E-Flows for Hydropower Projects: Good Practice Handbook

March 17, 2021

International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Prof. Cate Brown

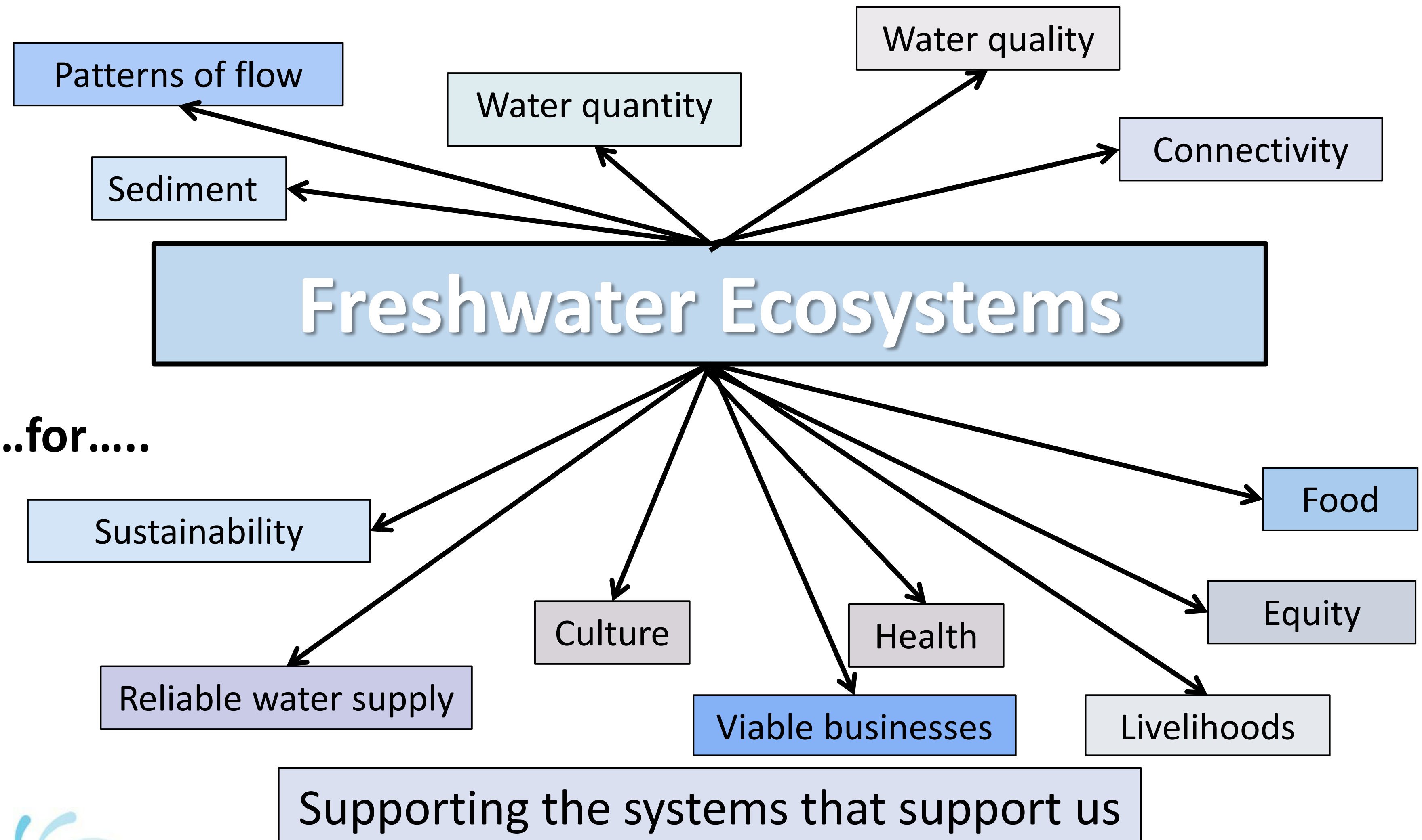
southern waters

UNIVERSITY of the WESTERN CAPE

Hydropower Developers' Working Group

Australian Aid

International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities


Patterns of flow
Water quantity
Water quality
Connectivity
Sediment
Freshwater Ecosystems
...for.....
Sustainability
Food
Culture
Health
Equity
Reliable water supply
Viable businesses
Livelihoods
Supporting the systems that support us

Objectives and Aims of GPH

To promote consistent approach to E-Flows assessments in WBG-funded Hydropower Projects (HPPs).

- Provides context in which E-Flows are assessed and applied
- Guides selection of project-appropriate level of detail for E-Flows assessments
  - Individual projects (ESHIAs)
  - Basin-wise assessments (CIAs/SEAs)

E-Flows and Hydropower

Good Practice Note recognises 'E-Flows' impacts of HPPs as:

- Dewatering of a reach
- Changes in pattern of flows of water *and sediment*
  - Diverted reach
  - Downstream of powerhouse/tailrace
    - Storage
    - Power production
- Lost of connectivity (flow of biota):
  - Longitudinal – dam wall and reservoir
  - Lateral – reduced flooding of floodplains

Factors Influencing Impact

- Location
- Design
- Operation
- Effectiveness of barrier:
  - longitudinal connectivity
  - lateral connectivity (floodplains)

Impact zone	Design/operation	Location in the basin	True 'RoR' - no diversion	True 'RoR' - with diversion	Medium storage, no diversion and baseload power	Medium storage, diversion returning to same river, and baseload power	Medium storage, diversion to different river, and baseload power	Medium storage, diversion and peaking power	Medium storage, diversion returning to same river, and peaking power	Medium storage, diversion to different river, and peaking power	Large storage, no diversion and baseload power	Large storage, diversion and baseload power	Large storage, diversion to different river, and baseload power	Large storage, no diversion and peaking power	Large storage, diversion and peaking power	Large storage, diversion to different river, and peaking power
Dewatered river reach	Impact on dry season	n/a	n/a	3	n/a	3	3	n/a	3	3	n/a	3	3	n/a	3	3
	Impact on wet season	n/a	n/a	0	n/a	1	1	n/a	1	1	n/a	3	3	n/a	3	3
Downstream of tailrace	Impact on dry season flow	On tributary	0	0	0	0	1	0	0	1	1	2	2	1	2	2
		Mainstem upstream of large trib	0	0	0	0	2	1	1	2	2	2	2	2	3	2
		Mainstem downstream of large trib	0	0	0	0	2	2	2	2	2	3	3	3	3	3
	Impact on wet season flow	On tributary	0	0	1	1	2	3	3	2	1	1	2	3	3	2
		Mainstem upstream of large trib	0	0	0	0	1	1	1	1	2	2	2	2	2	2
		Mainstem downstream of large trib	0	0	0	0	2	2	2	2	3	3	3	3	3	3
	Impact on timing of seasons	On tributary	0	0	1	1	1	1	1	1	1	1	1	1	1	1
		Mainstem upstream of large trib	0	0	1	1	1	1	1	1	2	2	2	2	2	2
		Mainstem downstream of large trib	0	0	2	2	2	2	2	2	3	3	3	3	3	3
Longitudinal connectivity	Upstream barrier effect	On tributary	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		On mainstem upstream of large trib	1	1	2	2	2	2	2	2	2	2	2	2	2	2
		Mainstem downstream of large trib	2	3	3	3	3	3	3	3	3	3	3	3	3	3
	Downstream barrier effect	On tributary	0	0	1	1	1	1	1	1	1	1	1	1	1	1
		Mainstem upstream of large trib	0	0	2	2	2	2	2	2	2	2	2	2	2	2
		Mainstem downstream of large trib	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Inter-basin impacts		n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	3	n/a	n/a	3	n/a	n/a	3

Combining factors will change their impact

E-Flows Assessment Methods

Low resolution

- Usually desktop
- Hydrological data are analyzed to derive standard indices as recommended E-Flows
- Typically prescriptive
- Based on data extrapolated from areas where studies have been done
- No consideration of sediment
- No detail on the responses of habitat or species

Medium and high resolution

Interactive through the use of scenarios.

Focus on relationships between river flow and aspects of the river. Address:

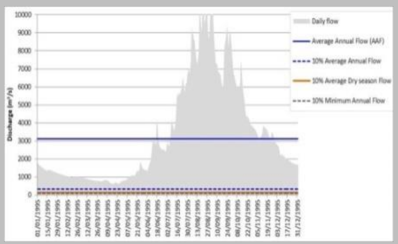
- Survival of individual species
- Migration and barriers
- Changes in sediment supply and transport
- Operation rules, such as peaking-power releases
- Other variables, such as management interventions

Resolution distinguished by:

- Number of components (water quality, plants, fish, birds, etc.)
- Level of effort in collecting and analysing local information

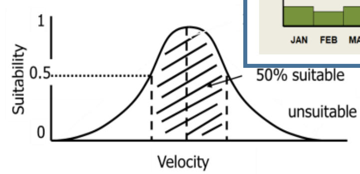
1970 — Evolution of EFlows discipline — 2020

Hydrological
Q_{95}; 10% AAF

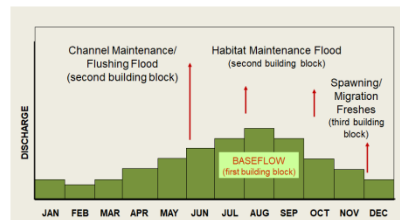


Hydraulic
Wetted perimeter

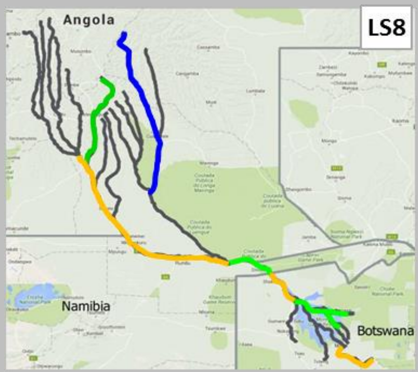
Habitat ra
IFIM; PHAE



Holistic
BBM; Benchmarking



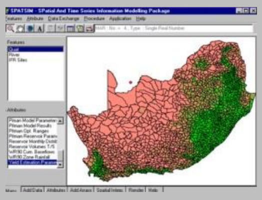
Ecosystem/social models
DRIFT; RANA-ICE, CaSiMiR

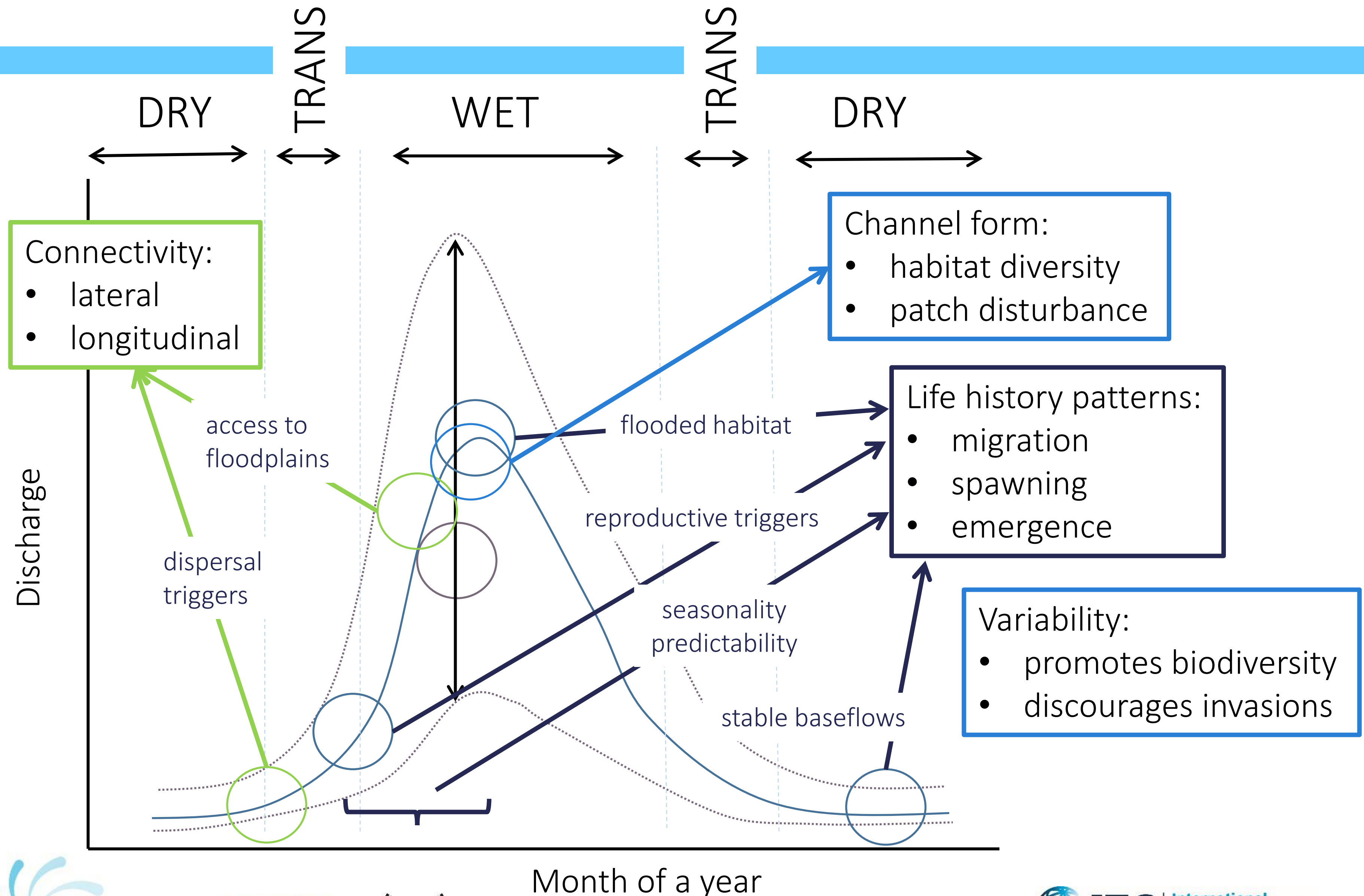


Forces pushing:

- Black box
- Ecosystems
- Social concerns
- Negotiations
- Capacity building
- Monitoring targets

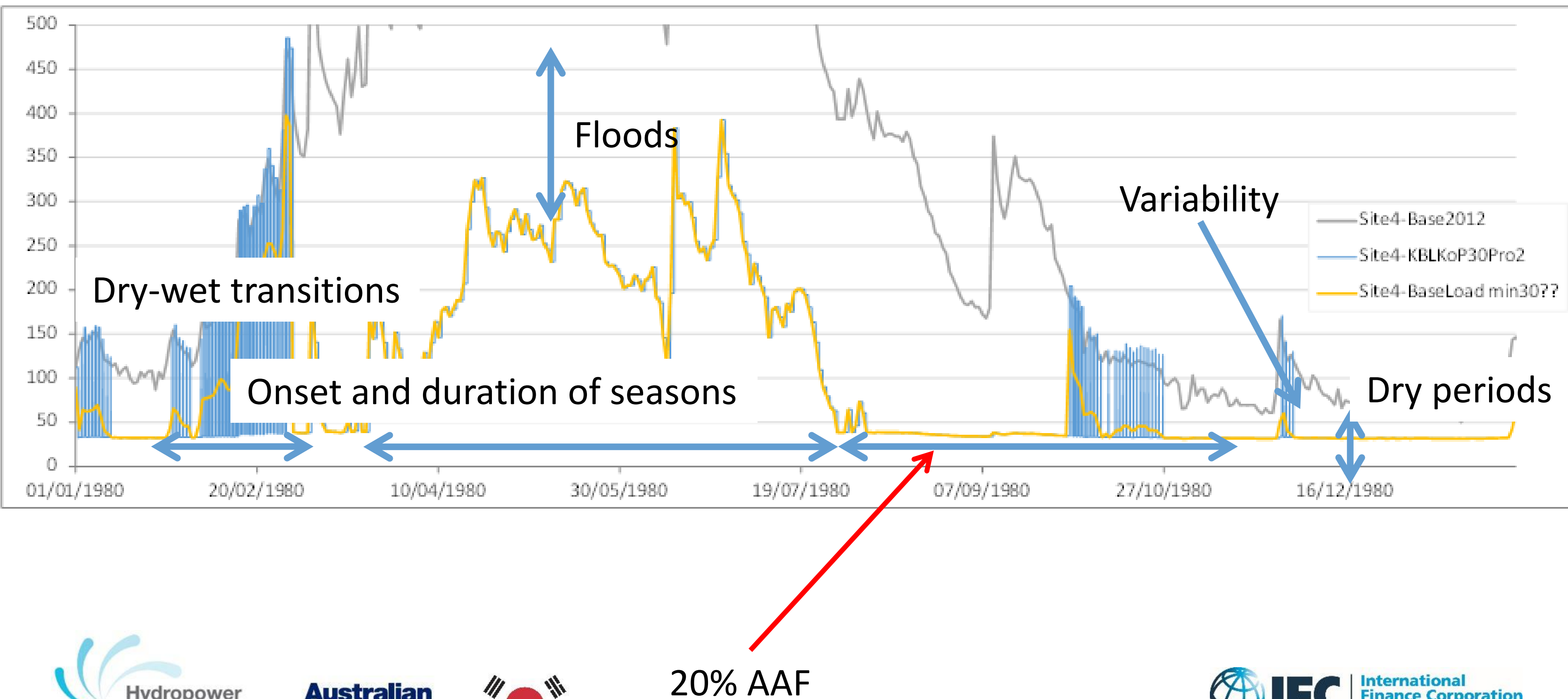
Rapid Frameworks
Desktop; ELOHA

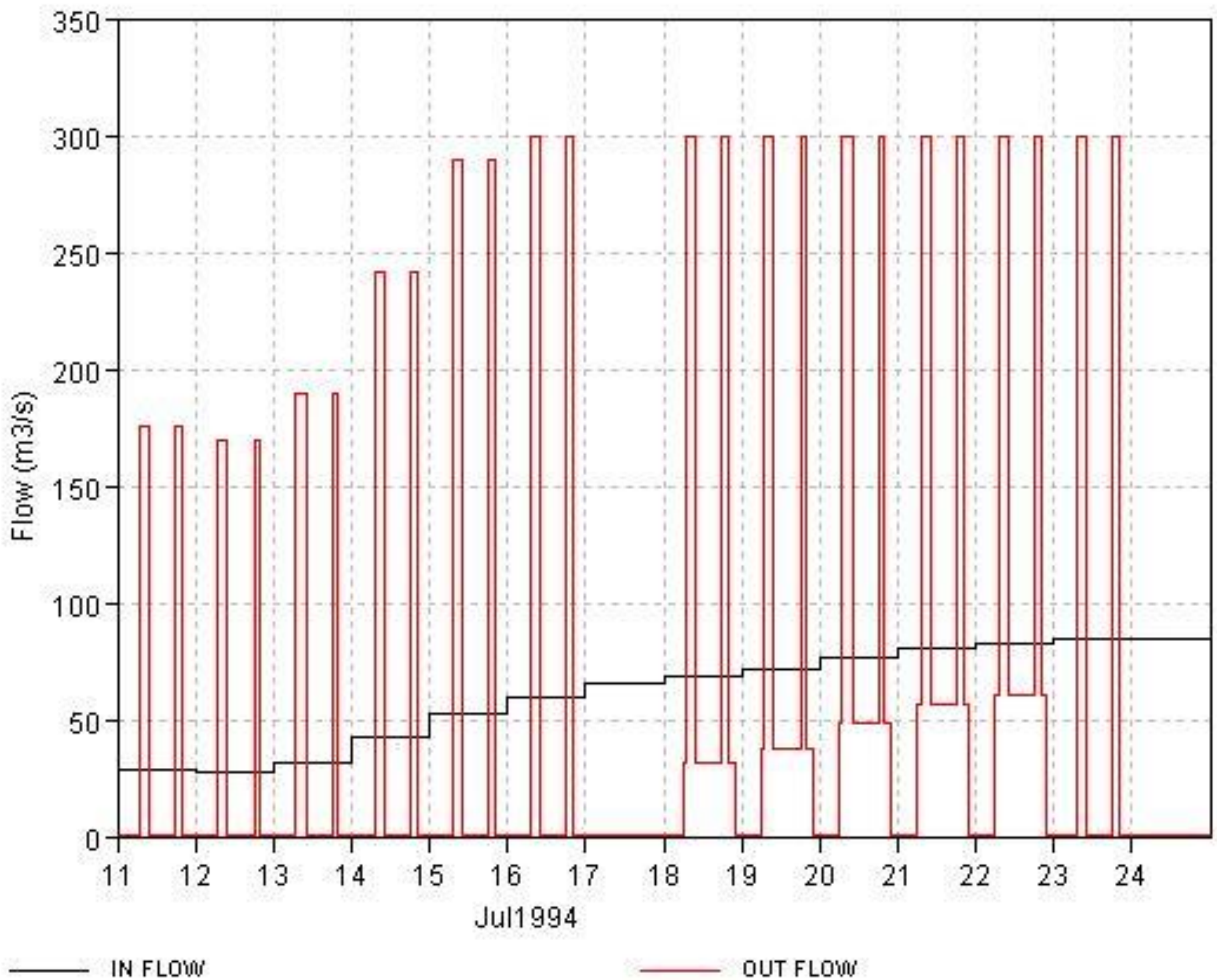



TRANS
TRANS
DRY
WET
DRY
Connectivity:
• lateral
• longitudinal
Channel form:
• habitat diversity
• patch disturbance
Life history patterns:
• migration
• spawning
• emergence
Variability:
• promotes biodiversity
• discourages invasions
access to floodplains
flooded habitat
reproductive triggers
dispersal triggers
seasonality
predictability
stable baseflows
Discharge
Month of a year

Hydrological Methods:

e.g., %AAF rule





350
300
250
200
150
100
50
0
Flow (m3/s)
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Jul1994
IN FLOW
OUT FLOW

Benefits of Detail

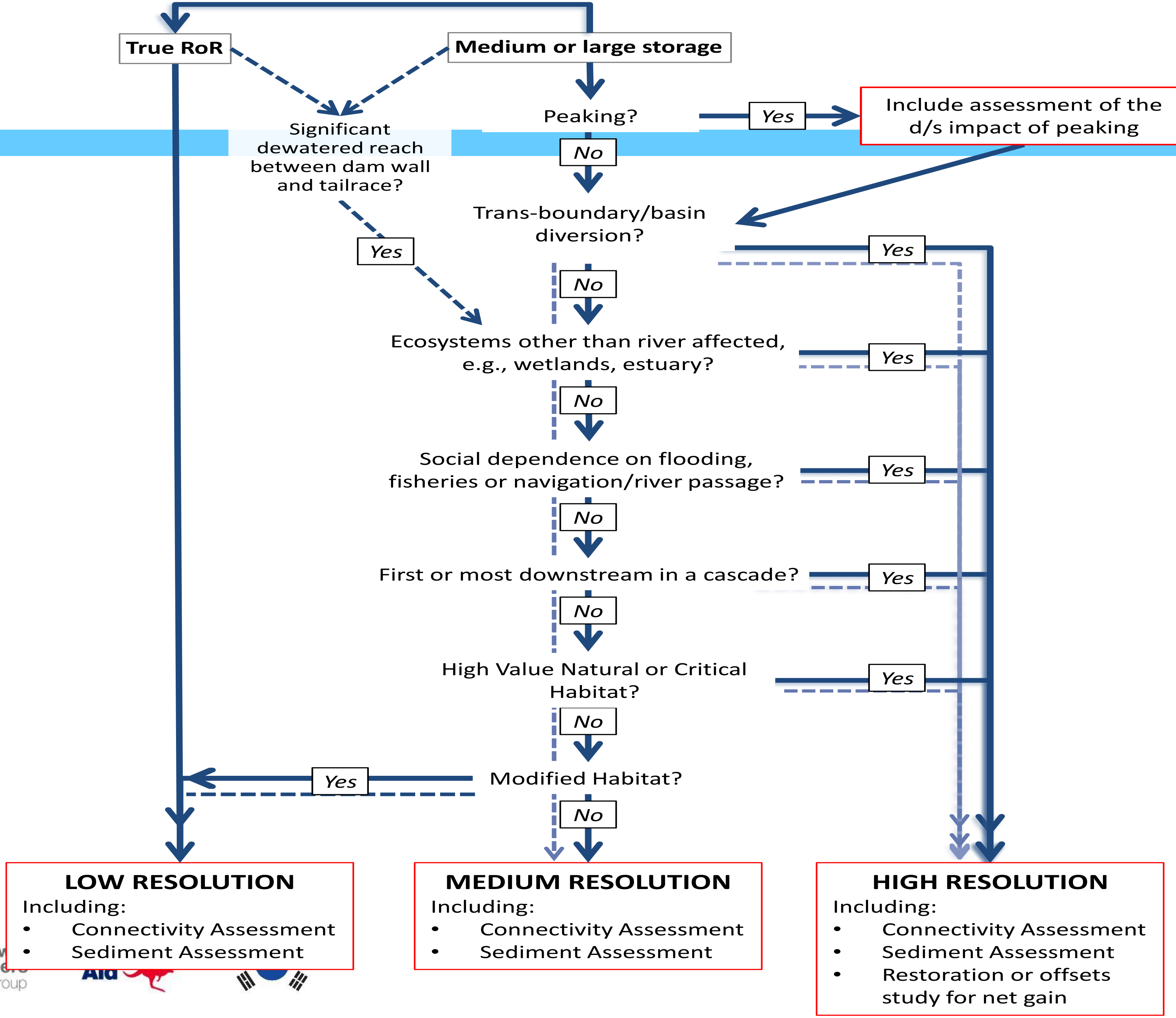
- Captures complexity of rivers and their response to development
- More transparent
- Informed and equitable decision making
- Evaluate a wider scope of mitigation options
- Optimise HPP design and location
- Fine-tune operating rules
- Generate targets for monitoring

Selection Criteria

What resolution ?

1. Storage volume (ability to control flows)
2. Peaking vs baseload operation
3. Transboundary/basin diversion
4. Ecosystems other than rivers, e.g., estuary
5. Social dependence on fish/river passage/other
6. 1st or most downstream in a cascade
7. High value Natural or Critical Habitat (IFC/WB definitions)
8. Modified habitat

What resolution ?

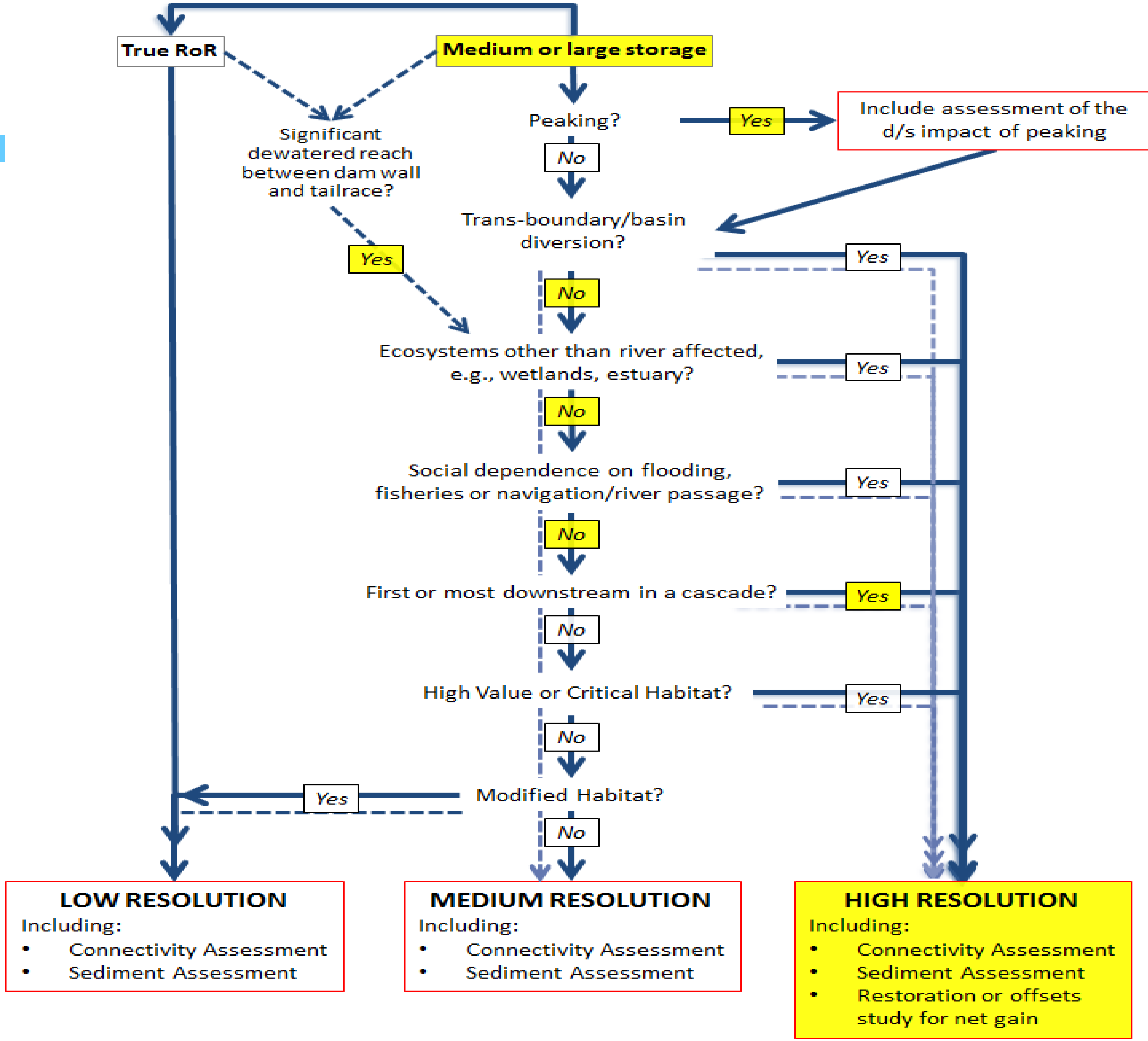


Poonch River Mahaseer National Park Pakistan

Kashmir Catfish

Golden Mahaseer

Gulpur HPP



Hydropower Developers' Working Group

Gulpur E-Flows Assessment (2014/15)

- Four sites
- The E-Flows scenarios incorporated considerations of:
  - changes to pattern and volume of downstream flows
  - the downstream effects of sediment trapping and/or flushing
  - changes in connectivity assessment for key migratory fish
  - options for turbine selection
  - options for management protection (i.e., offsets).
- Cost to client: ± US$ 300 000.00 *inclusive of disbursements*.

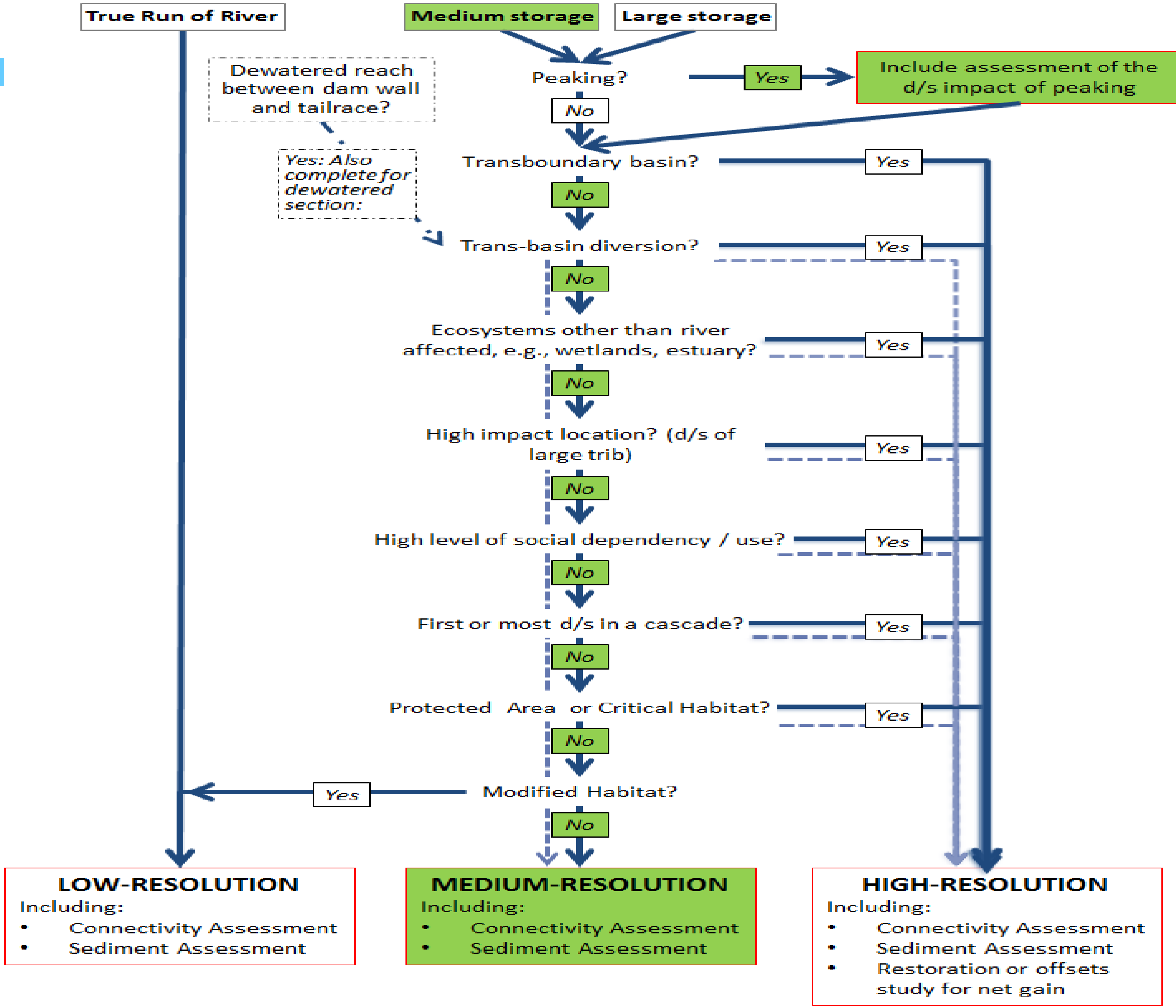
The use of the holistic environmental flow modelling was instrumental in proving our ability to achieve net gain to the lenders as well as local authorities, and in making the project an example of creating a win-win situation for the economic development and environment.

The financial costs of the study and subsequent negotiations were negligible relative to other development costs; the costs of the protection measures were incorporated into the power purchase agreements; and the redesign of the diversion tunnel resulted in a considerable reduction in construction costs.

Mira Power

Batoka E-Flows Assessment (2014)

Batoka HPP



True Run of River
Medium storage
Large storage
Dewatered reach between dam wall and tailrace?
Yes: Also complete for dewatered section:
Peaking?
Yes
Include assessment of the d/s impact of peaking
No
Transboundary basin?
Yes
No
Trans-basin diversion?
Yes
No
Ecosystems other than river affected, e.g., wetlands, estuary?
Yes
No
High impact location? (d/s of large trib)
Yes
No
High level of social dependency / use?
Yes
No
First or most d/s in a cascade?
Yes
No
Protected Area or Critical Habitat?
Yes
No
Modified Habitat?
Yes
No
LOW-RESOLUTION
Including:
• Connectivity Assessment
• Sediment Assessment
MEDIUM-RESOLUTION
Including:
• Connectivity Assessment
• Sediment Assessment
HIGH-RESOLUTION
Including:
• Connectivity Assessment
• Sediment Assessment
• Restoration or offsets study for net gain

Batoka E-Flows Assessment (2014)

- Two sites
- The EFlows scenarios incorporated considerations of:
    - changes to pattern and volume of downstream flows
    - the downstream effects of sediment trapping and/or flushing
    - no change in connectivity for migratory fish (Victoria Falls)
- Cost to client: ± US$ 110 000.00 *inclusive of disbursements*.

Dear Cate

I confirm that we found the E-Flows approach used in Batoka useful for the project.
The E-Flows approach helped us understanding the critical environmental issues, which concerned some specific periods of the year and minimize the impact of the environmental mitigation measures on Batoka's power production.

Kind Regards,

Antonioar Pietrangeli

Studio Ing. G. Pietrangeli s.r.l.
Via Cicerone 28
00193 - rome - italy
tel : + 39 06 32 10 880
mail : antonio.pietrangeli@pietrangeli.it

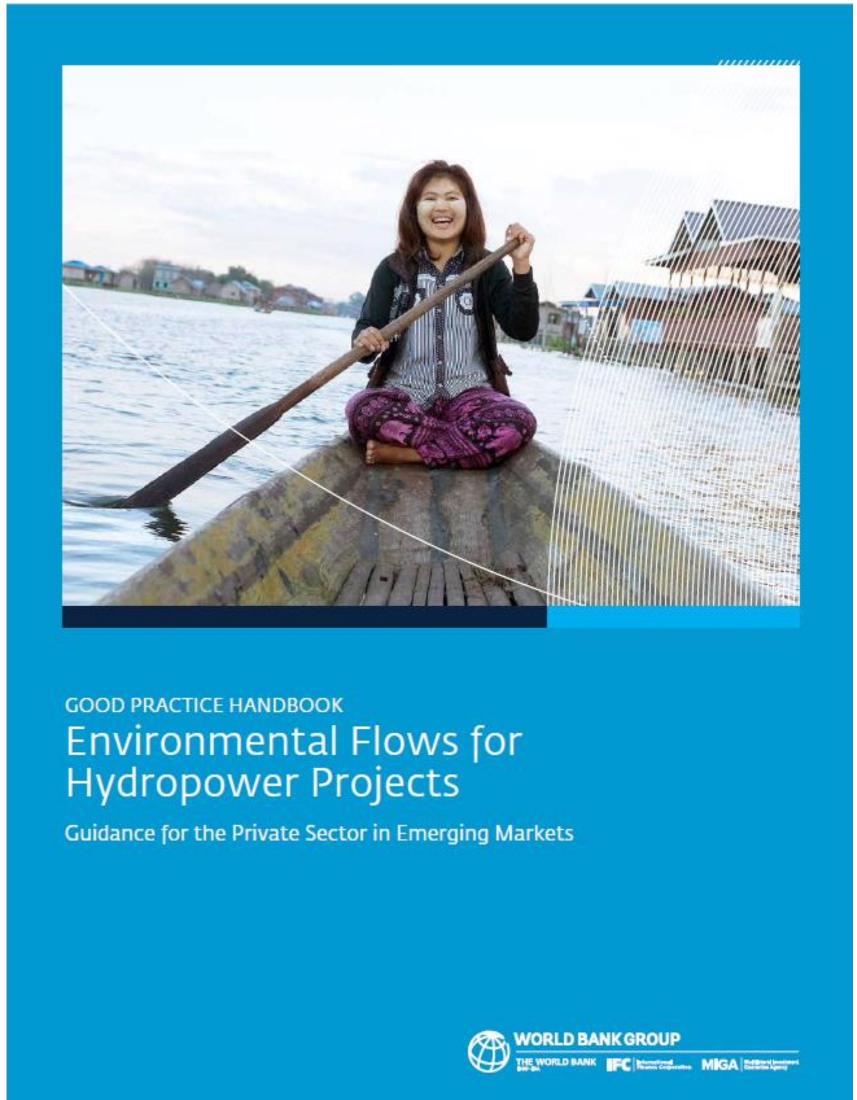
Summary

Good Practice Handbook promotes a more consistent approach to E-Flows assessments in WBG-funded HPPs:

- based on the context in which E-Flows are to be assessed and applied;
- assists in selection of project-appropriate levels of E-Flows assessment, and;
- promotes stronger links with ESIAs, CIAs and SEAs

Creating Markets, Creating Opportunities

www.ifc.org/sustainabilitypublications



Hydropower Developers' Working Group

Australian Aid

IFC International Finance Corporation WORLD BANK GROUP

Creating Markets, Creating Opportunities

Evolution of E-Flow Practice in Pakistan – Lessons Learnt and Way Forward

Vaqar Zakaria

Hagler Bailly Pakistan

E-Flow Assessments Conducted for Hydropower Projects in Pakistan

Kishenganga	330 MW	2010	(transboundary)
Neelum Jhelum	969 MW	2011	
Gulpur	100 MW	2013	
Karot	720 MW	2015	
Kohala	1124 MW	2016	
Athmuqam	450 MW	2018	
Balakot	300 MW	2018	
Azad Pattan	700 MW	2019	
Mahl	640 MW	2019	
Arkari Gol	99 MW	2019	
Sharmai	150 MW	2020	
Spat Gah	496 MW	2021	

There were E-Flows specified for other hydropower projects in their feasibility studies as well, but these were not based on any structured approach

HBP also conducted and supported assessments for the Upper Trishuli, Tamakoshi-V, and Upper Karnali hydropower projects in Nepal, and basin wide assessments for the Jhelum and Ravi Basins in Pakistan and Trishuli Basin in Nepal

Challenges Faced

- Initially, in almost all cases, minimum flow or environmental flow was specified at the feasibility or prefeasibility stage by engineering companies, and project approvals were awarded, or the projects were presented to private developers with the E-Flow already locked in
- When the stakeholders or environmental regulators raised concerns, the power development agencies were faced with difficult choices as the country was experiencing severe outages or load shedding
- This argument was hard to counter as the country was experiencing severe outages or load shedding
- Awareness of E-Flow assessment methodologies was low, and the freshwater biologists had not been engaged in analysis of impacts of changes in flow and sediment regimes on river ecology induced by the hydropower projects
- The cost of comprehensive E-Flow assessments was considered to be unreasonable as it often exceeded the cost of the whole ESIA and required additional time which could throw the project development schedule off course
- The government development agency, Private Power and Infrastructure Board (PPIB), the power purchaser, Central Power Purchase Agency (CPPA), and the electricity regulator National Electricity Regulatory Authority did not have a policy framework and the capacity to assess impact of Eflow requirements on electricity tariff in the context of sustainable development

Case Study: Kishenganga Hydropower Project – 2007 to 2011

Baseline Ecology

Fish Fauna Recorded from Neelum River

Salmo trutta fario

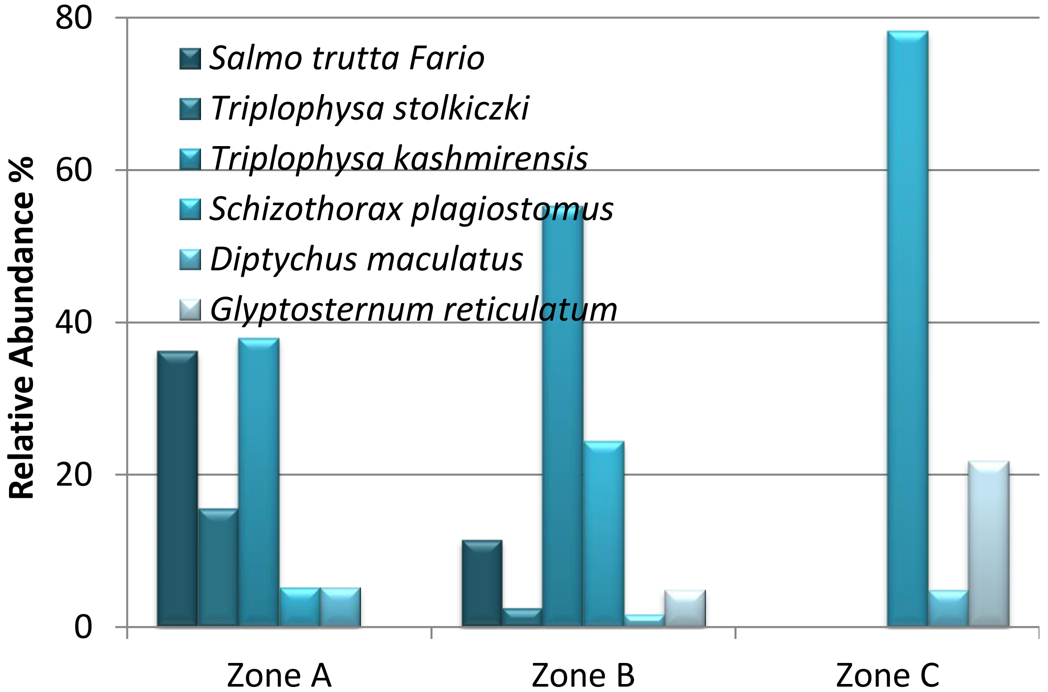
Diptychus maculatus

Schizothorax plagiostomus

Triplophysa stoliczkae

Triplophysa kashmirensis

Glyptosternum reticulatum



Environmental Assessment of Neelum River Water Diversion

Project Location

Scale	1 : 1,240,000 (for A3 printing)
Drawing	W1E11NVE
Date	March 2011
Client	Pakistan Commission for Indus Waters, Lahore

Hagler Bailly Pakistan

Hydropower Developers' Working Group

Australian Aid

IFC International Finance Corporation WORLD BANK GROUP

Creating Markets, Creating Opportunities

Process Followed, Issues and Outcomes

- Kishenganga HPP became a transboundary dispute between India and Pakistan and was referred to the Permanent Court of Arbitration located at Hague under the Indus Water Treaty signed by India and Pakistan in 1960
- Studies on river ecology and socioeconomic uses of the river including ecosystem services were conducted in 2007-8
- The first assessment of E-Flows was carried using the hydrological approach as developed by Richter et al.:

  Based on review of potential methods available the Range of Variability Approach (RVA) method developed by Richter et al. (1996, 1997, 2003) was the best method for determining an environmental maintenance flow regime for the Neelum River downstream from the proposed India diversion project. A recent review by Tharme (2003) found that the RVA approach was the most intensively applied, being used in the United States, Canada, South Africa, and Australia. The RVA-type approach is especially appropriate in developing world regions, where environmental flow research is in its infancy and water allocations for ecosystems must, for the time being at least, be based on scant data, best professional judgment and risk assessment.

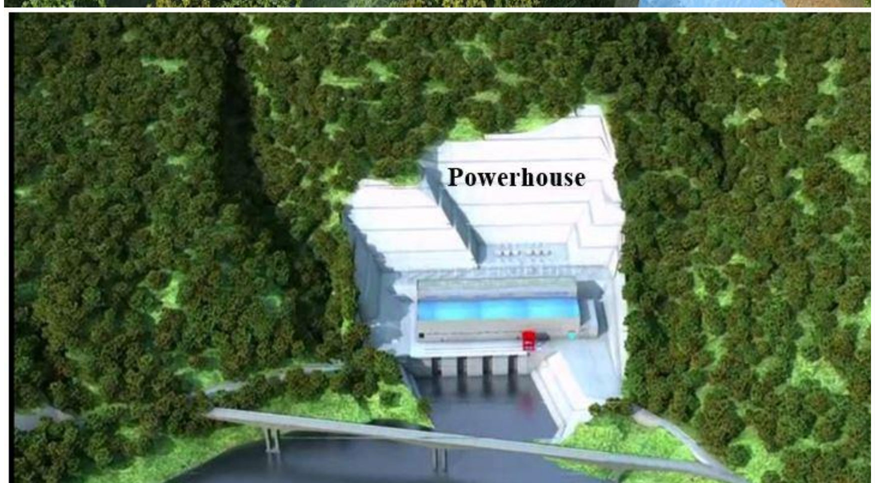
- Holistic method developed by King et al., 'Building Block Method' was not considered as it 'Requires detail knowledge of advanced ecological principles operating in specific river'

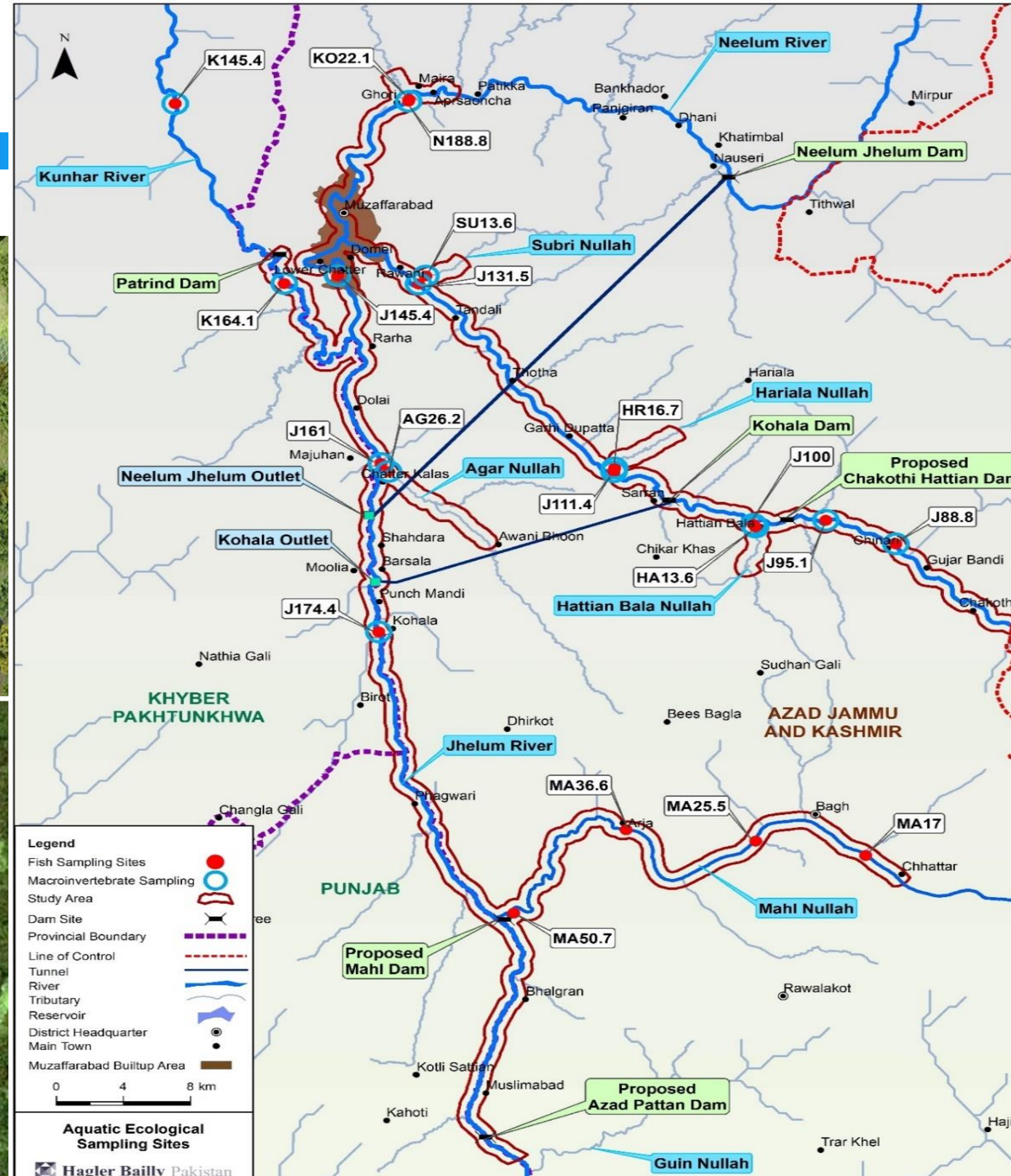
Process Followed, Issues and Outcomes

Contd.

- The first assessment was submitted for a peer review, and was rejected as it was not based on best available science and provided highly conservative estimates for E-Flow that would not be defensible in a transboundary case
- A holistic assessment using the DRIFT DSS was then conducted which took more than a year to complete
- The first set of 'Response Curves' for the Himalayan river ecosystem were developed based on extensive literature review and knowledge capture from discussions with leading biodiversity experts in the country
- Multiple E-Flow scenarios were presented for consideration of the Court, ranging from 4 m^3/s to 15 m^3/s, compared to a mean minimum 5-day flow of 21 m^3/s
- The Court made the final award setting the E-Flow at 9 m^3/s, recognizing that an appropriate flow would have been 12 m^3/s had the right of India to generate power were not to be accounted for
- Pakistan would have desired higher level of environmental flow release, while India was concerned about loss in economic value resulting from the same
- An immediate outcome was that Pakistan had to avoid 'double standards' in E-Flows for its own projects, where traditionally the level of environmental release was comparatively lower
- All the subsequent E-Flow assessments in Jhelum Basin were then conducted using holistic approach

Case Study: 1224 MW Kohala Hydropower Project – 2016-2020





Hydropower Developers' Working Group

Australian Aid

IFC International Finance Corporation WORLD BANK GROUP

Creating Markets, Creating Opportunities

Fish Baseline – Species of Conservation Importance

Cyprinus carpio
Vulnerable

Glyptothorax kashmirensis
Critically Endangered

Schizothorax plagiostomus (richardsonii)
Vulnerable

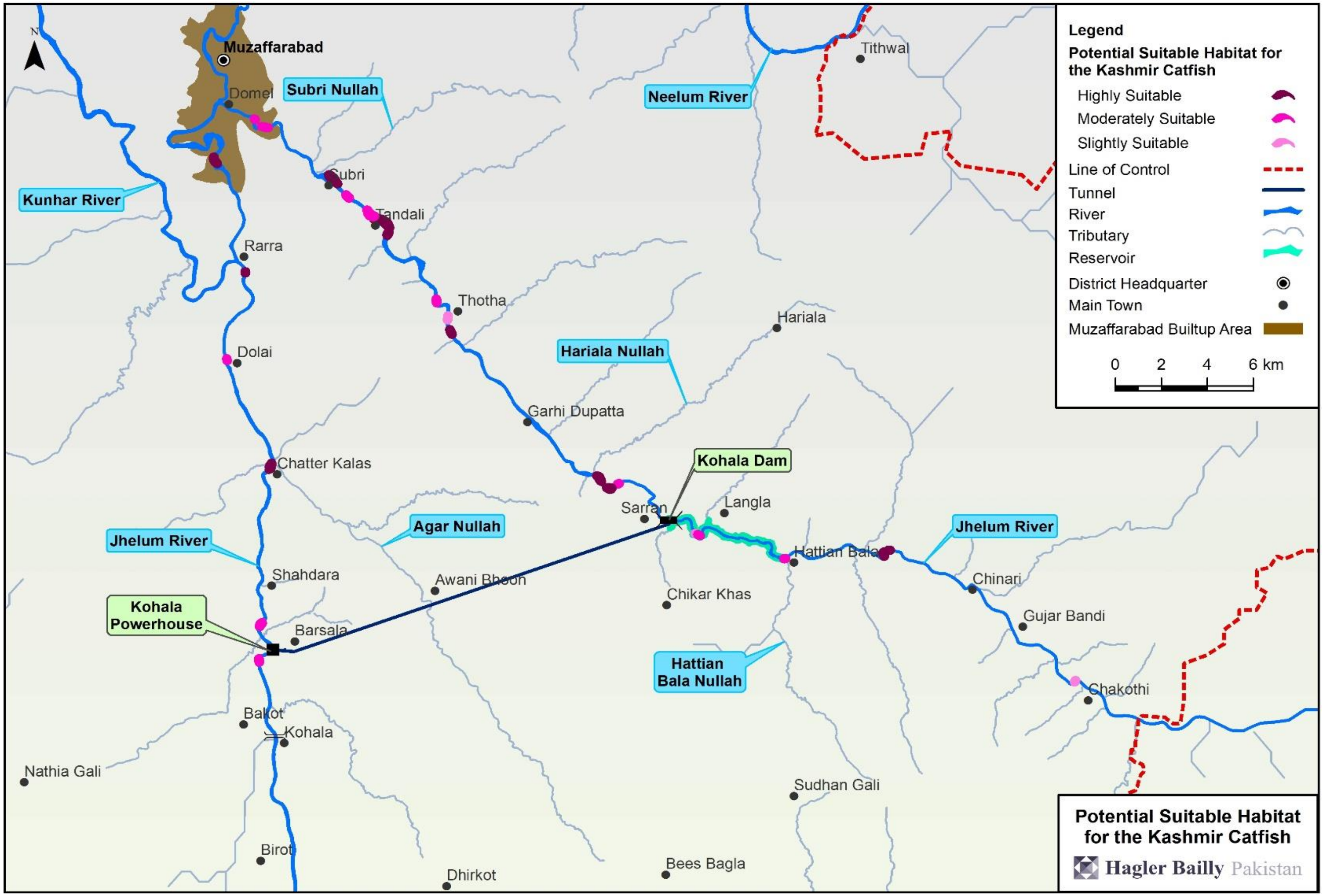
Tor putitora
Endangered

Garra gotyla

Labeo dyocheilus

There are total of 35 fish species in the Study Area of which eight are endemic species and six are migratory

Potential Suitable Habitat for Kashmir Catfish



Hydropower Developers' Working Group

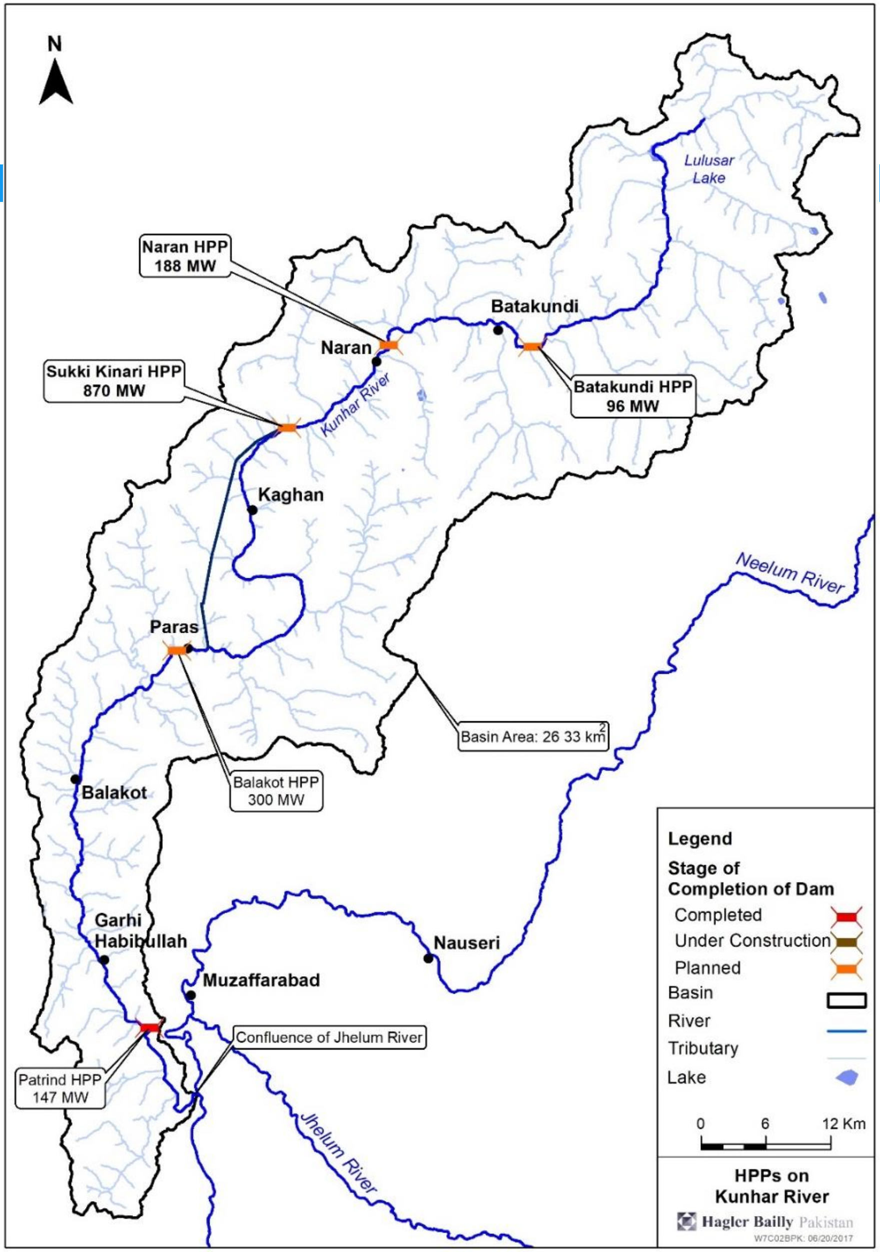
Australian Aid

International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Process Followed, Issues, and Outcomes

- The ESIA and the E-Flow assessment were completed in 2016 before the commissioning of the Neelum-Jhelum HPP
- Original feasibility had set the E-flow at 15 m^3/s, scenarios simulated were E-flow release of 22.5 m^3/s and 30 m^3/s
- EPA granted an approval for an E-flow of 30 m^3/s inclusive of a Biodiversity Action Plan that included actions for protection of aquatic fauna, regulation of extraction of sand and gravel from the river, a watershed management program, and contribution to an institute for research on river ecology to be set up by the government
- Following commissioning of the Neelum-Jhelum HPP in summer 2017, the residents of Muzaffarabad reacted strongly when the flow of the Neelum River at Muzaffarabad dropped to 15 m^3/s as compared to normal flow of over 200 m^3/s in September
- E-flow from the Neelum-Jhelum Project was increased to about 30 m^3/s following protests in the city
- Part of the river at the city became a sewage stream, and solid waste could be seen in the river
- The state government approached the federal government and complained about the E-flow from Kohala Project, and the need to set up wastewater treatment plants, and weirs in the river to increase the pondage in the low flow section
- The project company agreed to increase the E-flow to 40 m^3/s in 2019 after prolonged discussions with the governments

Case Study: The Balakot Hydropower Project, 2017 -2020



Hydropower Developers' Working Group

Australian Aid

International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Ecology Baseline

Fish Fauna: 10 species reported, 9 species observed. No Endangered or Critically Endangered species, 1 long-distance migratory species and 2 endemic/restricted range species

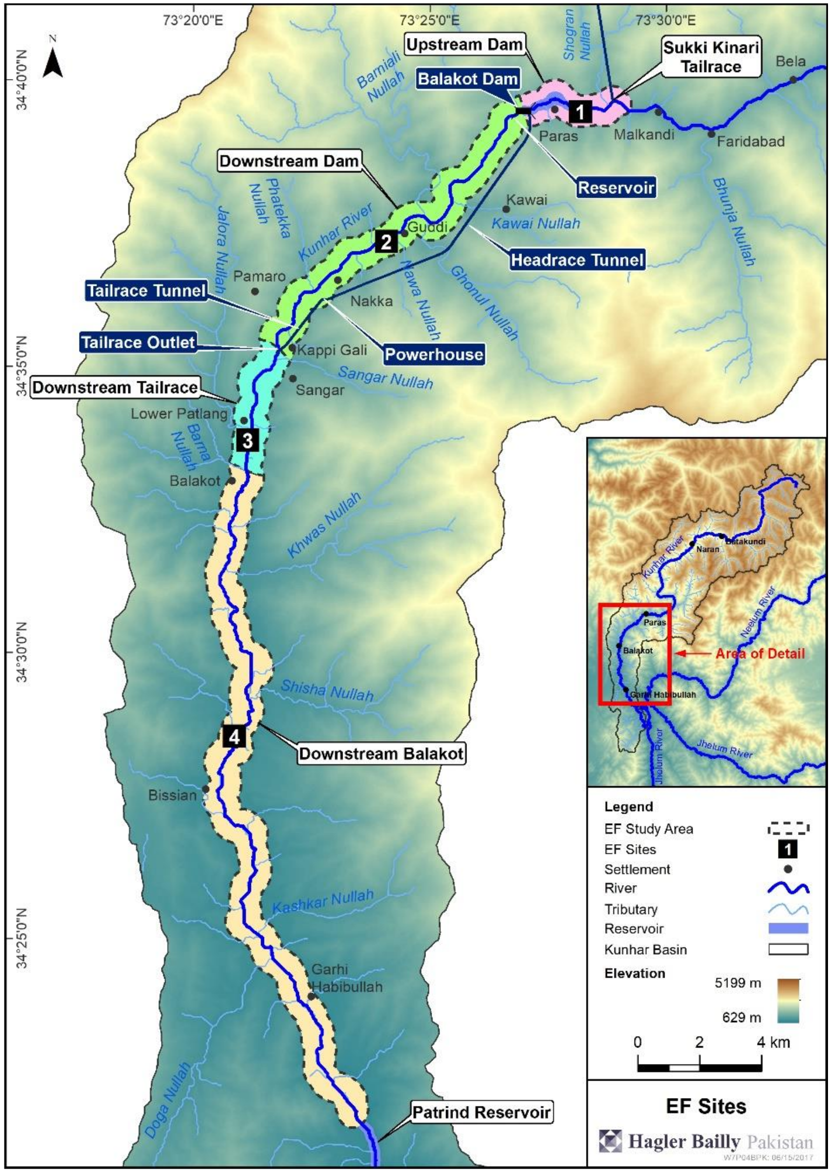
Alwan Snow Trout *Schizothorax richadsonii* Migratory

Kashmir Hillstream Loach *Triplophysa kashmirensis* Endemic/Restricted Range

Nalbant’s Loach *Schistura nalbanti* Endemic/Restricted Range

Environmental Flow Assessment using DRIFT

Dam Operation Type		*Baseload Operation (B)*				*Peaking Operation (P)*		
Environmental Flow m^3/s Release		*1.5 (B1)*	*3.5 (B3)*	*4.5 (B4)*	*6.1 (B6)*	*1.5 (P1)*	*4.5 (P4)*	*6.1 (P6)*
Protection Level	Business as Usual (BAU)	–	B3BAU	–	–	–	–	–
	Low Protection (LP)	–	B3LP	–	–	–	–	–
	Moderate Protection (HP)	–	B3MP	–	–	–	–	–
	High Protection (HP)	B1HP	B3HP	B4HP	B6HP	P1HP	P4HP	P6HP



Hydropower Developers' Working Group

Australian Aid

IFC International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Process Followed, Issues, and Outcomes

- Two operational scenarios are recommended for consideration of the stakeholders:
  - Preferred Case: Baseload operation with an E-Flow of 1.5 m^3/s and High Protection (corresponding to scenario B1HP)
  - Alternate Case: Peaking operation with an E-Flow of 6.1 m^3/s and High Protection (corresponding to scenario P6HP)
- With a baseload operation it will be possible to meet the requirement of Net Gain in population of fish species that trigger Critical Habitat, with a margin for uncertainties in predictions of E-Flow modeling of the order of 15%
- With a peaking operation and E-Flow release of 6.1 m^3/s, there will be a loss in power generation of the order of 3.5% compared to baseload operation with an E-Flow release of 1.5 m^3/s
- While the basic requirement of Net Gain will be met, there will be limited margin for accommodating uncertainties in E-Flow modeling predictions
- Peaking power is presently priced at a premium of about 30% for high end residential and commercial customers, however, power purchase tariff for the generation companies remains at a flat rate
- The operational configuration selected and agreed upon by the stakeholders, project owner, and the lenders will be presented in the final version of the EIA, along with the justification for the decision

Conclusions and Lessons Learnt

- It has taken over ten years to establish capacities in the country to conduct E-Flow Assessments following best international practices
- The transboundary case related to Kishenganga HPP provided an opportunity to consider and adopt best international practices in E-Flow assessment
- International collaboration in the initial phases and support from the IFC and other lending institutions was critical in transforming the assessments practices in the country
- There has been a continuing process of learning and improvement associated with assessments in varying environmental settings and project designs
- Capacities have been built in the institutions responsible for development and regulation of hydropower and environment, and in private sector
- The understanding of our river ecosystems and the value they bring to the society has improved considerably as the discussions on the trade-offs between environment and development has been supported by good science and research
- The E-flow assessments have materially contributed to investments in protection of river ecosystems such as inclusion of cost of protection of river ecosystems in electricity tariffs