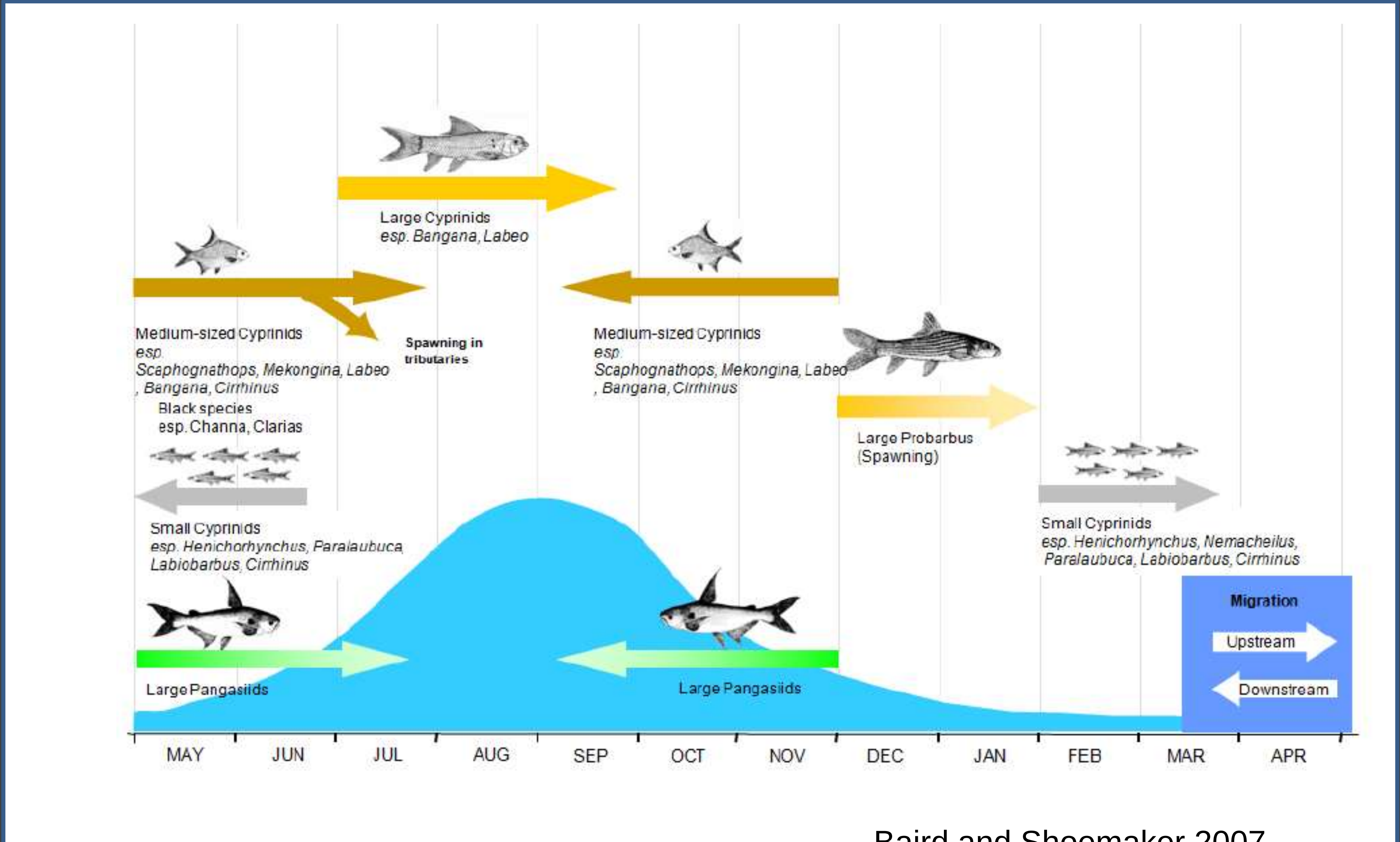
Rivers transport sediments and carve landscapes






SANDS
CLAY
SILT
FINE
MED
COA
G
PEB
COBBLES
BOULD
Key
MED= medium
COA - coarse
G - gravels
PEB - pebbles
BOULD - boulders
1000
100
10
1
0.1
0.001
0.01
0.1
1
10
100
1000
Velocity (cm s-1)
Sediment size (mm)
Erosion and transport
Critical erosion velocity curve
Transport as bedload
Settling velocity curve
Transport in suspension
Deposition

Flow of animals and plants

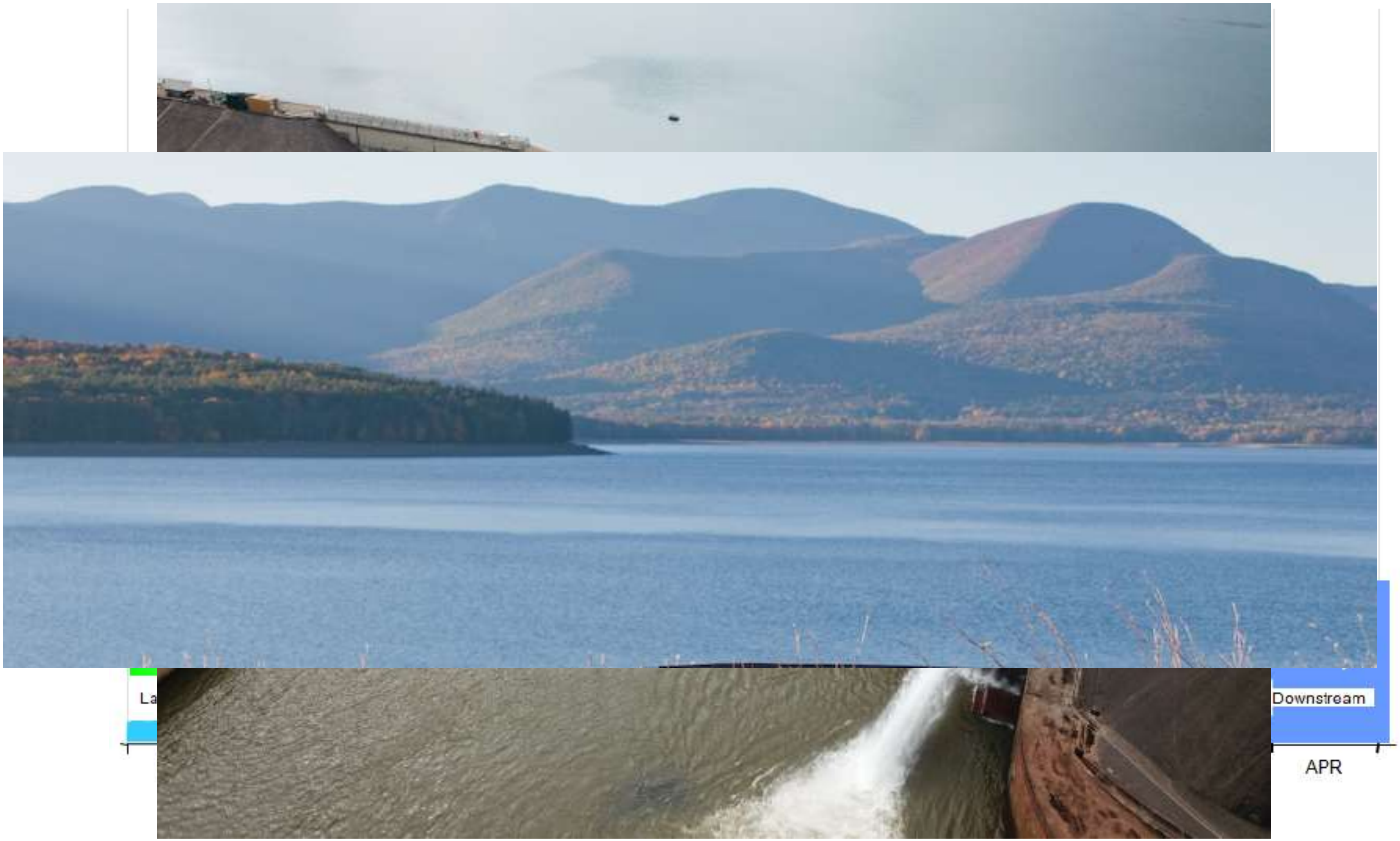


Baird and Shoemaker 2007

Flow of animals and plants

Baird and Shoemaker 2007

Flow of animals and plants



Baird and Shoemaker 2007

Main aspects of EFlows

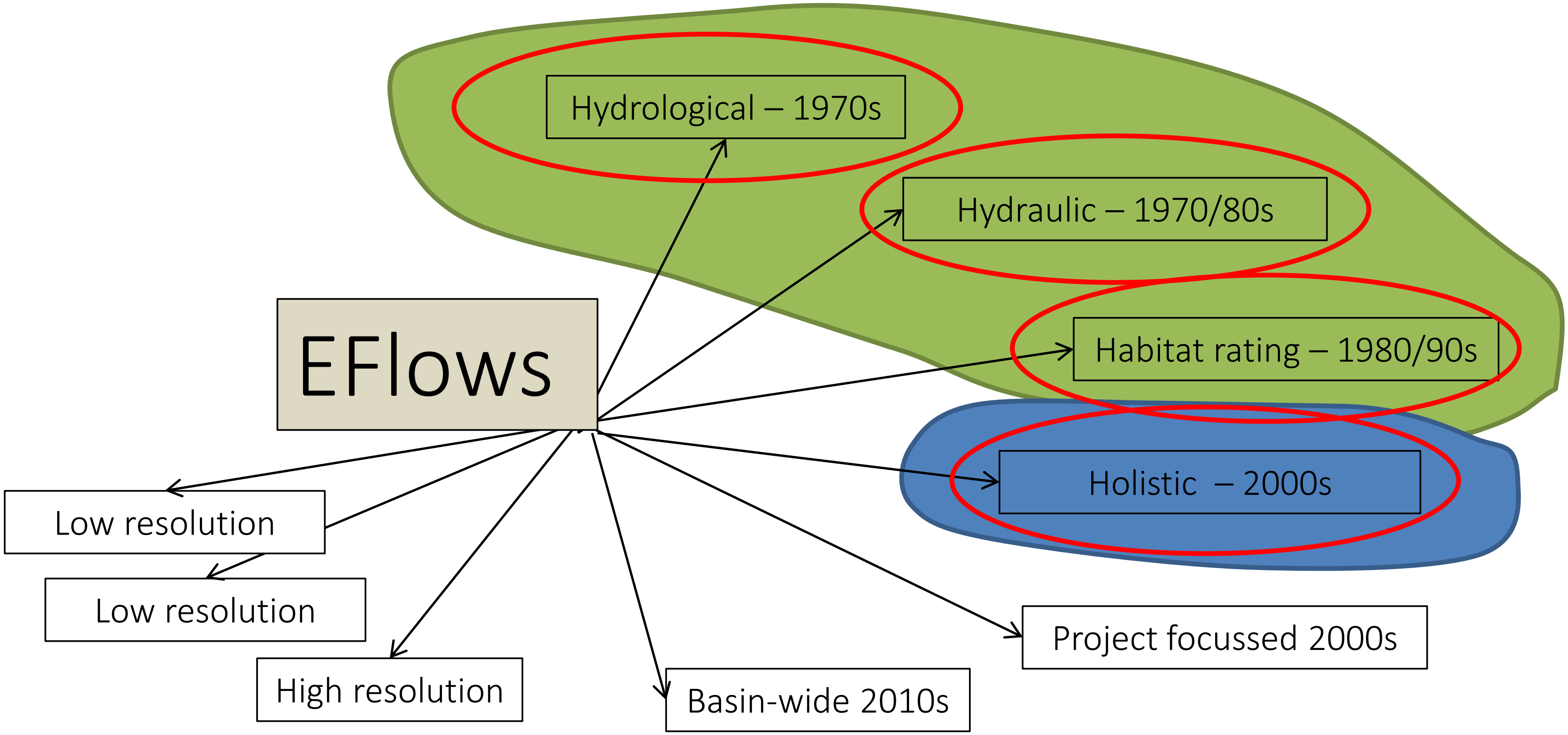
- Hydrology (flow of water)
- Sedimentology/geomorphology (flow of sediments)
- Connectivity (flow of biota):
  - lateral
  - longitudinal

Human developments (incl. climate change) affect all of these

EFLOWS METHODS OF ASSESSMENT

Methods for assessing EFlows

EFlows methods have been developing for more than 30 years and provide a wide array of options



Method	Categorisation	Level of resolution
The Tennant Method	Hydrological	Very low
New England Aquatic Base-Flow (ABF)		Very low
IHA/RVA		Low
The Desktop Model		Low
Wetted perimeter method	Hydraulic rating	Low
Instream Flow Incremental Methodology (IFIM)	Habitat simulation	Medium or high
CASiMir		Medium or high
System for Environmental Flow Analysis (SEFA)		Medium or high
The Building Block Methodology	Holistic	Medium or high
The Benchmarking Methodology		Medium or high
Eco Modeller		Medium or high
ELOHA		Medium
DRIFT		Medium or high
Murray-Darling Adjustment Ecological Elements		Medium or high

1970s → 2010s

No ecology → Whole ecosystem

Dry season lowflows → Whole regime of water, sediment and biota

Prescriptive → Interactive

Single location → Whole basin

Hydrological

10% 'rule'/Q_{95}

- Purely hydrologic
- No ecology
- Dilute pollutants
- Dry season habitat for game fish
- Single number – attractive and simple to use

Hydrological method

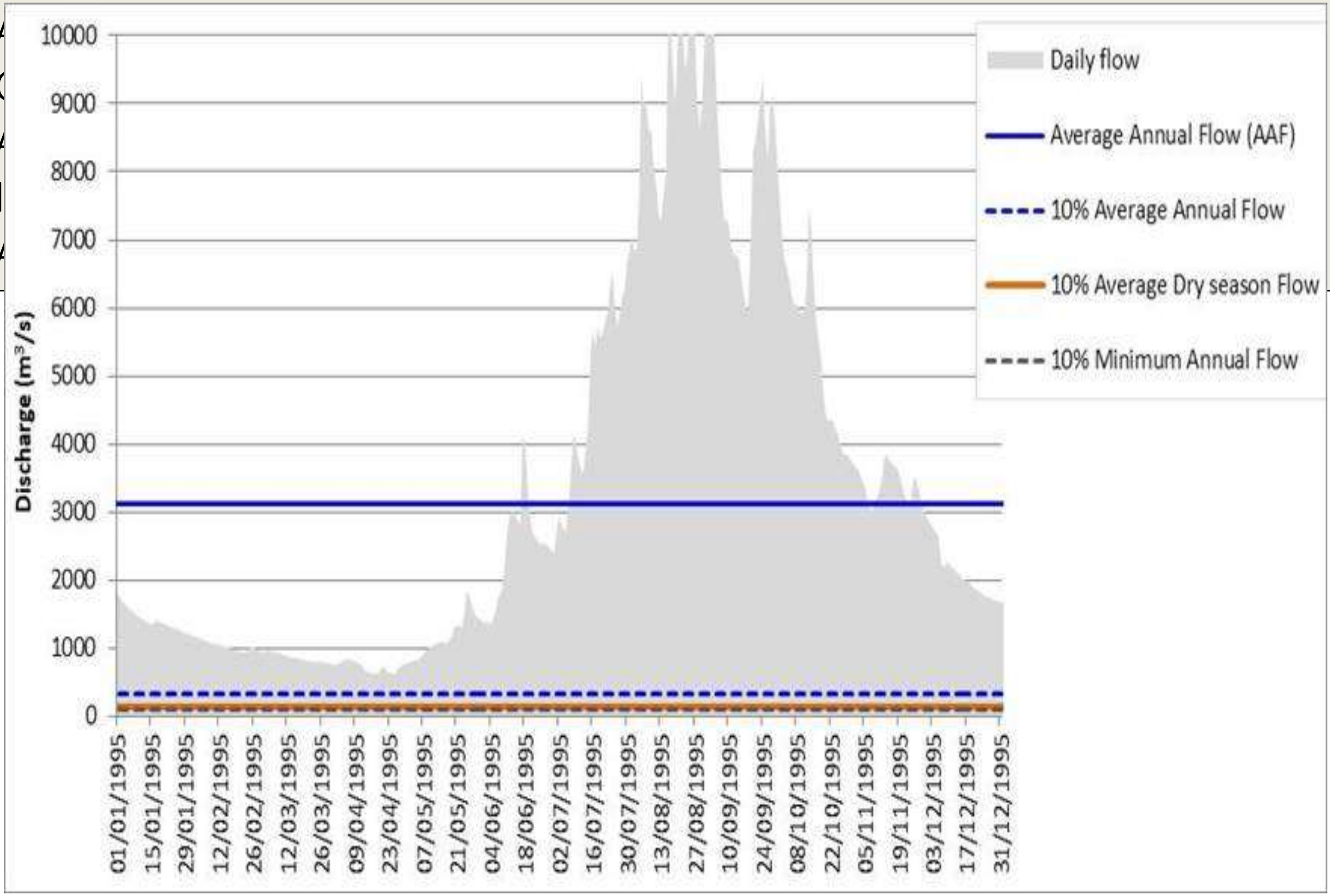
First attempt to halt/reverse degradation

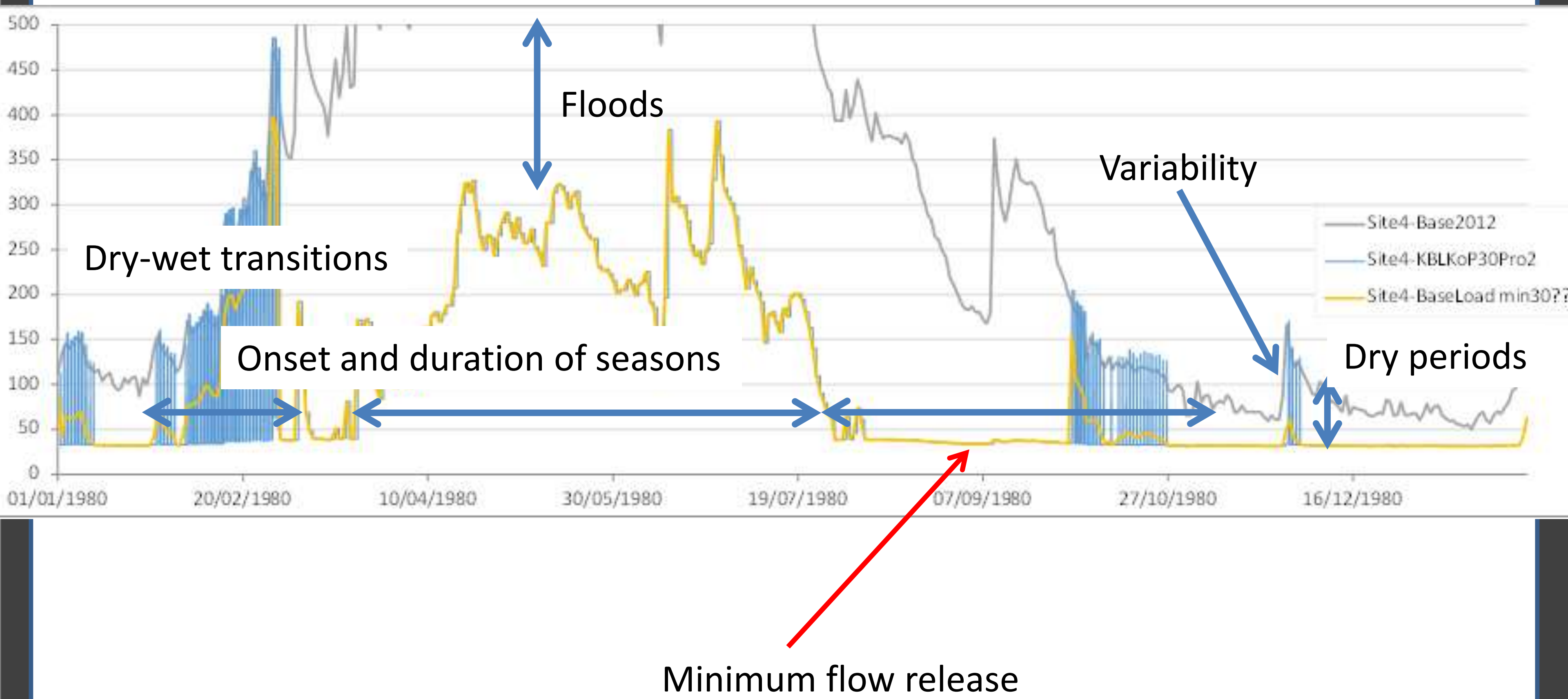
- Used a hydrological statistic (e.g., Q_{95}) to identify a flow that should remain in the river
- Q_{95} = Flow that is equalled or exceeded 95% of the time
- Used mainly in industrialised countries – usually to dilute effluents or to provide wet areas for game fish
- Engineering calculation – usually with no ecological relevance
- No/little acknowledgment that the full range of flows - and natural timing and variability - are needed to maintain river health
- Attractive to planners as allowed upfront allocation of water ‘for the environment’ in water resource models

This is what 10% looks like

Widely use - 10% of Average Annual Flow is claimed to be:

- A
- C
- A
- I
- A





Floods
Variability
Dry-wet transitions
Onset and duration of seasons
Dry periods
Minimum flow release
500
450
400
350
300
250
200
150
100
50
0
01/01/1980
20/02/1980
10/04/1980
30/05/1980
19/07/1980
07/09/1980
27/10/1980
16/12/1980
Site4-Base2012
Site4-KBLKoP30Pro2
Site4-BaseLoad min30??

1970s — 2010s

No ecology — Whole ecosystem

Dry season lowflows — Whole regime of water, sediment and biota

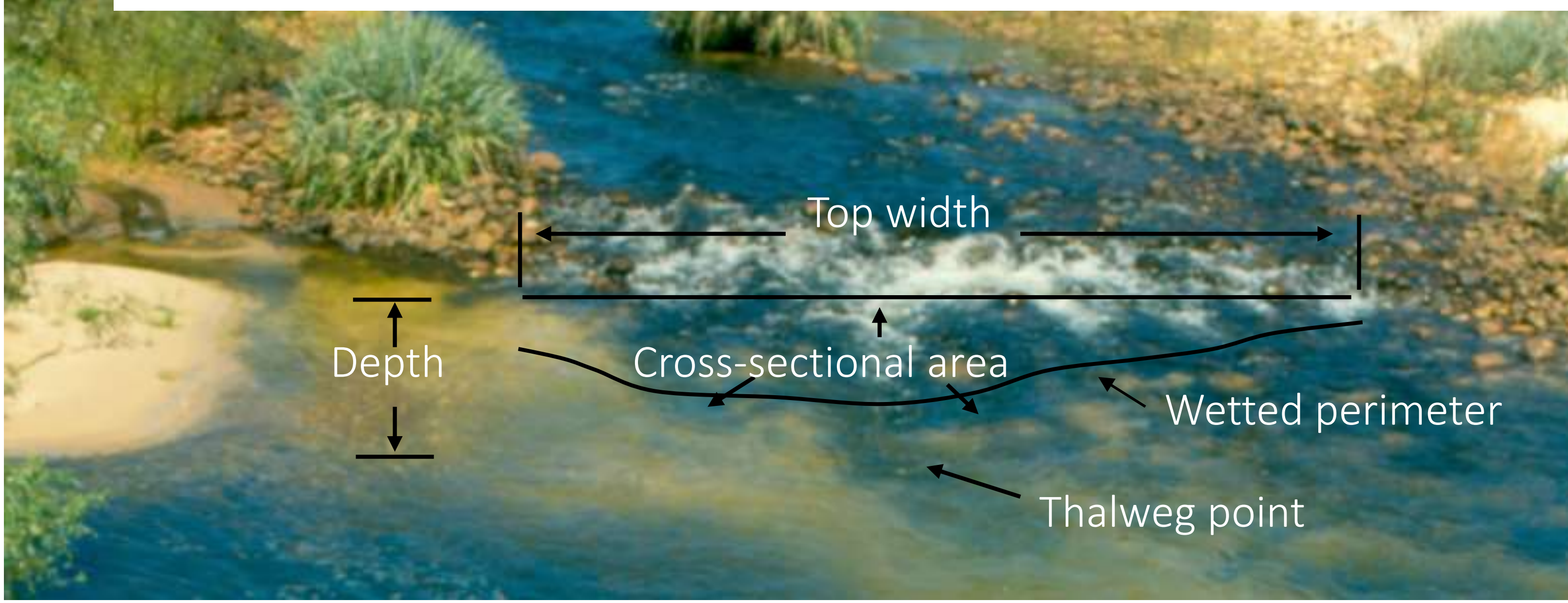
Prescriptive — Interactive

Single location — Whole basin

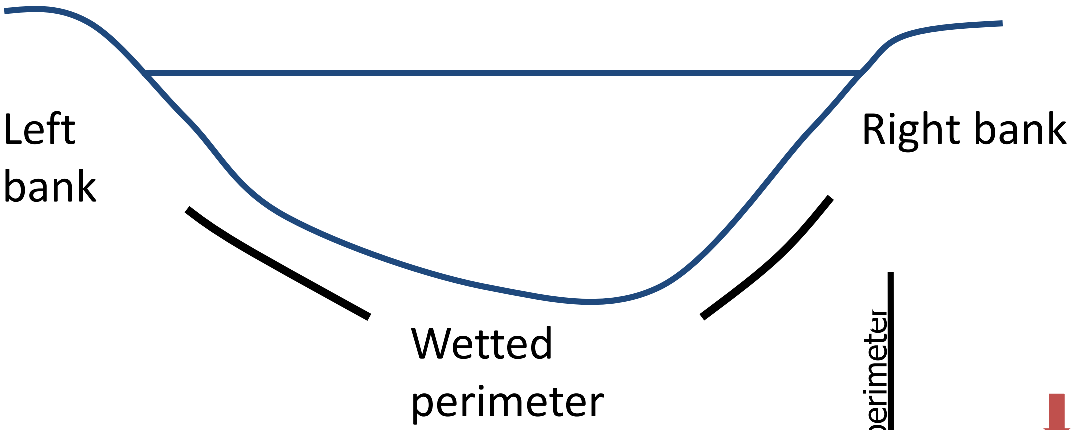
Hydrological	Hydraulic
10% 'rule'/Q_{95}	**Wetted perimeter**
• Purely hydrologic • No ecology • Dilute pollutants • Dry season habitat for game fish • Single number – attractive and simple to use	• Field measurements (depth width) • Habitat use as surrogate • Q vs. hydraulics - inflection points • Prescriptive

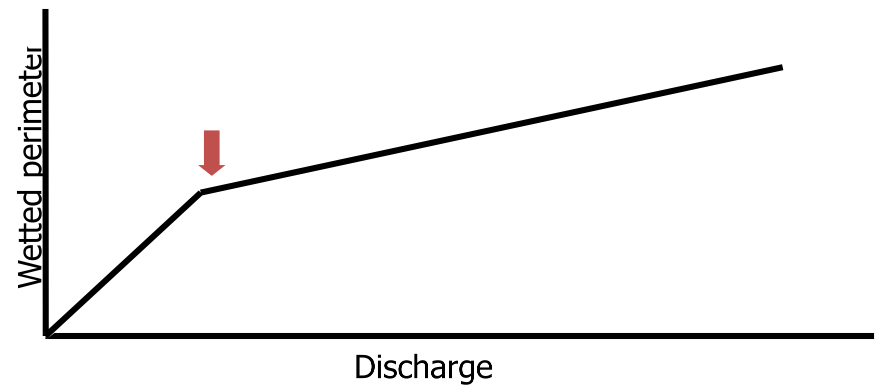
Hydraulic-rating methods

- Focus on individual river – need field measurements
- Use physical condition as surrogate for biological status
- Assume that maintaining an aspect of physical condition above a threshold will maintain a species (or the whole river system)



Example: Wetted perimeter method





- Single cross-section
- Create wetted perimeter vs discharge plot
- Look for inflection point - assumes this is where area of aquatic habitat starts to decline rapidly
- BUT:
  - there may be more than one inflection point
  - does not reveal details of habitat

1970s → 2010s

No ecology → Whole ecosystem

Dry season lowflows → Whole regime of water, sediment and biota

Prescriptive → Interactive

Single location → Whole basin

Hydrological	Hydraulic	Habitat Rating
10% 'rule'/Q_{95}	**Wetted perimeter**	**IFIM/Phabsim**
• Purely hydrologic • No ecology • Dilute pollutants • Dry season habitat for game fish • Single number – attractive and simple to use	• Field measurements (depth width) • Habitat use as surrogate • Q vs. hydraulics - inflection points • Prescriptive	• Field measurements • Focus on one or more species • Flow/habitat • Data intensive – initially • Most used in USA • Interactive

Habitat-rating methodologies

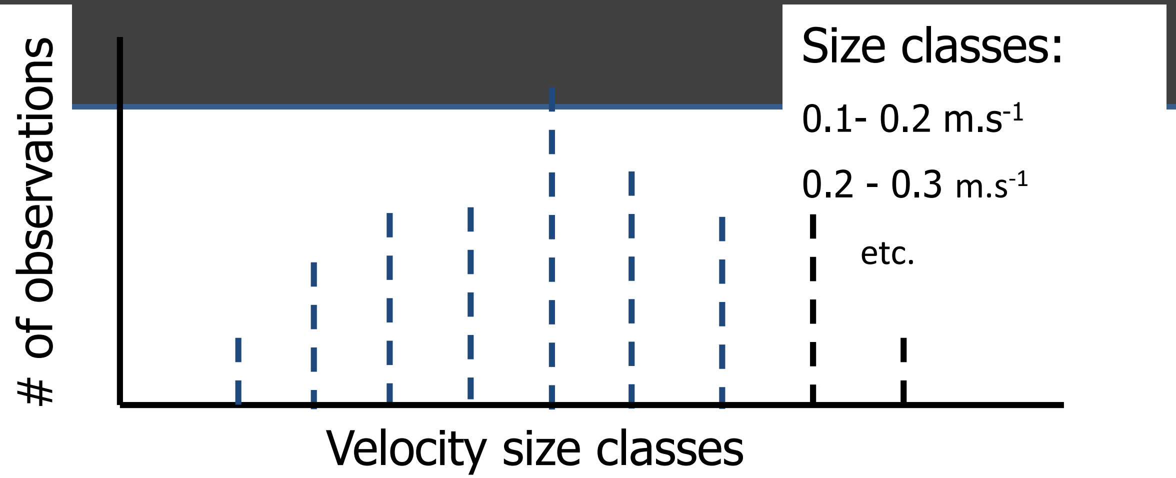
e.g. Instream Flow Incremental Methodology (IFIM)

Quantify the usability of a section of river, for named species, over a range of discharges

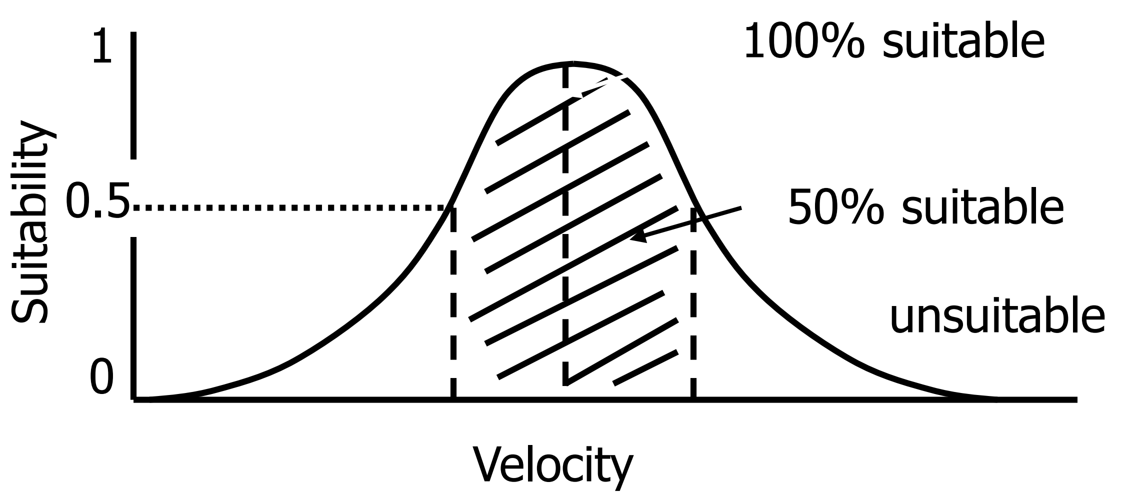
First, survey channel and develop a hydraulic model that describes depth, width and velocity of flow, and substratum

Next, identify and measure where the target species are found

Allocate values to size classes and create a frequency plot



4. Normalise by allocating value of 1 to the highest frequency class



This is an SI (Suitability Index) curve describing the current speed in which a named species was most often found

Changed over time …

1. Dealt only with instream biota
2. Focused on single species
3. Focused on single habitat of that species
4. Did not address floods
5. Data intensive
5. Made a huge impact worldwide
6. Main method used in USA for river rehabilitation
7. Has been developed further
8. Aspects also included in newer EFlows methods

1970s → 2010s

No ecology → Whole ecosystem

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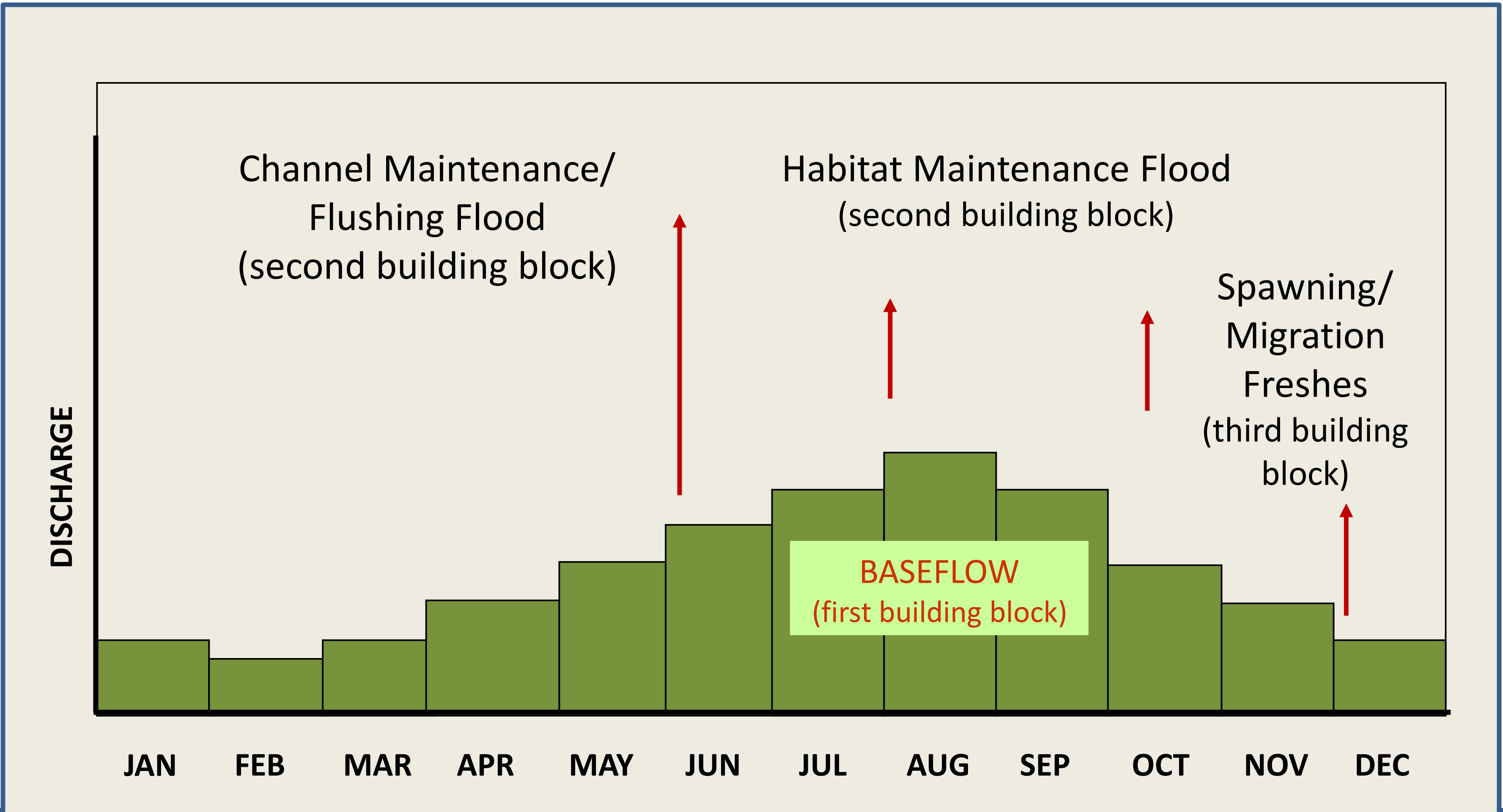
Prescriptive → Interactive

Single location → Whole basin

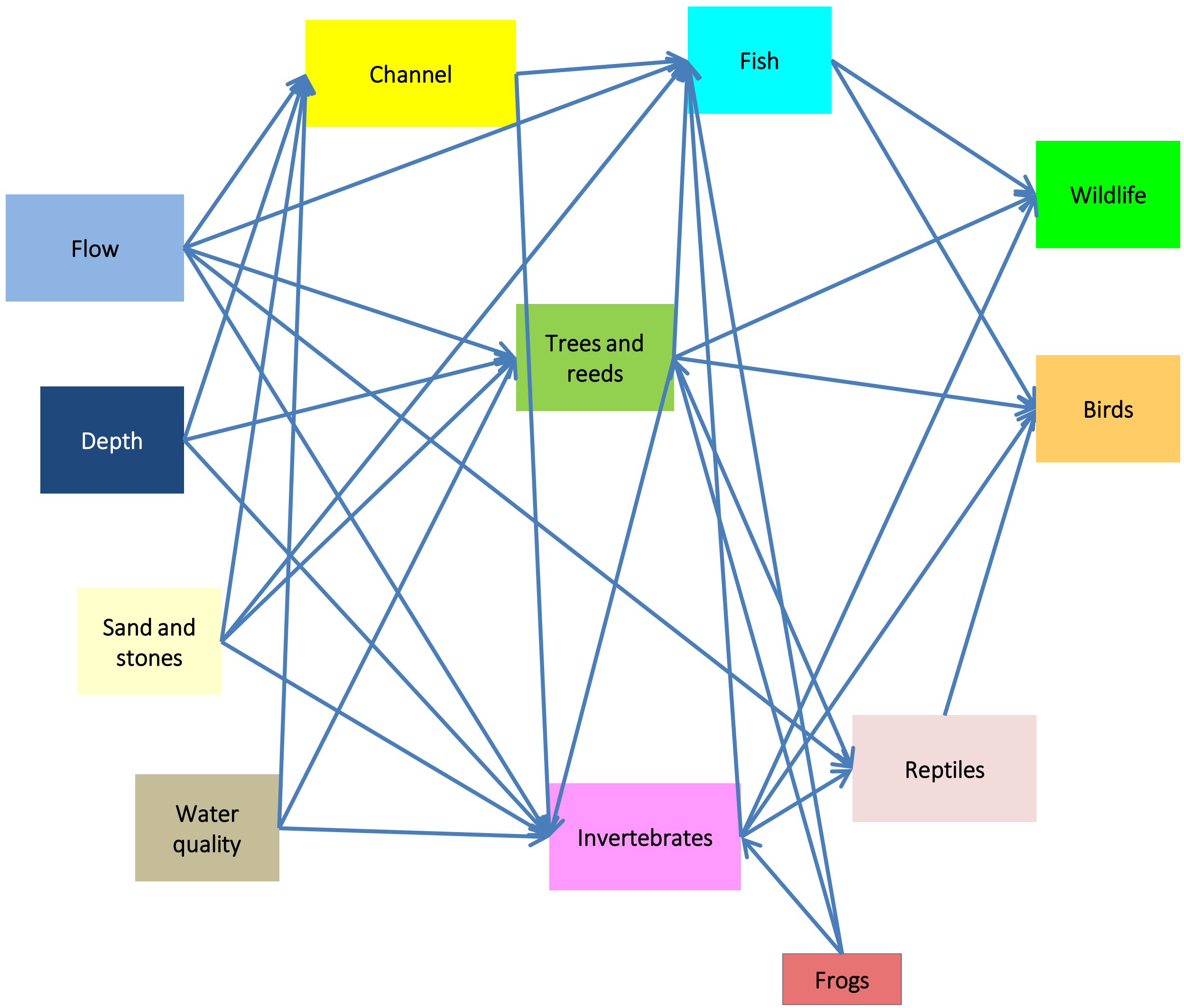
Hydrological	Hydraulic	Habitat Rating	Holistic
10% ‘rule’/Q_{95}	**Wetted perimeter**	**IFIM/Phabsim**	**BBM** / **DRIFT**
• Purely hydrologic • No ecology • Dilute pollutants • Dry season habitat for game fish • Single number – attractive and simple to use	• Field measurements (depth width) • Habitat use as surrogate • Q vs. hydraulics - inflection points • Prescriptive	• Field measurements • Focus on one or more species • Flow/habitat • Data intensive – initially • Most used in USA • Interactive	• Field measurements • Existing data and expert opinion BBM: • Focused on discrete flow events • Prescriptive DRIFT: • Ecosystem model • Time-series water, sediments, biota • Interactive

Example: Building block methodology (1990)

Uses a team of biophysical specialists *(hydrology, hydraulics, fluvial geomorphology, water chemistry, vegetation, invertebrates, fish, water birds, etc.)*

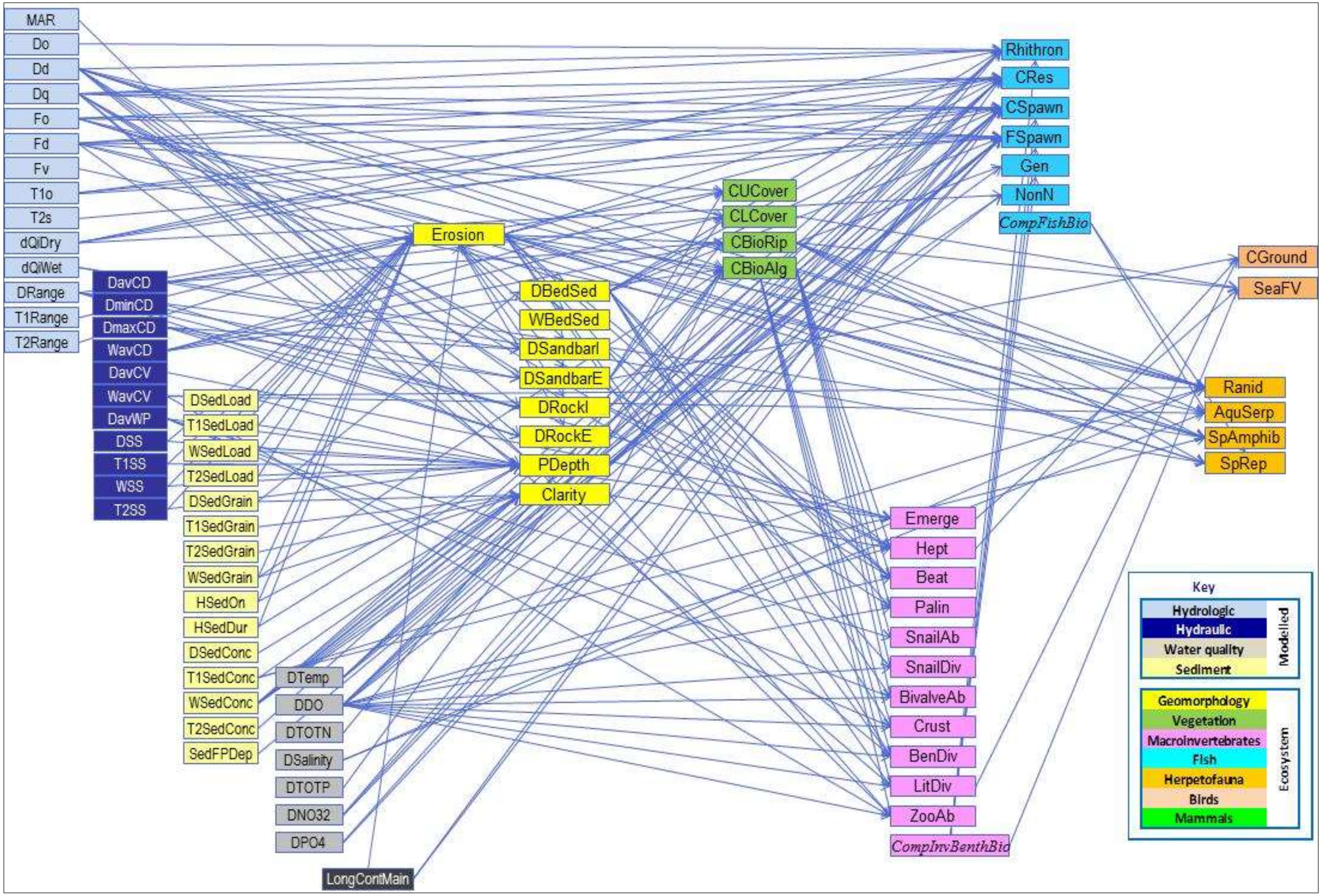


Example: DRIFT (1997)



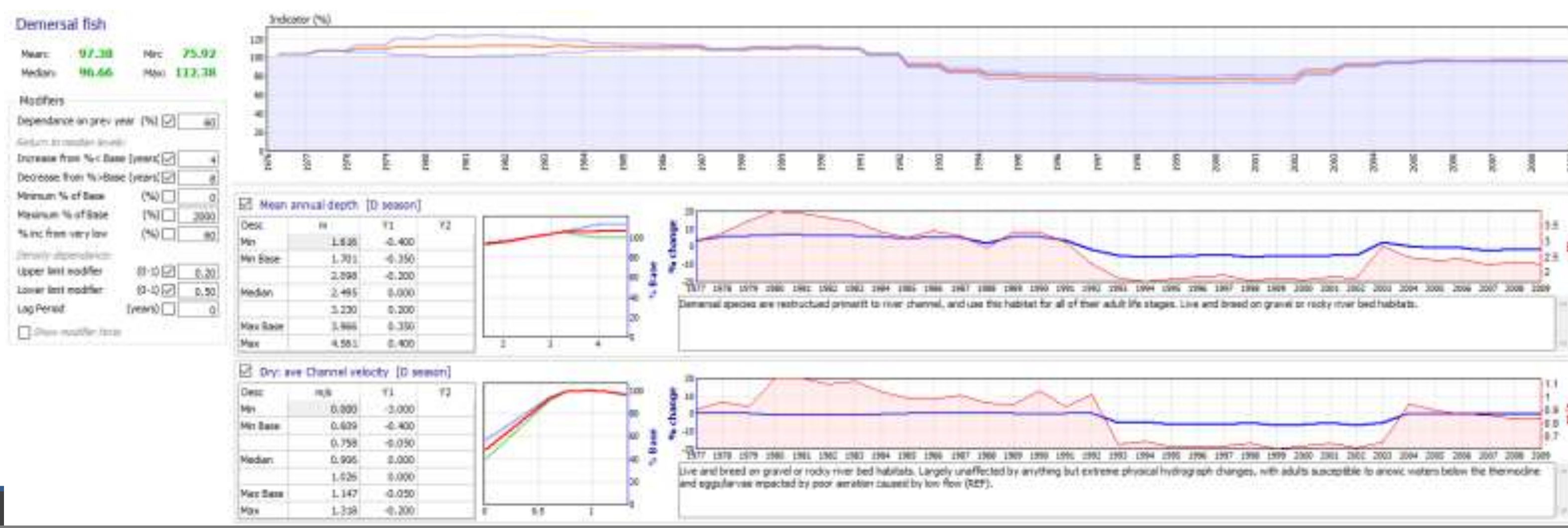
Complex, and 'everything' is linked

Each mapped link requires a response curve



Response curves

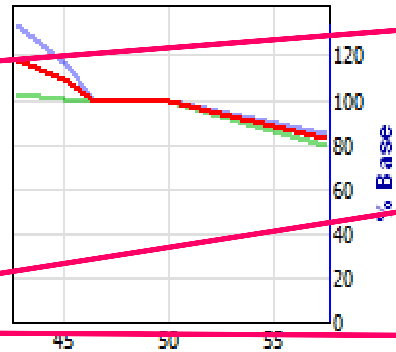
- Means of capturing information and understanding:
  - from in-depth scientific data, international knowledge, national knowledge or local wisdom
  - created by EF specialists with a working knowledge of the river ecosystem and its users
  - graphic and explicit with supporting explanations
  - allow qualitative as well as quantitative knowledge to be captured
  - amenable to adjustment as knowledge increases.



Rhithron fish vs onset of dry season

☑ Dry onset [D season]

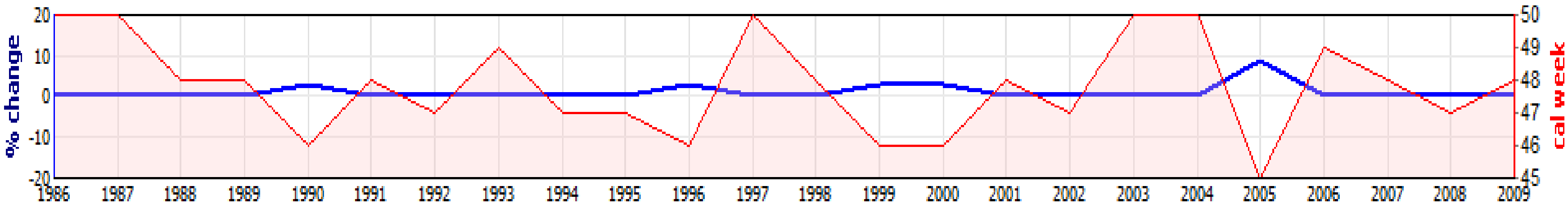
Desc	cal week	Y1	Y2
Min	42.750	1.260	
Min Base	45.000	0.625	
	46.500	0.000	
Median	48.000	0.000	
	49.000	0.000	
Max Base	50.000	0.000	
Max	57.500	-1.000	



6 weeks earlier median
c. 15% increase

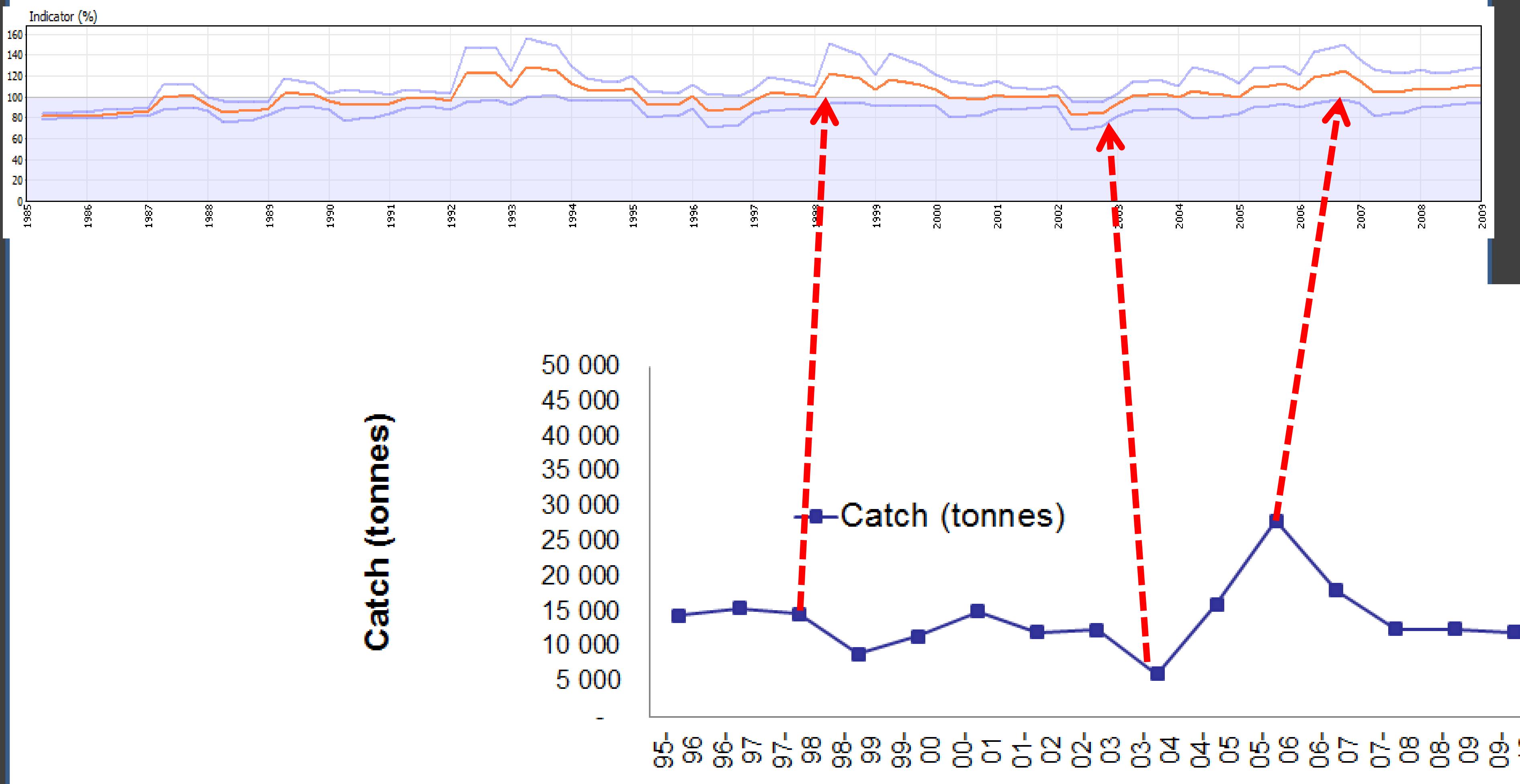
2 weeks later median
No change

10 weeks later median
c. 15% decrease



The onset of the dry season represents a time rhithron species are able to migrate to shallower areas with suitable substrate for spawning, earlier onset allows the fish greater time to migrate but late onset can disrupt spawning migration and maturation. Also if dry season starts earlier, it beneficial as fish can mature in less stressful conditions prior to spawning.

Compare with monitoring data
(where available)

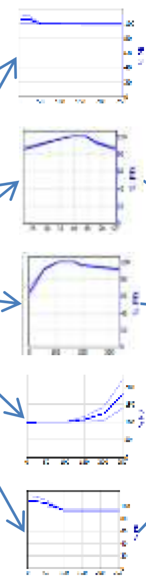


Analysis

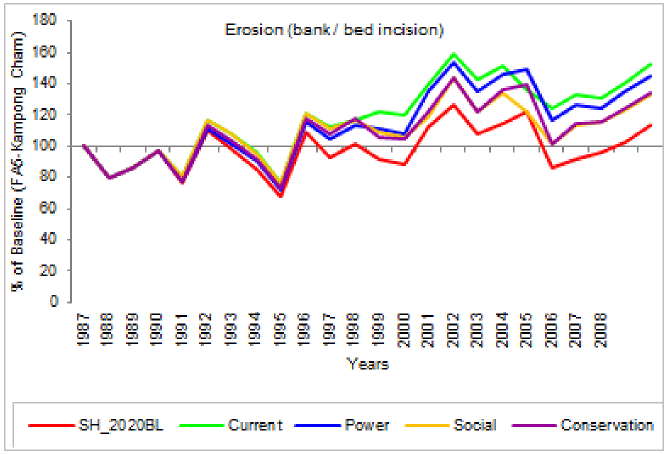
External modelled time series:
Hydrology
Sediments
WQ
Barriers

Transformed into time series of driving indicators

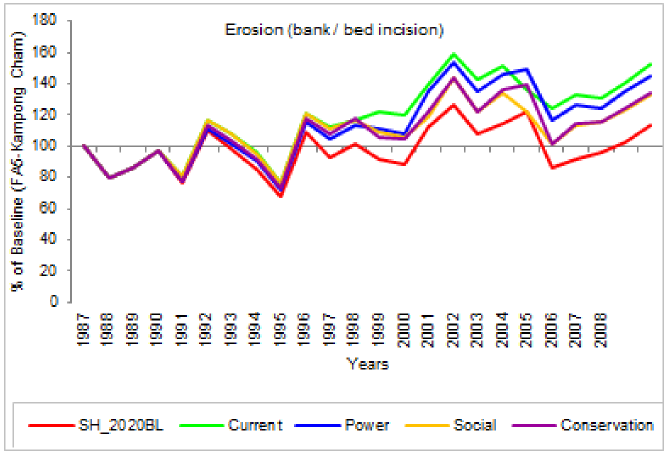
Each responding indicator

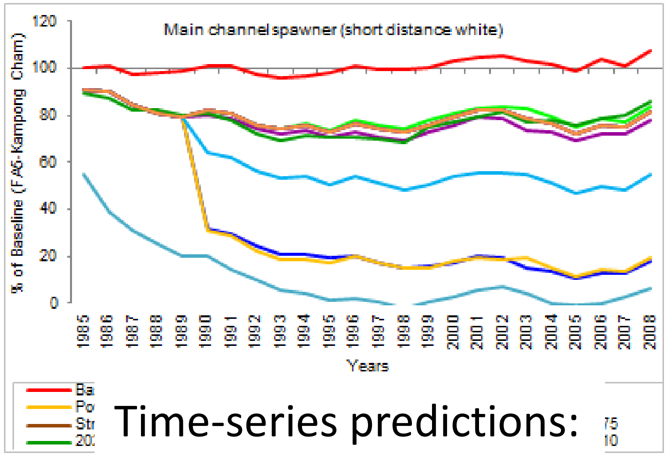


Prediction of change for each year
30 years of record = 30 values



Example of outputs (LMR)

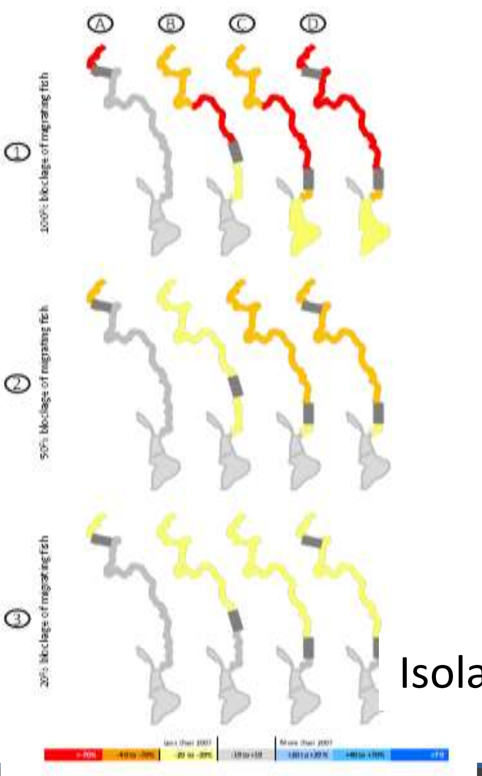




Time-series predictions:
- Developments
- Climate change

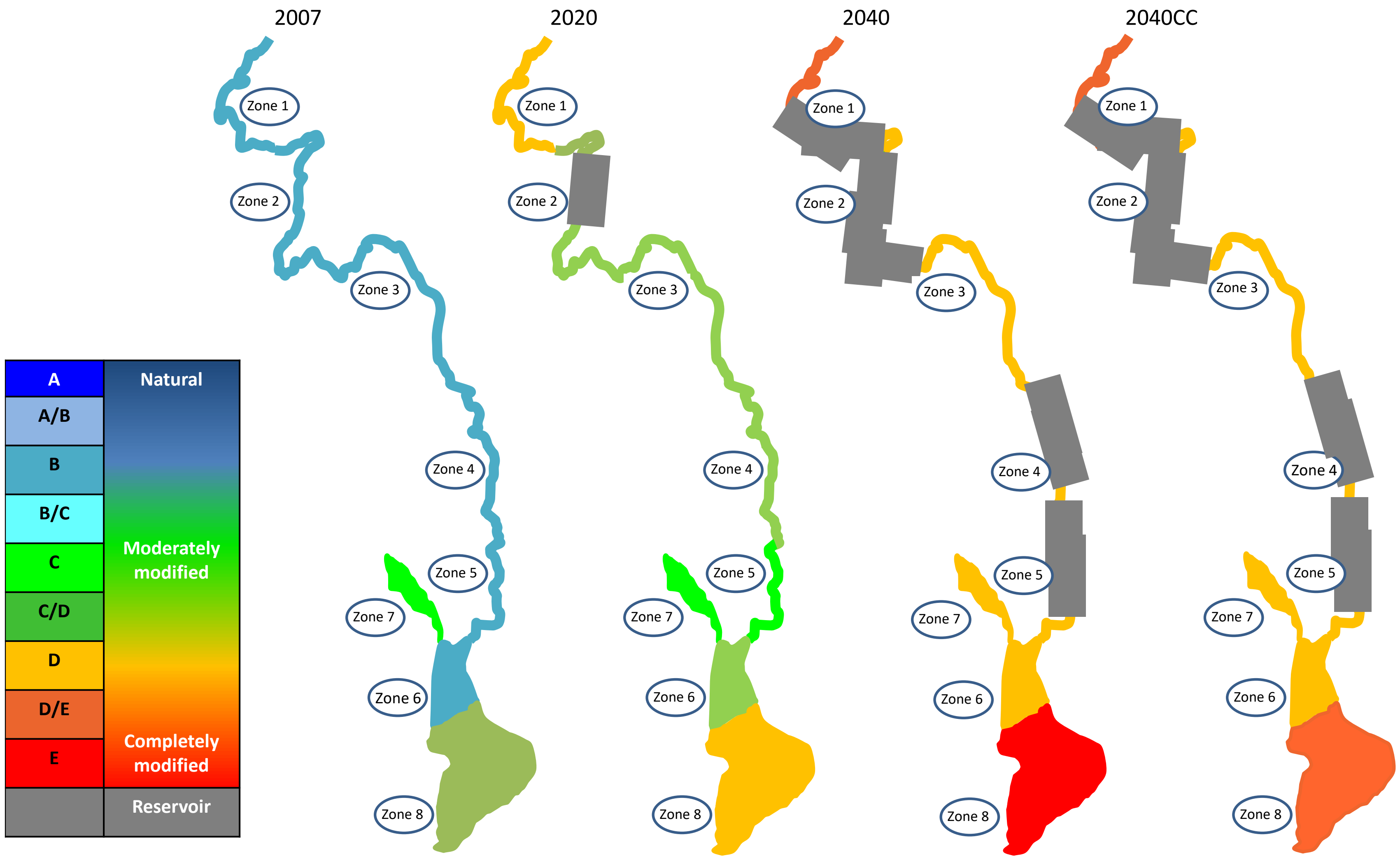
Zone	Indicator	Zone 1	2	3	4	5	6
Scenario 2020	Erosion (bank / bed incision)	120	40	25	35	60	-5
	Average bed sediment size in the Dry season	135	65	45	65	70	-10
	Availability exposed sandy habitat in Dry season	-55	-20	-15	-15	-30	
	Availab	[illegible]	-15	-10	-15	-20	
	Availab	[illegible]	30	10	20		
	Availability inundated rocky habitat in Dry season	45	20	10	20		
	Depth of bedrock pools in Dry season	15	10	0	15	20	
	Water clarity	60	10	0	15	10	15

End-point predictions



Isolated effects of barriers

Example of outputs



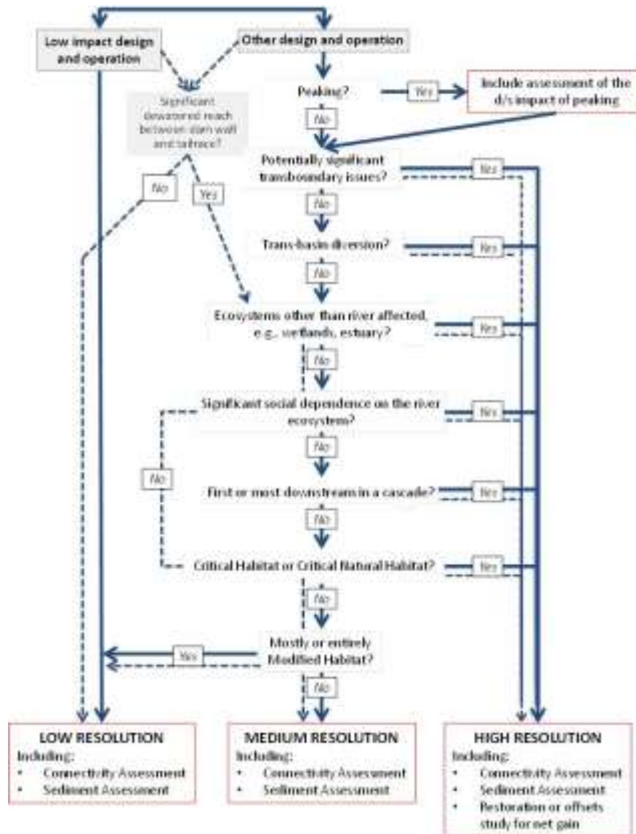
IN SUMMARY

Benefits of increased scale and detail

- True to the complexity of river ecosystems and their response to development
- More transparent
- More informed and equitable decision making
- Increased awareness and understanding of the dependencies on and functioning of the river
- Evaluate a wider scope of mitigation options
- Optimise design and location
- Fine-tune operating rules
- Generate metrics for monitoring
- Provide a resource for on-going planning/management
- Build understanding and CAPACITY

IF environmental sustainability is a high priority …

- Do not allocate an amount of water ‘for the environment’ up front
- Work with authorities to ensure the appropriate scale, sites, scenarios and EFlows approach(es)
- Invest in basin-wide EFlows studies that can be used by multiple clients
- Appoint experienced specialist EFlows teams – process managers; hydrologists; hydraulicians; water chemists; geomorphologists; botanists; zoologists; resource economists; and more
- Make use of data-poor techniques: bring together data, global understanding, expert opinion, local wisdom
- *No-one can learn to build a dam in a week; or how to manage an ecosystem in a week.*



Thank you