
National Colloquium on Water Demand
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Enhancing the Management of
Water Resources Towards
Sustainable Environment:
Managing Environment Flow
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Focus of Presentation

- Environmental Flow (e-flow) in Relation to Water Demand
- Global Mapping of Environmental Water Requirements and Water Scarcity
- E-flow Definitions
- The Science of Flow-Ecology Relationships
- E-flow Management Assessment and Strategies
- Examples on the Checklist on the Application of Environmental Flows in River Basin Management
- E-flow: Ensuring Clean, Living, Pristine River System
- Methods for flow assessment
- Study on Environmental Flows in Malaysia
- Conclusions

Environmental Flow (e-flow) in Relation to Water Demand

The driving forces for establishing water demand in water resources management may be based on resource scarcity, distribution system limitations, and/or efforts to manage operating costs. Responses to such needs can range from a conservation strategy that preserves available supplies to a resource-management strategy.

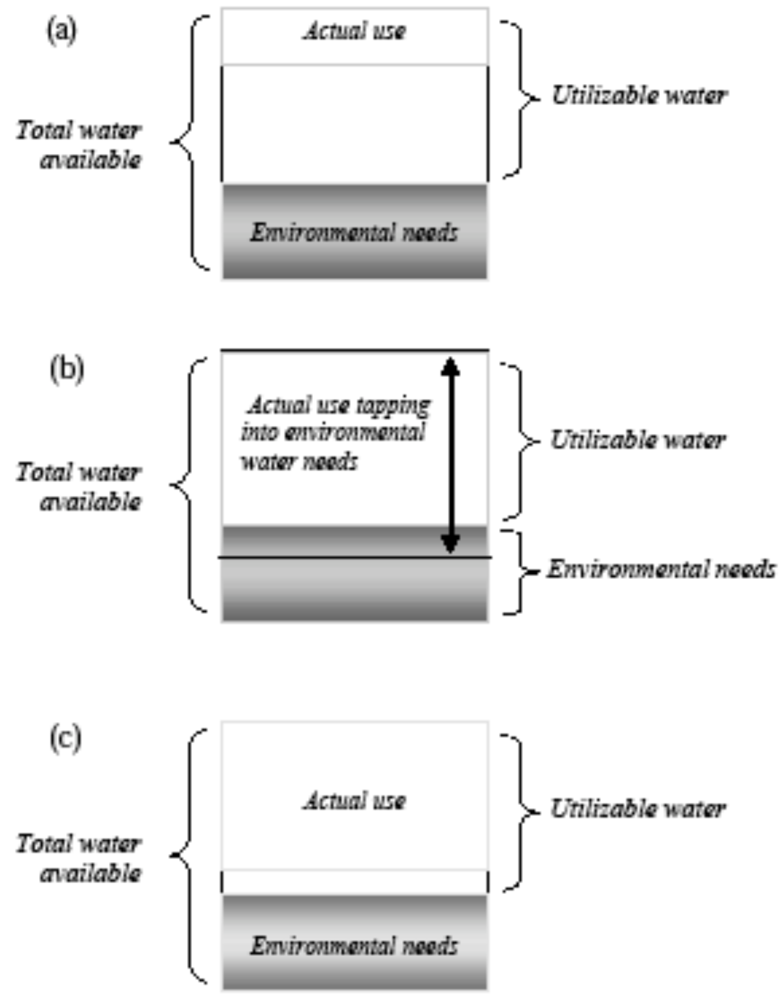
Environmental Flow (e-flow) in Relation to Water Demand

- One of the efforts on **resource-management strategy** is in **managing environmental flow (e-flow) in aquatic ecosystem.**
  - In **aquatic ecosystems**, such as rivers, wetlands, estuaries and near-coast marine ecosystems provide a great variety of benefits to people.
  - **Include** such as clean drinking water, fish and 'services' such as water purification, flood mitigation and recreational opportunities

Environmental Flow (e-flow) in Relation to Water Demand

- Rivers and other aquatic ecosystems need water and other inputs like debris and sediment to stay healthy and provide benefits to people.
- E-flows are a critical contributor to the health of these ecosystems. The absence of environmental flows puts at risk the very existence of ecosystems, people and economies.

Global Mapping of Environmental Water Requirements and Water Scarcity



(Smakhtin, et al. (2002))

Figure 1: Diagrams illustrating (a) environmentally safe, (b) environmentally water scarce and (c) environmentally water stressed basins.

Global Mapping of Environmental Water Requirements and Water Scarcity

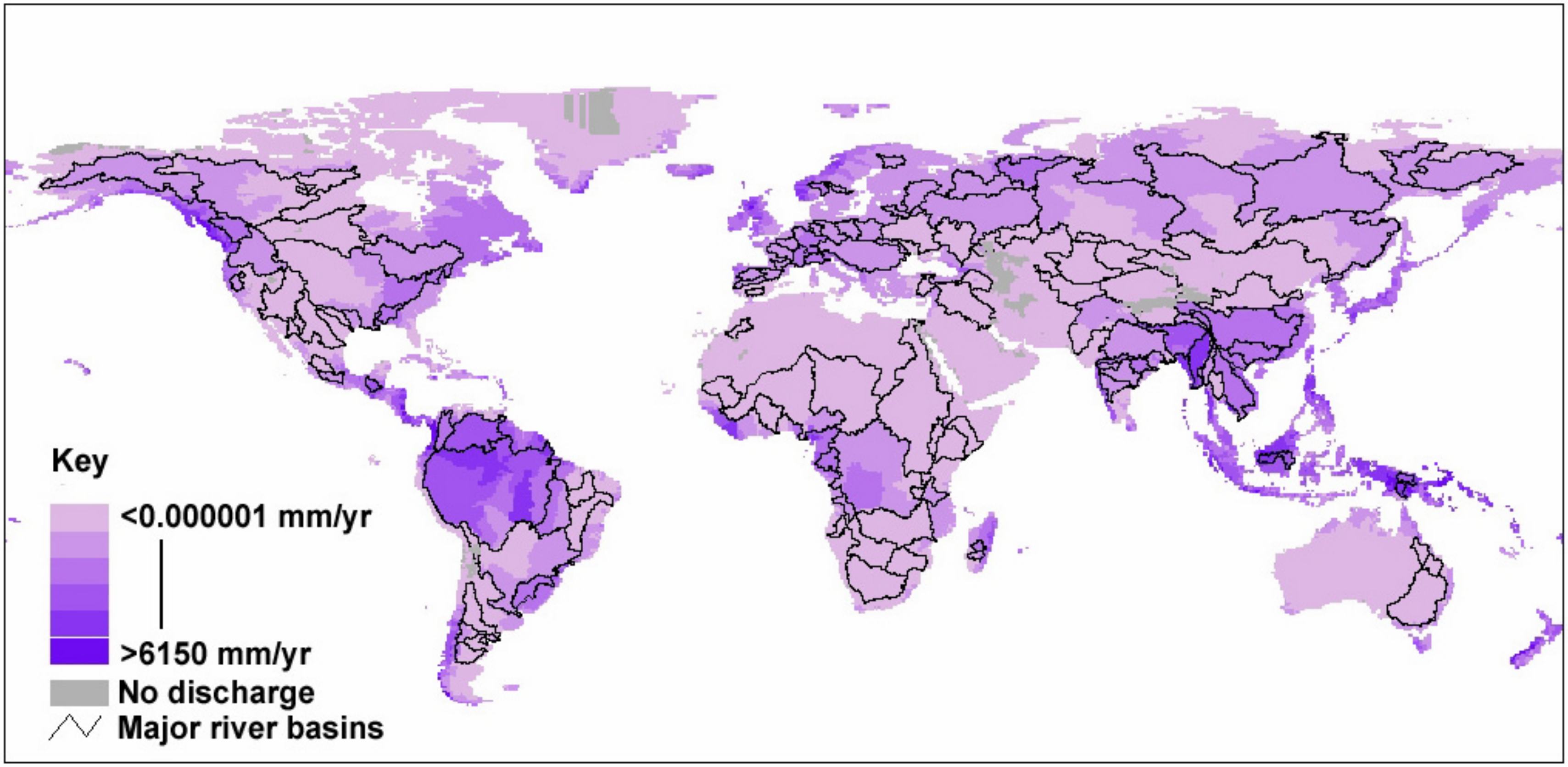


Figure 2: A map of long-term average annual water resources (MAR) by basin, calculated by the WaterGAP2 model (Smakhtin, et al. (2002))

Global Mapping of Environmental Water Requirements and Water Scarcity

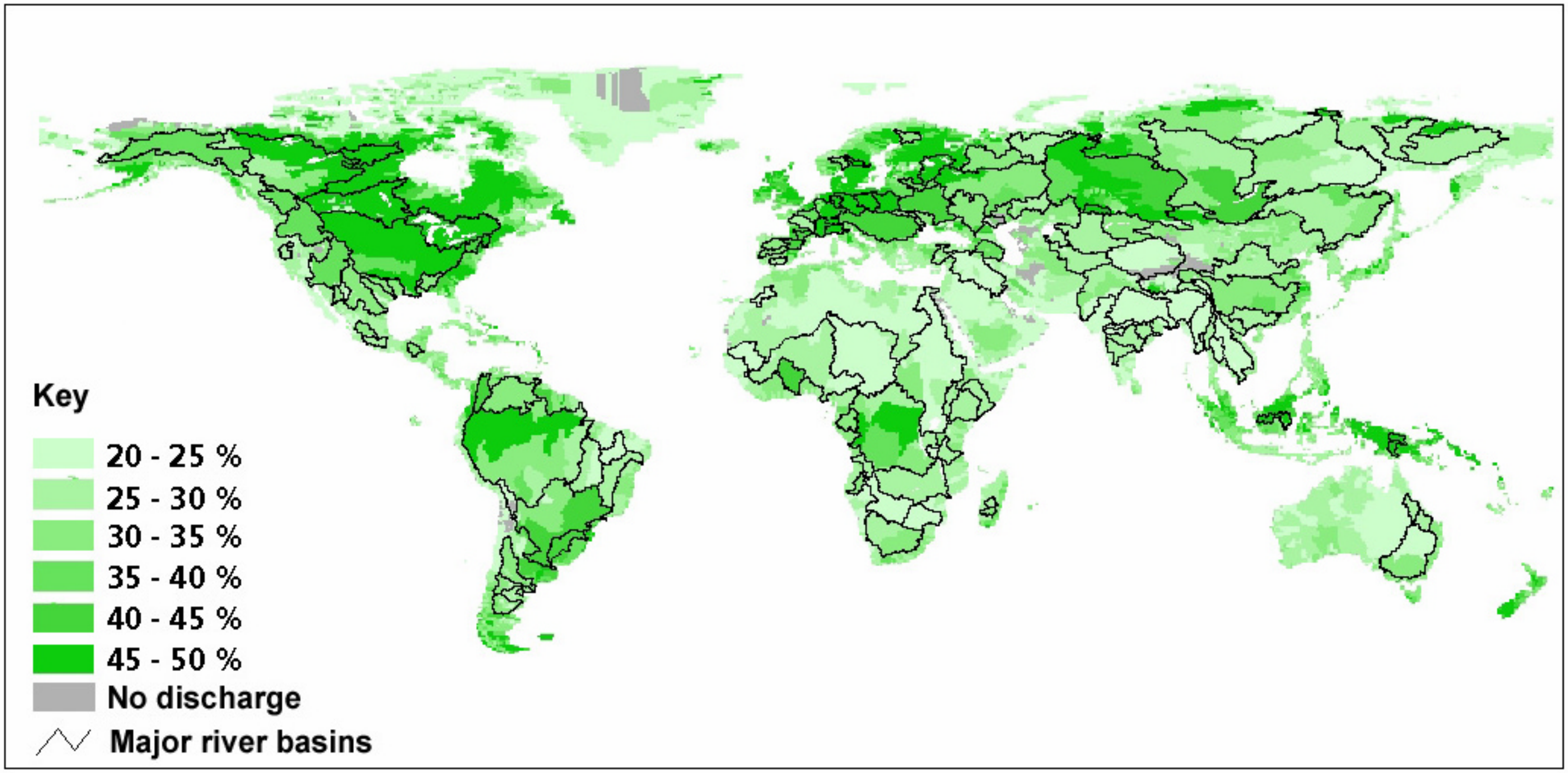


Figure 3: A map of estimated environmental water requirements as a percentage of total long term average water resources (Smakhtin, et al. (2002))

Global Mapping of Environmental Water Requirements and Water Scarcity

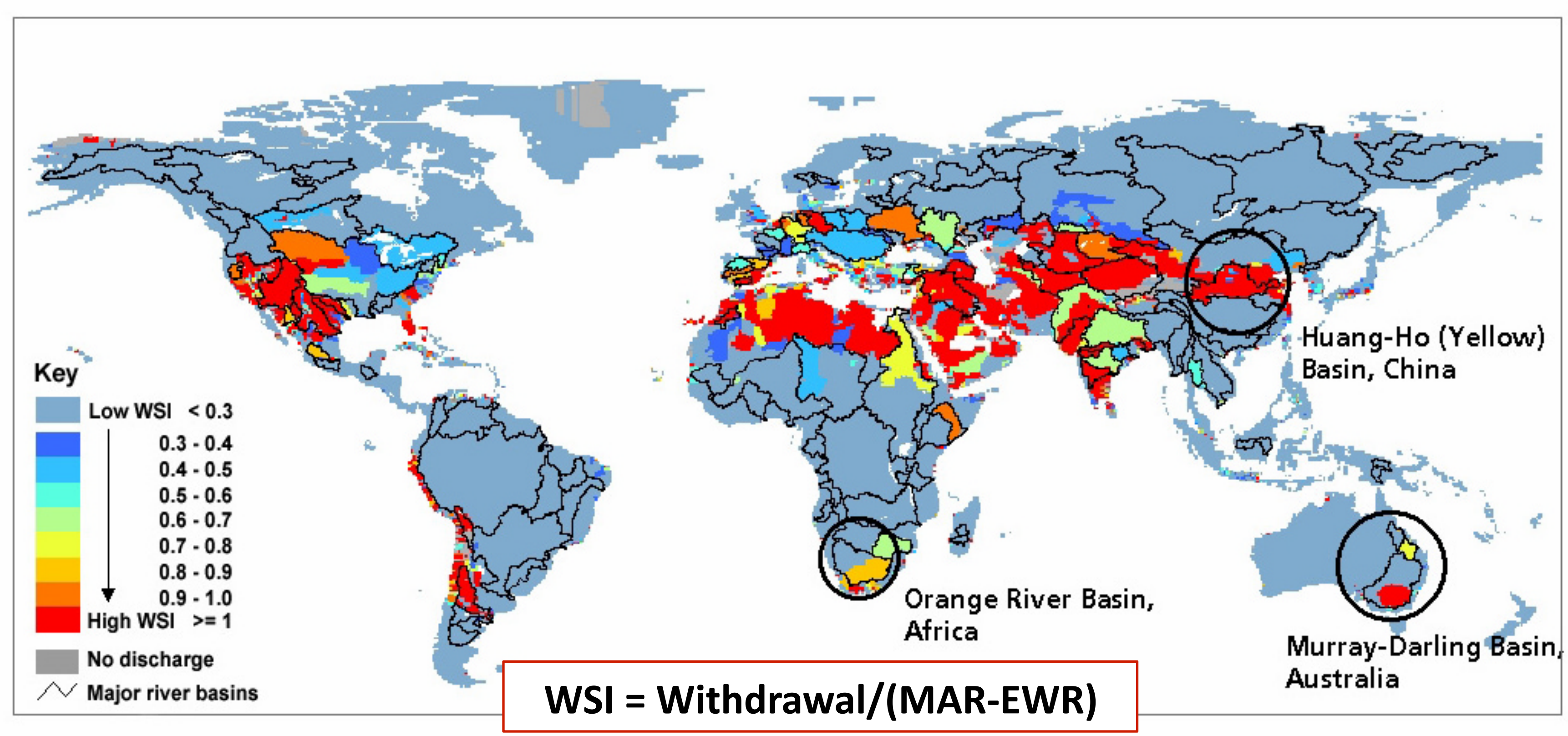
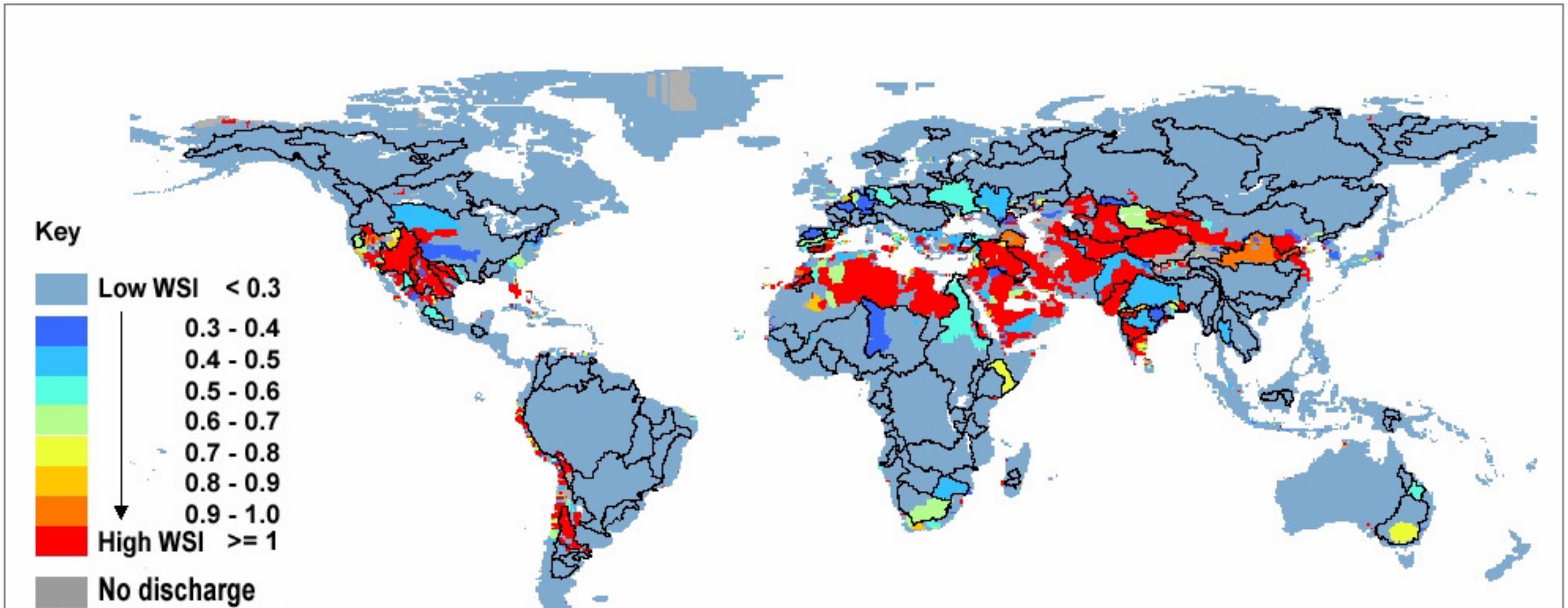


Figure 4: A map of a water stress indicator (WSI) which takes into account environmental water requirements in river basins (Smakhtin, et al. (2002))

Global Mapping of Environmental Water Requirements and Water Scarcity



WSI = Withdrawal/MAR

Figure 5: A map of the "traditional" water stress indicator (water withdrawals as a proportion of the long-term average total water resources) (Smakhtin, et al. (2002))

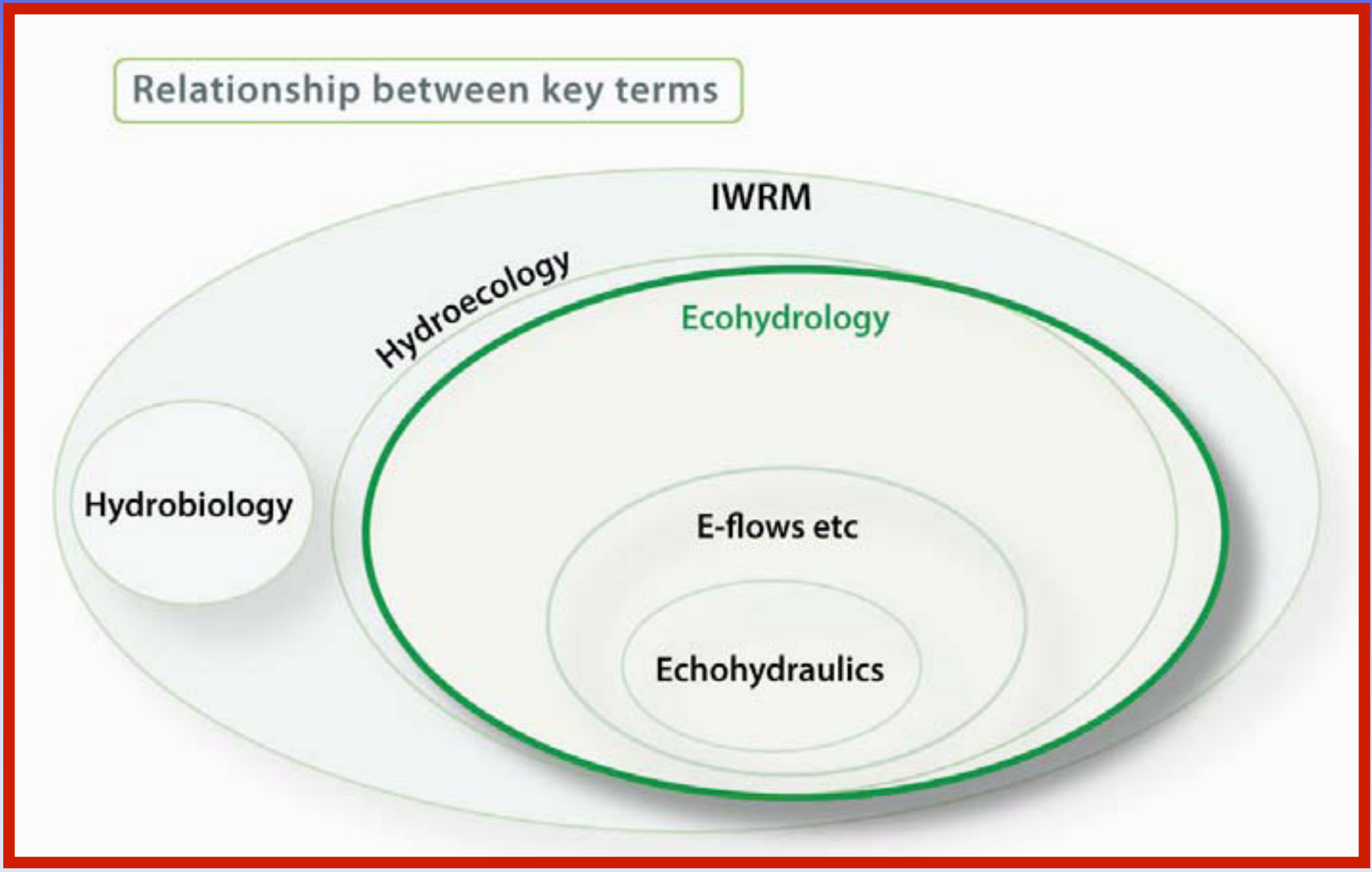
E-flow Definitions

- E-flow can be defined as 'The water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where they are competing water uses and flows are regulated' (IUCN, 2003).
- E-flow concept means enough water is left in our rivers, which is managed to ensure downstream environmental, social and economic benefits (The World Bank, 2003)

E-flow Definitions

- E-flow can also be defined as '**The water that is left in a river ecosystem, or release into it, for the specific purpose of managing the condition of that ecosystem**' (The World Bank, 2003)
- E-flow must be seen within the context of **applying IWRM in catchments and river basins**. E- flows will only ensure a healthy river if they are part of a broader package of measures, such as soil protection, pollution prevention, and protection and restoration of habitats (IUCN, 2003)

The Science of Flow-Ecology Relationships



Ref: Naiman, et al. (2007)

Environmental Flow Management Assessment and Strategies

How e-flow can be applied and plan for mobilising action in river basin management: The six (6) learning objectives (ICUN, 2008):

- Understanding the principles of e-flows;
- Familiarisation with methods for flow assessment and options for managing infrastructure;
- Understanding of how to define flow scenarios and negotiate flow regimes with stakeholders;
- Development of an implementation framework for e-flows, encompassing governance and economic requirements;
- Creation of roadmaps for fostering cooperation and social learning, generating political momentum and managing change;
- Formulation of action plans for application of e-flows in management plans for project basins.

Examples on the Checklist on the Application of Environmental Flows in River Basin Management (ICUN, 2008)

Checklist 1: Understanding Flow Requirements, Setting Up E-flow Applications:

- **Identify expertise – needed and available**
- **Collate existing data and establish data collection**
- **Create a data centres – a data management system and library**
- **Conduct training and build capacity – build multi-disciplinary teams**
- **Develop and start implementing a research programme**
- **Conduct pilot studies**
  - select method, based on problems, resources and goals
  - data acquisition and analysis
  - knowledge sharing and social learning
  - monitoring

Examples on the Checklist on the Application of Environmental Flows in River Basin Management (ICUN, 2008)

Checklist 2: Setting Objectives/ Working with Scenarios

Checklist 3: Modifying Management Infrastructure

Checklist 4: Understanding Costs and Benefits/Covering the Costs

[detail in the write up]

Examples on the Checklist on the Application of Environmental Flows in River Basin Management (ICUN, 2008)

Checklist 5: Elements of Reform Processes – Policy, Legal and Institutional

·**Review current policies and legislation, including hard and soft law. Identify entry points in national and international processes (eg in strengthening national planning for IWRM, transboundary cooperation agreements). Find basis for engagement in current policies and law. Capitalise on existing processes.**

·**Review institutional setup, including mechanisms for implementation and monitoring.**

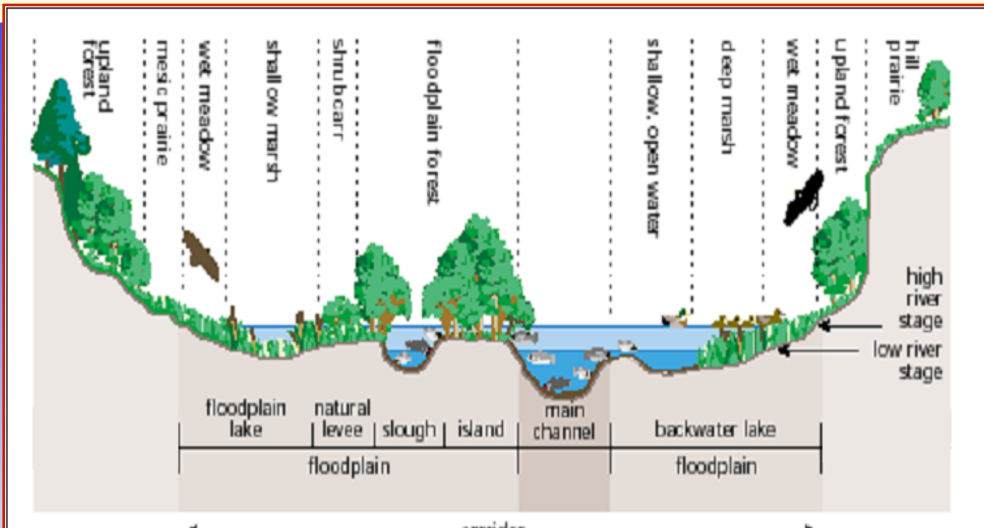
·**Properly define the e-flow concept – in legal, technical and practical terms. Seek input from technical experts, then influence policy processes in legislatures. Ensure all water users and sectors are well-informed.**

Examples on the Checklist on the Application of Environmental Flows in River Basin Management (ICUN, 2008)

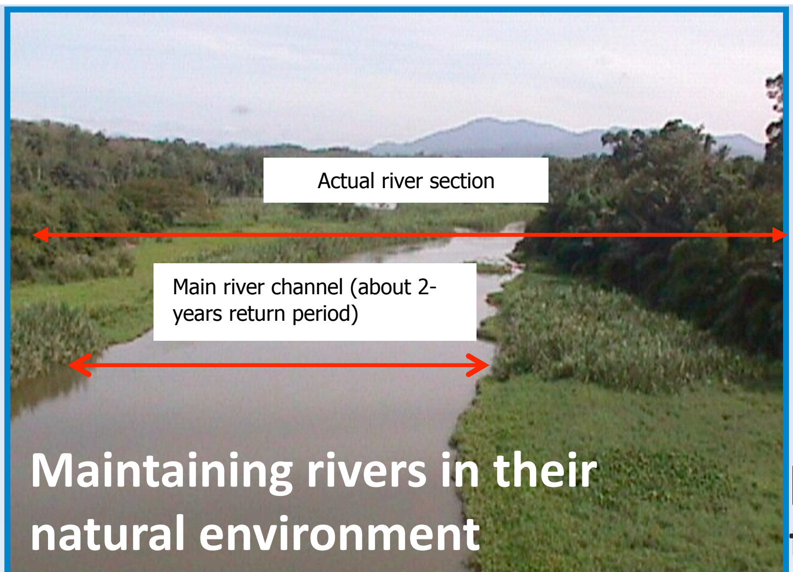
Checklist 5: Elements of Reform Processes – Policy, Legal and Institutional (continue ……..)

- **Incorporate public dialogue into reform processes, through 'socialisation' of concept and communication of practical meaning. Learn from practical pilots and testing. Support social learning. Facilitate civil society input into legislative reforms. Facilitate input and participation in planning.**
- **Identify opportunities for transboundary alignment among all riparians. Align bottom-up and top-down processes.**
- **Integrate e-flow and water management into wider policies, law and institutions relating to development in a basin.**
- **Consider institutional set-up that will enable implementation of policies and laws.**
- **Draft laws and policies and review.**

E-flow: Ensuring Clean, Living, Pristine River System



A natural river showing water at high river stage and low river stage



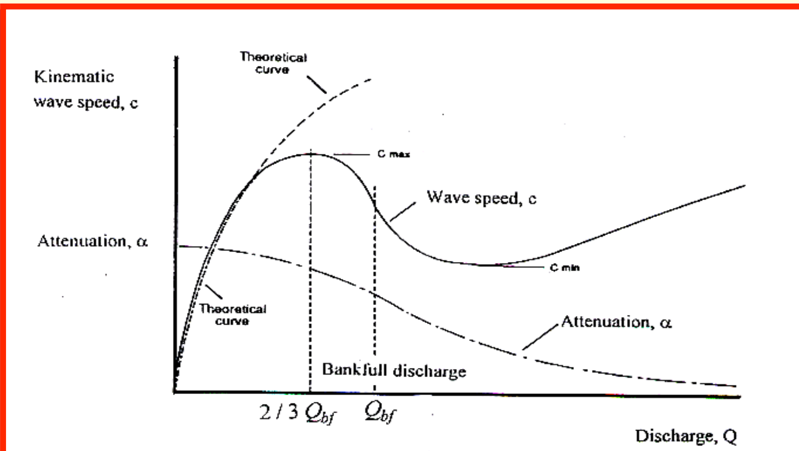
Ecological functions performed by different river flow levels:

- Flow component
  - **Low (base) flows**
  - **High pulse flows**
  - **Floods**

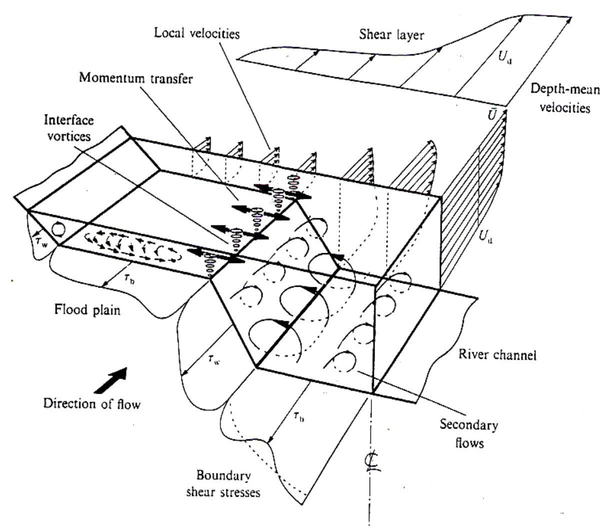
[See the Ecological Roles for each of these flow component in Table 1 from the write up]

E-flow: Ensuring Clean, Living, Pristine River System

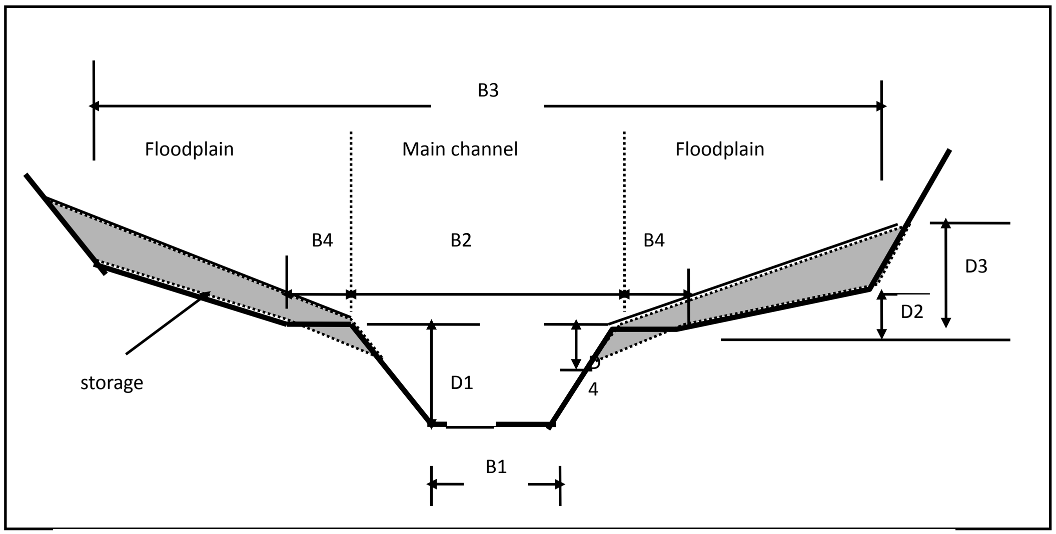
- **Through understanding river hydraulics – keeping water level at 2/3 bankfull flow**



Typical kinematic wave speed – discharge and attenuation parameter – discharge curve

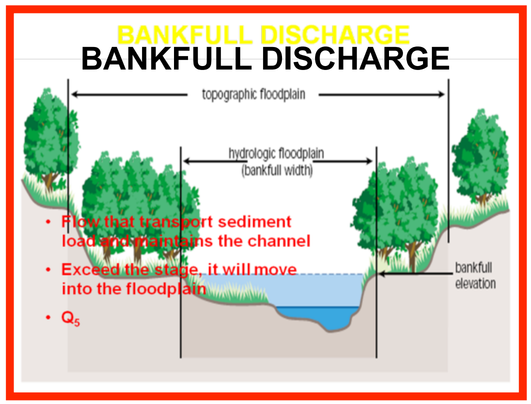


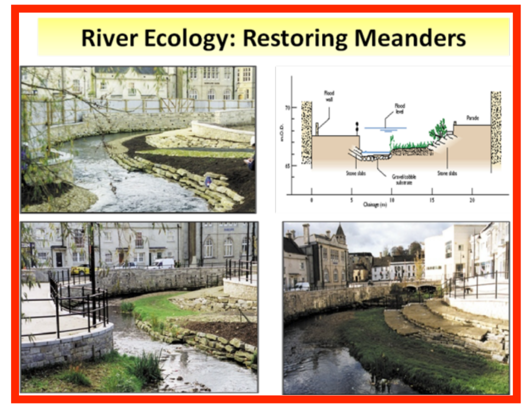
Hydraulic Parameters Associated with Overbank Flow (After Knight and Shiono, 1996)

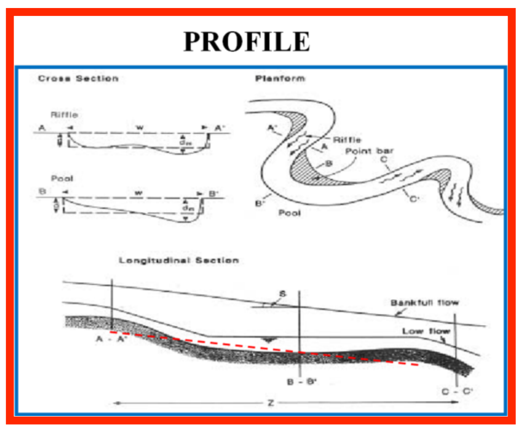


A typical compound channel with the concept of natural waterway features (after Roseli, 1999)

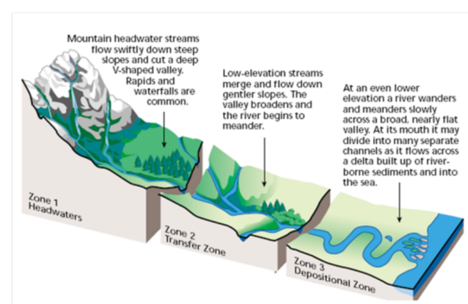
E-flow: Ensuring Clean, Living, Pristine River System: through understanding the river natural ecosystem [Stream Channel Morphology (Dimension, Pattern and profile), instream structure, floodplain connection, riverbank stabilization, riparian corridor vegetation, habitat enhancement]





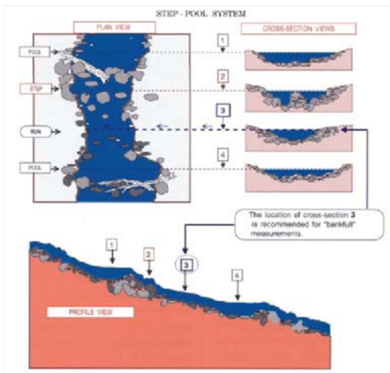


Three longitudinal profile zones. Channel and floodplain characteristics change as rivers travel from headwaters to mouth. Source: Miller (1990). ©1990 Wadsworth Publishing Co.



E-flow: Ensuring Clean, Living, Pristine River System: through understanding the river ecosystem

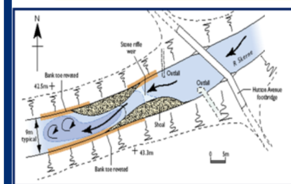
INSTREAM STRUCTURES: CHANNEL FEATURES

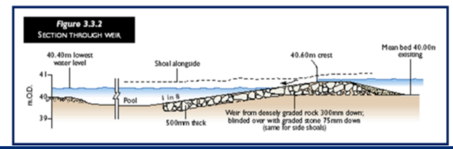


CHANNEL FEATURES

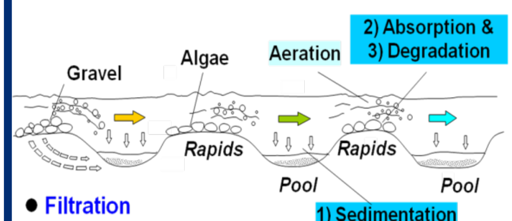
Ripples	- large rock particles - water depth shallow - slope steeper - remove sediment - provides oxygen
Pool	- flat surface, low slope - deeper than river average depth - depositional site at low flow

River Ecology: Creating Stone Riffle



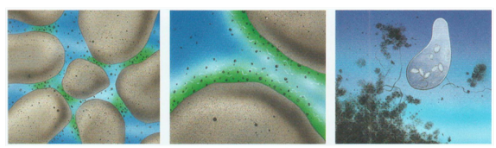


Self-purification Mechanisms of Rivers



- Filtration
- 1) Sedimentation
- 2) Biological Absorption and 3) Decomposition

Purification Mechanisms of Gravel Contact Process

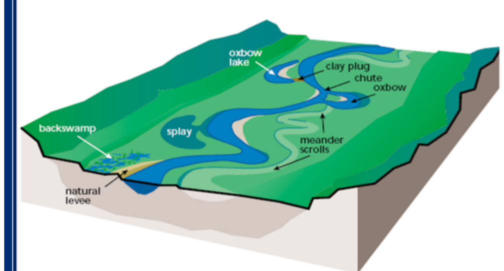


1) Contact Sedimentation
When polluted water goes through gravel, dirt in the water deposits on gravel.

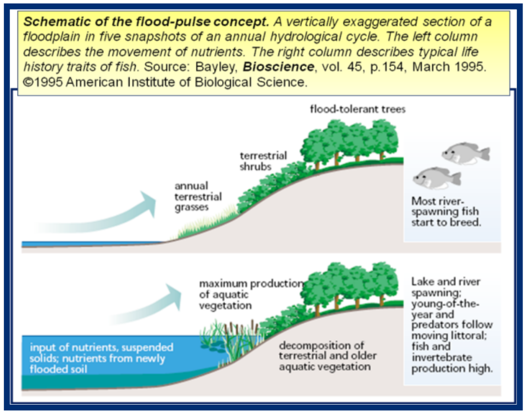
2) Absorption
Dirt is absorbed onto biofilm formed on the surface of gravel.

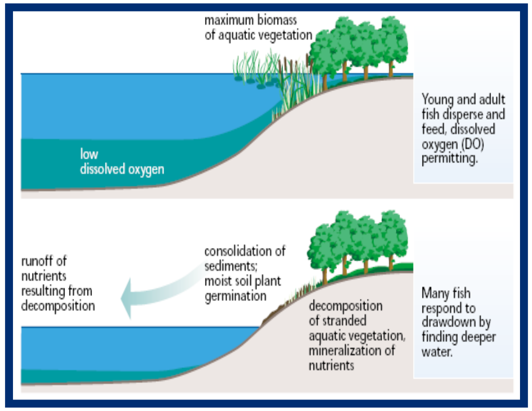
3) Degradation
Microorganisms on gravel decompose dirt into water and carbon dioxide.

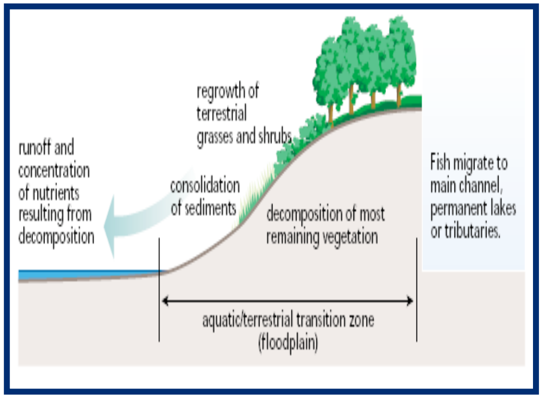
Landforms and deposits of a floodplain. Topographic features on the floodplain caused by meandering streams.



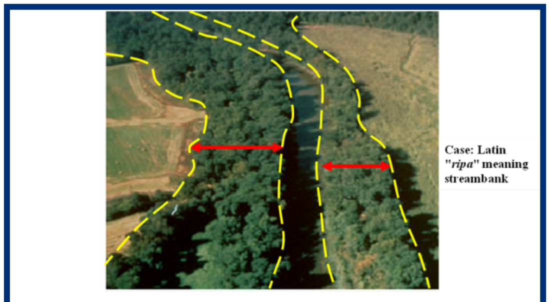
E-flow: Ensuring Clean, Living, Pristine River System: through understanding the river ecosystem



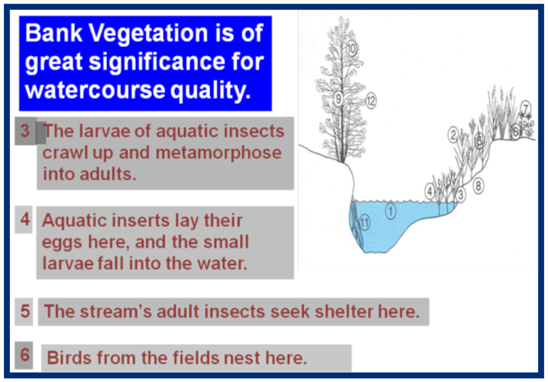


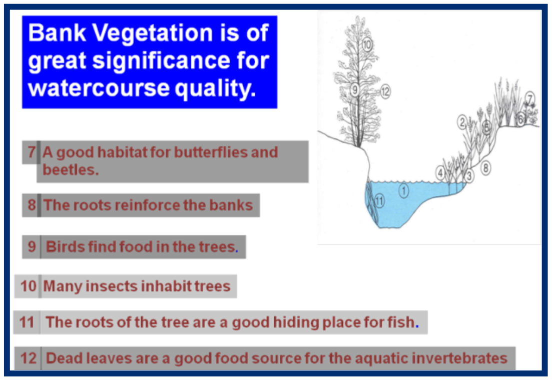


Fish spawning and migration



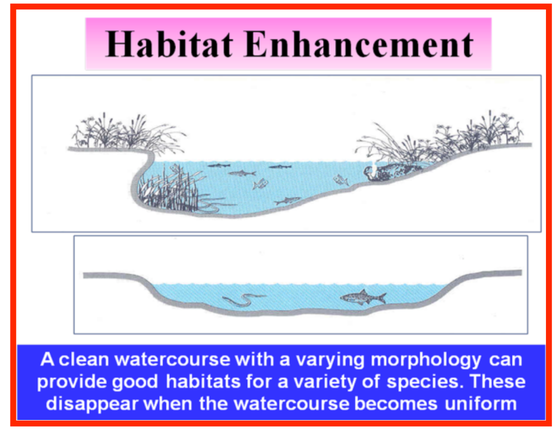
Riparian Zone – Area beside river which functions as a 'buffer zone'- protects the ecological system between water and surrounding land

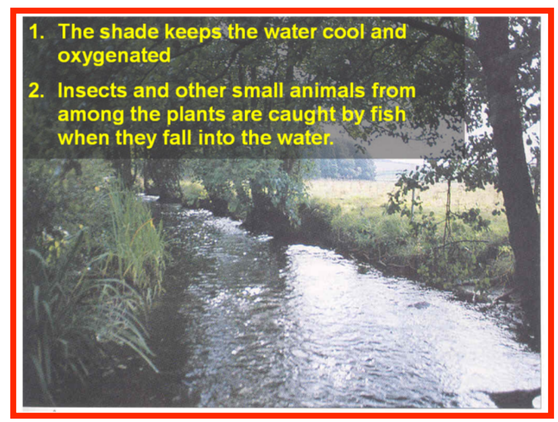




Riparian Zone management

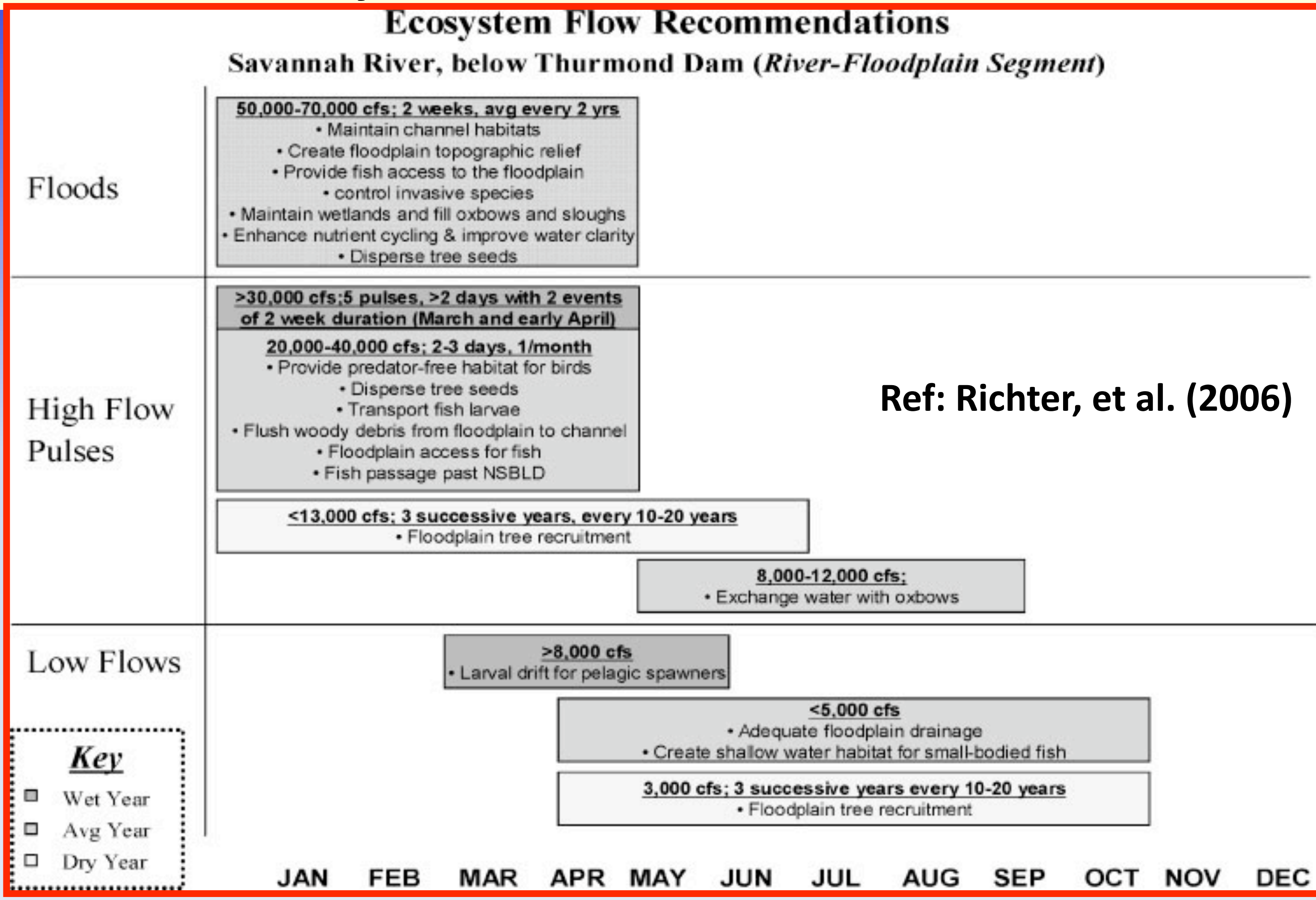
E-flow: Ensuring Clean, Living, Pristine River System: through understanding the river ecosystem





E-flow: Ensuring Clean, Living, Pristine River System:

Ecosystem Flow Downstream of Dam



This diagram highlights some of the key ecological objectives to be supported by the flow recommendations developed for the Savannah River floodplain segment. These objectives pertain to specific flow components (low flows, high flow pulses and floods), time of year, and water year type (dry, average, wet)

Overview of methods for flow assessment

What is an e-flow assessment?

"Is an assessment of how much of the original flow regime of a river should continue to flow down it and onto its floodplains in order to maintain specified, valued features of the ecosystem hydrological regimes for the rivers, the e-flow requirements, each linked to a predetermined objective in terms of the ecosystem's future condition..."

Source: Tharme, 2003

Developing environmental flows

- Tharme (2003) identified > 200 different methods
- Range from simple 'rules of thumb' to complex, multi-year processes integrating modeling and field data

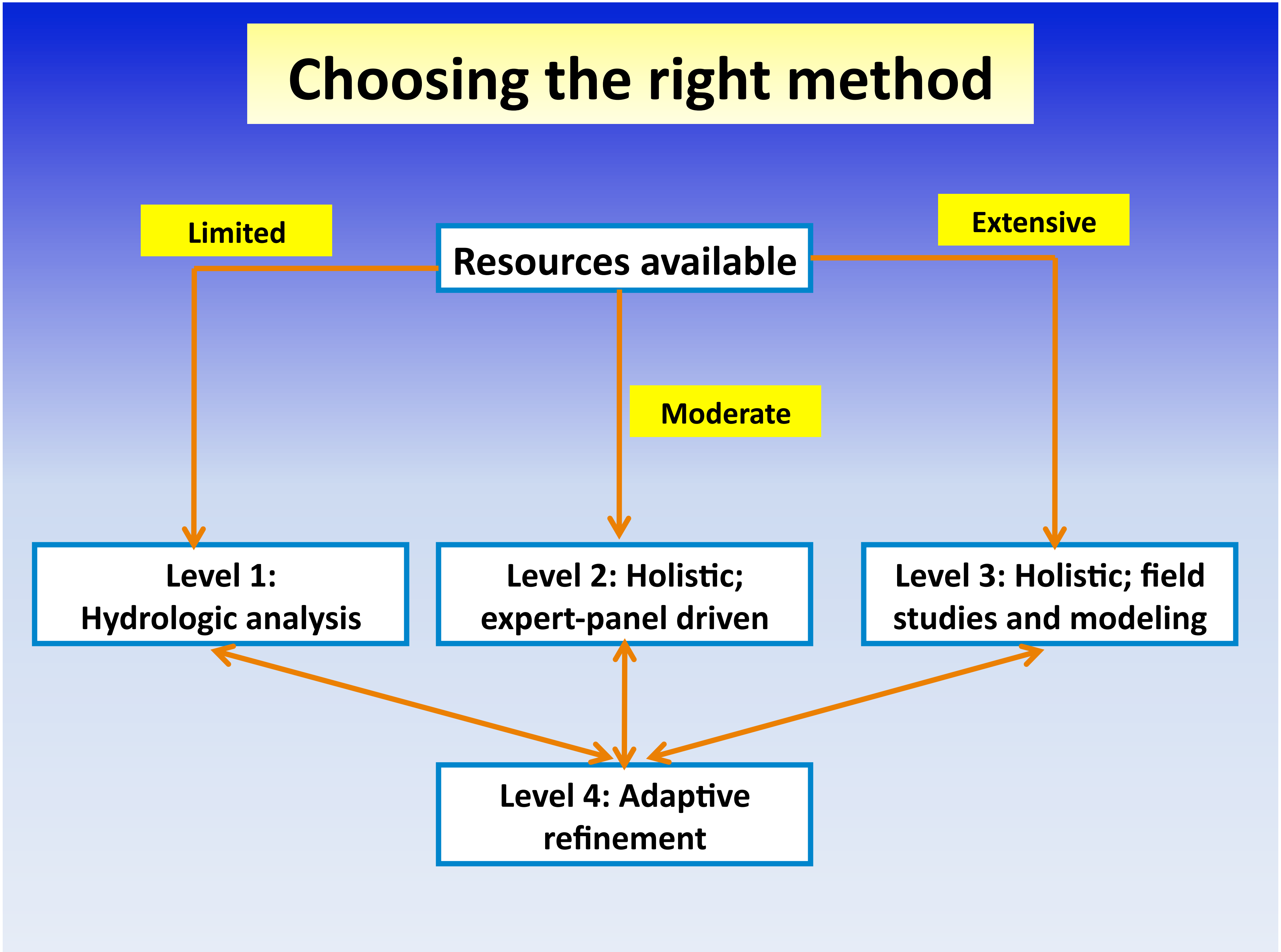
See Appendix D in the write up for detailed

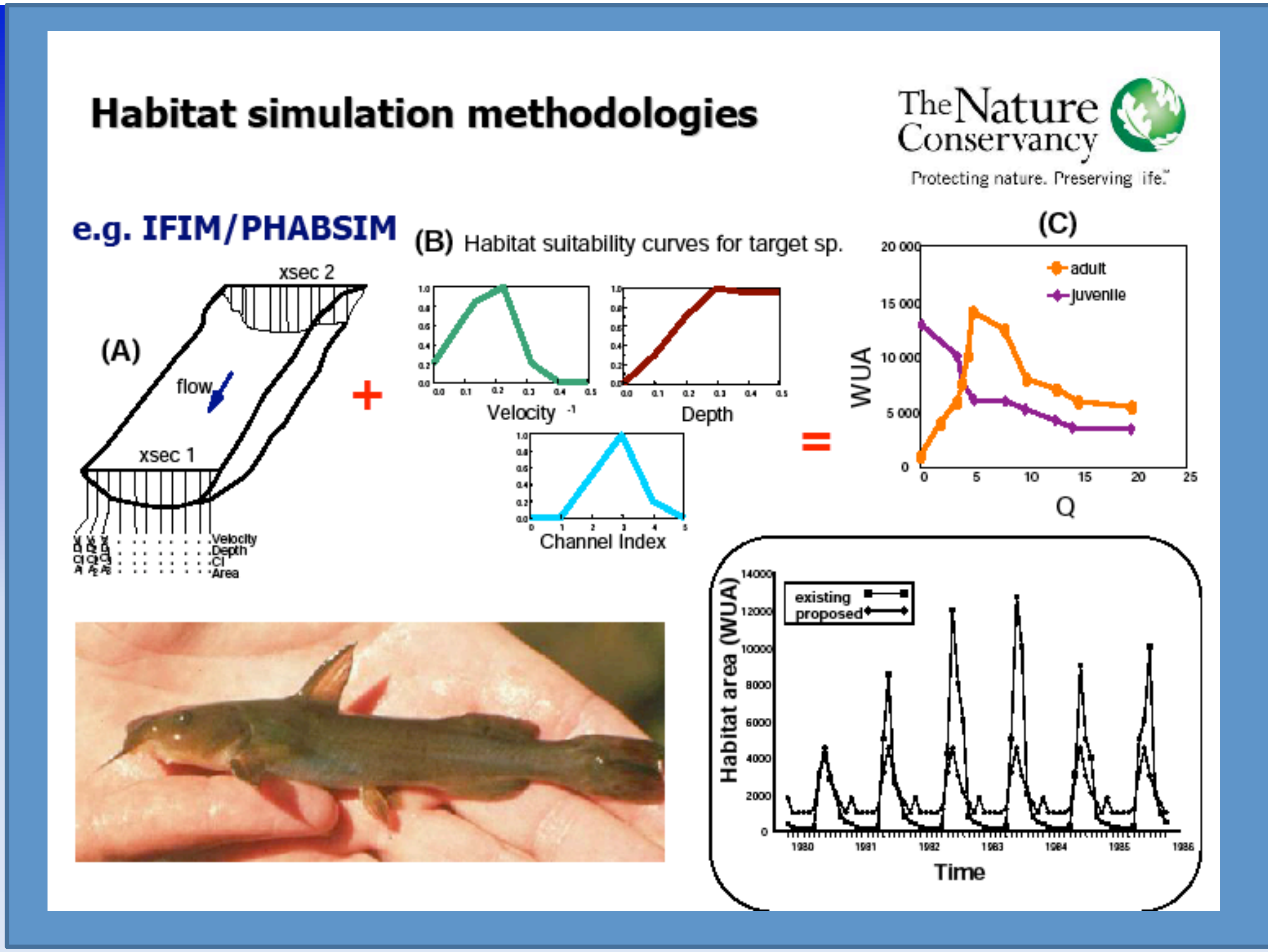
Categories of environmental flows methodologies and examples	
1. Hydrologic	Tennant Q 90
2. Hydraulic rating	Wetted perimeter method
3. Habitat simulation	IFIM PHABSIM
4. Holistic Methods	Building Blocks Methodology (BBM)

Source: Tharme, 2003

Methods for flow assessment

- **Hydrological** - Primarily use hydrological data (historical monthly or daily flow records) for making e-flow recommendations for maintaining river health at designated level
- **Hydraulic rating** - use changes in simple hydraulic variables (e.g. wetted perimeter) across single river cross-section as surrogate for habitat factors limiting to target biota
- **Habitat simulation** - Assess e-flows on basis of modeling of quantity and suitability of physical habitat available to target species under different flow regimes (integrated hydrological, hydraulic and biological response data)
- **Holistic** – identify important flow events for all major components of river, model relationships between flow and ecological, geomorphological and social responses, and use in interdisciplinary team approach to establish recommended e-flow regime/implications of flow scenarios (bottom-up or top-down)


Choosing the right method
Limited
Resources available
Extensive
Moderate
Level 1: Hydrologic analysis
Level 2: Holistic; expert-panel driven
Level 3: Holistic; field studies and modeling
Level 4: Adaptive refinement



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GEF IW:LEARN Regional Workshop on Application of Environmental Flows in River Basin Management, February, 11-15, 2008

Shift from minimum flow to flow regime:

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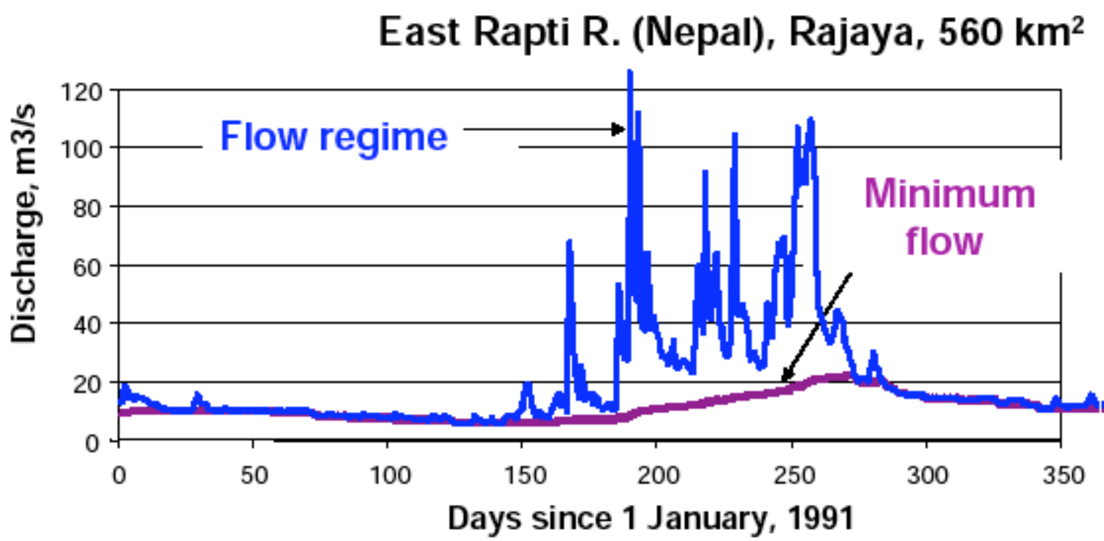
- * magnitude, frequency, duration, timing, rate of change
  * flow components (low flows, freshes, floods)



Source: Poff, *et al.* 1997

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Holistic Methodologies: natural flow paradigm

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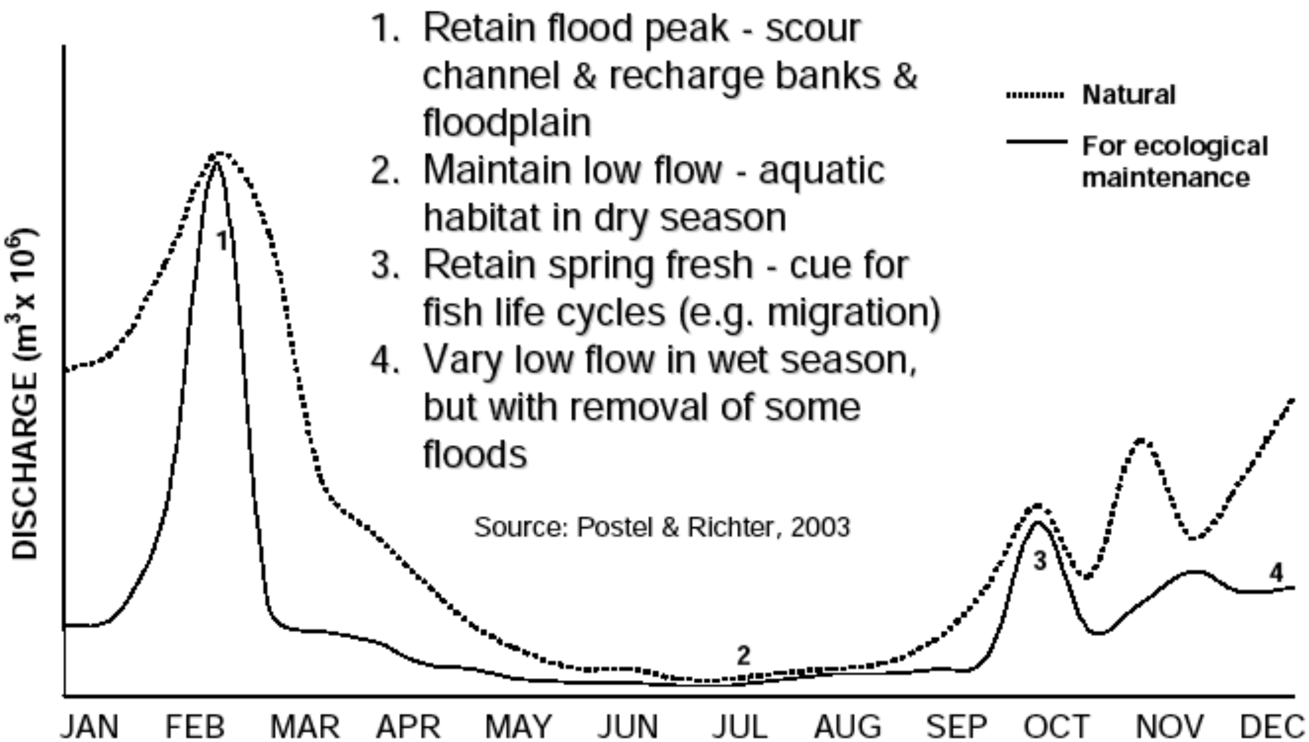

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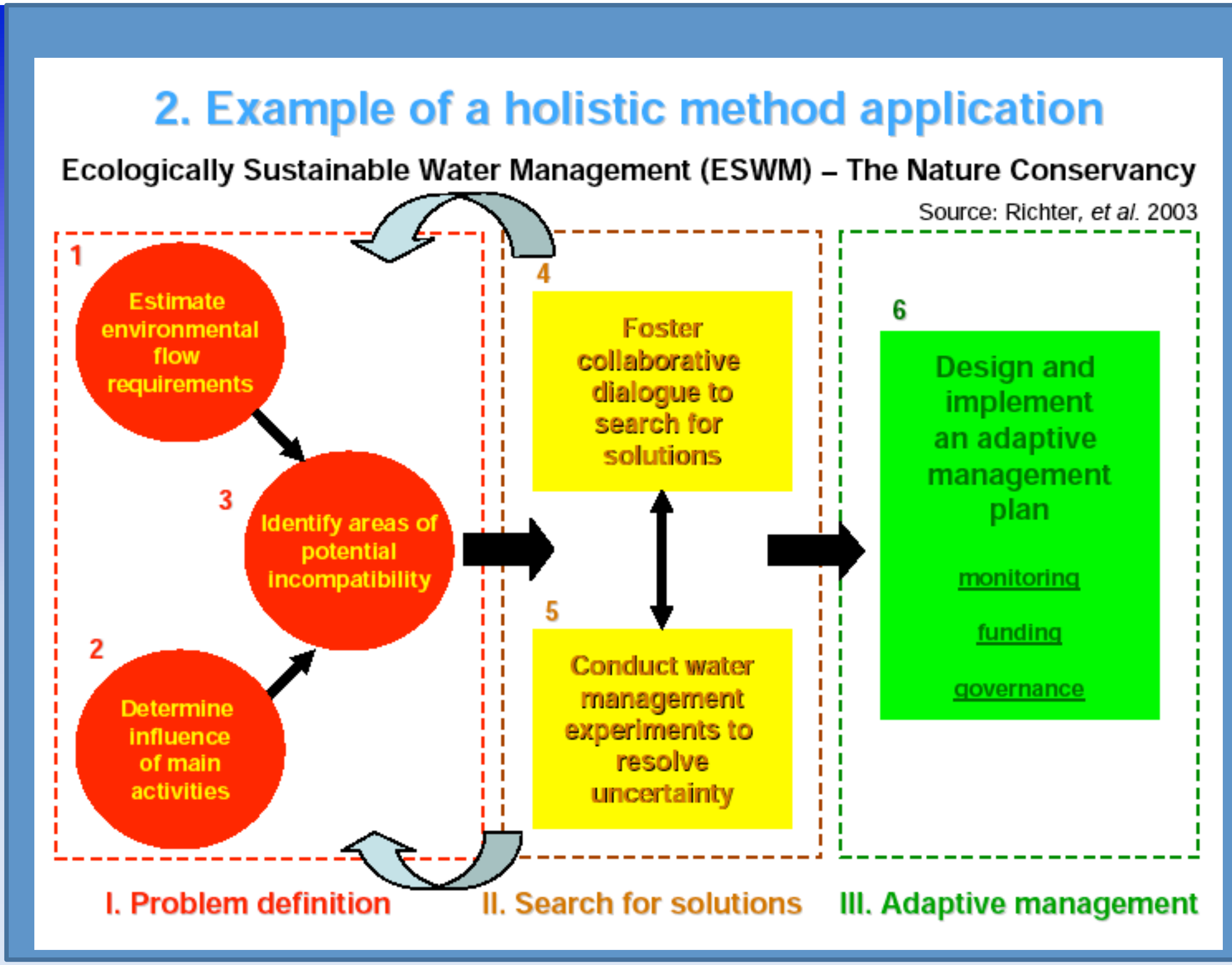

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2. Example of a practical holistic method application

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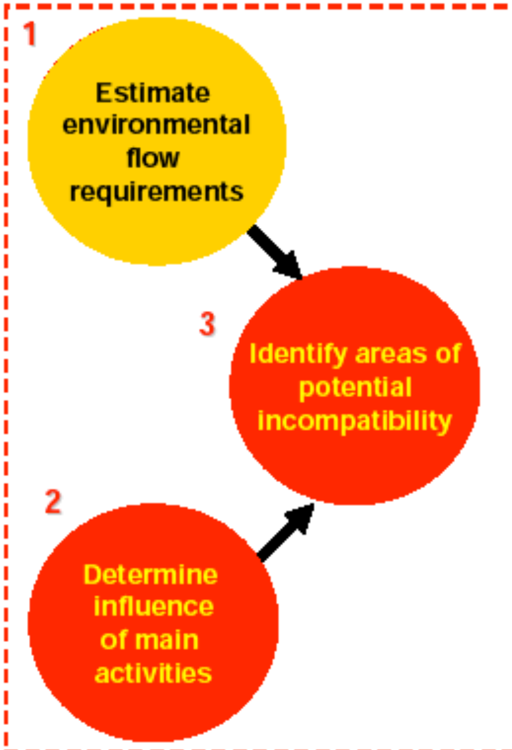

1. Estimate ecosystem flow requirements

- Gathering historical hydrological flow data series (*hydrological desk top analysis*)
- Characterization of the natural flow regime (*hydrological and hydraulic analysis*)
- Identification of critical flow events
- Development of simulation models to assess how biodiversity is related to the natural flow regime (*habitat modeling ex. PHABSIM*)

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Study on Environmental Flows in Malaysia

- The actual e-flow requirement in river basin management has not been considered yet, probably because lack of knowlwdge.
- Only compensation flow, maintenance flow, low flow concepts are used.
- As e-flow is often site specific, the minimum flow requirements are normally determined from its average natural flows for management purposes (hydrological methods)
- Used a rule-of-thumb of 10% Average Annual Flow (AAF) as the minimum flow required for planning purposes

Study on E-Flows in Malaysia

Case Study 1: Study on Integrated River Basin Management for Sungai Langat (2005):

- **Proposed a nominal amount equivalent to 20% of the estimated mean daily flow to be maintained in the river as e-flow base on Tennant Method (Hydrological Index Method).**
- **The method states that 40% of the Average Annual Flow (AAF) of a river is an 'outstanding' minimum flow and 20% of the AAF is a 'satisfactory' minimum flow.**
- **The analysis carried out in the Study with 22 years of flow data at Kajang gauging station stated that Average Daily Flow at the station is 7.5 m^3/s. As such, the outstanding and satisfactory minimum flow for Sg. Langat at Kajang is 3.0 m^3/s (40%) and 1.5 m^3/s (20%) respectively.**

The AAF of ungauged catchments in Peninsular Malaysia may be estimated from Water Resources Publication No.12

Study on Environmental Flows in Malaysia

Case Study II: Comprehensive Management Plan of Muda River Basin (JICA, 1995):

·The e-flows were **regarded as river maintaining flow** estimated **based on percentages of low flows** for four key components

- Necessary discharge to **maintain** the appropriate **river water quality**;
- Necessary discharge to **conserve natural low flow regime**;
- Necessary discharge to **conserve river ecology**; and
- Necessary discharge to **maintain river scenery**.

Study on Environmental Flows in Malaysia

Case Study II: Comprehensive Management Plan of Muda River Basin (JICA, 1995) continue ……:

a) Discharge Necessary to Maintain an Acceptable Water Quality.

- **The target is to upgrade or maintain at least the water quality standard of Class II for all rivers. Class II water will only necessitate conventional treatment if abstracted for water supplies while Class III waters would require extensive treatment.**
- **The river flow discharge was estimated by the following formula assuming that the discharge needs to dilute the BOD concentration to less than 6 mg/l, which is the allowable level for use of treated drinking water.**

$$Qm = 1000 \times PL/BOD(R)$$

Where,

Qm	:	Necessary river maintenance discharge (m^3/s)
PL	:	Gross weight of pollution loads generated at
BOD(*R*)	:	Required BOD concentration (assumed as 6 mg/l)

Classification

Table 1: Quality of sullage compared to the Malaysian National River Water Quality Standards (NWQS)

Parameter	Value for Sullage [5]	Malaysian National River Water Quality Standards (NWQS)				
		Class I	Class II	Class III	Class IV	Class V
		Excellent for water supply	Conventional treatment needed for water supply	Extensive treatment needed for water supply	Suitable for irrigation	Not suitable for any use
AN(mg/l)	4.9	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
BOD(mg/l)	49.6	< 1	1 – 3	3 – 6	6 – 12	> 12
COD(mg/l)	115.6	< 10	10 – 25	25 – 50	50 – 100	> 100
DO(mg/l)	1.6	> 7	5 – 7	3 – 5	1 - 3	< 1
pH	6.7	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	< 5.0
TSS(mg/l)	43.2	< 2.5	25 – 50	50 – 150	50 – 300	> 300
WQI	28.8	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

AN - Ammoniacal Nitrogen, BOD - Biochemical Oxygen Demand, COD - Chemical Oxygen Demand, DO - Dissolved Oxygen, pH - Phosphorus, TSS - Total Suspended Solids, WQI - Water Quality Indicators

Study on Environmental Flows in Malaysia

Case Study II: Comprehensive Management Plan of Muda River Basin (JICA, 1995) continue ….:

b) Discharge Necessary to Conserve Natural Low Flows.

- **Natural low flows are defined as the naturally occurring low flows due to prolonged periods without rain and that the outflow of water is from base flow and subsurface storage in the basins.**
- **The 1-day and 7-day low flows are reflective of natural low flow regimes and their return periods indicate water availability in the river system during low flow episodes.**
- **The 7-day low flow with a return interval of once in every 25 years is adopted as the minimum discharge assumed necessary to conserve the natural low flow regimes, river aquatic ecosystems and streambank stability.**
- **The 50-year return interval flow is not taken into consideration since the effects of such low flows on the aquatic life forms would have been quite drastic, and many aquatic and riparian species may not be able to survive such prolonged droughts and low flows.**

Study on Environmental Flows in Malaysia

Case Study II: Comprehensive Management Plan of Muda River Basin (JICA, 1995) continue …..:

c) Discharge Necessary to Conserve River Ecology.

- Certain stretches along rivers are active breeding locations for fish and other aquatic life, which are also sensitive to ecological alterations. The survival of these sensitive areas depends on the depth, volume and the quality of water in the river systems. Fish survival in natural rivers depends on certain limits of minimum water depth and velocity for breeding and swimming. There must also be sufficient water available for dilution so that the fish can survive in areas with high BOD loading in the water.
- Advocated a minimum depth of 30 cm to 50 cm for fishes in Sg. Muda. In the absence of rating curves to derive the relationship between volumetric flow rates with depth, a minimum discharge for Class II waters could be adopted as the minimum requirements for fish and aquaculture.

Study on Environmental Flows in Malaysia

Case Study II: Comprehensive Management Plan of Muda River Basin (JICA, 1995) continue ………..:

d) Discharge Necessary to Maintain River Scenery.

·The scenic quality of river depends, amongst other, on water quality, flow characteristics, riparian and stream bank vegetation. Places with waterfalls and cascades with rock boulders and sand banks could be converted to tourist attraction sites.

·With reference to the environmental guidelines in Japan, it was assume that about 20% of the river channel has to be constantly covered with water to maintain a desirable river scenery. The constant discharges is given in the study main report.

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Case Study III: The following are taken from Part of Section 6.4: Surface Hydrology from the Executive Summary, Volume 1 of the Report (2008), "The Detailed Environmental Impact Assessment For Hulu Terengganu Hydroelectric Project, Tenaga National Berhad" which is a multimillion dollar dam project:

·**The minimum flow analysis** was performed to determine the magnitude and frequency of low flow for the proposed project site.

·Analysis of minimum flow was determined based on **three methods**: 1) **Mean Annual Minimum Flow** (MAM), is 4,520 m^3/s for Sg. Terengganu Mati and 0.976 m^3/s for Sg. Tembat. 2) **10% of the average annual flow**; 4 m^3/s for Sg. Terengganu Mati and 0.55 m^3/s for Sg. Tempat and 3) **Based on the SMEC Engineering study**, minimum daily flow was 3.3 m^3/s (Sg. Terengganu Mati) and 0.80 m^3/s for Sg. Tembat.

Study on Environmental Flows in Malaysia

Case Study III: continue …….

·During reservoir filling and dam operation, the river stretches downstream of the dam (Sg. Tembat-4.14km and Sg. Terengganu Mati-4.82km) will be dried up if no water is released during reservoir filling. The river ecology will be completely destroyed. To mitigate the impact a minimum flow of 1.0 m^3/s for Sg. Terengganu Mati and 0.5 m^3/s for Sg. Tembat is recommended.

We can see that on the minimum flow values to sustain the river ecology, biodiversity and ecosystem based on certain design discharge as mentioned in the report is not good enough. Sand bars could still be form as already experience for reservoir/dam project in Malaysia. This will hinder flow, obstruct the sediment transport, river become shallow and reduces the river carrying capacity.

Conclusions

- E-flows: managing flow to meet the needs of both people and nature through integration of knowledge across numerous disciplines as law, policy, economics and ecology.
- E-flow: not a simple minimum flow for a river, but a means of integrating multiple needs into allocation and flow decisions for rivers, and is thus an important tool for sustainable development.
- Need to carry out river restoration programs, rivers back to nature using making space for water approaches thus e-flows may be obtain naturally.
- Nowadays as technology advances, the whole spectrum of e-flow should be considered as 'ecosystem flow' incorporating low flow, high river flow and above bankfull flow for different river ecological role rather than just concentrate on compensation flow , maintenance flow or low flow.


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THANK YOU
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