GOOD PRACTICE HANDBOOK

Environmental Flows for Hydropower Projects

Guidance for the Private Sector in Emerging Markets

WORLD BANK GROUP
THE WORLD BANK IBRD • IDA | IFC International Finance Corporation | MIGA Multilateral Investment Guarantee Agency

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Abbreviations and Acronyms

ABF	New England Aquatic Base-Flow Method
BAP	Biodiversity Action Plan
BMWP-CR	Biological Monitoring Working Party-Costa Rica
CIA	Cumulative Impact Assessment
DRIFT	Downstream Response to Imposed Flow Transformation
EFlows	Environmental Flows
EFMP	Environmental Flows Management Plan
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
ESS	Environmental and Social Standards
HPP	Hydropower Project
ICE	Instituto Costarricense de Elecricidad
IFC	International Finance Corporation
IFIM	Instream Flow Incremental Methodology
IHA	Indicators of Hydrologic Alteration
IHG	Hydro Geomorphologic Index
IQR	Inter Quartile Range
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
LFA	Logical Framework Approach
MIGA	Multilateral Investment Guarantee Agency
NNL	No Net Loss
PS	Performance Standards
RVA	Range of Variability Analysis
SEA	Strategic Environmental Assessment
SEFA	System for Environmental Flow Analysis
ToR	Terms of Reference
WBG	World Bank Group
WWF	World Wildlife Fund

Note: All dollar amounts in this publication are in U.S. dollars, unless noted.

Acknowledgments

This Good Practice Handbook provides guidance to practitioners on selecting an appropriate environmental flows assessment level for hydropower project developments. Southern Waters Ecological Research and Consulting prepared it under the direction of Environment, Social and Governance Department of the International Finance Corporation (IFC). Cate Brown, Jackie King, Jessica Hughes, and Vaqar Zakaria wrote the Handbook, under the direction of Pablo Cardinale (IFC).

The Handbook draws heavily on the lessons and experiences of IFC, the World Bank Group and its clients, and other organizations focused on promoting, assessing, and implementing environmental flows. It is intended to provide additional good practice guidance in support of IFC's Performance Standards on environmental and social sustainability and the World Bank's Environmental and Social Standards.

Thanks are due to all those who provided valuable comments to the team on various drafts during the peer review and public comment process, including those who provided written comment: Agi Kiss, Alison Joubert, Brij Gopal, Conrad Savy, Daniel Shrively, Justin Pooley, Kate Lazarus, Leeanne Alonso, Leanne Farrell, Lois Koehnken, Pablo Cardinale, Rafik Hirji, William Rex, and William Young.

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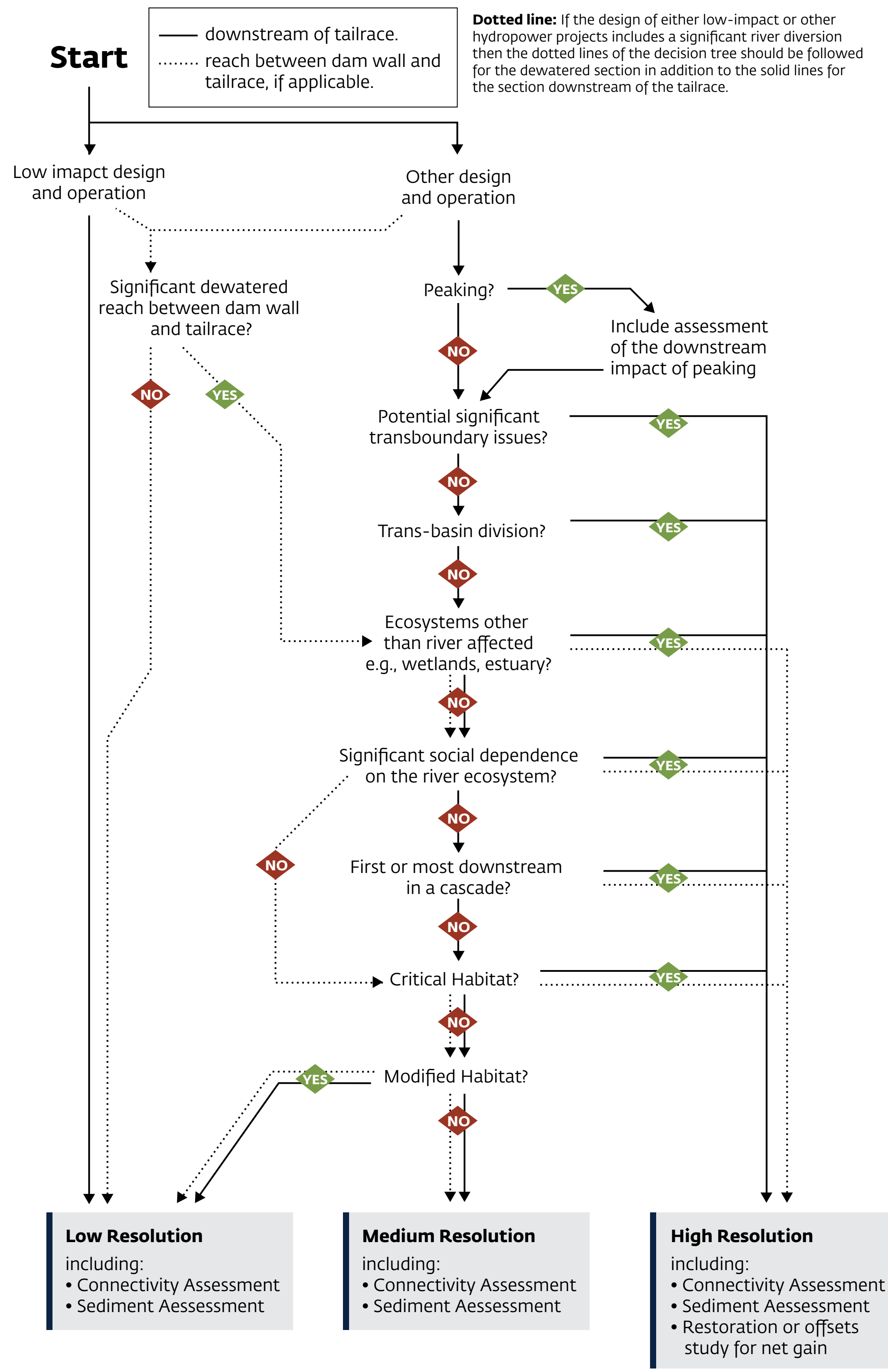
Executive Summary

This Good Practice Handbook provides guidance to practitioners on taking rigorous and consistent approaches to assess and manage hydropower project impacts on downstream river ecosystems and people through the assessment and provision of environmental flows (EFlows).

The specific approach can be summarized as follows:

- Understand the context of river functioning and the provision of ecosystem values and services into which EFlows will be introduced.
- Understand the potential downstream impacts associated with hydropower development and how these can be mitigated.
- Understand the kinds of information provided by EFlows Assessments.
- Apply a context-appropriate EFlows Assessment method.
- Conduct a comprehensive and appropriate stakeholder engagement program leading to a decision on EFlows and other mitigation measures based on the outcome of the assessment.
- Compile an EFlows Management Plan.

Figure A: Decision Tree for Determining Resolution for EFlows Assessment



The Handbook also provides the following:

- A logframe for integrating EFlows into hydropower projects (HPPs)
- Case studies to illustrate the main concepts addressed in the Handbook

The Handbook does not provide instructions on how to perform the following:

- Implement a specific methodology for an EFlows Assessment
- Select stakeholders
- Negotiate and make decisions on EFlows allocations
- Implement EFlows

A successful EFlows Assessment requires using a method that will provide the appropriate level of detail to guide sustainable development. The decision tree explained in the Handbook and shown in Figure A summarizes the recommended approach for selecting an EFlows method based on consideration of the proposed design and operation of the hydropower project, the sensitivity of the ecological and social environment, the types of ecosystems affected, and the presence of other relevant water-resource developments.

In general, the decision tree will recommend the following:

Low-resolution EFlows methods for hydropower projects that will not affect natural or critical habitat, or rare, endangered, or threatened species or species assemblages; **and** where there is no significant social reliance on the riverine ecosystem; **or** for low-impact design and operation projects[1], **or**; for baseload plants that have no substantial influence on the flow regime. Typically, this level of assessment could result in a minimum flow recommendation for the dry season—on the understanding that flows in the months outside of the dry season are relatively unimpacted.

Medium-resolution methods for hydropower projects that will not affect critical habitat, **or** rare, endangered, or threatened species or species assemblages; **and** where there is no significant social reliance on the riverine ecosystem; **or** part of an existing cascade of dams/ hydropower projects, as long as they are not the most downstream one (that is, they are not the last one in a cascade).

High-resolution holistic methods for hydropower projects that will affect critical habitat, or rare, endangered or threatened species and species assemblages; or may significantly degrade or convert natural habitat; **or** that will affect aquatic ecosystems other than rivers, such as an estuary or a floodplain; and/or where there is significant social reliance on the riverine ecosystem potentially affected by the hydropower project. The decision tree will also recommend high-resolution assessments for transboundary or trans-basin diversions.

If hydro-peaking is envisaged, then the EFlows method chosen should be augmented with an assessment of the subdaily downstream impacts of peaking releases. Some methods can incorporate such an assessment, while for others it will need to be done separately. Similarly, when the hydropower project is situated in natural or critical habitat and developers are requested to demonstrate either "no net loss" (NNL) or a "net gain" in biodiversity respectively, developers or others involved will need to consider restoration or offsets in addition to setting EFlows.[2]

1 Defined as: *Hydropower plants that release downstream into the same river, with a short or no diversion, have ≤ 48-hour dry-season storage and do not make peaking-power releases.*

2 NNL and Net Gain can be delivered via restoration offsets, avoided loss offsets or positive conservation actions. Offsets are to be used only as a last resort, when avoidance, minimization, and restoration have all been pursued to the fullest extent possible.

SECTION I

INTRODUCTION

Section 1. Introduction

1.1 PURPOSE AND ROLE OF THIS GOOD PRACTICE HANDBOOK

This Good Practice Handbook is designed to provide guidance to practitioners on taking rigorous and consistent approaches to assess hydropower project impacts on downstream river ecosystems and people, and determine their Environmental Flows (EFlows) commitments.

The Handbook seeks to do the following:

- Summarize the context in which EFlows are assessed and applied
- Guide the selection of project-appropriate EFlows Assessment methods
- Enhance the quality, content, and effectiveness of project-level Environmental and Social Impact Assessments (ESIAs) through the inclusion of EFlows evaluations and mitigation measures to maintain downstream ecosystems, ecosystem services, and water uses

Although the Handbook focuses on hydropower, the issues and concepts are broadly applicable to other types of dam projects, such as for water storage, irrigation, or flood control.[1]

Note: The terminology and abbreviations used in the Good Practice Handbook for Environmental and EFlows Assessment processes implicitly include social considerations.

1 The differences in EFlows-related impacts between dams for hydropower projects and dams for other purposes are chiefly related to operation. The basics of an EFlows Assessment are the same for both.

1.2 STRUCTURE AND FOCUS OF THE HANDBOOK

The Handbook outlines a good practice approach for integrating EFlows into hydropower projects, emphasizing the selection of context-appropriate EFlows Assessment methods. Its structure follows the main steps of this approach:

1. Understand the context of river functioning and the provision of ecosystem values and services into which EFlows will be introduced (Section 2);
2. Understand the potential downstream impacts associated with hydropower development (Section 3) and how these can be mitigated (Section 4);
3. Align ESIA and EFlows Assessments and ensure data sharing and good communication between the assessment teams (see Section 5);
4. Apply a context-appropriate EFlows Assessment method (Section 6);
5. Conduct a comprehensive and appropriate stakeholder engagement program leading to a decision on EFlows and other mitigation measures based on the outcome of the assessment (Sections 7 and 8); and
6. Prepare an Environmental Flow Management Plan (EFMP[2]; Section 9).

It also provides the following:

- A logframe for integrating EFlows into hydropower plants (Section 10); and
- Case studies to illustrate the main concepts addressed in the Handbook (Section 11).

2 Other terms used include Biodiversity Action Plan (for example, Hagler-Bailly Pakistan 2014 - Pakistan), EFlows Policy (for example, LHDA 2003 - Lesotho) or similar.

This Handbook does not provide instructions on how to do the following:

- Implement a specific methodology for an EFlows Assessment
- Select stakeholders
- Negotiate and make decisions on EFlows allocations
- Implement EFlows

1.3 ENVIRONMENTAL FLOWS (EFLOWS)

EFlows are defined as the quantity, frequency, timing, and quality of water and sediment flows necessary to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.[3] Box 1 presents related terms to EFlows.

EFlows Assessments ideally require collaboration of engineers, lawyers, ecologists, economists, hydrologists, sociologists, resource economists, water planners, politicians, stakeholders, and communicators. EFlows are negotiated through a process of data analysis and discussion of the physical, chemical, biological, social, resource-economic, economic, biodiversity, and land management implications of water-resource developments.[4] Because of their wide reach, they have become a central component of Integrated Water Resources Management (IWRM), which "promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[5]

Appropriate-level EFlows Assessments address the complexity of river ecosystems and their responses to development. They allow a more genuine consideration of a broader suite of possible impacts and increase the chances of achieving sustainability. They also allow for evaluation of a wider scope of mitigation options, support for more informed, and thus better, decision making, and help optimize hydropower plant design and location, along with fine-tuning operating rules and generating metrics for monitoring.

> Appropriate-level EFlows Assessments address the complexity of river ecosystems and their responses to development.

3 Amended from Brisbane Declaration (2007).

4 Note that EFlows Assessments are a technical process (including social interests and aspects as well as ecological), whereas EFlows negotiations are more of a political process.

5 Global Water Partnership 2010; www.gwp.org.

Box 1: Frequently-used Terms Related to EFlows

Environmental Water: commonly used in South Africa and Australia, this term refers to water managed to deliver specific ecological outcomes or benefits. It may refer to specific water allocations or releases made for ecological purposes.

Instream Flow Requirements: an older term, rarely used now, that originally addressed flows for maintaining fish habitat. The focus then was on low flows in the wetted channel, and typically did not consider riparian zones, floodplains, water quality, geomorphology, other biota, floods greater than the annual one, or social aspects.

Minimum Flow: a general term mainly used to describe a flow that must be maintained without further reduction over a specified period—generally either during the dry season or over the whole year. It implies that ecosystem functioning can be protected through the delivery of a minimum and constant flow; whereas, evidence shows within- and between-year flow variability is essential to maintain healthy rivers.

Downstream Flow: this term indicates the final flow regime once EFlows and flows for other water demands, such as irrigation and hydropower generation, have been combined. Some holistic EFlows Assessments analyze scenarios that include all such considerations. In such assessments, the scenario chosen through negotiation contains a flow regime that becomes the EFlows for the river and is effectively the downstream flow.

1.4 EFLOWS AND WORLD BANK GROUP STANDARDS

Aspects of EFlows are reflected across the World Bank Group's Safeguard Policies, World Bank Environmental and Social Standards (ESS), and IFC Performance Standards on Environmental and Social Sustainability (PSs), which set out good international practice for development projects (Figure 1.1). IFC PSs are also used by the Multilateral Investment Guarantee Agency (MIGA). The PSs also form the basis for the Equator Principles , a framework adopted by more than 85 financial institutions globally for determining, assessing, and managing environmental and social risk in projects.

Figure 1.1: Relevance of World Bank Safeguard Policies, World Bank Environmental and Social Standards, and IFC Performance Standards to EFlows Assessments

Policy Safeguards	Environmental Safeguards	Consequences for
OP 4.01 Environmental Assessment	**ESS1 / PS1** Assessment and Management of Environmental and Social Risks and Impacts	• aquatic ecosystems and ecosystem services • flooding risk • competing downstream water uses (e.g. irrigation)
OP 4.07 Water Resources Management	**ESS3 / PS3** Resource Efficiency and Pollution Prevention	• water quality (pollutants; temperature change) • sedimentation / nutrient loads • carbon emission
OP 4.37 Dam Safety	**ESS4 / PS4** Community health, Safety and Security	• river navigation / transport • water-borne disease • dam safety and flooding risk • risks from releases
OP 4.12 Involuntary Resettlement	**ESS5 / PS5** Land Acquisition & Involuntary Resettlement	• bank erosion / sedimentation • river structures • crops and livelihoods (fishing)
OP 4.04 Natural Habitats **OP 4.36** Forests	**ESS6 / PS6** Biodiversity Conservation and Sustainable Management of Living Natural Resources	• biodiversity • ecosystem services • river connectivity • nutrient recycling
OP 4.10 Indigenous People	**ESS7** Historically Underserved Traditional Local Communities / **PS7** Indigenous Peoples	• natural resources • livelihoods (e.g. fishing, hunting) • spiritual / cultural resources / practices
OP 4.11 Physical Cultural Resources **OP 4.36** Forests	**ESS8 / PS8** Cultural Heritage	• cultural heritage resources • cultural practices and ceremonies
	ESS9 Financial Intermediaries	• compliance with ESS by FIs
OP 4.01 Environmental Assessment **OP 4.04** Natural Habitats	**ESS10** Stakeholder Engagement and Information Disclosure	• river health / biodiversity • river-based livelihood dependencies • operational scenarios
OP 7.50 International Waterways		• all of the above

EFLOWS ASSESSMENTS

1.5 EVOLUTION OF EFLOWS IN THE WORLD BANK GROUP

Shortly after 2000, the World Bank Group produced a suite of EFlows publications[6] and made EFlows a thematic window in the World Bank-Netherlands Water Partnership Program that supported Bank operations from 2000 to 2008.

As a contributor to the Brisbane Declaration, the World Bank Group adopted the globally accepted Brisbane Declaration definition of EFlows.[7] The World Bank Group has continued to leverage support for EFlows Assessments and implementation through all stages of project decision-making. The World Bank typically provides this support to countries, for integration of EFlows in decision making, at four levels (Hirji and Davis 2009b):

- Water-resources policy, legislation, and institutional reform
- River basin and watershed planning and management
- Investments in new infrastructure
- Rehabilitation and re-operation of existing infrastructure

At present, the World Bank Group has recognized that the whole field of EFlows Assessment and implementation for hydropower projects, (including method selection, decision-making, reporting, and monitoring) would benefit enormously from a standardized approach and from consideration of EFlows within SEA, CIA, ESIA, and other environmental assessment frameworks. The World Bank Group developed this Good Practice Handbook to bring more consistency and discipline to the approach.

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6 For more information on topics covered in this section please see the following: Hirji et al. 2002; King and Brown 2003; Acreman 2003; Brown and Watson 2007; Hirji and Davis 2009a&b; Krchnak et al. 2009; Le Quesne et al. 2010.

7 http://www.watercentre.org/news/declaration


A
B
C

SECTION 2

ENVIRONMENTAL FLOWS, RIVERS, AND PEOPLE

Section 2. Environmental Flows, Rivers, and People

2.1 VALUE OF EFLOWS ASSESSMENTS

EFlows Assessments provide information on how the physical characteristics of the river could change with planned developments, how ecosystem services and biodiversity could be impacted, and how all these changes could affect people and local and wider economies. The information can underpin decision making in a variety of ways:

- Informing discussions on the trade-offs between resource protection and resource development
- Identifying the degree to which the river's natural ecosystem services should be maintained and thus the desired future condition of the river
- Identifying additional alternative benefits, the river should also provide through development
- Defining important monitoring targets

Experience has shown that to be most effective, EFlows studies are best done—

- As early as possible in the planning process
- At the basin level
- At a medium- to high-level of resolution
- Within a robust stakeholder engagement process
- Using scenarios to support negotiation and decision making

2.2 RIVER ECOSYSTEM

A river changes from day to day, and year to year, but this change is around a dynamic equilibrium that provides some level of constancy and predictability for the river's life. Some species thrive in wetter years, others in drier times, in a system of checks and balances that maintains the fundamental relationship between the flow of water and sediment, and the biotas supporting a strong and diverse ecosystem through time.

Large events—such as extreme floods, landslides, and earthquakes—can shift the river away from its physical equilibrium, but the river will typically move back toward its natural condition to the extent possible, if the outside influence stops, because that is the most energy-efficient expression of its geology, landscape, and climate (Leopold and Maddock 1953; William 1978; Vannote et al. 1980). Permanent interventions, such as a dam or water diversions, tend to shift the ecosystem toward a new equilibrium, which may only be reached over long-time scales, especially if interventions continue to modify the flow or sediment regime.

A river changes from day to day, and year to year, but this change is around a dynamic equilibrium that provides some level of constancy and predictability for the river's life.

The flow regime is regarded as the master variable because to a large extent it determines the nature of the river channel, sediments, water quality, and the life these support (Figure 2.1). All parts of the flow regime, including its variability, are important. Floods replenish groundwater, maintain the channel and support floodplains, leaving nutrient-rich sediments as they subside. Flow fluctuations between dry and wet seasons and years define the perenniality and degree of seasonality of the river and thus the biota the river can support. Plant and animal life cycles are linked to the onset, duration, and the magnitude of flow in each flow season. Changing these elements can alter flow cues so that life cycles are disrupted and species decline.

Because all parts of the flow regime play a role in sustaining the riverine ecosystem, altering any part can translate into physical and biological changes. The more the natural flow, sediment, or water quality regimes are changed, the more the river ecosystem will respond. This relationship may not be linear, and may be confusing as the rate of change can differ between ecological variables. For example, water chemistry changes can occur at an hourly time scale, while geomorphological change can require decades to reach a new dynamic equilibrium. Overall, change

may manifest as a general trend punctuated by major changes associated with thresholds being breached.

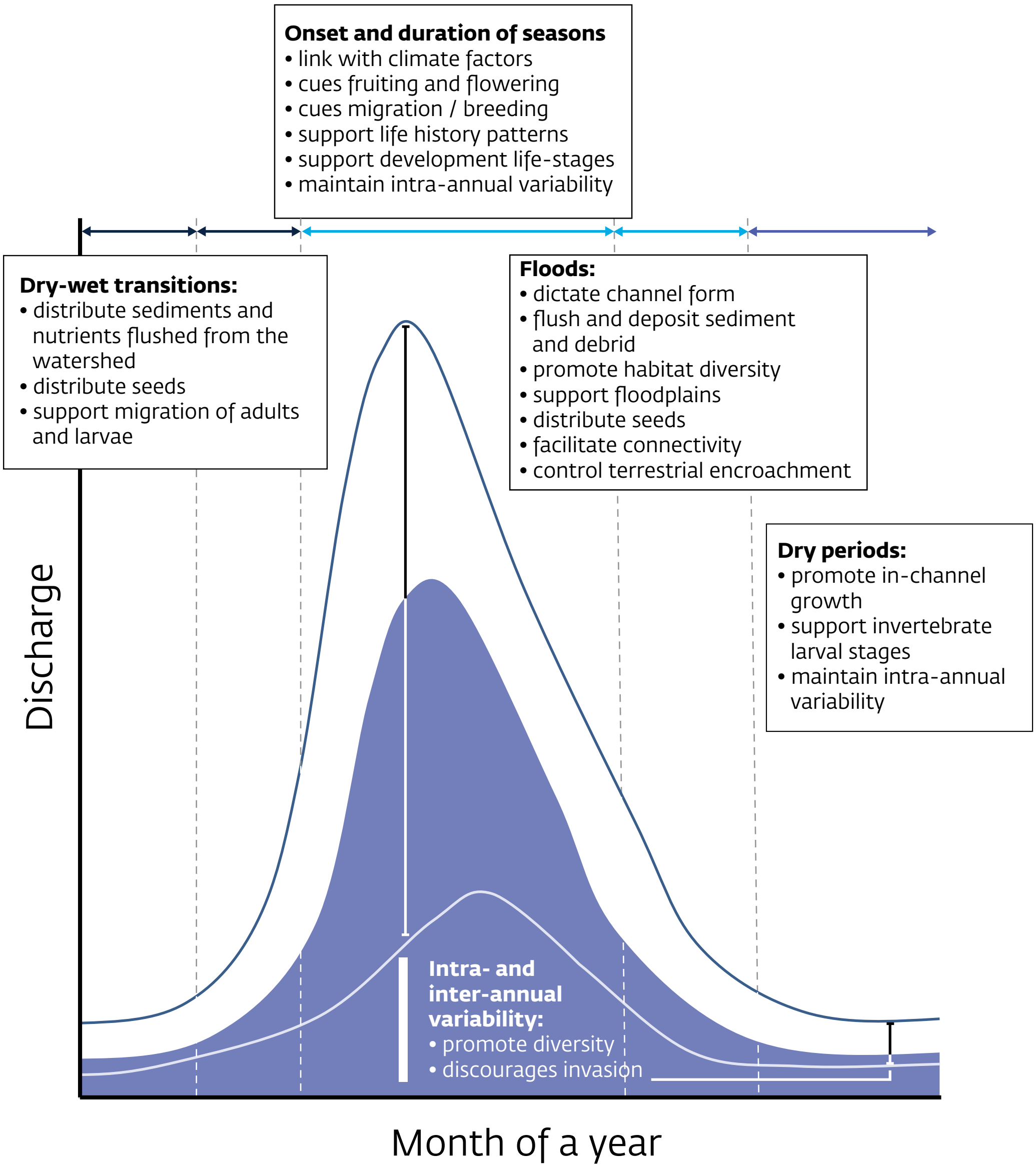
Three major thresholds can cause state changes in river ecosystems:

- Loss of longitudinal connectivity and thus the free movement of sediments, fish and organic material along the system
- Loss of floods leading to drying out of the river's floodplains and loss of lateral connectivity along the river
- Significant reduction or loss of baseflows leading to periodic drying out of all or part of a previously perennial channel

Some changes may be irreversible—such as the loss of a species or the loss or decrease of an ecosystem service—resulting in people who live near the river moving away permanently.

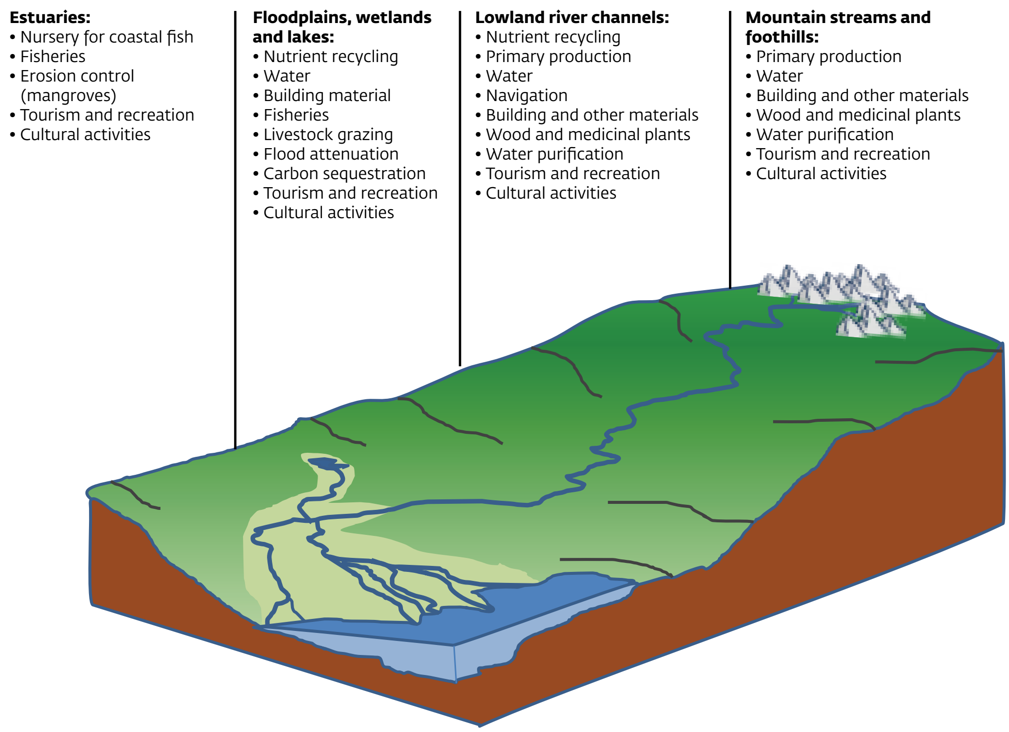
EFlows are set to support maintenance of the river ecosystem. They are selected to maintain riverine ecosystem services or values (see Box 2) at some pre-agreed or negotiated condition that is grounded in a consultative process with stakeholders. The EFlows should be a subset of the natural flow regime of the river, taking into account intra-annual and inter-annual variability of flow, and should not be limited to simple minimum low flow specification. EFlows should consider natural movements of sediment and the lateral and longitudinal migration of biota.

Figure 2.1: Importance of Different Parts of Flow Regime (after Poff et al. 1997; Bunn and Arthington 2002)



Box 2: EFlows, Ecosystem Services, and Values

Figure 2.2: Examples of Values or Services Provided by River Systems



Rivers support a range of environmental and social values for people through their natural functioning, which are variously referred to as ecosystem services or natural resource values (see Figure 2.2).

People, including businesses, derive many benefits from ecosystems: products from ecosystems; benefits from the regulation of ecosystem processes; non-material benefits from ecosystems; and the natural processes that maintain the other values.

Benefits obtained from the regulation of ecosystem processes reflect the inherent functioning of river ecosystems from which all of humanity benefits: natural water purification by the aquatic biota; stabilization of banks and coastlines; attenuation of floods; replenishment of groundwater; and support for an array of flora and fauna, including species of significance for people.

Nonmaterial benefits provided by rivers are valued worldwide: recreational opportunities; national symbols and borders; religious and spiritual ceremonies; inspiration for books, music, art and photography; and quality of life.

Natural ecosystem processes contribute to the wider functioning of the landscape: carbon sequestration; soil formation; nutrient cycling; pollination; and primary production.

These services or values tend to differ along the length of the river system, depending on the presence or absence of floodplains, and channel and flow characteristics (Figure 2.2). A similar value or service may also vary along the course of the river. Building materials available in the headwaters (gravels), for example, are likely to vary from those available on a floodplain (sands and muds for brick making). Similarly, a steep highland river offers different recreational opportunities than a low-lying meandering river bordered by floodplains.

SECTION 3

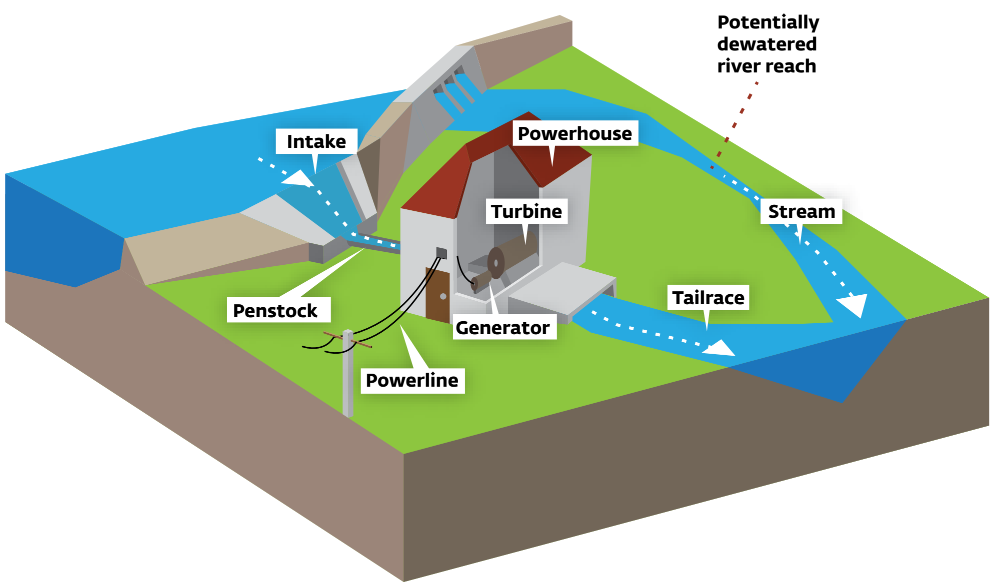
ENVIRONMENTAL FLOWS AND HYDROPOWER

Section 3. Environmental Flows and Hydropower

Hydropower projects can disrupt flows and alter the magnitude, frequency, duration, and timing of flow regimes and their sediments. The four main ways that these projects can affect a river ecosystem that are relevant here are the following:

1. **Total loss of flow:** A partially or wholly dewatered river reach (for example, Figure 3.1) may be created between the dam wall and the tailrace as flow is diverted out of the channel through the turbines, often for some distance and sometimes into other watersheds, which is discussed in (iv) on interbasin transfers.

Figure 3.1: Schematic of a Hydropower Project Diversion Facility[8]



8 Source: https://wiki.uiowa.edu/display/greenergy/Hydroelectric+Power

2. **Altered flow regime:** The reach downstream of the tailrace receives diverted water in a pattern (and quality) of flows dictated by operation of the dam, augmented by any flows entering from the dewatered reach and downstream tributaries. The downstream extent of flow modifications because of the hydropower project's operation defines the zone of dam-driven change.
3. **Changes to connectivity:** Longitudinal connectivity (which is up and downstream) is lost or reduced because of the barrier effect of the dam wall and the reservoir; and lateral connectivity between the main channel and floodplains and secondary channels may be lost or diminished because of reduction in the frequency of flooding. This situation can affect how animals move between habitats to successful complete their life cycles (with both upstream and downstream implications), and the transport of sediments and organic material downstream.
4. **Interbasin transfers:** Diversions of water out of a river basin affects two rivers, permanently reducing the Mean Annual Runoff of the donor river, while increasing that of the receiving river. The interbasin transfer of water can also introduce new species to the receiving basin, possibly triggering dangerous proliferation of pest species, the decline or extinction of valued species, or other changes to the ecosystem.

Not all hydropower projects have the same level of impact on their host river system, as many factors influence the potential severity. These factors relate to the location, design, and operating pattern of the hydropower project, and the associated degree of connectivity lost along the river. Combining two or more of the factors will usually increase the impact.

As an overview, the matrix in Table 1 identifies the level of impact likely from 14 permutations of dam location, design, and operation of a single hydropower project.[9] These are presented as five groups: Group 1 has two low-impact design and operation options with baseload generation (see also Box 3 on 'run-of-river' schemes); Group 2 has three options for medium storage dams with baseload generation; and Group 3 has three options for large storage dams with baseload generation. Groups 2 and 3 are repeated in Groups 4 and 5 with the inclusion

9 The following assumptions and broad definitions were used in creating the matrix in Table 1:

Low-impact design and operation	The authors use this term instead of any reference to "run-of-river" hydropower project (Box 3).
Large storage	Greater than 0.5 Mean Annual Runoff storage.
No diversion	Power generation in the channel at the dam wall.
Baseload	Constant power generation to the extent supported by inflow/storage.
Peaking power	Power generation at peak periods followed by periods of no power generation (peak power/baseload combination not considered).
Assumed	Any impoundment will trap inorganic and organic material, including seeds, invertebrates, eggs, and juvenile fish.

of peaking power generation. Rows define potential affects linked to each dam, in terms of the impact on the flow regime and river connectivity. Each of these permutations may have different and important effects on the river and its users.

Each box in the matrix is rated in terms of the expected level of impact from 0 (no or minimal impact) to 3 (large impact) and is color-coded with clear, blue, orange, or red reflecting the scores 0 to 3, respectively.

As the hydropower projects increase in terms of storage and extent of inter- or intra-basin diversion, the associated impacts on the host (and in some cases receiving) river's ecosystem increase. The scenarios with the highest scores (that is, worst impacts) are large projects (greater than 0.5 Mean Annual Runoff) that generate peaking power, are located on the mainstream of a river system downstream of a large tributary, and have a substantial diversion. These projects have the greatest potential to alter flow regimes and the nature of both donating and receiving rivers. They can prevent organic and inorganic material from moving up and down the waterway.

If more than one dam is situated within a basin, cumulative impacts can be greater than shown in Table 1. However, generalizations are difficult, and impacts are not always cumulative. Additional hydropower projects, for instance, may not cause significant additional environmental impacts in rivers that are already seriously impacted. To a point, synchronization of the operation of a cascade of dams can also reduce downstream impacts.

Table 1: Matrix of Relative Levels of (unmitigated) Impact Typically Associated with 14 Permutations of Design and Location of a Single Hydropower Project, in Five Groups (Groups 1[10] through 5 by column). 0 = no or minimal impact; 3 = large impact.[11]

			Group 1		Group 2			Group 3			Group 4			Group 5		
			low-impact design and operation-no diversion	Low-impact design and operation - with diversion	Medium storage, no diversion and baseload power	Medium storage, diversion returning to same river and baseload power	Medium storage, diversion returning to different river, and baseload power	Medium storage, no diversion and peaking power	Medium storage, diversion returning to same river and peaking power	Medium storage, diversion returning to different river, and peaking power	Large storage, no diversion and baseload power	Large storage, diversion returning to same river and baseload power	Large storage, diversion returning to different river, and baseload power	Large storage, no diversion and peaking power	Large storage, diversion returning to same river and peaking power	Large storage, diversion returning 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 taillace	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 downsteam 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	0	0	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 downsteam of large trib	0	0	0	0	2	2	2	2	3	3	3	3	3	3
	Impact on timing of season	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 downsteam 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
		Mainstem upstream of large trib	1	1	2	2	2	2	2	2	2	2	2	2	2	2
		Mainstem downsteam 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 downsteam 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

10 Note that hydropower projects that include a diversion may fall into the definition of "Group 1: Low impact design and operation" with an impact rating of "3". With a low-impact design, most of the flow regime is not impacted because storage is low, and if there is also no diversion then most of the dry season is also not impacted, as water passing through the turbines finds its way directly into the river. However, if a low impact design is combined with a diversion that takes water away from the river and through turbines, the part of the river between diversion and tailrace could be dry in the dry season.

11 The levels of impact shown in the table are indicative, and site-specific conditions may vary considerably from those illustrated.

Box 3: Run-of-River Hydropower Plants

Run-of-river is a term that is widely used to convey the message that a hydropower project will have a low impact on its host river ecosystem. However, no standard definition of a 'run-of-river' hydropower project exists and, as a result, the term embraces a considerable range of designs:

- Hydropower projects with no storage: that is, inflow matches outflow minute by minute, such as Sechelt Creek Generating Station, Canada.
- Hydropower projects with limited storage and no peaking-power releases: for example, inflow matches outflow over about 24 hours, such as Gulpur Hydropower Plant, Pakistan.
- Hydropower projects with moderate storage and peaking-power releases: for example, Ruacana Hydropower Project, Namibia.
- Hydropower projects that rely on large upstream storage facilities: such as, Hale Hydropower Plant and New Pangani Falls Hydropower Plant, Tanzania, which rely on the water stored at Nyumba ya Mungu Dam 200 km upstream.[12]
- Hydropower projects where the flow of a river is diverted from the host river, and may or may not feed back into the same river many hundreds of kilometers downstream: for example, Kishenganga Hydropower Project, India.

The term "run-of-river" covers such a wide array of design and operation features, and thus such an equally wide array of potential environmental and social impacts, that it has limited value from an environmental and social perspective.

Thus, this publication defines 'run-of-river' of hydropower projects as:

"Hydropower plants that release downstream into the same river, with a short or no diversion, have 48 hours or less dry-season storage and do not make peaking-power releases."

12 Nyumba ya Mungu Dam and the requirement to supply water to Hale Hydropower Project resulted in the destruction of Kirua Swamp and the livelihoods that were dependent on it (IUCN/PBO 2007).

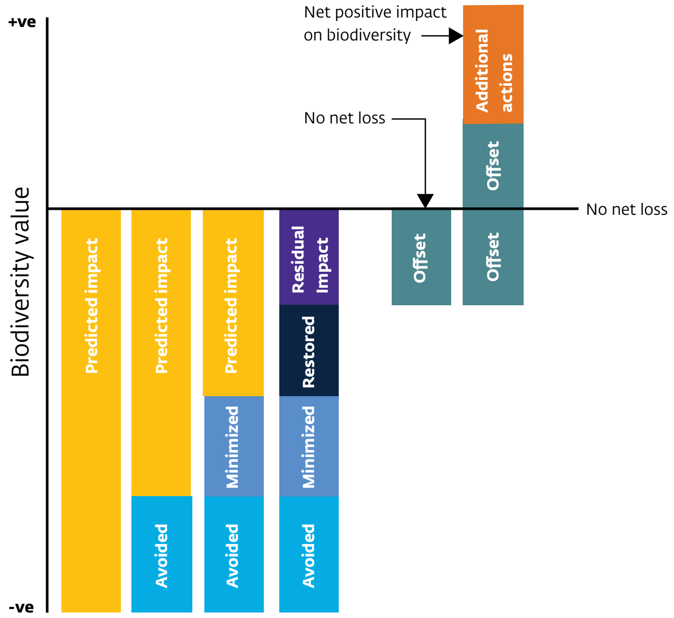
SECTION 4

ENVIRONMENTAL FLOWS AND THE MITIGATION HIERARCHY

Section 4. Environmental Flows and the Mitigation Hierarchy

A hydropower project should seek to minimize impacts on natural ecosystems and ecosystem services, while optimizing the project's energy generation potential. Adherence to the mitigation hierarchy from the earliest planning phase throughout the project life cycle can achieve hydropower generation that is more sustainable. This requires close attention to applying mitigation in sequence through the four main mitigation steps: avoid, minimize, restore, and offset (Figure 4.1).[13]

Figure 4.1: The Mitigation Hierarchy (after Mitchell 1997)



13 Based on IFC Performance Standards. Note that in the World Bank Environmental and Social Framework, the terminology used is "Avoid, Minimize/Reduce, Mitigate, and Offset."

Avoidance and **minimization** measures offer the greatest opportunity to reduce potential impacts of hydropower projects on rivers and can reduce the project's liability for **restoration** and **offset** measures, which are often harder and costlier to achieve.

Avoidance, in terms of the location of the dam site, is the single most important factor that dictates how a hydropower project affects a river system (Ledec and Quintero 2003). For many projects this might be the only means of preventing irreplaceable loss of biodiversity and the derived ecosystem services. A combination of **avoidance**, **minimization**, or **restoration** measures may be sufficient to achieve "no net loss" of natural habitat for some hydropower projects. **Offsets** are to be used only as a last resort, when avoidance, minimization, and restoration have all been pursued to the fullest extent possible.

"No net loss" and "net gain" can be delivered via restoration offsets, avoided loss offsets, or positive conservation actions. The best opportunity to identify and apply mitigation measures for hydropower projects is at the earliest design stage of a project when siting of the project's infrastructure is being considered. This is best done during a basin-level study involving some level of EFlows Assessment (see Section 5.1).

In general, mitigation for hydropower projects can include some combination of the following measures:

- **Avoid** through careful dam siting, design and operation.
- **Minimize** upstream or downstream effects through the provision of EFlows or fish passways.
- **Restore** through improved species, habitat or catchment management interventions, releases for cultural and religious rituals, or relocation of cultural infrastructure.
- **Offset** residual impacts through off-site actions, such as protection of other rivers with similar biodiversity in the same or adjacent catchments.

Implementing these mitigation measures may suggest that the planned level of power production would not be achieved, but experience has shown that this need not be the case.

The emphasis of a mitigation hierarchy focused on avoidance in high risk projects, and on no net loss versus net gain for high adverse impacts on natural habitat or critical habitat, is reflected in the values and guidelines developed by the World Bank Group and other funding institutions.[14] For instance:

14 Detailed guidance on World Bank Group policy and environmental and social safeguards is available at www.ifc.org/performancestandards and www.worldbank.org/safeguards

IFC emphasizes safeguarding protected areas, internationally and nationally recognized areas (such as key biodiversity areas) and areas that meet criteria for natural and critical habitats.[15] Critical habitats are the highest risk sites for biodiversity, where the greatest mitigation rigor is required and achievement of net gain expected. Natural habitats indicate a second tier of biodiversity risk, where mitigation is expected to achieve no net loss, where feasible. In all cases, biodiversity offsets should only be considered after all prior steps in the mitigation hierarchy have been fully assessed and implemented. Furthermore, the options for offsets in aquatic ecosystems are likely to become increasingly limited, costly, and technically complex as more rivers are developed.

The World Bank[16] distinguishes between natural habitats and critical habitats, with the latter including protected and proposed protected areas that meet the criteria of IUCN classifications: sites that maintain conditions vital for the viability of these protected areas; and areas recognized as highly suitable for biodiversity conservation, important to traditional communities (such as sacred groves), or are critical for rare, vulnerable, migratory, or endangered species.

The World Bank will not finance a project that may cause significant degradation or conversion of critical habitat, and that does not make adequate provision for net gain through an acceptable offset, which itself should involve a critical habitat. It may finance projects that cause significant conversion or degradation of natural habitat, but only if there are no feasible alternatives for the project and its siting and comprehensive analysis demonstrates that overall benefits from the project substantially outweigh the environmental costs. For projects in natural habitat, the mitigation hierarchy should be applied and may require establishing and maintaining an ecologically similar protected area (such as an offset).

EFlows Assessment within this context can help to minimize the upstream and downstream effects of water-resource developments by describing the consequences of dam location, design, and operation options based on identified ecosystem values to assist decision-making. In addition, some high-resolution holistic EFlows

15 The World Bank distinguishes between natural habitats and critical habitats, with the latter including protected and proposed protected areas. IFC distinguishes modified, natural, and critical habitats, whereby either modified or natural habitats that meet the threshold criteria can be critical habitats (for definitions see IFC 2012).

16 The World Bank Environmental and Social Standards (ESS) requires a differentiated risk management approach to habitats based on their sensitivity and values. The ESS addresses all habitats, categorized as "modified habitat," "natural habitat," and "critical habitat," along with "legally protected and internationally and regionally recognized areas of biodiversity value," which may encompass habitat in any or all of these categories. For more information, see: http://www.worldbank.org/en/programs/environmental-and-social-policies-for-projects/brief/the-environmental-and-social-framework-esf

Assessment methods (Section 6) can also provide information useful to evaluate other on-site design or mitigation measures, such as turbine size and type, release capacities, operating rules, location of the outlets, lateral and longitudinal river connectivity issues, catchment management interventions, and permanent protection for alternative important biodiversity areas.

EFlows scenarios have helped to identify good ecological and social outcomes linked to little or no production losses (Beilfuss and Brown 2010; Renofalt et al. 2010; Hagler-Bailly Pakistan 2014). They have demonstrated that a genuine commitment to explore the potential of EFlows considerably enhances the prospects for sustainability.

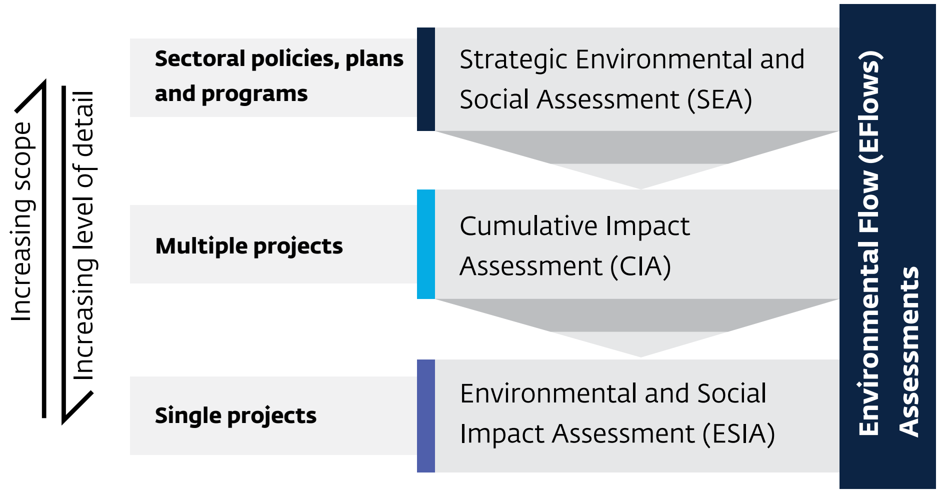
SECTION 5

EFLOWS ASSESSMENTS AND OTHER ASSESSMENT TOOLS

Section 5. EFlows Assessments and other Assessment Tools

To be most effective, EFlows Assessments should also be an integral part of a wider body of environmental planning and assessment tools. The four main assessment tools that aid water-resource planning and development are Strategic Environmental Assessments (SEAs), Cumulative Impact Assessment (CIAs), Environmental and Social Impact Assessments (ESIAs), and EFlows Assessments. SEAs and CIAs tend to have a broader geographic and sectoral scope than project-focused ESIAs. EFlows Assessments can be (and have been) done within the framework of any of these (Figure 5.1).

Figure 5.1: Scope and Level of Detail of Four Impact Assessment Processes[17]



17 EFlows Assessments are relevant and can be use at all levels—SEA, CIA, and ESIA—but the resolution and use vary and are relevant to the scale and purpose of the assessment at hand (for example, the EFlows Assessment for a project ESIA has more granularity and resolution than that for a SEA.)

For additional reference, The WBG Water Working Note 25: Integration of Environmental Flows in Hydropower Dam Planning, Design and Operations describes the tools and approaches aimed at protecting the ecological health of river ecosystems and the wellbeing of human communities that depend on them, while meeting human needs for water and energy through improved hydropower dam development and operation (Krchnak et al. 2009).

5.1 EFLOWS ASSESSMENTS IN SEAS, CIAS, AND ESIAS

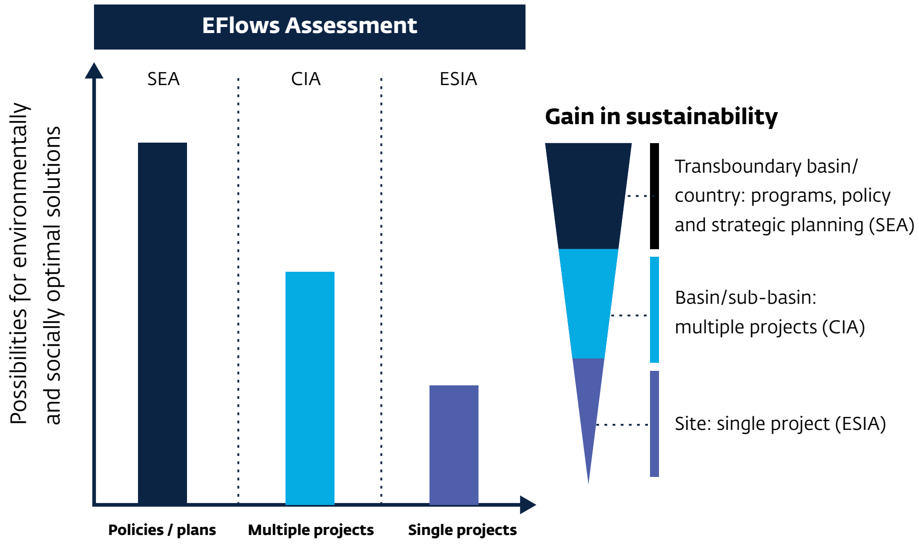
An integrated assessment of water resources, energy, biodiversity, natural resources, human demographics, and other strategic considerations at the scale of a basin, region or energy grid reveals opportunities and risks not apparent or available at the level of single projects. At a wider basin or subbasin level, it is possible to select optimal locations, balance such strategic and sectoral priorities as protecting ecosystem integrity and community livelihoods, enhance social cohesion, and highlight mitigation strategies that are far less possible to implement at the project scale (King and Brown 2015).

The concept of intact rivers, whereby a part of the river basin remains without structures that block or divert the flow, is important. This situation provides multiple benefits of sustaining riverine connectivity, retaining some natural variability in the downstream flows of water and sediments, and possibly reducing the operational constraints on hydropower projects in other parts of the basin. Removal of ecologically damaging dams from river systems has mostly focused on reintroducing river connectivity (of mainly sediments and fish passage) and reducing operational constraints on the remaining dams (for example, Penobscot River, Sandy River, White Salmon River, and Rogue River in the United States). Removal of these dams is often justified in cost-benefit terms because they contribute minor benefits relative to other dams in the same basin. In some cases, their economic, social, and environmental costs might have been avoided if the decision of whether to build them had been part of an initial basinwide planning exercise.

EFlows Assessments done within the framework of SEAs and CIAs allow the cumulative effects of such proposed developments to be clearly identified and so provide better protection of the environment through joint local-regional planning. This also allows developers to include the details of required EFlows in the feasibility studies and final design stages of their projects, prior to project-scale ESIA. The results can be a win-win solution, maximizing sustainability of the selected development (Figure 5.2).

Although governments and developers may view such large-scale planning as onerous and individual project developers feel it is outside the ambit of their

Figure 5.2: Potential for Achieving an Environmentally and Socially Optimal Solution at Different Levels of Environmental Assessment (after Clark 2015)



responsibility and scope of operations, the World Bank Group encourages such an approach whenever possible as the approach can benefit all operators (Opperman and Harrison 2008). They are in line with World Bank Group policy safeguards, which recognize the value of regional and strategic assessments and encourage consideration of broader regional and strategic development plans and priorities.

The sequence of planning and assessing the hydropower project is important. The shared experience of planners, scientists, engineers, governments, funders, and financial institutions during the last two decades has produced a clear recommendation that a basinwide EFlows Assessment should be done prior to the final decision on the hydropower project's location and design.[18]

In the absence of such basinwide studies, the EFlows Assessment for a specific hydropower project should be done in coordination with the project's ESIA (Table 2). Closely aligning the two processes makes sense as an ESIA should require the findings of the EFlows Assessment to properly ascertain the flow-related impacts of the hydropower project (Figure 5.3). Although the situation is improving, many ESIAs are still done without proper integration of, or alignment with, EFlows Assessments.

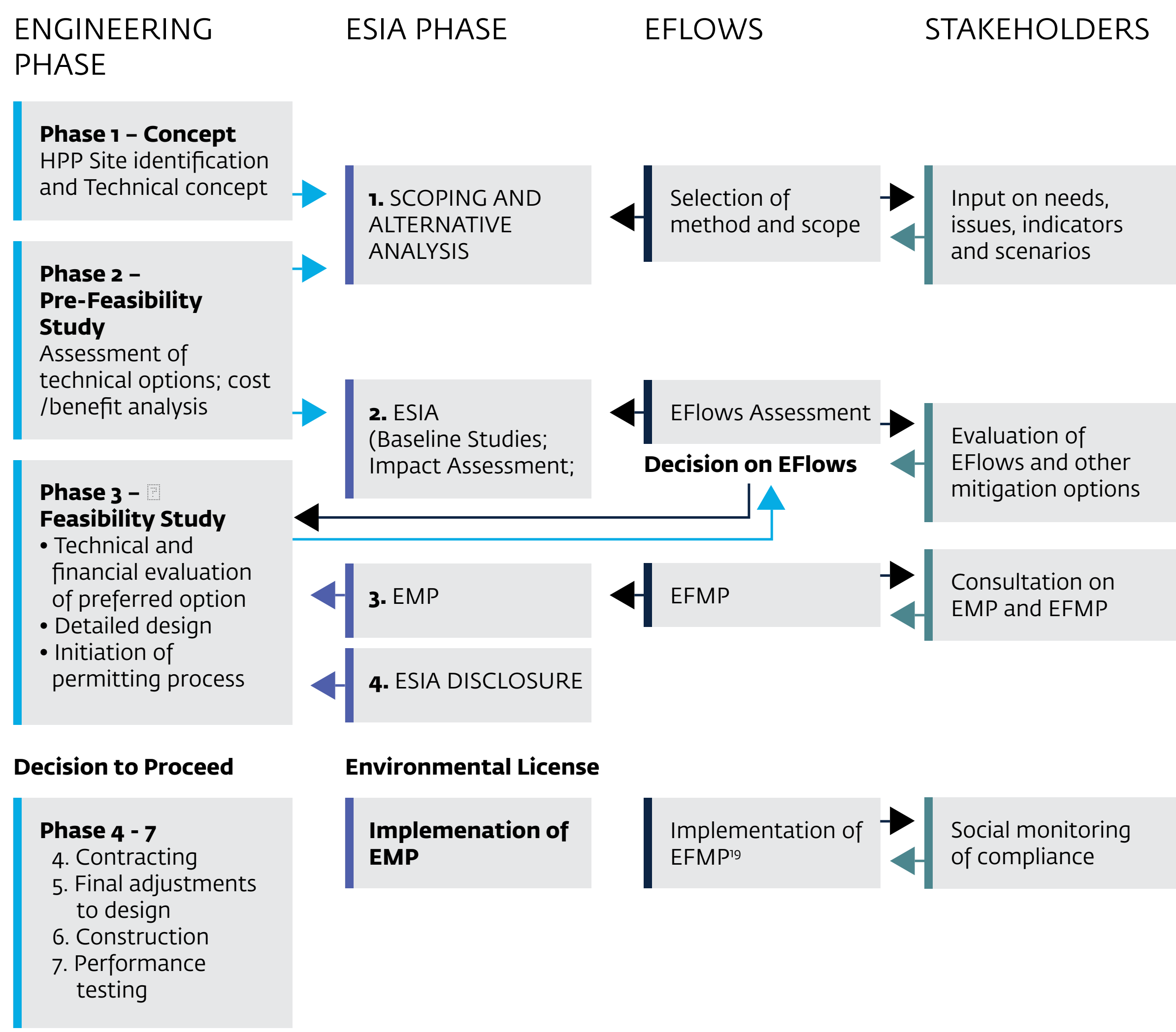
18 See joint statement on System-Scale Planning for Hydropower Development by The International Finance Corporation and The Nature Conservancy in 2017 at http://www.ifc.org/wps/wcm/connect/0304f0be-0b0e-410c-9d2c-bbb61547106e/2017+IHA+Congress+-+TNC_IFC+Joint+Statement_FINAL.pdf?MOD=AJPERES

Table 2: Support from EFlows Assessments for ESIA Fundamental Principles

ESIA Fundamental Principle	Relevant EFlows Assessment Activities
Alternatives Analysis	
Assess technically feasible alternatives.	Analyze scenarios associated with different locations, designs, and release regimes to assess the risks; determine the extent of deviation from the ecological and social baseline; support identification of optimal design/operation.
Mitigation Hierarchy (see Section 4)	
Prioritize measures to avoid impacts, followed by technically feasible measures to minimize impacts. Residual impacts should be addressed through restoration or offsets.	**Avoid**—consider EFlows implications of alternative HPP locations. **Minimize**—consider different operational flow scenarios in the EFlows Assessment (such as baseload versus peaking options; release of water and sediments). **Restore or offset**—incorporate restoration interventions into EFlows scenario analyses. Results of EFlows Assessments can provide input to design and operation of the HPP to meet EFlows releases, leading to optimization of energy production and the balancing of competing development and river protection goals.
Area of Influence	
Determine the area of influence of a project and scope the extent and scale of specialist studies required, and stakeholder engagement.	EFlows Assessments provide predictions for the full upstream and downstream extent of influence related to alterations in river flow.

Stakeholder Engagement	
Ensure meaningful stakeholder engagement commensurate with project risks and appropriate to the stakeholders affected.	Stakeholders in EFlows Assessments include representatives of government ministries and departments (such as water, agriculture, or planning), and a wide array of other interested parties, including HPP developers, conservation authorities, and representatives of other water users (such as agriculture power generators, industry, conservation, and tourism and recreation), as well as subsistence users of the river. In some cases, such as for transboundary rivers, the stakeholders may be represented on bilateral steering committees. The findings of EFlows Assessments need to be presented in a manner accessible to all stakeholders, particularly those directly affected by the proposed project. The EFlows process should obtain input from stakeholders on ecosystem uses, livelihood dependence, conservation priorities, possible water resource developments, and other aspects of concern to them that should be included in the flow scenarios to be investigated. EFlows Assessments that consider a range of possible scenarios can better support discussion and negotiation among all the stakeholders through examination of trade-offs.

Figure 5.3: Recommended Alignment of Project Planning with ESIA and EFlows Assessment



If a specific hydropower project has been selected based on a previously completed basinwide planning exercise that included a detailed EFlows Assessment, the results can be integrated into the ESIA and no further EFlows Assessment may be needed (Section 5.1). If an appropriate basinwide EFlows Assessment has not been done, then the scope and method for the EFlows Assessment should be agreed at the earliest engineering stages (concept and prefeasibility; Figure 5.3) and coordinated with the ESIA phases.

19 The EFMP is discussed in Section 9

The outputs of the EFlows Assessment and ESIA should feed into the engineering feasibility stage, leading to negotiation with stakeholders, and decisions on the nature of the development, the condition of the downstream river, the EFlows, and the final design features and operating rules to achieve this.[20]

Following the final design and compilation of an operational regime, a comprehensive Environmental Management Plan (EMP) with EFlows Management Plan (EFMP) should be developed. When the host country grants an environmental license prior to an EFlows Assessment or compilation of an EFMP, then project design and EFlows decisions should be revisited.

20 Often, the results of the EFlows Assessment are only fed into the operating rules after the ESIA has been completed and the environmental license awarded, which may result in the EFlows not being achievable or the developer seeing EFlows released as power lost. The same issue applies to other findings of ESIAs, which may be produced too late in the planning process to influence design or operational rules.

SECTION 6

EFLOWS ASSESSMENT METHODS

Section 6. EFlows Assessment Methods

Over the years, hundreds of methods for assessing EFlows have been proposed (Tharme 2003). Most methods are specific to a project or site, have only ever been applied once, or have never been published or peer reviewed. Some of the more enduring, broadly applicable and commonly used EFlows Assessment methods for rivers are listed in Table 3. These have been loosely categorized in terms of whether they are broadly hydrological, hydraulic, based on habitat simulation or holistic in approach. They are also grouped by the level of resolution at which they provide EFlows information.

Table 3: Commonly Used EFlows Assessment Methods for Rivers[21]

Method	Categorization	Level of Resolution	Type of Analysis	Assesses Peaking Power Impacts	Ecosystem	Attributes	Reference
The Tennant Method	Hydrological	Very low	Desktop	No	River	• **prescriptive:** does not react to scenarios • quick and simple • only fish habitat, not floods, sediments or any other ecosystem components • only rapid after local calibration of biological responses • not suitable for detailed planning	Tennant (1976); http://pubs.usgs.gov/of/2002/ofr02-340/html/comparison.html
New England Aquatic Base-Flow (ABF) Method	Hydrological	Very low	Desktop	No	River		
Indicators of Hydrologic Alteration/ Range of Variability Analysis (IHA/ RVA)	Hydrological	Low	Desktop	No	River	• software for hydrological analysis • reduces hydro data to summary statistics • restricted to hydro analysis	www.nature.org
The Desktop Model	Holistic	Low	Desktop	No	River	• **prescriptive:** does not react to scenarios • uses past EFlows Assessments in South Africa to predict flows needed per river health class • detailed instructions • limited to flows with a return period of ≤ one year	Hughes and Hannart (2003); www.ru.ac.za/iwr/research/software

21 Commonly Used EFlows Assessment Methods for Rivers

Method	Categorization	Level of Resolution	Type of Analysis	Assesses Peaking Power Impacts	Ecosystem	Attributes	Reference
Wetted Perimeter Method	Hydraulic rating	Low	Hydraulic habitat modelling	No	River	• **prescriptive:** does not react to scenarios • measures attributes of river channel • assumes hydraulic attributes have ecological meaning • concept mostly used now within more complex methods	Gippel and Stewardson (1998)
Instream Flow Incremental Methodology (IFIM) and Physical Abstract Simulation Model (PHABSIM)	Habitat simulation	Medium or high	Hydraulic habitat modelling	Yes	River	• **interactive:** can be used for scenarios • widely applied • quantifies habitat for target species as a function of flow • focuses on low flows • data intensive • weak or no link to subsistence use or stakeholders	Stalnaker et al. (1995);www.fort.usgs.gov/products/software/ifim/
CASiMir	Habitat simulation	Medium or high	Hydraulic habitat modelling	Yes	River	• **interactive:** scenario based • evaluates habitat quality for fish and benthic invertebrates • addresses alterations in riverine habitats with development	Jorde (1999)); www.casimir-software.de

Method	Categorization	Level of Resolution	Type of Analysis	Assesses Peaking Power Impacts	Ecosystem	Attributes	Reference
System for Environmental Flow Analysis (SEFA)	Habitat simulation	Medium or high	Hydraulic habitat modelling	Possibly	River	• **interactive:** scenario based • quantifies habitat for target species as a function of flow • focuses on low flows • software, guidelines for data collection and user manual	www.sefa.co.nz
The Building Block Methodology	Holistic	Medium or high	Functional analysis	Possibly	River, lake, wetland, floodplain	• **prescriptive:** does not react to scenarios • simple concept • extensive user manual • translated into several languages • weak or no link to subsistence use or stakeholders	King and Louw (1998); http://www.wrc.org.za/Knowledge%20Hub%20Documents/Research%20Reports/TT%20354-CONSERVATION.pdf
The Benchmarking Methodology	Holistic	Medium or high	Functional analysis	Possibly	River, lake, wetland, floodplain	• pools knowledge on all rivers of a similar type to predict change in another one • does not address higher floods • precursor of ELOHA	Brizga et al. (2002); www.researchgate.net/publication/259044960

Method	Categorization	Level of Resolution	Type of Analysis	Assesses Peaking Power Impacts	Ecosystem	Attributes	Reference
Eco Modeller	Holistic	Medium or high	Functional analysis	Possibly	River, lake, wetland, floodplain	• **interactive:** scenario based • software and manual • requires considerable expert input • semi-quantitative/ quantitative predictions of change • used in basin planning	http://ewater.org.au/products/ewater-toolkit/eco-tools/
ELOHA	Holistic	Medium	Functional analysis	No	River	• region-scale approach for coarse planning • provides initial, broad-brush estimates of flow • cannot be used for detailed planning and management • does not have or specify models and methods to use • useful for synthesizing and using data and knowledge	Poff et al. (2010); www.nature.org
Downstream Response to Imposed Flow Transformation (DRIFT)	Holistic	Medium or high	Functional analysis	Yes	River, lake, wetland, floodplain, estuary	• **interactive:** scenario based • provides semi-quantitative or quantitative predictions of change, for use in planning, design and operation • strong socio-economic module • includes barrier effects • software, guidelines for data collection and user manual	King et al. (2003); Brown et al. (2013); www.southernwaters.co.za

Method	Categorization	Level of Resolution	Type of Analysis	Assesses Peaking Power Impacts	Ecosystem	Attributes	Reference
Murray-Darling (MD) Basin Plan SDL Adjustment Ecological Elements Method	Holistic	Medium or high	Functional analysis	Possibly	River	• **interactive:** scenario based • provides semi-quantitative or quantitative predictions of change, for use in planning, design and operation • not used widely outside of the MD Basin	Overton et al. (2014); www.researchgate.net/publication/262935957
RANA-ICE	Holistic	Medium or high	Functional analysis	Possibly	River	• **interactive:** scenario based • provides semi-quantitative or quantitative predictions of change, for use in planning, design and operation • used in Costa Rica	Chaves et al. (2010); http://iahs.info/uploads/dms/15068.50-198-199-Chaves.pdf

- **Hydrological methods** use summary statistics from hydrological data sets, such as a percentile from the annual flow duration curve, or the lowest recorded flow, to set what is often called a "minimum flow" for the river.
- **Hydraulic-rating methods** use simple hydraulic variables, such as wetted perimeter or depth, as surrogates for ecological data on habitat and predict how these will change with variations in discharge.
- **Habitat-simulation techniques** measure the most-often used hydraulic habitat of indicator species and then model how much of this habitat would be available over a range of flows.
- **Holistic methodologies** address the condition of the whole river ecosystem, including individual species or guilds in the channel, the riparian zones, floodplains and estuary where relevant. These methodologies are often connected to societal, resource, and economic issues. This category has become less relevant with time, as many methods have elements of all four.

In general, hydrological and hydraulic methods are inherently low-resolution methods; habitat-simulation methods are of medium resolution; and holistic methods cover the full spectrum from low- to high-resolution methods but are generally the latter.

6.1 LEVEL OF RESOLUTION

As stated, EFlows Assessments can provide information at a low-, medium- or high-level of detail, depending on the requirements.[22]

Low-resolution methods are usually desktop techniques involving the analysis of hydrological or hydraulic data to derive standard indices as recommended flows. The outcomes are typically a recommended 'minimum flow' for ecosystem maintenance, based on data extrapolated from areas where more detailed studies have been undertaken. These approaches do not provide any detail on how parts of the river ecosystem (for example, channel, water chemistry, vegetation, invertebrates, fish, and wildlife) are likely to change. It may include a short field trip.

Medium- and high-resolution methods tend to be similar in their approach. Many can be used at either a medium or a high resolution, but when applied at a high resolution they incorporate additional detail, such as the survival of individual species, impacts of sediment reduction, effects of peaking-power releases, and other river- or project-specific variables, including management interventions.

22 Appendix A and B provide generic Terms of Reference (ToR) for EFlows Assessments at each of these levels of resolution for ESIAs and SEAs/CIAs, respectively. Appendix C is a basic checklist for reviewing EFlows Assessments.

As such they tend to be better able to meet the information needs of individual projects than the low-resolution methods.

Both medium- and high-resolution approaches collect and use data from the study river and focus on identifying relationship between changes in river flow and one or more aspects of the river system. The two methods vary by the number of components of an ecosystem addressed and the level of effort invested into collecting and analyzing local information. Many medium- and high-resolution methods also have social modules and can evaluate the potential implications for people in terms of, for instance, resources harvested, flood-reliant agriculture, navigation, household incomes, and environments of religious or cultural significance.

6.2 PRESCRIPTIVE OR INTERACTIVE

Depending on their conceptual approach, EFlows Assessment methods can be either prescriptive or interactive (see Table 3, under "Attributes").

Prescriptive EFlows methods address a specific objective and tend to recommend a single flow value or flow regime to achieve it. Their outcomes do not to lend themselves to consultation or negotiation, because effort is mostly directed to justifying the single value, and frequently insufficient information is supplied on the implications of not meeting the recommended value to allow an informed compromise (Stalnaker et al. 1995). For this reason, prescriptive methods are not well suited to situations where the implications of flow change need to be explored and/or negotiated.

Interactive methods evolved to meet the IWRM requirement of greater inclusion of stakeholders in the decision-making process. They focus on the relationships between changes in river flow and a range of aspects of the river. Once these relationships are established, the outcome is no longer restricted to a single interpretation of what the resulting river condition would be. Instead, scenarios of different management plans or flow regimes can be compiled, each with their predicted ecological and social outcomes. The scenarios provide information that was not available to decision makers and stakeholders until the last decade or two, supporting negotiations for a preferred future. The chosen scenario contains a flow regime that will become the EFlows for that river. These approaches are invaluable in stakeholder, sector, and transboundary negotiations.

6.3 METHODS FOR NONRIVER AQUATIC ECOSYSTEMS

Established EFlows methods have been developed to address rivers, because flowing water is a major focus of water-resource developments. Some estuarine-specific methods exist, but few are dedicated exclusively to lakes or wetlands. For this reason, where the potential impacts of a hydropower project extend beyond the river to other ecosystems, the EFlows Assessment should be done at a high resolution using a combination of methods, or one that can address a variety of ecosystem types. Examples of nonriverine ecosystem changes that can be affected by hydropower project development and operation include the following:

- The extent and timing of salt-water intrusion within estuaries
- The extent, depth, and timing of inundation of floodplains or wetlands
- Changes to water levels in lakes
- Changes to groundwater levels and recharge

6.4 DATA REQUIREMENTS

The data requirements for an EFlows Assessment (Table 4) are closely related to the level and type of method that is applied and the nature of the downstream ecosystems. Medium- and high-resolution methods rely on published information for life histories and other flow-related requirements of species present in a river, augmented by limited data collection.[23] Table 4 shows data requirements for EFlows assessments at different resolutions.

6.5 TIME AND COST

The scope and details of EFlows Assessments dictate their cost. Most medium- to high-detailed EFlows Assessments require at least 6 to 12 months to complete, even if life history data are based mainly on readily published information, as incremental data collection requires consideration of seasonal changes. This time frame allows data to be collected at relevant times throughout a year. Ideally, assessments should start in the dry season, because the features of the river channel can be seen, along with identifying sites, cross-sectional profiles, and characteristics of sampling.

Table 5 presents a useful guide for estimating the technical aspects of a low, medium and high-resolution EFlows Assessment for a single hydropower project under different scenarios and situations. Although the location of the project, travelling time, and extent of stakeholder liaison required can indicate the effort needed, they have been excluded from Table 5 because they vary widely between projects and sites.

23 Note: Even high-resolution methods tend to be based mainly on published information, and only involve limited augmented data collection, because much of the life history information takes years to collect and is the product of long-term research, and often multiple research projects targeting different aspects of a species. Often, collection of such data within typical timelines for HPPs is not possible. If the EFlows considerations were introduced on the same timeline as engineering considerations, more data collection would be possible.

Table 4: Data Requirements for EFlows Assessment for Hydropower Projects

Data		Resolution	
		Low	Medium / High
Socio-economic	Production, regulatory, cultural and supporting ecosystem services (including spiritual, tourism and navigational uses) and river-related health threats.	Yes	Yes
Hydrology[24]	Long-term, ideally ≥30 years, time-series of natural and present-day discharge at sites of interest.	Yes	Yes
Hydraulics	For example, depths and velocities in the river channel; depths or area of inundation on a floodplain or water levels in a lake.	No	Yes
Water quality	This includes chemical and thermal aspects.	No	Yes
Geomorphology	Availability and distribution of key aquatic habitats; sediment loads; bank erosion and other vulnerable channel features.	No	Yes
Plants	Abundance, species composition, distribution and recruitment of key riparian and aquatic plant communities and links to flow.	No	Yes
Invertebrates	Habitat and species conservation status, abundance, distribution and recruitment (including migration routes and timing) of species of concern, and links to flow. Invertebrates and fish would normally be included and other faunal groups, if they have links to river flow and are perceived to be important in the specific river.	No	Yes
Fish		No	Yes
River-dependent herpetofauna, birds and mammals, and others		No	Yes

24 Usually at a monthly time-step for low-resolution approaches, at a daily time-step for medium-and high-resolution approaches, and at an hourly time-step for evaluation of peaking HPP operations.

Table 5: Costs for Low-, Medium- and High-Resolution EFlows Assessments[25]

Level of Resolution	Units	Low Resolution[26]	Medium Resolution	High Resolution
Team and Effort				
Number of EFlows practitioners	People	1	1-2	1-2
Number of specialists	People	1-2	2-6	6-10
Number of site visits	Trips	1	1-2	2-3
Number of scenarios	Number	1-4	3-4	4+
Duration	Months	1-2	6-12	6-24
Time and Cost Estimates				
Preparation	Person days	1-2	10-30	20-50
Data collection	Person days	2-4	10-40	40-80
Assessment	Person days	1-3	10-40	40-110
Write-up	Person days	1-3	10-30	30-50
Total	Person days	5-12	40-140	130-290
Cost	$ (x 1,000)	4-10	30-110	100-400
Additional Time and Level of Effort				
Flow routing for peaking	Person days	n/a	10-20	15-30
Restoration and offset measures	Person days	n/a	10-20	20-60
Social aspects/Stakeholder engagement	Person days	n/a	20-40	30-60
Additional specialist	Person days	n/a	15-25	20-40
Additional scenario	Person days	n/a	2-10	2-10

25 After King and Brown (2015). All numbers are estimates indicating the relative costs of each level of assessment. Actual costs may vary widely depending on the nature and location of the required study.

26 Low-resolution assessments may still include a field trip, for example, spanning 5 to 12 person days, depending on the methods and on the number of people involved in site visit.

6.6 CLIMATE CHANGE AND EFLOWS ASSESSMENTS

The changes in volume, intensity, and frequency of flows associated with climate change will have consequences for all rivers. World Bank Water Working Note No 28: Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation provides guiding principles, processes, and methodologies for incorporating climate change adaptation for water sector projects, emphasizing the impacts on ecosystems (Le Quesne et al. 2010). Additionally, the Hydropower Sector Climate Resilience Guidelines commissioned by the World Bank provides guidance to those working in the hydropower sector on how to screen for climate change given the uncertainties that climate change brings (Mott MacDonald 2017).

When deciding to build hydropower projects and in evaluating their potential impact on rivers, one needs to consider the effects of climate change and this can be done by including climate change in different scenarios of the EFlows Assessment. Most interactive EFlows methods can incorporate climate change predictions, provided the changes in the flow regime can be simulated via a Climate Change Model and a Rainfall-Runoff Model.

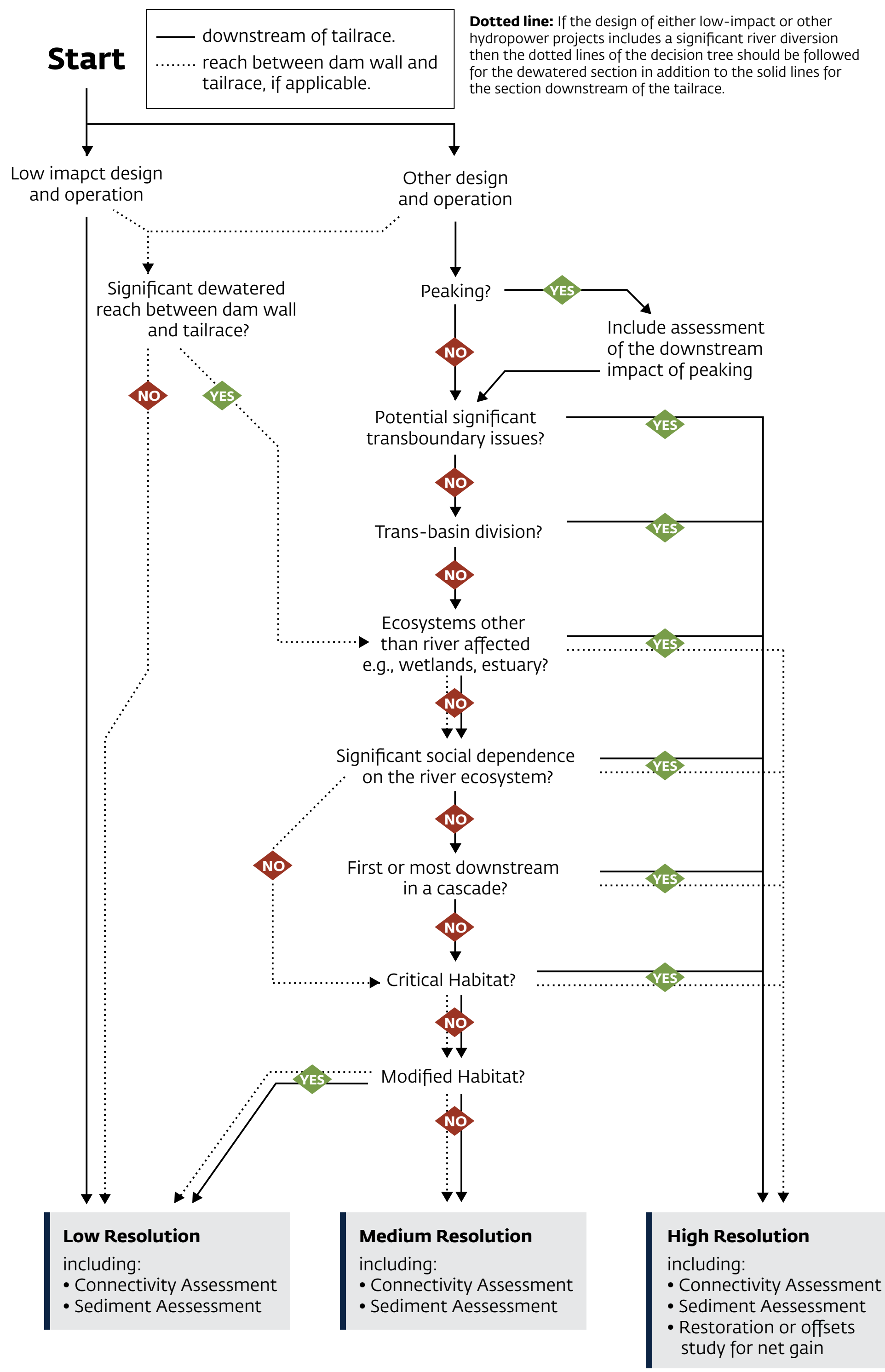
SECTION 7

EFLOWS DECISION TREE

Section 7. EFlows Decision Tree

The EFlows decision tree in Figure 7.1 can help select an appropriate EFlows method for hydropower projects. Section 7.1 explains the YES/NO decision points to consider when working through the decision tree for individual hydropower project; and Section 7.2 discusses how to use the decision tree at the basin or subbasin level.

Figure 7.1: Decision Tree for Selecting EFlows Method



In general, the decision tree will recommend the following:

> **Low-resolution** EFlows methods for hydropower plants that will not affect natural **or** critical habitat; **or** rare, endangered or threatened species or species assemblages; **and** where there is no significant social reliance on the riverine ecosystem; **or** for low-impact design and operation projects[27], or; for baseload plants that have no substantial influence on the flow regime. Typically, this level of assessment could result in a minimum flow recommendation for the dry season—on the understanding that flows in the months outside of the dry season are relatively un-impacted.
>
> **Medium-resolution** methods for hydropower plants that will not affect critical habitat, **or** rare, endangered or threatened species or species assemblages; **and** where there is no significant social reliance on the riverine ecosystem; **or** part of an existing cascade of dams or hydropower plants, as long as they are not the most downstream one (that is, they are not the last one in a cascade).
>
> **High-resolution holistic** methods for hydropower plants that will affect critical habitat, **or** rare, endangered or threatened species and species assemblages; **or** may significantly degrade or convert natural habitat; **or** that will affect aquatic ecosystems other than rivers, such as an estuary or a floodplain; and/**or** where there is significant social reliance on the riverine ecosystem potentially affected by the hydropower plants. The decision tree will also recommend high-resolution assessments for transboundary or trans-basin diversions.

In addition to considering flow-related impacts, all EFlows Assessments should address the potential impacts on the river system of any disruption in connectivity along the river and of the capture of sediments by the hydropower projects.

If hydro-peaking is envisaged, then the EFlows method chosen must be augmented with an assessment of the downstream impacts throughout the day of peaking releases. Some methods can incorporate such an assessment, while for others it must be done separately. Similarly, when the hydropower plant is situated in natural or critical habitat, in order for developers to demonstrate either 'no net loss' (NNL) or a 'net gain' (respectively) in biodiversity, there is likely to be a need to consider restoration or offsets in addition to setting EFlows.[28]

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27 Defined as: *Hydropower plants that release downstream into the same river, with a short or no diversion, have ≤ 48-hour dry-season storage and do not make peaking-power releases.*

28 NNL and Net Gain can be delivered via restoration offsets, avoided loss offsets or positive conservation actions. Offsets are to be used only as a last resort, when avoidance, minimization, and restoration have all been pursued to the fullest extent possible.

7.1 APPLICATION OF THE EFLOWS DECISION TREE FOR INDIVIDUAL HYDROPOWER PROJECTS

7.1.1 Choosing an Appropriate Line in the Decision Tree

The first step in the decision tree is to categorize the hydropower project under evaluation in terms of its storage capacity, and whether the design includes significant river diversion.

'Low-impact design and operation' hydropower projects are defined as *"hydropower plants that release downstream into the same river, with a short or no diversion, have ≤ 48-hour dry-season storage and do not make peaking-power releases"* (see Section 3). For the decision tree, all hydropower projects that will not be operated according to the definition of *"low impact design and operation"* will fall under **'Other design and operation.'**

If the design of either low-impact or other hydropower projects includes a river diversion (see Section 7.1.3) then the dotted lines of the decision tree should be followed for the dewatered section in addition to the solid lines for the section downstream of the tailrace (see Figure 7.1).

The subsequent direction follows the logic set out in the matrix in Section 3, that is, based on the level of impact associated with the location, design, and operation of the hydropower project.

7.1.2 Peaking versus Baseload Generation

The decision point **'Peaking?'** refers to a hydropower project that releases water for power generation at the time of peak demand. These releases typically have the following characteristics: a high frequency, high magnitude, a short duration relative to unregulated rivers, and not confined to times of natural flood events. The potential impacts associated with such releases require special consideration, including evaluation of flows on an hourly basis. Specific impacts associated with peaking can include the following:

- Flushing away of organisms during the rapid rise of flows at the start of the release
- Stranding of fish and other aquatic organisms as the peaking release recedes.
- Increased bank instability because of water-logged banks slumping
- Rapid changes in water quality, including temperature and dissolved oxygen levels, which can affect aquatic organisms
- Downstream navigation and safety issues

7.1.3 Dewatered Reach between Dam Wall and Tailrace

The decision point **'Significant dewatered reach between the dam wall and the tailrace?'** refers to dams that divert water away from the river channel through turbines and return it downstream, leaving a partially or wholly dewatered reach. One should assess the significance of the diversion's impact on an individual basis taking into account the diversion's length, the condition of the river ecosystem between the abstraction and the tailrace, the habitat and species that will be affected, and the rivers' social importance. Generally, diversions that would dewater more than a few hundred meters of river should be deemed significant and the affected river reach should be assessed separately from the reaches downstream of the tailrace (see dotted lines in Figure 7.1).

In practice, ESIAs often consider only the dewatered reach as subject to potential adverse impacts, and neglect assessment of changes in flow patterns downstream of the tailrace, for example, from peaking or reservoir-filling. They also do not always consider impacts on receiving rivers when there is an interbasin transfer.

7.1.4 Significant Transboundary Issues

The decision point **'Significant transboundary issues?'** refers to a hydropower project situated on an international river basin, where the project's effects in one country are expected to extend to another country. One should assess the transboundary effects on an individual basis, taking into account the degree of change in flow and sediment regimes relative to the pre-project baseline and the impact, if any, on migratory species.

If the answer to this question is **YES,** then a high-resolution methodology is recommended. This recommendation is because in situations where flow and other changes as a result of the hydropower project materially affect a downstream country, the decision on the EFlows should be a joint decision between the project's host country (which is presumably reaping its benefits) and the downstream country. Such negotiations tend to require more information than low- and medium-resolution methods typically offer. Moreover, in transboundary settings it is recommended that the method is high-resolution and interactive, producing options (scenarios) for consideration and with the downstream country involved from the start of the process.

7.1.5 Trans-basin Diversion

The decision point **'Trans-basin diversion'** refers to a hydropower plant that diverts water from one river into another, even if the receiving river is a tributary of the host river.

If the answer to this question is **YES,** then a high-resolution methodology is recommended. This recommendation is because much higher flows than natural may affect the receiving system, which is often not dealt with in low- and medium-resolution methods. As an example, the previously unimpacted Ash River that transports water from the Lesotho Highlands Water Project to the Vaal River in South Africa (via the Muela Hydropower Project), became severely eroded because of receiving unnaturally high discharges and had to be canalized.

7.1.6 Ecosystems other than River Affected, such as Wetland or Estuary

The decision point **'Ecosystems other than river affected, such as a wetland or an estuary?'** refers to a hydropower project with a design or operation that is expected to affect an aquatic ecosystem other than a river. This distance downstream to be considered depends on the river, dam design, and operation, so should be assessed for each hydropower project. Section 6.3 provides examples of possible nonriverine ecosystem changes.

If the answer to this question is **YES,** then a high-resolution methodology is recommended. This recommendation is because there are few regionally-generic methods for estuaries, lakes, and wetlands, and so the EFlows Assessment is usually done at a high resolution either using a combination of methods, or a method that can address a variety of ecosystem types.

7.1.7 Social Dependence on River Ecosystem

The decision point **'Significant social dependence on the river ecosystem?'** refers to situations where riparian communities or other river users depend on ecosystem services provided by the river that may be significantly affected by introducing a hydropower project. The following are livelihood activities that could be at risk: flood-recession agriculture; irrigation system (for example, quantity or timing); river and floodplain fisheries; use of the river for navigation, tourism, recreation or river crossings; harvesting of resources (for example, reeds or sand); spiritual purposes: and any other use that could be disrupted by the hydropower project's presence or operation.

If the answer to this question is **YES,** then a high-resolution method is recommended.

7.1.8 First or Most Downstream in Cascade

The decision point **'First or most downstream in a cascade?'** refers to either the hydropower project that is the first to be constructed or considered in a planned cascade of hydropower projects, or the most downstream hydropower project in the cascade.

If the answer to this question is **YES,** then a high-resolution method is recommended because it can be used to negotiate EFlows for the entire cascade, thereby maximizing the opportunities for mitigation and forgoing the need for additional EFlows Assessments for subsequent upstream hydropower projects in the sequence.

7.1.9 Critical Habitat Affected

The decision point **'Critical Habitat?'** refers to situations where the hydropower project may be located within or upstream of, and may impact on the ecological integrity or attributes of, areas that are defined as critical habitat (as defined by IFC and the World Bank Group, respectively), or other areas with high value biodiversity. These situations raise the risk profile of a project significantly.

Natural and critical habitats are treated differently in the decision tree because the level of assessment and mitigation required by the World Bank Group.

The decision point refers to situations where the affected habitat contains high-value biodiversity (such as species, ecosystems, or other sites) that do not satisfy thresholds for critical habitat. This acknowledges that biodiversity values lie on a spectrum from low to high value and that values that come close to such thresholds, though not triggering them, may still pose risks that require mitigation. These values could exist within natural or modified habitats.

If the answer is **YES** then a high-resolution methodology is recommended. Where the answer is **NO**, the decision tree moves on to a choice between 'modified' (and noncritical habitats).

7.1.10 Modified Habitat Affected

The decision point **'Modified Habitat?'** provides guidance on EFlows resolution for the remaining habitats, recognizing natural habitats that do not support high biodiversity values at risk from the hydropower project and modified habitats that do not meet any other criteria. The World Bank Group generally encourages development within modified habitats but acknowledges that some mitigation may be required. Projects in natural habitats, even without high values, trigger additional World Bank Group requirements of "no net loss."

If the answer is **YES** then a low-resolution methodology is recommended. Where the answer is **NO,** the assumption is that the potentially affected area represents natural habitat that is not critical and does not contain high biodiversity value at risk of hydropower project developments, and a medium-resolution approach should be applied.

7.1.11 Connectivity Assessment

A connectivity assessment ascertains the requirements of migratory aquatic species based on ecological processes, such as links and movement between breeding and feeding areas, and explores how the hydropower project's barrier may affect these processes. The first and minimum step in a connectivity study is to identify whether migratory species are present in the rivers. This should be followed by assessing the extent of migration required to sustain their populations, and the ecological triggers and processes that may be influenced by flow modifications caused by the hydropower project's construction and operation.

7.1.12 Sediment Assessment

The sediment and connectivity assessments are linked, with the former being particularly important in rivers with high sediment loads. Hydropower projects can trap sediments, altering the flow downstream and affecting channel morphology and habitats. They can substantially reduce the bedload and suspended loads in the reaches immediately downstream of the dam, inducing channel instability, bed coarsening, loss of sand deposits along the marginal areas, and loss of key habitats, such as gravel spawning beds. Flushing sediments from a reservoir may help re-introduce them to the downstream river but this has the risk of anoxic sediments moving downstream, which can blanket habitats, smother gills, increase the embeddedness of riffles, and detrimentally affect water quality. The EFlows Assessment needs to address all such potential effects, as managing flows alone will not mitigate them. A comprehensive sediment assessment requires an understanding of sediment budgets at a basin scale.

7.2 APPLICATION OF EFLOWS DECISION TREE AT BASIN OR SUBBASIN LEVEL

EFlows Assessments done at the basin or subbasin level can use the same methodologies as those done at project-specific level and at different levels of resolution, depending on the study's objective. Low-resolution, rapid methods are useful exercises to encourage basinwide thinking and guide the selection of strategic priorities. Higher-resolution methods are needed for detailed water-resource planning, including location, design and operating rules for dams.

Considering water developments at the basin or subbasin level can avoid many environmental and social impacts through careful dam siting. The hydropower project's location in a catchment can determine how the project affects the riverine ecosystem (see Section 3), and hence the recommended level of the EFlows Assessment. Ideally, there should be a suite of options for the siting of hydropower plants (and other developments) to help decide the level of resolution of the EFlows

Assessment. Here are the basic steps for assessing the potential impacts of planned hydropower projects at the basin or sub basin level:

1. Define the geographical scale of the assessment exercise.
2. Complete a geomorphological delineation of the aquatic ecosystems in the study basin, which should identify similar river reaches and ecosystems other than rivers, such as, wetlands, lakes, floodplains, and estuaries.
3. Complete a hydrological and sediment-supply assessment, and map the key areas and issues.
4. Complete a conservation/biodiversity assessment, and map the key areas of sensitivity.
5. Complete an assessment of social uses and values of the rivers, and map the key resources used.
6. Overlay plans for water and energy developments on the maps generated in steps 2-5.
7. Engage with relevant stakeholders to evaluate various hydropower-conservation trade-offs and permutations.
8. Select an environmentally and socially sustainable set of locations for proposed hydropower project and other developments.

After identifying a short list of possible locations for the hydropower plants, the next steps are the following:

9. Work through the decision tree for each of the potential developments to decide on the level of resolution for the EFlows Assessment.
10. Select a suitable interactive method or methods (see Section 6.2) according to the outcomes of Step 9.

The outcome of Step 9 may yield different resolution levels for different hydropower projects, which can be accommodated in the EFlows Assessment. See the term of reference (ToR) for basinwide EFlows Assessments in Appendix B.

SECTION 8

ENVIRONMENTAL FLOWS AND ADAPTIVE MANAGEMENT

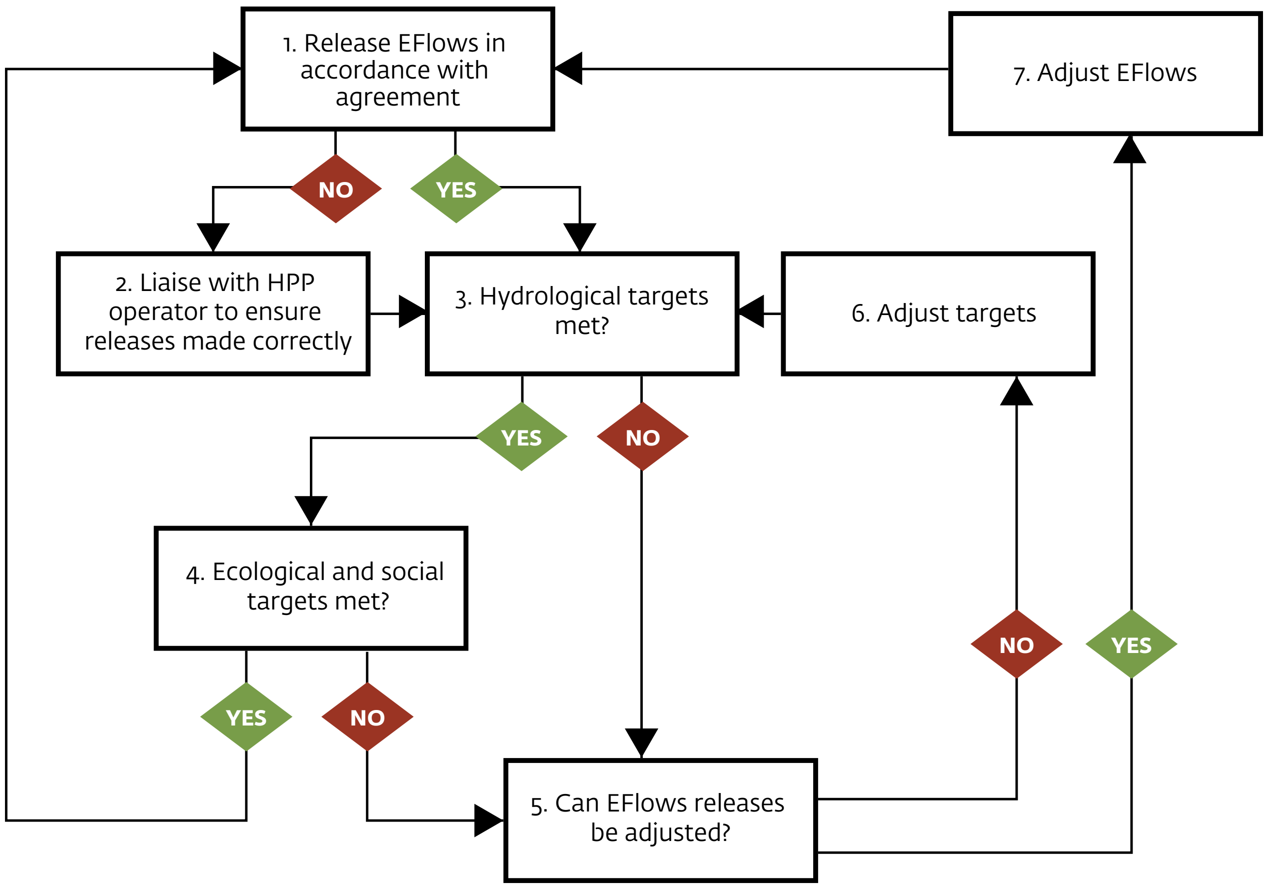
Section 8. Environmental Flows and Adaptive Management

The environmental consequences of developing and operating a hydropower project cannot be predicted with complete certainty. To be ecologically and socially sustainable, water and energy development and management need to be "perpetually informed by monitoring, carefully targeted data collection and research, and further analysis to address new uncertainties or surprises." (Krchnak et al. 2009)

A system of monitoring, evaluation, and adjustment—commonly referred to as adaptive management—should be fully and explicitly integrated into management of a river whose flows have been altered by development or a re-operation plan. Adaptive management allows management approaches to be updated and modified at intervals guided by monitoring results (Figure 8.1).

For an adaptive management system to be effective, there should be cooperation and communication among the dam operators, the organization responsible for monitoring, and the relevant authorities. These key actors will need to broadly agree on the baseline condition, the expected condition of the river, the EFlows predicted to maintain the expected condition, and the indicators and targets that will be used to measure whether these are being achieved. Implementation of EFlows should be accompanied by an EFlows monitoring program that provides the necessary data to inform each step, and supported by transparent reporting and independent auditing.

Figure 8.1: Environmental Flow Management Plan - Adaptive Management System



SECTION 9

ENVIRONMENTAL FLOW MANAGEMENT PLAN

Section 9. Environmental Flow Management Plan

An Environmental Management Plan (EMP) is a precise record of management actions and agreements related to all aspects of a proposed hydropower project development. The Environmental Flows Management Plan (EFMP) focuses on the EFlows aspects of the EMP. It describes the activities needed to implement, monitor, and review of the EFlows and clearly defines the responsibilities and key performance indicators (Box 4).

The EFlows practitioner can compile the EFMP as a stand-alone document, but the EFMP should be integrated into the project's overall EMP. The EFlows practitioner should be part of the team involved in integrating the EFlows mitigation and monitoring measures into an EMP to ensure correct interpretation of recommendations and agreed decisions.

In addition, the EFMP/EMP should be aligned with other related sector plans and other rehabilitation plans of relevance to maintenance of the river's ecosystem services.

The EFMP (and other provisions of the EMP) should be contained in or reflected by the Concession Agreement, lender financial agreements, covenants, or commitment plans (where appropriate), and the environmental license issued by the host country under which the hydropower project will operate.

Box 4: Example Contents of EFMP[29]

1. **Details of the EFMP:**
   - Client and consultants
   - The dates of initialization, duration and provisions for revision
   - The spatial scope
   - Objectives.

2. **A policy statement that does the following:**
   - Specifies relevant national legislation, international agreements, regulations WBG safeguards or performance standards, and confirms adherence.
   - Allocates responsibility (including financial) for implementation of the EFMP.
   - Defines the environmental and social objectives and principles for environmental and social protection.
   - Summarizes the process that led to the specifications in the EFMP.

3. **A record of decision that specifies:**
   - Values to be protected / trade-offs
   - The agreed target ecological and social conditions across each season[30]
   - Power generation
   - Dam designing to meet the target conditions
   - The measures adopted for restoration, or preventing or mitigating impacts, such as:
     - operating rules for EFlows releases and/or water quality targets
     - sediment management procedures
     - provisions for the passage of aquatic plants and animals
     - initiatives to restore and/or offset impacts.

4. **A monitoring program that includes:**
   - The objectives and scope
   - The baseline data to be collected
   - Timing and monitoring schedules
   - Data analysis procedures
   - Quality assurance
   - Regular reporting.

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29 A more detailed annotated Table of Contents for an EFMP is provided in Appendix D.

30 These could also include limits to maximum flow releases in different seasons, such as for peaking HPPs.

5. **A framework for implementing the EFMP that:**
    - Delegates institutional responsibility
    - Defines the organizational capacity and competency.
6. **Reporting, record keeping and auditing/quality control arrangements.**
7. **Provisions for adaptive management, including the following:**
    - The adaptive management system
    - Interval and basis for EFlows reviews
    - Decision-making
    - Stakeholder involvement
    - Auditing.
8. **Funding arrangements, including sources and financial management.**

SECTION 10

LOGFRAME

Section 10. Logframe

The Logical Framework Approach (LFA or 'logframe') is a general approach to project planning, monitoring and evaluation. It comprises a series of connecting activities and outcomes between a project's aims and objectives, and delivery of the intended results.

The logframe provided in Table 6 is intended to guide integration and oversight of EFlows Assessments for hydropower projects. Column headings similar to those in Table 6 are standard for most logframes, as are the headings in the first three rows. The last row, Supporting Activities, is drawn from the generic ToRs provided in Appendix A and covers the scope of work for an EFlows Assessment. Together they cover the integration and standardization of EFlows, the activities needed to realize the objectives, the indicators to be used to verify if the objectives are being met, and the means of verification.

For all but the most basic EFlows Assessment, a wide range of specialist skills is needed and the choice of the lead EFlows practitioner and specialist team is an important part of a successful study. As with ESIAs, the lead EFlows practitioner should guide the appointment of specialists appropriate for the region and level of assessment being undertaken. Specialists need to have local understanding of the river system involved as well as considerable experience in their discipline. Since few (if any) experienced EFlows practitioners are in many of the countries where hydropower projects are planned, a pragmatic approach to creating a successful team is to use a core group of experienced international EFlows practitioners who understand the process, teamed with local specialists who have good knowledge of the river (see Gulpur Hydropower Project case study in Section 11.1).

Table 6: Logframe for Integration of EFlows into Hydropower Projects

Category	Narrative Summary	Objective Indicators	Means of Verification	Assumptions
Goal	Environmentally and socially sustainable HPP development.	World Bank safeguards and performance standards.	World Bank safeguards and performance standards met.	There is scope within basin plans for achievement of environmentally sustainable allocation and use of water resources.
Purpose of Activities	A standard approach to EFlows Assessment and implementation in HPPs.	An appropriate level of EFlows. Assessment done for HPPs, either at an individual level or for a basin.	Review of EFlows method used and output for each HPP.	
Project Outputs	Consistency in EFlows Assessments.	Implementation of an EFMP	Auditing of EFMP activities.	
Key Requirements	Establish project context.	Study area delineation.	Review of study area delineation.	-
	Use of EFlows Method Decision Tree to choose appropriate methods.	Appropriate resolution EFlows. Assessment method used.	Review of decision.	EFlows Method Decision Tree correctly applied.
	Assessment of EFlows.	EFlows Assessment report.	Review of EFlows Assessment report.	EFlows Assessment method correctly applied.
	Engagement with stakeholders.	Stakeholder engagement in accordance with WBG requirements.	Documented stakeholder process and FPIC if IP significantly impacted.	All major stakeholder groups represented.
	Transparent decision-making.	Decision-making process for HPP development agreed before EFlows Assessment undertaken.	Review of implementation of decision-making process.	
	Production of an EFMP or integration of EFlows mitigation into EMP and mitigation into HPP operating rules.	EFMP and/or EMP.	Review of EFMP/EMP.	Budget and means for implementation.
	Implementation of the EFMP.	Operating rules and environmental targets.	Audits of EFMP implementation.	Delegated body (for example, HPP operator / Government agency) and external review processes (for example, by government and/or funding agencies.

SECTION 11

CASE STUDIES FOR INDIVIDUAL PROJECTS

Section 11. Case Studies for Individual Projects

11.1 GULPUR HYDROPOWER PROJECT: POONCH RIVER

The Poonch River originates in the western foothills of the Pir Panjal Range, and the steep slopes of the Pir Panjal form the upper catchment of the river. From there, it flows into Mangla Dam reservoir, which floods the confluence of the Poonch and Jhelum rivers. For 85 km upstream of the reservoir, the river is in the Poonch River Mahaseer National Park, recognized for its scenic beauty and high levels of fish endemism including the critically endangered Kashmir catfish, *Glyptothorax kashmirensis*, and the endangered Mahaseer, *Tor putitora*, which is also a prized angling fish. Funding for maintaining the national park is scarce. Sediment mining from the river, destructive fishing practices, nutrient enrichment from effluent discharges, and removal of riparian vegetation all exert pressure on the system. Within the park, the 102-MW Gulpur Hydropower Project is being developed 50 km upstream of the Mangla Dam (Figure 11.1), by Mira Power Ltd. from South Korea.

The initial design of the hydropower project included a 35-m weir[31], a 3.1 km headrace tunnel connecting the intake to the powerhouse; and a tailrace that would discharge water back into the river about 6 km downstream of the weir. The powerhouse would comprise three Francis 33.33-MW turbines with a minimum operational discharge of 33 m^3s^{-1}.[32] The originally designed EFlows were planned

31 A 35-m high wall, with release structures, is effectively a dam in terms of its effect on the river but the authors of this publication have retained the term 'weir' in line with other project literature.

32 The minimum operational discharge is significant because, in the dry season, inflows to Gulpur reservoir can drop below 33 m3/s and the turbines would have to be switched off until sufficient inflow was available to restart them. Thus, even in the absence of peaking power generation, the downstream river would experience short-term fluctuating flows.

Figure 11.1: Poonch River and Gulpur Hydropower Project Setting

as a minimum release of 4 m^3s^{-1} compared to the baseline minimum 5-day dry-season discharge of 20.4 m^3s^{-1}. The weir would not materially alter the wet-season flows, but would affect the dry-season onset, duration, and discharge magnitude between the weir and the tailrace under base-power operation, and much of the remaining river under peaking-power operation.

Because the Poonch River is both a national park and critical habitat, IFC and other international lenders recommended an exhaustive analysis of alternatives and **high-resolution** EFlows Assessment.

Because of the alternative analysis, the project was modified. The weir was located a few kilometers downstream from the original location, resulting in a dewatered segment of only 700 meters instead of the original 6 to 7 kilometers. This modification also resulted in complete avoidance of any resettlement of people in the reservoir flooding area.

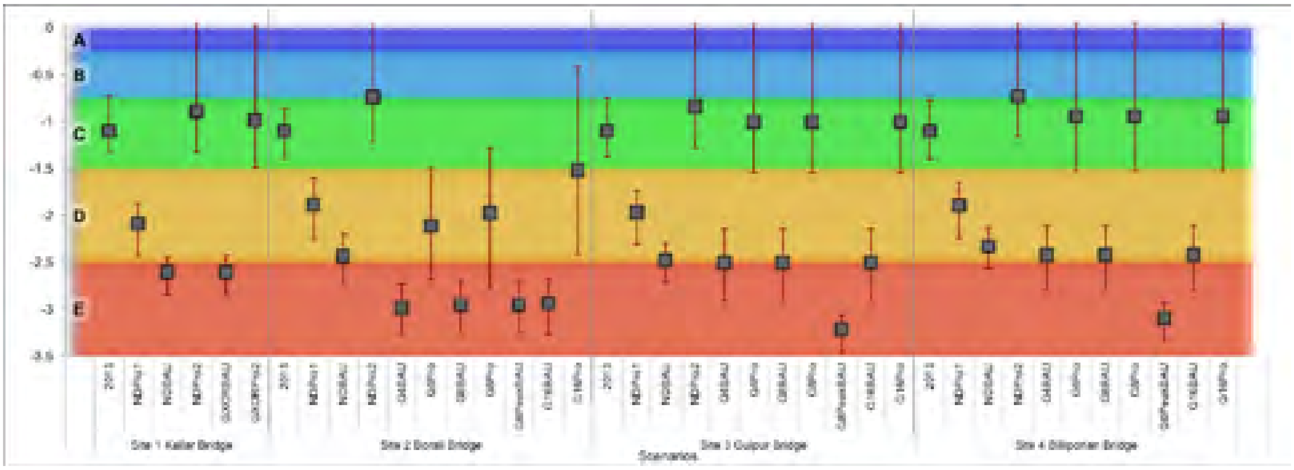
The sponsors used DRIFT EFlows Assessment method for the following:

- To evaluate more than 20 scenarios comprising different permutations of **minimum releases** between 4 and 16 m^3s^{-1}
- Three future **levels of management** aimed at reducing the nonflow related pressures on the system[33]
- **Peaking versus baseflow operation**
- Options for reducing the **distance of the dewatered section of river between the weir and tailrace**
- Options for **turbine selection**

All the scenarios considered the effects of **trapping bedload and suspended sediments** in the Gulpur reservoir, as well as the **barrier effect of the weir on fish** movement between downstream overwintering areas and upstream breeding areas.

For each scenario, the outcome of the EFlows Assessment was expressed as an overall ecosystem condition in different river reaches using an integrity range from A to E (Figure 11.2; where A = natural and E = highly degraded); as semi-quantitative changes for 16 indicators of ecosystem condition, including fish (Table 7); and in terms of its implication for power generation.

Figure 11.2: Predicted Overall Ecosystem Condition in Poonch River Upstream of Gulpur, between Weir and Tailrace, and Downstream of Tailrace



Note: Scenarios displayed include options for no dam (ND), various release magnitudes (Gx – upstream so no releases, G4, G8, G16) and various basin protection (Pro) levels. Baseline (2013) river condition integrity is labelled 2013.

33 No protection = business as usual – do nothing and allow pressures to increase in line with 1976-2013 trends. Moderate protection = manage the system to ensure no increase in human-induced basin pressures over time relative to 2013; High protection = reduce 2013 pressures by 50 percent.

Table 7: The Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Fish Indicators for the Selection of Scenarios Shown in Figure 11.2.

Blue and green are major changes that represent a move towards natural: green = 40-70 percent; blue = >70 percent. Orange and red are major changes that represent a move away from natural: orange = 40-70 percent; red = >70 percent. Baseline, by definition, equals 100 percent. The scenario colored bright yellow was the one chosen.

Location	Species	Baseload									Peaking
		No dam – moderate protection	No dam – low protection	No dam – high protection	$4\ m^3s^{-1}$ – no protection	$4\ m^3s^{-1}$ – high protection[34]	$8\ m^3s^{-1}$ – no protection	$8\ m^3s^{-1}$ – high protection	$16\ m^3s^{-1}$ – no protection	$16\ m^3s^{-1}$ – high protection	$8\ m^3s^{-1}$ – no protection
Upstream of Weir[35]	Pakistani labeo	-64	-86	62	-79	69	-79	69	-79	69	-79
	Mahaseer	-60	-97	47	-82	80	-82	80	-82	80	-82
	Twin-banded loach	4	-70	34	-87	23	-87	23	-87	23	-87
	Kashmir catfish	-3	-67	31	-84	22	-84	22	-84	22	-84
	Garua bachwaa	-66	-100	73	-100	8	-100	8	-100	8	-100
	Snow trout	-50	-61	57	-30	88	-30	88	-30	88	-30
Weir to Tailrace[36]	Pakistani labeo	-598	-77	58	-100	-26	-100	-5	-99	7	-99
	Mahaseer	-55	-92	51	-100	-93	-100	-87	-100	-41	-100
	Twin-banded loach	-1.4	-54	47	-100	-90	-100	-80	-93	-21	-100
	Kashmir catfish	-8	-62	15	-100	-91	-100	-88	-99	-54	-100
	Garua bachwaa	-60	-94	86	-95	-898	-95	-88	-95	-12	-95
Tailrace to Mangla Reservoir[37]	Pakistani labeo	-59	-88	59	-88	63	-88	63	-88	63	-100
	Mahaseer	-58	-94	51	-100	-6	-100	-6	-100	-6	-100
	Twin-banded loach	-1	-53	48	16	93	16	93	16	93	-100
	Kashmir catfish	-8	-62	20	-20	76	-20	76	-20	76	-100
	Garua bachwaa	-60	-96	80	-99	67	-99	67	-99	67	-100

34 Scenario selected for implementation.

35 ~ 20 km upstream of the reservoir.

36 ~ 1 km.

37 ~ 40 km.

Figure 11.2 and Table 7 show that even without the Gulpur weir, the integrity of the river ecosystem and its biodiversity would continue to decline in the absence of focused management interventions. The findings include the following:

- With the weir, there would be a net positive effect on overall ecosystem condition upstream, provided high-level conservation protection (funded by hydropower generation) was also implemented, largely because of some fish species colonizing the reservoir
- Increasing the EFlows releases from 4 to 8 m^3s^{-1} would not significantly improve the outcome for the river section between the weir and the tailrace
- Downstream of the tailrace to the Mangla reservoir, peaking power operations would significantly adversely affect both overall condition and biodiversity

The full range of scenarios was presented to the stakeholders, who comprised local communities, government officials, the developer, Pakistan Power Authority, and representatives from the lending financial organizations, including the Asian Development Bank and IFC.

The results of the EFlows Assessment underpinned the following decisions:

- Forgo peaking power generation.
- Relocate the weir closer to the powerhouse to, inter alia, reduce the dewatered section from about 6 km to about 700 meters.
- Release an EFlows of 4 m^3s^{-1} for the (shortened) section of river between the weir and tailrace.
- Select different turbines that would allow greater operating flexibility under low-flow conditions.
- Implement a management and finance structure for high levels of protection in the Poonch River National Park.
- Establish a fish hatchery and use it to stock the reach downstream of Gulpur tailrace with the Mahaseer fish.

These last two bullets also contributed to biodiversity offsets that offer better overall biodiversity protection than increasing the EFlows release above 4 m^3s^{-1}.

The environmental regulator, the Department of Fisheries and Wildlife, the Himalayan Wildlife Foundation, and World Wildlife Fund (WWF)–Pakistan all reviewed the EFlows Assessment. The environmental regulator and Wildlife Department approved the EFlows Assessment on condition of adoption of a Biodiversity Action Plan (BAP) that would ensure a 'net gain' in the key fish species. The government has committed to the BAP, which includes conservation measures, arrangements for environmental groups and communities to participate in implementation, independent monitoring, and more. The BAP also defines the financial commitments to be made by the project owner.

11.1.1 Scope and Costs

The EFlows Assessment focused on four sites, one upstream, one between the dam wall and the tailrace, and two in the river between the tailrace and Mangla Dam.

The EFlows scenario evaluation for Gulpur Hydropower Project incorporated considerations of the following:

- Changes to downstream:
  - dry-season flows
  - duration of seasons
  - seasonal variability.
- Downstream effects of sediment trapping and flushing
- Changes in connectivity assessment for key migratory fish
- Options for turbine selection
- Options for management protection (that is, offsets) for the Poonch River, funded by Gulpur Hydropower Project, to reduce the existing impacts of overharvesting and poaching, and in-river mining.

The EFlows team comprised four international consultants with extensive EFlows experience, who guided a team of Pakistan specialists with extensive local knowledge of the river system through the assessment process.

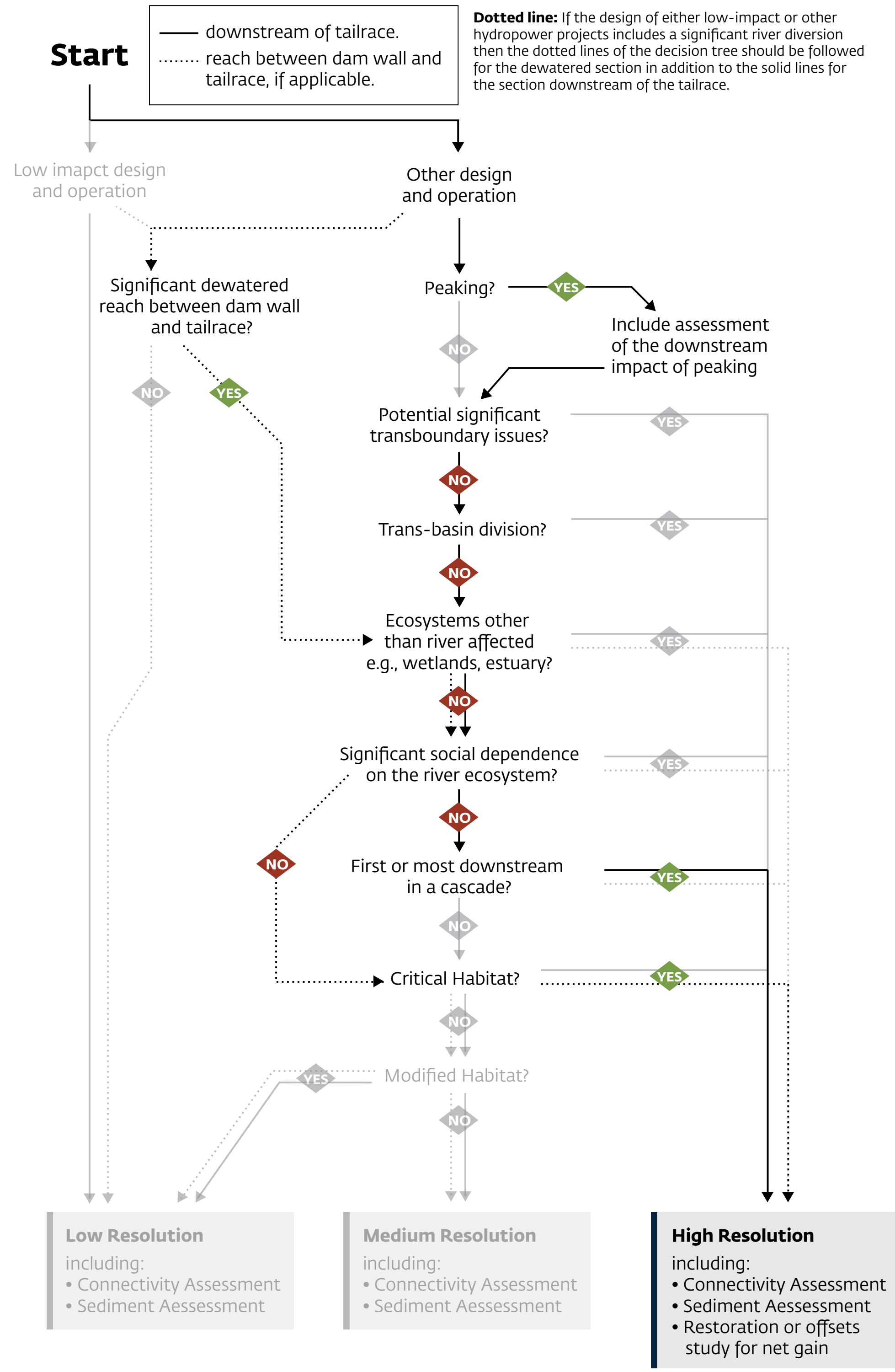
The cost[38] of the EFlows Assessment was about $300,000 inclusive of reimbursable expenses. The combined cost of the EFlows Assessment, ESIA, a Biodiversity Action Plan (which incorporated the EFMP), and a monitoring plan was about $610, 000.

11.1.2 Retrospective Selection of Appropriate EFlows Method for Gulpur Hydropower Project Using Decision Tree

Figure 11.3 shows the EFlows decision tree retrospectively populated for Gulpur Hydropower Project. Use of the decision tree would have resulted in a recommendation for a high-resolution EFlows Assessment method, which is what was implemented for the Gulpur Hydropower Project after IFC rejected the original ESIA.

38 In 2013-2015.

Figure 11.3: EFlows Decision Tree Retrospectively Populated for Gulpur Hydropower Project



Box 5: A message from Mira Power about Gulpur Hydropower Project

With the project located in a National Park, the presence of Endangered and Critically Endangered fish species, and the Poonch River classified as Critical Habitat, the Gulpur Project faced a very serious challenge in project development as the project had to prove 'net gain' in key biodiversity values, the fish species in this case. This requirement was mandated by both IFC Performance Standards as well as the local environmental regulations.

Given the need for a credible assessment of impacts of the project on aquatic biodiversity, the DRIFT model was selected for impact assessment as it adopted a holistic approach and provided for an indicator- and scenario-based approach for design of a project that meets the requirements of IFC and conforms to the principles of sustainable development. Drawing on the results of DRIFT modeling, the design of the project was first modified to reduce the low flow and highly impacted section downstream of the outlet of the power generation tunnel.

Subsequently, a non-peaking turbine design and operation combined with an Enhanced Protection management scenario incorporated in DRIFT model was selected to achieve the net gain. 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.

11.2 REVENTAZÓN HYDROPOWER PROJECT, COSTA RICA

The Rio Reventazón originates on the Caribbean side of Costa Rica in the Cordillalera de Talamança, and flows east to the Caribbean Sea. The area is rich in biodiversity and the Rio Reventazón is bounded by the Parque Nacional Braulio Carrilo and the Parque Nacional Barbilla.

The state-owned electricity company Instituto Costarricense de Elecricidad (ICE) is developing the 305-MW Reventazón Hydropower Project on the Rio Reventazón, 8 km southeast of Siquires. The Reventazón Hydropower Project comprises a 125-m high weir, which is 535 m long at its crest; several tunnels; and a dewatered segment of 4.2 km. Three other major hydropower projects are in the basin (Figure 11.4).

IFC defines the river near the Reventazón Hydropower Project as natural habitat on the basis of its ecological integrity and migratory fish pathways. The river valley also intersects the Meso-American Biological Corridor, which in the context of the Reventazón Hydropower Project is particularly relevant for the jaguar. The terrestrial area was assessed as critical habitat for its association with migration patterns of terrestrial fauna, including large American felines, such as the jaguar. The most significant predicted impacts on the aquatic system include the inundation of 8 km of flowing river, blockage of fish migration in 38 km of the Reventazón mainstream and tributaries downstream of Angostura Hydropower Project, and impact of altered hydrology, sedimentation, and water quality on the downstream Rio Reventazón, including the coastal Tortuguero National Park. The flooded habitat was predicted to form a barrier to the structural and functional integrity of the Barbilla-Destierro Biological Subcorridor of the Meso-American Biological Corridor. In terms of IFC's PS6, the project needed to achieve net gain for impacts on the critical habitat of the Meso-American Biological Corridor and 'no net loss' for impacts on the river ecosystem.

From the perspective of EFlows, only the 'no net loss' on the river ecosystem was applicable, as the net gain on the sub-corridor formed part of the wider ESIA. No threatened or endangered aquatic species were identified. The migratory fish species of concern included the Mountain mullet (*Agonostomus monticola*) and Bobo mullet (*Joturus pichardi*), both of which migrate down the river to spawn in the estuary.

The infrastructure associated with the two hydropower projects upstream of the Reventazón Hydropower Project was not predicted to impact the migratory pathway of the mullet, but the Reventazón Project would create a significant barrier to the migration of these fish, with significant residual impacts.

Figure 11.4: The Rio Reventazón and Reventazón Hydropower Project Setting (Google Earth, 2016)

ICE developed an in-house $2 million hydro-ecological flow model known as RANA-ICA (Chaves et al. 2010), which integrates hydrological, social and biological data to determine downstream flow requirements to avoid environmental and social impacts. Habitat preference curves were also developed for key (native) fish species to determine needs and potential habitat loss in the affected reaches. Through the ESIA process, using a considerable amount of data and the RANA model, ICE determined the following: (a) no significant modification of the natural habitat would take place if there was a 15 m^3s^{-1} minimum release in the dewatered segment; and (b) that a minimum of 40 m^3s^{-1} would be required to sustain the ecological and social flow needs downstream of the powerhouse, including river rafting activities. In addition, ICE plans to operate a hatchery and restock the river with migratory fish.

The hydropower project ‘s major residual impact was the barriers effect to longitudinal migration of mullets. To offset this loss of connectivity for the mullet species, this impact on Natural Habitat will be address by protection the Rio Parismina, an ecologically similar river system, as an averted loss plus restoration offset and it will be maintained as a healthy and free flowing aquatic habitat. Although ICE had earmarked the Rio Parismina for a separate hydropower project, the

Box 6: Metrics Developed for Aquatic Habitat No Net Loss (NNL)

Structural Metrics

- "Quality x Length", where "quality" refers to the quality of the river habitat as the mean of four indices (ICA, BMWP–CR, IQR and IHG), and where "length" is the length of main-stem river in km
- NNL would be achieved when:

  $$q^1 * y * p + \Sigma (q^2 - q^o) * z > q^3 x$$

- Where:
  - p = probability of the Parismina dam being built without ICE's intervention for the sole purpose of meeting its no net loss requirements
  - y = km of habitat that would have been disconnected by the proposed Parismina dam
  - x = km of habitat that will be disconnected by the Reventazón project (i.e., below Angostura dam)
  - z = km of habitat across four sections (z^1, z^2, z^3 and z^4) of the Parismina catchment
  - q = water quality:
    - q^1 = quality now in the catchment above the proposed Parismina dam,
    - q^o = quality before offset actions (baseline) across the Parismina watershed (assuming that this level is maintained for the duration of the Reventazón project)
    - q^2 = quality after offset actions across the Parismina watershed
    - q^3 = quality now before flooding (baseline) between PH Reventazón and the Angostura

Functionality of Habitat Metrics

- Based on the abundance of indicators species.
- NNL would be achieved when:

  $$(a^1 - a^o) > a^2$$

- Where:
  - a^o = abundance in the middle and upper lengths of the Parismina, before offset actions
  - a^1 = abundance in the middle and upper lengths of the Parismina, after offset actions
  - a^2 = abundance between the Angostura and Reventazón dams, before offset actions
- This metric is to be used for the following species: *Agonostomus monticola* [Mountain Mullet], *Sicydium altum* [goby] and *Brycon guatemalensis* [Machaca] and *Macrobrachium* spp. [shrimps]

company agreed to forgo their development rights and secured a guarantee from the government to protect this river system from hydropower project development as an offset for the Reventazón project. The offset river will have a variety of restoration interventions: work with farmers and landowners to reduce erosion, sedimentation, and pesticide run-off in the watershed; and riparian restoration and other habitat enhancement measures that promote river conditions to support native fish and invertebrate species. ICE developed metrics for the river system to assess the habitat quality for fish and functional connectivity to confirm that the averted offset and restoration interventions meet 'no net loss' (see Box 6).

11.2.1 Scope and Costs

The EFlows scenario evaluation for Reventazón Hydropower Project incorporated the following considerations:

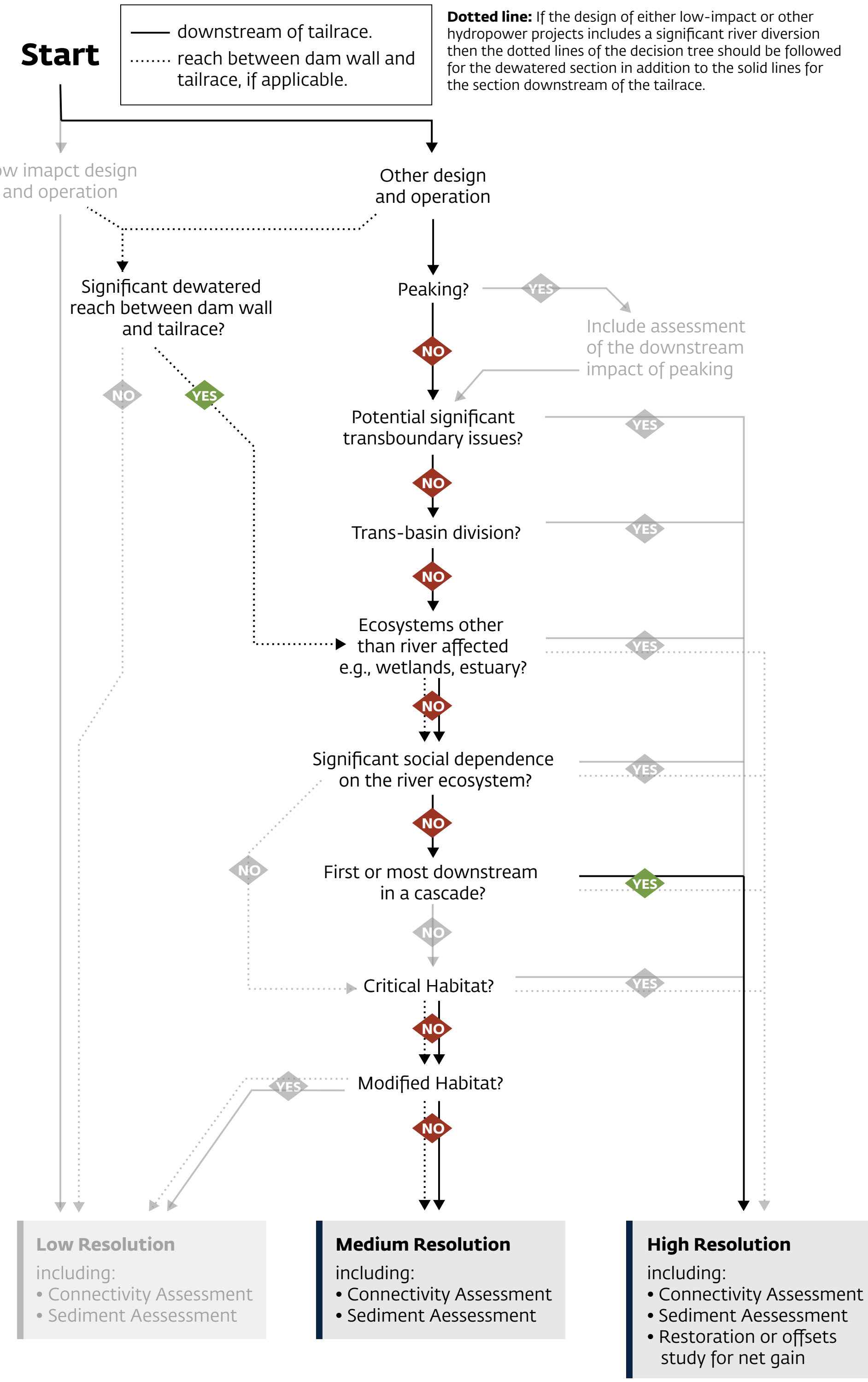
- Changes to downstream:
    - dry-season flows
    - seasonal variability
- Changes in connectivity assessment for key migratory fish
- Social uses of Rio Reventazón (for example, river rafting)

ICE is a state-owned company with multiple hydropower generation, which makes it difficult to determine the costs and team as the company performs its own ESIA and has a team of more than 100 in-house specialists.

11.2.2 Retrospective Selection of Appropriate EFlows Method for Reventazón Hydropower Project using Decision Tree

Figure 11.5 shows the EFlows decision tree retrospectively populated for the Reventazón Hydropower Project. Use of the decision tree would have resulted in recommending a high-resolution EFlows Assessment method downstream of the tailrace, which is the same as the resolution level implemented for the Reventazón Hydropower Project. For the dewatered section, the decision tree recommended a medium-resolution EFlows Assessment, as there are no significant values in the dewatered segment.

Figure 11.5: The EFlows Decision Tree Retrospectively Populated for Reventazón Hydropower Project



SECTION 12

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Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects

#	Activity	Low	Medium	High
1	**Scoping**	Gather the information on the following: the location and design of the HPP under evaluation; location and extent of the study area; scope of the assessment; hydrology and sediment dynamics; presence and location of other water-resource developments; types of ecosystems affected; general condition of the affected ecosystems; biodiversity issues; extent and nature of social use; proposed operation; intended use of the results.		
2	**Selection of appropriate level of resolution for the EFlows Assessment**	Apply the EFlows Method Decision Tree, and select an EFlows Assessment method of an appropriate level based on the outcome as below.		
		Use a low-resolution, desktop EFlows method based on an understanding of the natural flow regime and character of the host river and the design and operation of the HPP. Support the selection of the chosen method by: • Reference to a peer-reviewed scientific paper where the method was used or described • Outlining the data on which it was based and its applicability to the study river • Demonstrating that only dry-season flow would be materially affected by the HPP If the method used does not take account of changes in sediment supply and the longitudinal migration of biota then, in addition to the application of the EFlows method, undertake separate desktop assessments for these factors.	Use a holistic EFlows method that can consider the main habitat and biotic features of the study river and be used to assess the outcomes for the river ecosystem of various scenarios of HPP operations. Support the selection of the EFlows method by: • Reference to a peer-reviewed scientific paper where the method was used or described • Discussion on its relevance for application for the study river If the method used does not take account of changes in sediment supply and the longitudinal migration of biota then, in addition to the application of the EFlows method, undertake separate desktop assessments for these factors.	Use a holistic EFlows method that can consider the main habitat and biotic features of the study river and be used to assess the outcomes for the river ecosystem of various scenarios of HPP operations. Ensure that the method selected can take account of peaking-power operations (if applicable – see Activity 15a), changes in sediment supply, and interruptions to longitudinal migration of biota. In the case of natural or critical habitat, ensure that the method can provide predictions specific to the habitats or species that triggered such. Support the selection of the EFlows method by: • Reference to a peer-reviewed scientific paper where the method was used or described • Discussion on its relevance for application for the study river

Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects (Continued)

#	Activity	Low	Medium	High
3	**Engagement of stakeholders in EFlows Assessment**	Undertake a formal and socially appropriate Stakeholder Engagement Process as per World Bank Group guidelines for stakeholder engagement. Ensure meaningful and inclusive stakeholder engagement in all phases of the EFlows Assessment, including but not necessarily limited to the following: • Definition of the value of the ecosystem and the resources it provides • Scenarios (options) to be assessed, if appropriate • Selection of indicators for the assessment • Consideration of scenario results • Consideration of offsets, if required • EFlows release commitments and other related mitigation measures		
4	**Selection of scenarios**	Not applicable.	Review the design and operating rules for the proposed HPP and, together with the client and design engineers. After consultation with key stakeholders, identify the baseline scenario against which other scenarios will be compared, and a set of design, operational, climate change, and climate variability scenarios for evaluation in the EFlows Assessment. These scenarios may differ in terms of the following: • Predicted future climatic conditions • The location and design of the HPP • The pattern of flow releases • The pattern of sediment releases • The barrier effect of the HPP	
5	**Delineation of basin or subbasin**	Use topographical information (longitudinal profile), Google Earth imagery, available maps and other available data to do the following: • Identify the main types of aquatic ecosystems likely to be affected by the proposed HPP • Identify settlements and socioeconomic uses likely to be affected by the proposed HPP, and map stakeholders relevant to the EFlows analysis • Delineate socially and morphologically uniform zones along the river to facilitate the selection of EFlows sites/ reaches		

Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects (Continued)

#	Activity	Low	Medium	High
6	**Selection of EFlows sites or reaches**	Select study sites or reaches to represent the downstream and upstream aquatic ecosystems likely to be affected by the HPP. The minimum number of EFlows sites or reaches is the following: 1. Upstream of the HPP reservoir 2. Between the HPP weir and the tailrace outlet (if relevant) 3. Downstream of the tailrace outlet—preferably a sequence to the expected furthest point of effect of the HPP		
7	**Identification of main issues and selection of EFlows Assessment team**	Hydrologist plus others as appropriate to method selected.	Select a set of disciplines to represent the downstream and upstream aquatic ecosystems, and the socioeconomic and cultural uses, likely to be affected by the HPP. Select an EFlows assessment team with specialist experience in these disciplines. Typically, the team will comprise: • Project leader • Hydrologist • Ecohydraulic modeler • Water quality specialist • Geomorphologist/sedimentologist • Botanical ecologist • Macroinvertebrate ecologist • Fish ecologist • Social, cultural resources and stakeholder engagement specialist(s) • Other biological and social specialists as appropriate	
8	**Preparation of hydrology**	For each EFlows site or reach prepare the following hydrological time-series: • Monthly data for natural flows (>/= 30 years).	For each EFlows site or reach prepare the following hydrological time-series: • Daily data for baseline flows (>/= 30 years, until as recent as possible) • Daily data for baseload operational scenarios over the same period of record • Subdaily (hourly) data for peak-power release scenarios over the same period as the baseline record	

Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects (Continued)

#	Activity	Low	Medium	High
9	**Review of literature**	Overview of existing reports on the river system.	The duration of the project is such that relationships between the riverine ecosystem and flow that will provide the basis for the EFlows Assessment will for the most part have to be obtained from existing reports and studies conducted elsewhere. Thus, the aims of Task 6 are to do the following: • Identify key biophysical aspects of the aquatic ecosystems that can be used as indicators of flow and sediment related changes • Identify key social uses of the aquatic ecosystems that could be affected by changes to the ecosystems, including flow and sediment related changes • Develop initial relationships between the indicators and flow based on existing information • Identify key aspects for additional EFlows data collection	
10	**Selection of indicators**	Not applicable.	Select social and ecosystem indicators that are expected to respond to a change in the flow, sediment, or migration routes. Include stakeholder consultations or engagement as part of the selection process. There are no general guidelines as to what makes an ideal indicator, except the obvious: that they relate to the issue being addressed, have some link to flow/inundation, encompass the relevant factors affecting the ecosystem (for example, quantity, duration, variability, range, frequency, predictability), be amenable to quantification in some form, and broadly reflect stakeholder concerns.	
11	**Assessment of status and trends**	For each of the EFlows sites or reach, provide an assessment of the overall baseline ecological and social status of the aquatic ecosystem(s).	For each of the EFlows sites or reach, provide an assessment of the current ecological and social status of the aquatic ecosystems, per discipline, and to the extent possible describe historic trends in condition and possible causes thereof. Use data from the basin to substantiate your assessments.	

Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects (Continued)

#	Activity		Low	Medium	High
12	**Screening for off-sets**		Not applicable.	Not applicable.	If the HPP is in critical habitat, where a 'net gain in biodiversity' is requested, undertake a scoping level assessment of possible restoration or offset options that could be adopted to ensure achievement of net gain. Include consideration of these options in the EFlows Assessment and production of scenarios:[A] • Management initiatives to protect aspects of the ecosystem from existing non-flow related impacts, such as overfishing or sand mining • Stocking of fish species from hatchery • Restoration of previously-damaged breeding or feeding areas • Establishing a nearby river reserve
13	**Collection of field data**	**Dry Season**	Not applicable.	Undertake field surveys of each of the EFlows sites or reaches during low flows to address gaps in the data record and to provide a baseline data set against which any future changes can be benchmarked.	
		Transitional		Not applicable.	Undertake field surveys of each of the EFlows sites or reaches in the transition seasons between wet and dry, to address gaps in the data record and provide a baseline data set against which any future changes can be benchmarked.
		Wet Season		Undertake field surveys of each of the EFlows sites/reaches in high flows to establish the high-flow stage: discharge relationships.	

A Note: If the EFlows Assessment is done as part of, or in parallel with, the ESIA, the screening for offsets could form part of the ESIA and need not be done specifically as part of the EFlows Assessment.

Appendix A: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments for Hydropower Projects (Continued)

#	Activity	Low	Medium	High
14	**Ecohydraulics**	Not applicable.	At each site or reach develop a stage: discharge curve/hydrodynamic model that can be used to provide ecologically relevant hydraulic parameters (for example, average velocity, average and maximum depth, wetted perimeter, extent and depth of floodplain inundation) as a function of discharge.	
15	**Assessment of EFlows**	Use a low-resolution EFlows Assessment methodology that has been published as a peer-reviewed paper, for each EFlows sites or reach: • Provide the minimum dry season discharge • Write report	Use a recognized interactive holistic EFlows Assessment methodology and for each EFlows sites or reach: • Describe the relationships between the indicators chosen and the changes in flow, sediment and connectivity associated with the proposed HPP scenarios • If applicable, describe the knock-on effects of these changes on people using the system • Write report	
15a	**Assessment of peaking operations, if applicable.**	Not applicable.	If peaking operations are planned for the HPP include an assessment of the impact of subdaily fluctuations in flow on habitats and biota.	
16	**Options analysis to contrast various scenarios**	Not applicable.	Assess the scenarios in terms of pre-agreed criteria.	
17	**Implementation of offset studies**	Not applicable.	Forms part of an EFMP.	
18	**Preparation of the EFMP**	Prepare an EFMP in accordance with Section 7.		

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level

#	Activity	Low	Medium	High
1	**A: Where the decisions on siting of HPPs (and other developments) have already been made as part of a CIA or SEA**	Collate, augment and evaluate as necessary, input used in the SEA/CIA to make decisions on siting of HPPs (and other developments).		
	B: Where the decisions on siting of HPPs (and other developments) have not already been made as part of a CIA or SEA	Gather the information on the following: the location and design of the HPPs under evaluation; location and extent of the study area; scope of the assessment; hydrology and sediment dynamics; presence and location of other water-resource developments; types of ecosystems affected; general condition of the affected ecosystems; biodiversity issues; extent and nature of social use; proposed operation; intended use of the results. • Define the geographical scope of the assessment exercise • Complete a geomorphological delineation of the aquatic ecosystems in the study basin, which will identify similar river reaches and ecosystems other than rivers, such as, wetlands, lakes, floodplains, estuary • Complete a hydrological and sediment-supply assessment, and map the key areas and issues • Complete a conservation or biodiversity assessment, and map the key areas and issues • Complete an assessment of social uses and values of the rivers, and map the key areas and issues • Overlay plans for water or energy developments on the maps generated above • In engagement with stakeholders, evaluate various hydropower-conservation permutations • Select an environmentally and socially sustainable set of locations for proposed HPP (and other) developments		

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level (Continued)

#	Activity	Low	Medium	High
2	**Selection of appropriate level of resolution for the EFlows Assessment**	Apply the EFlows Method Decision Tree, and select an interactive EFlows Assessment method (for example, a method that allows for evaluation of scenarios of flow and other change) of an appropriate level for each of the HPPs and other water resource developments.		
		Use one or more EFlows methods that match the resolutions identified in the Decision Tree to assess the outcomes for the river ecosystem of various scenarios of HPP operations. Select the EFlows method by: • Reference to a peer-reviewed scientific paper where the method was used or described • Discussion on its relevance for application for the study river If the method used does not take account of changes in sediment supply and the longitudinal migration of biota then, in addition to the application of the EFlows method, undertake separate desktop assessments for these factors. In the case of natural or critical habitat, ensure that the method can provide predictions specific to the habitats or species of concern. Justify the selection of the EFlows method by: • Reference to a peer-reviewed scientific paper where the method was used or described • Detailed explanation of its relevance for application for the study river		
3	**Engagement of stakeholders in EFlows Assessment**	Undertake a formal Stakeholder Engagement Process as per IFC 2007: Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets[B], or World Bank 2011: Stakeholder Consultations in Investment Operations.[C] Ensure meaningful and inclusive stakeholder engagement in all phases of the EFlows Assessment, including the following: • (Sub-)basin-wide scenarios to be assessed, if appropriate. • Selection of indicators for the assessment. • Consideration of scenario results. • Consideration of offsets, if required. • EFlows release commitments and other related mitigation measures.		

B www.ifc.org/HB-StakeholderEngagement

C http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1164107274725/Consultations-Note.pdf

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level (Continued)

#	Activity	Low	Medium	High
4	**Selection of scenarios**	Review the design and operating rules for each of the proposed HPPs and, together with the client or design engineers. After consultation with key stakeholders, identify the baseline scenario against which other scenarios will be compared, and a set of design, operational, and climate change scenarios for evaluation in the EFlows Assessment. These scenarios may differ in terms of the following: • Predicted future climatic conditions • Locations and designs of the HPPs • Pattern of flow releases from the HPPs • Pattern of sediment releases from the HPPs • Barrier effects of the HPPs.		
5	**Selection of study EFlows sites or reaches**	Select study sites or reaches to represent the downstream and upstream aquatic ecosystems likely to be affected by the HPP. Locate the EFlows sites/reaches in such a manner as to capture the potential upstream and downstream effects of each of the HPPs under consideration, and where applicable the implications for reaches that will remain unaffected by flow changes as a result of the HPPs.		
6	**Identification of main issues and selection of EFlows Assessment team**	Hydrologist plus others as appropriate to method selected.	Select a set of disciplines to represent the downstream and upstream aquatic ecosystems, and the socioeconomic and cultural uses, likely to be affected by the HPP. Select an EFlows Assessment team with specialist experience in these disciplines. Typically, the team will comprise the following: • Project leader • Hydrologist • Ecohydraulic modeler • Water quality specialist • Geomorphologist/sedimentologist • Botanical ecologist • Macroinvertebrate ecologist • Fish ecologist • Social, cultural resources specialists • Stakeholder engagement specialist(s) • Other biological and social specialists as appropriate.	

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level (Continued)

#	Activity	Low	Medium	High
7	**Preparation of hydrology**	For each EFlows site or reach prepare the following hydrological time-series: • Monthly data for natural flows (>/= 30 years).	For each EFlows site or reach prepare the following hydrological time-series: • Daily data for baseline flows (>/= 30 years, until as recent as possible). • Daily data for baseload operational scenarios over the same period of record. • Subdaily (hourly) data for peak-power release scenarios over the same period the baseline record.	
8	**Preparation of sediment, water quality and any other required time series data**	Not applicable.	For each EFlows site or reach prepare the following external time-series (if required and available): • Daily data for baseline suspended sediment supply (>/= 30 years, until as recent as possible). • Daily data for baseline suspended sediment supply (>/= 30 years, until as recent as possible). • Daily data for baseload operational scenarios over the same period of record. • Subdaily (hourly) data for peak-power release scenarios over the same period as baseline day record.	
9	**Review of literature**	The duration of the project is such that relationships between the riverine ecosystem and flow that will provide the basis for the EFlows Assessment will for the most part be obtained from existing reports and studies conducted elsewhere. Thus, the aims of Task 6 are to do the following: • Identify key biophysical aspects of the aquatic ecosystems that can be used as indicators of flow and sediment related changes. • Identify key social uses of the aquatic ecosystems that could be affected by changes to the ecosystems, including flow and sediment related changes. • Develop initial relationships between the indicators and flow based on existing information. • Identify key aspects for additional EFlows data collection.		

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level (Continued)

#	Activity		Low	Medium	High
10	**Selection of indicators**		Not applicable.	Select social and ecosystem indicators that are expected to respond to a change in the flow, sediment, or migration routes. Include stakeholder consultations or engagement as part of the selection process. There are no general guidelines as to what makes an ideal indicator, except the obvious: that they relate to the issue being addressed, have some link to flow/inundation, encompass the relevant factors affecting the ecosystem (for example, quantity, duration, variability, range, frequency, predictability), be amenable to quantification in some form, and broadly reflect stakeholder concerns.	
11	**Assessment of status and trends**		Provide an assessment of the current ecological and social status of the aquatic ecosystems, per discipline, and to the extent possible describe historic trends in condition and possible causes thereof.		
12	**Screening for offsets**		Undertake a scoping level assessment of possible restoration or offset options at the (sub-)basin level that could be adopted to ensure achieve not net loss/net gain. Include consideration of these options in the EFlows Assessment and production of scenarios. Such options could include the following: • Management initiatives to protect aspects of the ecosystem from existing nonflow related impacts, such as overfishing or sand mining. • Protection of key river reaches or tributaries. • Stocking of fish species from hatchery. • Restoration of previously damaged breeding or feeding areas.		
13	**Collection of field data**	**Dry Season**	Not applicable.	Undertake field surveys to each of the EFlows sites or reaches during low flows to address gaps in the data record and to provide a baseline data set against which any future changes can be benchmarked.	
		Transitional		Not applicable.	Undertake field surveys to each of the EFlows sites or reaches in the transition seasons between wet and dry, to address gaps in the data record and to provide a baseline data set against which any future changes can be benchmarked.
		Wet Season		Undertake field surveys to each of the EFlows sites/reaches in high flows to establish the high-flow stage: discharge relationships.	

Appendix B: Generic Terms of References for Low-, Medium- and High-resolution EFlows Assessments at Basin or Subbasin Level (Continued)

#	Activity	Low	Medium	High
14	**Ecohydraulics**	Not applicable.	At each site or reach develop a stage: discharge curve/hydrodynamic model that can be used to provide ecologically relevant hydraulic parameters (viz. average velocity, average and maximum depth, wetted perimeter) as a function of discharge. If peaking is part of operational scenarios identified in Task 4, establish hydrodynamic model to route peaking flows down the channel, so as to evaluate attenuation.	
15	**Assessment of EFlows**	Use a low-resolution EFlows Assessment methodology that has been published as a peer-reviewed paper, for each EFlows sites or reach: • Provide the minimum dry season discharge • Write report.	Use a recognized interactive holistic EFlows Assessment methodology and for each EFlows sites or reach: • Describe the relationships between the indicators chosen and the changes in flow, sediment and connectivity associated with the proposed HPP scenarios. • If applicable, describe the knock-on effects of these changes on people using the system. • write report.	
15a	**Assessment of peaking operations, if applicable.**	Not applicable.	If peaking operations are planned for the HPP include an assessment of the impact of subdaily fluctuations in flow on habitats and biota.	
16	**Options analysis to contrast various scenarios**	Not applicable.	Assess the scenarios in terms of pre-agreed criteria.	
17	**Implementation of offset studies**	Not applicable.	Forms part of an EFMP.	
18	**Preparation of the EFMP**	Prepare an EFMP in accordance with Section 7.		

Appendix C: Basic 10-point Checklist for Review of EFlows Assessment

#	Criteria	Y	N
1	Were stakeholders adequately engaged at all points in the process?		
2	Is there a review of existing knowledge about the host river system? • Hydrological characteristics • Ecological attributes and key features of sensitivity • Ecological condition • Social uses and level of dependence on aquatic ecosystem services.		
3	Is there a desktop delineation of the basin/subbasin affected by the HPP? • Are there any floodplains likely to be affected? • Are there any aquatic ecosystems other than rivers likely to be affected by the HPP?		
4	Does the level of assessment undertaken correspond with that recommended through using the decision tree? • If not, are compelling reasons provided for not implementing the recommended level of assessment?		
5	Is the level of resolution of the EFlows Assessment justified?		
6	Is the EFlows Assessment method correctly applied and referenced? • Are the dewatered section and the river downstream of the tailrace assessed separately? • Are the calculations shown? • Are the calculations done correctly? • Are the EFlows contextualized within the hydrological regime of the river? • Are the limitations of the EFlows Assessment made clear?		
7	Are the potential effects of changes in the longitudinal movement of sediments, fish and other organic and inorganic materials adequately described and addressed?		
8	Does the EFlows Assessment consider at least: 1. A site upstream of the HPP reservoir? 2. A site between the HPP weir and the tailrace outlet (if relevant)? 3. At least one site (and preferably more) downstream of the tailrace outlet?		
9	Is peaking-power generation planned? • If so, were the potential impacts of peaking-power releases assessed at an appropriate time-step?		
10	Is an EFMP in place for the construction and operation phases?		

Appendix D: Annotated Table of Contents for EFMP (for Individual Hydropower Projects)

1. Background		
Scope	**Description**	A brief description of the project.
	Context	Detail the location of activities with the national, regional and project-level context.
	Timing	Provide the date of initialization of EFMP, its duration and provisions for revision, if any.
	Framework	Explain where the EFMP and associated subplans fit within the overall management framework for the HPP.
	Stakeholders	Identify the key stakeholders and provide their affiliations and contact details.
	Assumptions and risks	List the key assumptions and risks.
Policy statement	**Objectives**	List the environmental and social objectives, and principles for protection; key performance indicators and targets.
	Management structure	Provide an organogram and outline compliance with national legislation and international agreements.
		Delegate institutional responsibility for implementing the EFMP.
		Define the organizational capacity and competency required to implement the EFMP.
	Funding	Provide names, roles, responsibilities and authorities (including financial) of personnel involved in the implementation and operation of the EFMP.

2. Environmental and Social Management		
Environmental and social Impacts	**Impacts**	List or briefly summarize the environmental and social impacts (such as impaired connectivity or habitat loss).
	Mitigation measures	List the measures to be adopted for preventing, mitigating, offsetting, or compensating for impacts of the identify flow-related impacts (for example, flow releases, fish passages/ ladder, operation flushing rules).
Legal requirements		Outline the legal requirements (including consents) applicable to the environmental and social aspects of HPP operations. This may include lenders' or other financiers' requirements.
3. Implementation and Operation[D]		
Management plans		Include, where applicable, environmental management plans, for example, erosion and sediment control plan, turbine maintenance plans
Operating rules	**Environmental**	Detail the HPP operating rules for (as applicable): • EFlows releases (for example, flows, duration, timing) • Water quality targets and multilevel outlets • Sediment management • Provisions for the passage of plants and animals past the dam wall.
	Social/safety	Detail the provisions to be applied to ensure the safety of local communities, for example, against unscheduled releases and flooding.
Offsets		Outline any initiatives to offset biodiversity impacts. Refer to documentation for detail on these.
Compensation		Outline any initiatives to compensate affected communities for losses/inconveniences. Refer to documentation for detail on these
Training		Identify training or experience for EFMP personnel.
Emergency contacts	**Impacts**	Identify the contact person(s) for emergencies. Include 24-hour contact details. Detail procedures for notifying relevant stakeholders.

D Significant downstream social and environmental damage can take place during initial plant commissioning and operational testing. This annotated ToC does not cover commissioning phase, but practitioners should be aware of the E&S risk associated to this phase and act accordingly. Good practice involves a specific Reservoir Filling and Commissioning Management Plan.

4. Monitoring and Review	
Monitoring	Outline procedures for monitoring environmental and social management activities to ensure they meet the requirements of the EFMP, including the following: objectives and scope; baseline data to be collected, timing and monitoring schedules; and data analysis.
Reporting and quality control	Outline the reporting, record keeping and quality control arrangements.
Audits	Provide a procedure detailing how internal audits of the EFMP at planned intervals will be conducted, and how the audit recommendations will be used as an input into an external audit of the EFMP.
	Include a procedure for external audits/reviews of the EFMP.
Adaptive management	Outline the provisions for adaptive management, including the following: the adaptive management system; procedures for corrective and preventive action within the EFMP; decision-making; and stakeholder involvement.

SECTION 13

GLOSSARY

Section 13. Glossary

Biodiversity offset:
Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development and persisting after appropriate avoidance, minimization and restoration measures have been taken.

Cascade:
An arrangement of separate devices so that they multiply the effect of each individual device.

Channel morphology:
Physical characteristics of a water channel (e.g., rate of sedimentation transport).

Critical Habitat:
Areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.

Dewatered reach:
Area or section of a water body where water flow/volume is reduced or removed via diversion to another section.

Diversion:
Involves redirection of a body of water that can be used to supply irrigation systems, reservoirs, or hydroelectric power generation facilities.

Geomorphological delineation:
The delineation of homogenous reaches/zones along a river based on a systematic assessment of similarities in geographic location, size, climate, geology, topography, landuse and river zonation (slope, channel types, biotic distributions, condition).

Hydro-peaking:
An operating mode in hydropower generation in which water from the dam is released and power generated for only part of the day, corresponding to peak demand for power in the system.

Intake:
Main entry of water into hydropower system.

Lateral connectivity:
Connectivity between a channel with floodplains or other secondary channels around it, which results in the exchange of water, sediment, organic matter, nutrients, and organisms.

Longitudinal connectivity:
Connectivity of the entire length of a river or stream.

Modified Habitat:
Areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands.

Natural Habitat:
Areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition.

No Net Loss:
The point at which project-related impacts on biodiversity are balanced by measures taken to avoid and minimize the project's impacts, to undertake on-site restoration and finally to offset significant residual impacts, if any, on an appropriate geographic scale (e.g., local, landscape-level, national, regional).

Powerhouse:
The hydropower structure that houses generators and turbines.

Tailrace:
The channel that carries water away from the powerhouse.

Trapping bedload:
Trapping in a reservoir of the sediments that move along the bed of a river by rolling, sliding, and/or hopping

Weir:
A low wall built across a river to raise the level of water upstream across a river to raise the level of water upstream, regulate flow and/or direct the water towards the intake.

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