FISH-FRIENDLY IRRIGATION

GUIDELINES TO PRIORITISING FISH PASSAGE BARRIERS IN THE LOWER MEKONG RIVER BASIN

February 2023
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Fish-Friendly Irrigation

Guidelines to Prioritising Fish Passage Barriers in the Lower Mekong River Basin

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Citation


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## ABBREVIATIONS AND ACRONYMS

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<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>LMB</td>
<td>Lower Mekong Basin</td>
</tr>
<tr>
<td>MAFF/Japan</td>
<td>Ministry of Agriculture and Forestry and Fisheries of Japan</td>
</tr>
<tr>
<td>MRC</td>
<td>Mekong River Commission</td>
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<tr>
<td>NGO</td>
<td>Non-government organization</td>
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<tr>
<td>O&amp;M</td>
<td>Operations and maintenance</td>
</tr>
<tr>
<td>PIT</td>
<td>Passive integrated transponder</td>
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<tr>
<td>US-DOI</td>
<td>Department of the Interior of United States of America</td>
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EXECUTIVE SUMMARY

Background

The Lower Mekong Basin (LMB) supports the health and wellbeing of 60 million people, many of whom rely on the fisheries production of the Mekong River system for food and income. The river fisheries of the region provide a major source of protein for this population, making the sustainable use of this resource critical to the ongoing wellbeing of the population.

Within the LMB, there are about 1,150 species of fish, the vast majority of which migrate upstream and downstream in the river system throughout the year and in the floodplains during flood events. They migrate to spawning areas, disperse into new habitats or to access food resources. Without the free movement of fish throughout the basin, fisheries productivity would decline.

Throughout the LMB, tens of thousands of barriers to fish migration have been constructed. Dams, weirs, regulators, floodgates and road crossings may all form steps in the river that are too high for fish to pass. Although high dams for hydropower are obvious barriers to fish migration, the most numerous barriers are low-level structures, built mainly for irrigation, which are the focus of these guidelines.

These barriers have a significant impact on fish by preventing migration and completion of life cycles, and by concentrating fish into areas where they can be over-exploited. The cumulative impact of these barriers on the LMB fish populations is large and has long-term implications for the continued productivity of the system. In order to achieve a balance of irrigation development and fisheries production and preserve biodiversity, the passage of fish (or ‘fish passage’) is required. Hence, fish passages or ‘fishways’, which are devices that allow fish to ascend a barrier by creating a series of small steps and resting pools to slow the velocity of water, is to be installed with irrigation facilities such as headworks and weirs. Fish also migrate downstream, so fishways need to be designed to pass fish downstream. Typically, most river flow passes over a barrier (gates or spillway) and not through a fishway, so the barrier itself may also need to be modified to improve fish survival.

Prioritisation

Since constructing a fishway or fish passage at a barrier is a significant task, it should be undertaken at high-priority sites first. However, there is little guidance available on the assessment and Prioritisation of fish passage barriers, or on fishway design for low-level structures such as irrigation facilities. Therefore, in 2015, the Mekong River Commission initiated a ‘Fish-Friendly Irrigation Project’ with two components: barrier Prioritisation and fishway design. These were initially included in one document, “Guidelines to Prioritising Fish Passage Barriers and Creating Fish-Friendly Irrigation Structures in the Lower Mekong Basin, but now in separate documents because they target different users for each component. The second component, Guidelines on Fishway Design, Construction, Maintenance, Monitoring
and Adjustment – can be used independently on a project, or they may follow the selection of a high-priority barrier using the present guidelines.

The barrier Prioritisation methods were initially based on experience in Lao PDR and Australia, and needed to be examined for broader practical use in the LMB. Therefore, from 2018 to 2020, the MRC examined the adaptability of these methods by conducting pilot testing in Lao PDR, Thailand, Cambodia and Viet Nam, with the U.S. Department of Interior (US DOI), the Australian Centre for International Agricultural Research (ACIAR) and Charles Sturt University (Australia). The MRC revised the Prioritisation Guidelines based on the results of the pilot testing.

The Prioritisation Guidelines provide a concise method for practitioners to identify the highest priority barriers for installing fishways in a selected catchment. The method is based on physical, biological and socio-economic considerations, and uses remote sensing tools and analysis to assess and rank large numbers of barriers.
INTRODUCTION

Background

The LMB is the most important aquatic ecosystem in South-East Asia, with extremely high fish diversity and habitat complexity. It has one of the world’s richest fish faunas, with about 1,150 species now recorded (MRC, 2018). The Mekong River Basin supports one of the world’s largest inland capture fisheries, a resource that provides food and livelihoods for millions of people (MRC, 2010). The total catch from the LMB has been estimated at about 2.3 million tonnes per year of fish and other aquatic animals, which supports millions of livelihoods and provides a significant part of the food supply across the entire basin (Hortle, 2009).

Traditionally, many small dams were built to divert water locally to rice fields, but the scale and pace of dam building increased during the late 20th century, particularly in northeast Thailand. Many Mekong Basin dams have been designed to store wet-season inflows for release during the dry season, and these storage dams even out seasonal variations in flows (MRC, 2017). However, there are tens of thousands of smaller structures, such as dams, weirs, regulators, floodgates and road crossings, which can affect fish migrations in the LMB (Figure 1). This scale of river development is expected to negatively impact the LMB fisheries, and one of the main impacts of which is on fish migration. These barriers limit the migration of fish, affecting the completion of life cycles, and leads to overharvest where local communities exploit fish accumulations below the instream structures.

Fish passage at these structures can be restored using fishways. The question, however, is: “Which barrier to fix first?” These Guidelines outline a step-by-step method for the identification and Prioritisation of all existing barriers to fish migration in the natural stream system. They do not include structures within irrigation systems, such as channels, pumps and other headworks. The Guidelines provide a prioritized list of barriers to enable informed investments by NGOs and government organizations in rehabilitating fish passage.
Figure 1. Existing and planned irrigation projects in the LMB (Source: MRC, 2018)
**Fish migration**

In the LMB, three migration systems have been proposed to describe general patterns of migration for large numbers of fish species along and near the mainstream (Figure 2). The Lower Mekong Migration System extends along the mainstream from the delta to Khone Falls and includes the Tonle Sap and the lower reaches of Mekong tributaries in Cambodia (yellow line). Many fish within this system feed and grow during the wet season within the floodplains of the Tonle Sap and Delta, the ‘fish factory’ of this system, migrating out of flooded areas as water levels fall, and then swimming to dry season refuges, particularly deep pools along the Mekong in upper Cambodia. At the beginning of the wet season, many fish spawn in upper Cambodia with their larvae subsequently drifting downstream to productive floodplains; others migrate to floodplains to spawn, and many adult fish migrate downstream to access productive floodplains.

The Middle Mekong Migration System is partly separated from the lower system by Khone Falls, a natural barrier (red line). Within this system, fish typically reside in deep pools in the mainstream during the dry season and migrate upstream to either spawn in the Mekong River, its tributaries, or in floodplains at the start of the wet season. Fish move off floodplains as water levels fall and return back downstream to their dry season refuges in the Mekong.

The Upper Mekong Migration System encompasses the upland Mekong from around the Loei River confluence upstream to and probably extending into China and is separated from the middle system by long reaches of shallow sandy habitat near Vientiane (blue line). This upland reach of the Mekong is confined within a steep valley and lacks large floodplains, which are also relatively limited in extent along the tributaries. Hence, fish primarily migrate upstream within the main channel in the late dry season or early wet season, followed by spawning and downstream drift of larvae, with later return downstream migration of adults. More background information and details of the three migration systems are provided in Poulsen et al. (2002).

**Barrier Prioritisation**

There are hundreds of thousands of barriers restricting fish migration in the LMB. However, only a few fishways have been installed in the irrigation structures due to limited funds of governments. Therefore, it is necessary to identify and prioritize barriers that significantly impact fish migration and local economies, and that can be cost-effectively rehabilitated.

Dams on tributaries together with other barriers on smaller watercourses and floodplains have already interrupted these migration systems to some extent, and large dams on major tributaries or on the mainstream will further block fish migration. While all dams have some impacts on fish passage, the most disruptive for fisheries will be the large dams proposed on the Lower Mekong mainstream (near productive floodplains).

There are many smaller dams in the tributaries that impact fish migration. As well as effects on productivity, it should be noted that most of the Mekong’s endemic species are small, specialized fishes found in tributaries, and many are confined to one or a few rivers in the
eastern part of the catchment along the Animate range, so tributary dams are likely to have a disproportionate effect on regional fish biodiversity (Ziv et al., 2012).

Figure 2. Three migration patterns in the LMB
(Source: MRC, 2021)
Overview of Prioritisation Method

The Prioritisation comprises a five-step process (Figure 3) that identifies barriers, evaluates the fishery and ecosystem, and assesses the economic cost and social benefit of barrier repair:

- **Step 1. Identification** – Identify the locations of the potential barriers by using satellite imagery;
- **Step 2. Remote Assessment** – Analyse the scale of fish habitat and fish community by using five attributes of the potential barriers;
- **Step 3. Field Appraisal** – Record physical attributes of potential high-priority barriers identified by the remote assessment;
- **Step 4. Biological Assessment** – Analyse five properties of the barrier and site related to the fish habitat and the local economy;
- **Step 5. Socio-economic Assessment** – Analyse four socio-economic factors related to construction cost and ease of maintenance.

One of the advantages of this process is to assess and prioritize thousands of potential barriers prior to requiring site visits. An initial desktop study employs the efficiency and unique decision-making capabilities of an automated GIS system to assess wide-ranging spatial habitat characteristics associated with each potential barrier. The approach allows limited resources to be directed towards assessing the highest-ranking potential barriers after the initial GIS stage.

A significant part of this method is using proxies (or substitutes) in the GIS data. For example, many studies have demonstrated the link between habitat condition and fish community condition, with highly degraded habitats having reduced fish communities. The degradation of habitats is directly related to the intensity of land use in the surrounding catchment, which can be easily identified in a GIS. Thus, the intensity of land use can be used as a substitute for the condition of the fish communities, with fish community condition in pristine, undisturbed catchments highly likely to be better than those in intensively developed catchments. In this way, mapping characteristics assessed by the GIS can substitute for characteristics that are difficult to collect and represent spatially.

The aim of this Prioritisation process is to identify barriers against migration impacting the entire fish community and in both up and downstream directions.
However, it is important to note that downstream migration may involve eggs and larvae, and requires a very specific set of criteria and design considerations. This is different from assessment criteria of other barrier Prioritisations biased towards particular fish families, economically important fish species or specific river reaches. Subjective Prioritisations, particularly those focused on primarily high-value species, inadvertently create environmental conditions that are unsuitable for some sections of the fish community, either by upsetting the balance of predator to prey relationships or by disadvantaging fish species that occupy specialized trophic niches that are fundamental to aquatic ecosystem functioning (Kemp and O’Hanley, 2010).

Barrier Prioritisations that only investigates particular river reaches or sub-sections of catchments have the potential to neglect or inadequately investigate downstream barriers (Moore and Marsden, 2008). This inappropriate investigation could cause a downstream barrier, which is not found, to prevent or delay sections of the fish community from reaching upstream habitats.

**Barrier Assessment Procedure**

![Flowchart representing the various stages (steps) of the prioritisation](image)

**Figure 3.** Flowchart representing the various stages (steps) of the prioritisation
The system considers the importance of various migration patterns and the likelihood of localized extinctions caused by the barrier. As a result, the process is designed to prioritize barriers located close to the Mekong River or the East Sea (South China Sea), if they are on large streams. Barriers located on large streams close to these large water bodies will prevent many fish from migrating upstream to feed or breed.

A large portion of juvenile fish in a population can be lost if adult fish cannot find suitable spawning habitat, and juveniles are unable to find suitable nursery habitats. If fish passage is prevented year after year, fish populations can severely decline, leading to: localized extinctions of species; the reduction of livelihoods of local communities; and broader reduction in food security in the region. The impact of barriers on the large fish communities close to the Mekong River or East Sea is considered more critical than their effect on the smaller fish communities in the headwater streams. In addition, these headwater streams have much greater gradients that can create natural barriers to fish movement.

It is important to note, however, that there are also significant migrations of fish within tributaries, which could change priorities within a catchment. These are not as well documented as migrations along the mainstream Mekong River but should be considered during the field appraisals.

The Prioritisation process used in these guidelines has been successfully conducted in seven catchments of the Lower Mekong, the Xe Champhone and the Nam Ngum in Lao PDR, Huay Luang in Thailand, Pursat in Cambodia, and Dac Lac and Nong in Viet Nam. These trials have demonstrated that the Prioritisation process can be undertaken successfully in the LMB and it is suitable for implementation in other sub-catchments throughout the basin.

**Adjustment of scores or weighting of attributes**

As individual regions will have different priorities for the fish passage rehabilitation as well as unique conditions that may influence the results of the Prioritisation process, the adjustment and/or weighting of scores may be appropriate. These Guidelines have outlined a scoring regime that is suitable across most of the LMB.

An example where the score adjustment may be inappropriate can be found in the two sections of the Mekong River Basin in Viet Nam. In the upper reaches of the Vietnamese Mekong, many of the structures are very large due to the steep gorges of the streams in the area, while in the delta section of the Mekong River barriers are unlikely to be very large since the country is very flat. In this example, the small barriers are likely to block large migrations just as effectively as a high barrier and should therefore be scored similarly. In this case, the score can be adjusted so that smaller barriers score the same as large barriers.

An example of where the weighting of attributes might be appropriate would be where a regional committee believes that the productive benefit to local villages should be the highest priority within the scoring system. As such, the committee may determine that proving a 100% weighting to the Productive Benefit score (thereby doubling the score) will ensure that this aspect is given the correct consideration within the scoring system. In this
way, the committee can ensure that projects with the most benefit to the local community will be considered the highest priority.

The adjustment of scores or the weighting of different attributes can allow the local project officers to refine the priority list to reflect the unique circumstances that occur in their local area or that are of concern to their local communities. However, it should be recognized that overuse of the score adjustment or attribute weighting can have a detrimental impact on where rehabilitation works are undertaken and thus should be used sparingly and with caution. However, in areas where funding becomes available for fish passage, it should be encouraged, even if the structure does not rank highly from the Prioritisation.
Step 1 – Identify potential barriers to migration

The first step identifies all potential barriers to migration within a catchment, even if, at a later stage, they are proven not to be a barrier. These potential barriers are listed for the field assessment step.

1.1 What is a fish migration barrier?

A fish migration barrier is any structure that crosses a fish migration pathway along rivers or streams, or into wetlands. These barriers can take many forms and impact on fish communities in a variety of ways. Large barriers such as dams and weirs create a vertical drop that fish are not able to jump, while lower barriers like culverts and regulators create high velocities that fish cannot swim against. The main structure types impacting on migrations are shown in Annex 1.

1.2 GIS utilization

GIS assessment of all potential barriers enables the Prioritisation process to assess tens of thousands of potential barriers and systematically rank them. GIS software, e.g. Google Earth, Quantum GIS, ArcGIS, can be utilized for:

- identifying barriers remotely using satellite imagery and GIS data and mapping them;
- analysing data within GIS programs to score Prioritisation metrics;
- undertaking field assessments of potential barriers;
- recording data into portable field tablets in GIS;
- scoring various metrics to prioritize barriers;
- outputting maps and reporting the highest priority barriers in a catchment.

1.2.1 Identify catchment and collect GIS data

The spatial data are best suited for a rapid assessment of barriers rather than using paper maps. The spatial data plots:

- Catchment boundary;
- Streams;
- Land use;
- Villages;
- Roads;
- Railways;
- Irrigation headworks, weirs, pumps, regulators;
- Satellite imagery/aerials (Figure 4).

To identify a catchment, it is desirable to use a GIS (watershed delineation) and determine boundaries by using GIS expert knowledge and digitize them over a topographic map. In
addition, on the topographic map, it is necessary to mark the mouth and the highest points around a stream, and draw a line from the mouth to the first high point crossing the contour lines at right angles.

1.2.2 Identify potential fish barriers

Satellite imagery and aerial photography are analysed to identify any potential barriers (i.e. any structure that intersects a waterway and appears to create a barrier), within a target catchment. Figure 5 shows the locations of potential barriers identified by GIS in a catchment of Stung Pursat, Cambodia. Each barrier is coloured according to stream order. Barrier classification by stream order is necessary to conduct the Remote assessments. This is corroborated with any secondary vector data available that identifies structures likely to be a barrier such as irrigation infrastructure or road crossing data layers. Barrier reference numbers should be allocated to each identified barrier on the GIS mapping database and maps. Once all potential barriers have been identified, they are given an initial Prioritisation using the second-step remote assessment in the catchment regardless of the type of barrier (or non-barrier).

All structures that intersect waterways are potential barriers and need to be recorded and investigated by traveling to the site so they can be prioritized. However, large weirs and dams should be excluded from the barrier identification process because they are not low-head irrigation facilities.
Figure 5. Potential barriers to fish migration in Stung Pursat catchment, Cambodia
Step 2 – Remote assessment of barrier Prioritisation

Step 2 of the barrier Prioritisation incorporates a desktop GIS process to efficiently investigate spatial habitat characteristics associated with each potential barrier identified in Step 1.

The initial GIS process allows the Prioritisation to set an achievable target of potential barriers for field appraisal in Step 3. If resources are unlimited, all potential barriers could be ground-truthed. However, due to the high numbers of barriers and limited funding available for fisheries-based riverine restoration projects, this is rarely achievable. Therefore, the GIS is used to rapidly assess large amounts of geospatial vector data for each potential barrier and produce a list of the top-ranked barriers. The GIS process is using only remotely sensed data and does not provide detailed information, which is why it is then necessary to visit each of the top-ranked barriers in Step 3.

The potential barriers are assessed against four geospatial attributes:

- **Attribute 1. Stream order** (used as a proxy, or substitute, for stream size);
- **Attribute 2. Intensity of land use** (used as a proxy for habitat quality, and fish diversity and abundance);
- **Attribute 3. Number of barriers downstream** (used to indicate the extent of upstream-migrating fish that could be present);
- **Attribute 4. Sub-catchment area upstream** (used to estimate).

Each potential barrier is assigned a score (1–5) for each attribute. Scores for all questions are combined and totaled.

The following attributes will determine if a potential in-stream barrier is a high priority after Step 2:

- affect **large fish populations** – Large rivers provide the best and most diverse habitats, maintain refuge pools throughout the dry season, and have the most diverse fish communities. Therefore, barriers on these rivers are likely to have a greater impact on a larger range of species, especially if fish are migrating upstream or downstream to refuge pools;
- affects **excellent habitats upstream** – Good catchment condition – Fish communities in catchments with minimal adverse surrounding land use practices are generally in better condition than those that are negatively affected by pollution from the surrounding land;
- **easy fish access** – Minimal to no barriers located downstream – Barriers downstream of a site restrict the movement of fish up to the site; conversely, barriers downstream of a site will impact downstream migration. As it is always harder for fish to move upstream past a barrier, having many barriers downstream reduces the number of fish that can move up to the site, making the downstream barriers more critical;
- **Barrier location** – The barrier located in the lower reaches of the river system – Since barriers have the greatest impact on upstream movement and the large habitats of
the Mekong River or East Sea contain the most fish, barriers close to these water bodies will have the largest impact on fish communities. It should be noted that if downstream migration is of concern, then this also needs to be considered in the opposite direction (i.e. from upstream to downstream).

The project team will categorize each of these attributes and score them. The scores are weighted by the importance of that attribute to determine the priority of the barrier. Figure 6 shows an example of the output, with the locations of 60 barriers in the Stung Pursat catchment and indicates the highest scores using the remote assessment of Step 2. The output is visually easy to understand and enables rapid selection of sites for field appraisal.

Figure 6. Ranking and location of high-scored barriers in Stung Pursat catchment developed by remote assessments

2.1 Remote biophysical assessment attributes

Attribute 1 – Stream order

The first attribute to be assessed is the stream order of a river; i.e. whether it is a major river, medium river, or small stream. A major river scores the highest, and a small stream or wetland, the lowest (Figure 7).

River and stream size is a powerful proxy for habitat. Large stream and wetlands generally contain a greater complexity of habitats, a higher diversity and abundance of fish species, and larger additional subsistence and economically profitable fish species than small streams and wetlands (IUCN, 2011).
Stream order can be utilized to categorize the size of a river and stream, and is a globally recognized system of categorizing rivers. A barrier located in the lowest reach of a catchment has the highest score (Table 1) because it represents the larger stream that covers the greater river and habitat area upstream; it also impacts fish migration more than the other barriers in rivers with small stream order.

First-stream order barriers located on small ephemeral (i.e. not flowing all year) waterways can be deleted from the process. First-streams are small and flow into and feed larger streams, but do not have tributaries that flow into them.

Table 1. Scores for stream order for all potential barriers

<table>
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<tr>
<th>Waterbody Category</th>
<th>Score</th>
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<tbody>
<tr>
<td>a. Barrier located in the lower reaches of the river, more than the 6th stream order</td>
<td>5</td>
</tr>
<tr>
<td>b. Located on the 5th stream order</td>
<td>4</td>
</tr>
<tr>
<td>c. Located on the 4th stream order</td>
<td>3</td>
</tr>
<tr>
<td>d. Located on the 3rd stream order</td>
<td>2</td>
</tr>
<tr>
<td>e. Located on the 2nd stream order</td>
<td>1</td>
</tr>
<tr>
<td>d. Located on a small ephemeral waterway with 1st stream order (removed)</td>
<td>-</td>
</tr>
</tbody>
</table>

Attribute 2 – Intensity of land use

This attribute is determined by the percentage (%) of intensive land use within the sub-catchment where the barrier is located. The percentage is calculated by dividing the area of intensive land use into the one of the sub-catchments. Using ArcMap or Quantum GIS, land use data is clipped to the sub-catchment. Intensive land use practices are then grouped
together and total intensive land use calculated. Intensive land use categories include: rice, agricultural plantation, other agricultural land, and urban or built-up areas.

The intensity of agriculture directly affects the fish communities within a river system due to many negative effects on the fish habitats within the system. The clearing of land or riparian zones often leads to high levels of sediments that smother habitats and reduces refuge pool size (Figure 8). These impacts negatively affect the fisheries of the catchment, reducing catches to local communities. **Sub-catchments with minimal intensive land use (Figure 9) can produce more diverse and abundant fish communities and score higher in this attribute.**

![Figure 8. land Clearing conditions](image)

![Figure 9. Pristine catchments](image)

<table>
<thead>
<tr>
<th>Catchment Condition</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ≥5% intensive land use</td>
<td>5</td>
</tr>
<tr>
<td>b. 5–15% intensive land use</td>
<td>4</td>
</tr>
<tr>
<td>c. 16–30% intensive land use</td>
<td>3</td>
</tr>
<tr>
<td>d. 31–50% intensive land use</td>
<td>2</td>
</tr>
<tr>
<td>e. ≥ 50% Intensive land use</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 2. Scores to the catchment condition for all potential barriers**
Attribute 3 – Number of barriers downstream

This step assesses the number of potential barriers downstream in a direct path to the confluence with the Mekong River (or East Sea). The logic is that a barrier that has many barriers downstream from it will have less fish being able to access it from downstream. Therefore, a barrier that has less barriers downstream achieves a higher score than those that have more barriers downstream. For example, in Figure 10, Barrier “A” has the highest score because there are no barriers downstream, whereas Barrier “B” has the lowest score due to five barriers downstream.

There are two significant assumptions to be aware of with this logic: the major source of fish in tributaries is from fish migrating upstream from the Mekong River or East Sea; and downstream migration occurs safely over weirs and through sluice gates. In some cases, however, tributaries are likely to have self-sustaining populations of migratory fish so the barriers that are between spawning and nursery habitats will become more important. The priorities for downstream migration may be difficult to assess as it will depend on populations of fish upstream; if these have drifting larvae, then it is possible that an upstream barrier with undershot gates (which injure and kill larvae) could be a higher priority. Practitioners using these guidelines should seek local knowledge to evaluate these issues.

![Figure 10. Number of barriers downstream](image)

Table 3. Scores to the number of barriers downstream for all potential barriers

<table>
<thead>
<tr>
<th>Total number of barriers downstream</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. No potential barriers downstream</td>
<td>5</td>
</tr>
<tr>
<td>b. One potential barrier downstream</td>
<td>4</td>
</tr>
<tr>
<td>c. Two to four potential barriers downstream</td>
<td>3</td>
</tr>
<tr>
<td>d. Five to nine potential barriers downstream</td>
<td>2</td>
</tr>
<tr>
<td>e. Ten or more potential barriers downstream</td>
<td>1</td>
</tr>
</tbody>
</table>
Attribute 4 – Sub-catchment area upstream

This step assesses the catchment area (ha) upstream of the potential barrier (including the catchment of all tributary streams) as a proportion (%) of the total catchment area (ha). For example, in Figure 11, the percentage of the catchment upstream of Barrier “A” is larger than that of Barrier “B”. Barriers that block a high proportion of the catchment have a greater impact than those that only block small section of the catchment. **Hence, potential barriers that are at the lower end of a catchment will score higher than those in the upper reaches.** Scoring is shown in Table 4.

![Figure 11. Sub-catchment area upstream](image)

**Table 4.** Scores to be attributed to the percentage of the catchment upstream of the potential barrier

<table>
<thead>
<tr>
<th>Area of upstream habitat as a proportion of total catchment</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 50+% of total catchment</td>
<td>5</td>
</tr>
<tr>
<td>b. 30–49% of total catchment</td>
<td>4</td>
</tr>
<tr>
<td>c. 10–29% of total catchment</td>
<td>3</td>
</tr>
<tr>
<td>d. 5–9% of total catchment</td>
<td>2</td>
</tr>
<tr>
<td>e. ≤ 4% of total catchment</td>
<td>1</td>
</tr>
</tbody>
</table>
Step 3 – Field appraisal of highest priority potential barriers

Step 3 is a field appraisal of the highest-ranked potential barriers. It determines if the site is an actual barrier and defines the key barrier characteristics that cannot be determined by remote assessments (Figure 12). Barriers that have no impact on fish passage at low, medium or high flows, are removed from the assessment process. During the field appraisal, the team also collects data for Steps 4 (Biophysical assessment) and 5 (Socio-economic assessment).

The scope of the field appraisal will be determined by the staff available to visit the sites and record data on potential barriers. Around 200 sites are an achievable number of sites for a small team to visit in a month. If available, larger field appraisals can be conducted by scaling up the number of staff for each area.

To undertake the field appraisal, a team composed of fisheries biologists, engineers, and local irrigation officials should be assembled. This mix of expertise allows all factors associated with the barrier to be understood and enables various and comprehensive data to be collected.

The barriers should be pinpointed on portable mapping software that can be taken to the site with the team. Utilizing tablets loaded with mapping software is the most efficient means to navigate to the site. Relying on local knowledge is useful, but also limited as many barriers are old and unused. Local knowledge should be used because an adjunct to the mapping but at no stage should replace the GIS mapping tools, since this can compromise the data collection process.

**Figure 12.** Two potential barriers identified in stage 1 visited

*Note: A is a bridge and not a barrier, while B is determined to be an actual barrier and further measurements are being taken.*
A field appraisal needs to be conducted in both the rainy and dry seasons. In the rainy season, a biological assessment can be conducted because it is the best timing to observe fish migration and flow conditions at the barrier. However, it is difficult to measure the structure of a barrier during high water levels. Therefore, the structure should be assessed in the dry season when river flow and water levels are lower. If a field appraisal is conducted in both seasons, the difference in water levels at the barrier can be observed, which is a key characteristic for assessing fish passage. If there is difficulty in implementing the field appraisal twice, it should be conducted in the rainy season but avoiding a flood period.

### 3.1 Tools

Tools that will prove useful for the team to locate, identify, measure and record data from the site include:

- car/van (four-wheel drive) and driver;
- GPS, tablets installed with GIS mapping/navigation software with potential barriers database;
- dumpy level or other accurate height measuring tool (theodolite, laser level) capable of measuring the relative height of objects across the entire site;
- digital camera and/or video;
- tape measures of 10 m and 50 m or a laser distance measure in order to measure entire site;
- data sheets and recording tools.

![Figure 13. Tools required for site inspection](image)

### 3.2 Collect and record data and information on individual sites

The team needs to record collected data and information on individual sites on the Field Appraisal Sheet (Annex 2). The collected data and information on the Sheet can be utilized for conducting the remote assessments, which are indicated in Step 4 and 5, and in designing a fishway. Annex 3 indicates how to fill in this sheet in detail.
Step 4 – Refined biophysical assessment

Step 4 scores the data collected from the field appraisal and refines the priority list created in the remote assessment. This assessment identifies the highest priority barriers in terms of biological productivity.

The confirmed barriers are assessed against five physical attributes that affect biological productivity, relating to the barrier size, stream condition, water quality, instream habitat and fisheries production.

Each barrier is assigned a score (i.e. 1–5) for each of the physical criteria.

The biophysical assessment assigns a score to all inspected barriers based on the following five attributes:

- **Attribute 5. The extent of barrier to fish migration** (whether or not fish can pass the barrier) – High barriers that have a greater impact on the bidirectional movement of fish score highly in this criterion. Low barriers that are easily passed by fish have less impact and have a low score;
- **Attribute 6. The river condition upstream of the barrier** – Barriers in catchments with intact riparian (river edge and river corridor) zones are likely to have a greater impact as the fish communities in these catchments are usually more productive than those in degraded catchments; hence, they will score highly;
- **Attribute 7. The stream flow and waterhole permanence** – Streams with natural, permanent flows (i.e. perennial) have more abundant and diverse fish communities than those where flow is either not permanent (i.e. intermittent or ephemeral streams) or regulated and released from an upstream dam. Barriers score highly if there is permanent, natural flow, and receive a low score if flow is not permanent or is regulated;
- **Attribute 8. The habitat for migratory fish species upstream** – Streams with diverse and abundant instream habitats support more abundant and diverse fish communities, so barriers on these streams have a greater impact and score highly;
- **Attribute 9. The importance of Fishing at Barrier** – Streams with good fish populations are more popular and productive fishing grounds. If a barrier site is within an important fishing ground, it is likely that any barriers in the stream would negatively impact fish communities and fisheries. Sites that are highly valued by fishers will score higher for this criterion.

4.1 Biological assessment criteria

**Attribute 5. – The extent of barrier to fish migration (whether or not fish can pass the barrier)**

The size of the water drop over the barrier or the velocity of the water through the barrier reflects the proportion of the fish community that is able to pass the barrier when migrating
upstream. High barriers, such as dams without fishways, are not considered passable, even on large streams, as fish are not able to migrate upstream past them during any flows. Weirs have varying levels of passage depending on their height and the stream size where they are built. A low weir on a large stream has high passage levels since it will ‘drown out’ (i.e. be submerged in high flows) more frequently than a large weir on a small stream, which will have low passage levels. Culverts can also be barriers during low to medium flows (up to drown-out), due to high drops or high velocity at the downstream end.

In this Attribute, **barriers are categorized by their height and type, with higher barriers achieving a greater score because their repair is more critical for fish movement.**

Table 5. Scores to be attributed to the passage opportunity of the barrier

<table>
<thead>
<tr>
<th>Barrier type</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Dam, weir or regulator ≥ 4 m high</td>
<td>5</td>
</tr>
<tr>
<td>b. Dam, weir or regulator between 2.0 m and 4.0 m high</td>
<td>4</td>
</tr>
<tr>
<td>c. Dam, weir or regulator between 1.0 m and 2.0 m</td>
<td>3</td>
</tr>
<tr>
<td>d. Weir or Causeway less than 1.0 m high, culvert or pipe ≤ 50% of stream width</td>
<td>2</td>
</tr>
<tr>
<td>e. Causeway or Ford less than 0.3 m, culvert or pipe &gt; 50% of stream width</td>
<td>1</td>
</tr>
<tr>
<td>F. No Barrier – DO NOT SCORE REMAINING CRITERIA</td>
<td>-</td>
</tr>
</tbody>
</table>

**Figure 14.** Regulator ≥4m high (left), weir 2–4 m high (middle), weir 1–2 m high (right)

**Figure 15.** Weir less than 1 m high (left), culvert ≤ 50% of stream width (middle), ford less than 0.3 m high (right)

**Attribute 6 – The stream condition upstream of the barrier**

The catchment condition at the site is important for the fish community because a healthy catchment has greater numbers of fish than a degraded one. The team inspects the
catchment condition around the barrier with the local community and looks for conditions suitable for thriving fish communities, generally large deep pools and intact riparian vegetation. The riparian (riverside) vegetation can be used as a proxy for catchment condition, because a catchment with extensive clearing of the riparian zone will have degraded catchment conditions.

Therefore, fully vegetated banks score highly compared with banks that are cleared with little vegetation. Riverbanks with little vegetation cause bank instability, and increasing sediment in the river which smothers instream habitats.

**Table 6**. Scores to be attributed to the catchment condition upstream of the barrier.

<table>
<thead>
<tr>
<th>Stream condition</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. No clearing upstream, banks fully vegetated</td>
<td>5</td>
</tr>
<tr>
<td>b. Some clearing upstream, banks have most riparian vegetation</td>
<td>4</td>
</tr>
<tr>
<td>c. 25–50% of vegetation upstream removed and banks partially cleared</td>
<td>3</td>
</tr>
<tr>
<td>d. 51–75% of vegetation upstream removed and banks mostly cleared</td>
<td>2</td>
</tr>
<tr>
<td>e. Little vegetation upstream and banks fully cleared</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 16.** No clearing upstream (left), some clearing upstream (middle), 25–50% vegetation removed (right)

**Figure 17.** 51–75% of vegetation removed (left), little vegetation upstream and banks fully cleared (middle and left)

**Attribute 7 – The stream flow and waterhole permanence**

Streams that maintain water flow and waterholes throughout the year have greater year-round fish-carrying capacity. *Therefore, these streams have greater long-term fisheries productivity than streams that dry up. This attribute identifies the sites with the greatest*
potential for high-value fisheries, and the sites with year-round good quality water will score higher.

The field team uses local available flow data or interviews with local officials and the local community to determine the existing flow conditions at the site and to identify if the stream flows all year-round and at what intensity. If the stream ceases to flow, the team will try to establish the permanence of existing waterholes in the stream. Streams that dry up completely during the dry season provide no permanent habitat for fish, and the productivity in these systems is considered to be less than those where fish can seek refuge over the wet season.

Table 7. Scores to be attributed to the flow and permanence of the stream upstream of the barrier

<table>
<thead>
<tr>
<th>Water supply / Quality</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Natural permanent flow</td>
<td>5</td>
</tr>
<tr>
<td>b. Regulated permanent flow (via supplemented flow)</td>
<td>4</td>
</tr>
<tr>
<td>c. Stream stops most years. Pools remain at all times</td>
<td>3</td>
</tr>
<tr>
<td>d. Stream stops flowing every year. Pools remain at all times (drought refuge)</td>
<td>2</td>
</tr>
<tr>
<td>e. Stream ceases to flow every year. There are no permanent pools</td>
<td>1</td>
</tr>
</tbody>
</table>

Attribute 8 – The habitat for migratory fish upstream

The presence of good quality instream habitat will improve the productivity of the fisheries in that stream. Weed beds, woody debris and riparian vegetation provide food and shelter for fish and improve the likelihood of there being healthy and productive fish communities.
Field teams will look for streams that have high levels of instream habitat suitable for migratory fish species.

The **streams with high levels of intact habitats will score higher than the streams with little or no habitat in them**. Well-managed habitats or those without development will generally provide the best habitats within this attribute.

**Table 8. Scores to be attributed to the instream habitat of the stream upstream of the barrier**

<table>
<thead>
<tr>
<th>Instream habitat</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Very good. Large quantities of suitable habitat for all migratory fish</td>
<td>5</td>
</tr>
<tr>
<td>b. Good. Moderate instream habitat suitable for all migratory fish</td>
<td>4</td>
</tr>
<tr>
<td>c. Ok. Little instream habitat suitable for all migratory fish</td>
<td>3</td>
</tr>
<tr>
<td>d. Poor. Poor instream habitat for all migratory fish</td>
<td>2</td>
</tr>
<tr>
<td>e. Very poor. Fish cannot live there</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 20.** Large quantities of suitable habitat (left), moderate instream habitat (middle), little stream habitat suitable for all migratory fish (right)

**Figure 21.** Poor instream habitat (left), dry riverbed unsuitable for fish (right)

**Attribute 9 – The importance of fishing at the barrier**

The importance of a barrier to the local fishing community is intrinsically linked to the number of migrating fish being negatively affected by the barrier. Barriers with large numbers of fish immediately downstream are more heavily fished than barriers with few fish. This attribute identifies sites where reinstating fish passage could significantly increase productivity in the waters upstream of the barrier. This provides an indication of where rehabilitating fish passage rehabilitation would benefit all local communities.
The field team will look for evidence of fishing activities at the barrier such as traps, nets or casting stands, and interview local villagers about the fishing activities and the timing and intensity of migrations at the site. Fishing intensity below a structure can indicate the priority for fishway rehabilitation (Figure 22). **Sites with high levels of fishing pressure score higher.**

![Figure 22. Fishing intensity below a structure](image)

**Table 9.** Scores to be attributed to the importance of fishing at the barrier

<table>
<thead>
<tr>
<th>Importance of fishing at the barrier</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Most important fishing location for villagers (fish more than 180 days per year)</td>
<td>5</td>
</tr>
<tr>
<td>b. Regularly fish, second most important fishing location for villagers (fish at the site for more than 90 days and less than 179 days per year)</td>
<td>4</td>
</tr>
<tr>
<td>c. Occasionally fished by villagers (fish for more than 30 days and less than 89 days per year)</td>
<td>3</td>
</tr>
<tr>
<td>d. Minimal fishing effort from villagers (fish at the site for less than 29 days per year)</td>
<td>2</td>
</tr>
<tr>
<td>e. Never fished by villagers</td>
<td>1</td>
</tr>
</tbody>
</table>

Once scoring for all attributes has been collated, the scores for each barrier are totalled and added to the score for that barrier from Step 2, the remote assessment. The barrier with the highest-combined score becomes the highest-ranking barrier with the greatest impact on the life cycles and abundance of fish in the catchment.

These barriers impact fisheries productivity the most by limiting the movement of fish between productive habitats upstream and downstream. Therefore, these barriers will provide the largest increase in fisheries productivity if they are rehabilitated. However, while the increase in fisheries productivity is an essential outcome of the Prioritisation process, selecting a barrier for rehabilitation can also be influenced by other factors such as linking it with other nearby projects.
Step 5 – Socio-economic assessment of high-priority barriers

The socio-economic assessment introduces many social and economic factors to further refine the Prioritisation list. This step identifies the most cost-effective barrier for repair with the greatest benefit to the local community. It is important in determining whether the cost of construction is justified by the social and biological benefits that the fishway will generate for both local community and the environment.

The socio-economic assessment assigns a score to all high-priority barriers based on the following five attributes:

- **Attribute 10. Restoration cost** – The lower the cost to remediate, the more likely the barrier is to be rehabilitated. Generally, smaller barriers with simple fishway requirements will be cheaper to remediate than larger barriers with complex ones, hence will score higher than the more complex structures;

- **Attribute 11. Accessibility for maintenance** – Regular fishway maintenance is necessary for keeping a good fishway condition and prolonging its life-time service. Easy fishway access is essential for defective maintenance; barriers with easier access will score higher than ones with difficult access;

- **Attribute 12. Effectiveness of constructing a fishway at the site** – Unless a barrier is completely removed, any fish passage solution will only provide partial passage for the fish community. Some fishway designs will provide better results than others: full-width rock-ramp fishways are able to pass nearly all fish on all flows, while steep submerged-orifice fishways only pass a small proportion of the fish attempting to migrate. If the barrier is suitable for a highly effective fishway design that can pass many fish, it will score higher than those barriers where only sub-optimal designs can be implemented.

- **Attribute 13. Productivity benefits of constructing a fishway** – Improvement in fishery productivity is the primary aim of fishery rehabilitation in the LMB. For fish passage to be effective, it must provide productivity gains where they can be accessed by the local community. Accordingly, barriers providing greater productivity gain to more villages will have a higher score than those benefiting few villages.

A very important aspect of this step is considering the net benefits of fixing the barrier versus the economic repair cost. Since much of the fish passage rehabilitation will be funded by governments and NGOs whose funding capacity is often quite limited, this step of the Prioritisation is important in understanding which barrier can be affordably fixed in line with resources.
5.1 Socio-economic assessment criteria

Attribute 10 – Restoration cost

Since funds for fishway construction are generally limited, the construction cost is one of important factors to ensure the value of each fishway. Fishways that are lower in cost score higher than those that are expensive to build.

Sites with simple fishway requirements will score higher than sites that require large, complex fishway devices. For example, rock ramp fishways are cheaper and easier to build than large fish locks and will score higher for this attribute (Figure 23). However, this does not mean that expensive sites are less important from the perspective of fish or people, but rather, that the scoring favours cheaper sites over expensive ones. In addition, small barriers usually cost less for restoration than large barriers. The team will determine what fishway options are available for each site during the field appraisal. Therefore, it is essential that both biologists and engineers are present to determine the potential fish passage options.

![Figure 23. Rock ramp fishways (left) and large fish locks (right)](image)

Table 10. Scores to the estimated cost of providing fish passage at the barrier

<table>
<thead>
<tr>
<th>Barrier type</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Low cost small/low nature-like fishway (&lt;1.0 m) or short culvert baffles (&lt;1.0 m)</td>
<td>5</td>
</tr>
<tr>
<td>b. Moderate cost nature-like fishway (1.0 m – 3.0 m) or low technical fishway (&lt;1.0 m)</td>
<td>4</td>
</tr>
<tr>
<td>c. Low-medium height technical fishway (1.0 m–3.0 m)</td>
<td>3</td>
</tr>
<tr>
<td>d. Medium-high height technical fishway (3.0 – 6.0 m)</td>
<td>2</td>
</tr>
<tr>
<td>e. High height or large technical fishway (&gt;6.0 m), fish lock or lift</td>
<td>1</td>
</tr>
</tbody>
</table>

Attribute 11 – Accessibility for maintenance

Accessibility to a fishway significantly influences its maintenance. Some irrigation structures in the LMB are not well maintained or are abandoned due to locations far from operation/maintenance offices or residential areas. Fishways need to be regularly maintained to fulfill their expected function. If a site is hard to access, the fishway may not be well maintained. Therefore, sites that have easy access receive a higher score than sites that have difficult access.
Table 11. Scores to be attributed to the technical viability of providing fish passage at the barrier

<table>
<thead>
<tr>
<th>Access to a site</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Easy site access (no more than 1 km from an operation office or staff residential area)</td>
<td>5</td>
</tr>
<tr>
<td>b. Relatively easy site access (no more than 5 km from an operation office or staff residential area)</td>
<td>4</td>
</tr>
<tr>
<td>c. Modest site access (no more than 10 km from an operation office or staff residential area)</td>
<td>3</td>
</tr>
<tr>
<td>d. Relatively hard site access (no more than 20 km from an operation office or staff residential area)</td>
<td>2</td>
</tr>
<tr>
<td>e. Hard site access (more than 20 km from an operation office or staff residential area)</td>
<td>1</td>
</tr>
</tbody>
</table>

Attribute 12 – The effectiveness of constructing a fishway at the site

Depending on the type of a barrier and operation requirements, the fishway installation and operation may be difficult, or very simple. The fishway installation on a small overflow weir would be simple compared to installing fishway at an irrigation structure having many gates or a high barrier.

![Image](image.png)

Figure 24. A full-width rock-ramp fishway (left) and a partial width fishway (right)

Simple full-width designs are more effective than complex partial-width designs. A full-width rock-ramp fishway will provide fish passage over all flows, while a partial width fishway can only operate on a low range of flows (Figure 24). The degree to which a potential fishway passes all fish on all flows will be determined by the type of structures, fishways and flows. **Structures with simple fishway designs that operate over a wide flow range will score higher because they have a better ability to pass fish.**

Table 12. Scores to be attributed to the effectiveness of providing fish passage at the barrier

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. All species at all migration flows will pass</td>
<td>5</td>
</tr>
<tr>
<td>b. All species at most migration flows or many species at all migration flows will pass</td>
<td>4</td>
</tr>
<tr>
<td>c. All species at some migration flows or some species at all migration flows will pass</td>
<td>3</td>
</tr>
<tr>
<td>d. Some species at some migration flows or few species at all migration flows will pass</td>
<td>2</td>
</tr>
<tr>
<td>e. Some species on a narrow range of flows will pass</td>
<td>1</td>
</tr>
</tbody>
</table>
**Attribute 13 – The productivity benefits of constructing a fishway**

A fishway at high-priority sites should boost fisheries productivity for the local community. During the field appraisal, the field team will examine how many villages may benefit from a barrier rehabilitation.

**Sites with more villages nearby receive a higher score.** The number of villages that would benefit from a fishway is estimated by GIS tools. The score of the beneficiary villages is indicated in Figure 25. If a fishway is installed on Barrier A, fish can move to a river between Barrier A and B.

Therefore, a fishway will benefit local people who can access to the river between Barrier A and B. The number of the expected beneficiary villages will be estimated within a certain distance from a river. Figure 25 shows the fishway beneficiary area as a red square. The ‘beneficiary area’ will be set in the range of 5 km from both sides of the river by GIS tools, and the number of villages are counted within the area.

**Table 13.** Scoring of constructing a fish passage at the barrier, according to number of beneficiary villages

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Benefits more than 10 villages within 5 km from both sides of a river</td>
<td>5</td>
</tr>
<tr>
<td>b. Benefits 5–9 villages within 5 km from both sides of a river</td>
<td>4</td>
</tr>
<tr>
<td>c. Benefits 2–4 within 5 km from both sides of a river between</td>
<td>3</td>
</tr>
<tr>
<td>d. Benefits a single village within 5 km from both sides of a river</td>
<td>2</td>
</tr>
<tr>
<td>e. No villages nearby gain from improved production from both sides of a river</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 25.** Scope of the beneficiary villages
The scores for each barrier from socio-economic assessment are totalled and added to the score for that barrier from the remote and biological assessments. The barrier with the highest combined score becomes the highest-ranking barrier for repair in this Prioritisation process. Those barriers will provide the largest productive benefit for local communities if they are rehabilitated. The final result of this Prioritisation can be mapped by GIS for selecting the rehabilitation site (Figure 26).

Figure 26. Top seven high-scored barriers in Stung Pursat catchment, Cambodia
Step 6 – Select sites for rehabilitation

With many thousands of barriers found in the LMB, finding the right barrier to be rehabilitated is very difficult. If the rehabilitation site is not selected based on the assessment of the barrier Prioritisation, but rather on the preference of local project officers, repair works may not improve fish migration in a catchment. The site-selection methods outlined in the previous chapters have been developed to improve the selection process and enable effective repair. By using tools such as GIS to identify potential restoration sites and by developing assessment criteria that consider ecological, socioeconomic, ownership, and maintenance factors, potential restoration sites can be narrowed to those most likely to succeed. The process can also be undertaken in a relatively short period of time.

The Prioritisation process provides a rapid assessment of the barriers in a target catchment, creating a priority list that can be rapidly acted upon. Much more detailed Prioritisation processes could be undertaken, but they will use vital resources that could be utilized for rehabilitation and possibly produce a list similar to that produced by the rapid assessment.

Before selecting sites for rehabilitation, the team should consider the possibility of removing a barrier from a river or stream because a fishway is the second-best option to ensure fish migration. Many aged, broken or non-used irrigation weirs, gates, and regulators block fish migration. If unneeded barriers are identified after consultation with national and local governments and farmers, they should be demolished.

After examining the possibility of removing barriers, the team will conduct site selection for rehabilitation. While the Prioritisation process develops a ranked list of barriers to be remediated, it is by no means a definitive list that should necessarily be tackled in the order in which it is presented. It is perfectly reasonable to tackle barriers further down the list of structures if there are valid reasons to do so.

Initially, it may be preferable to undertake rehabilitation in areas that can be used as demonstration sites for the broader community in order to generate interest and momentum behind rehabilitation projects. Hence, barriers that are still significant, but not necessarily of the highest priority may be suitable for fish passage rehabilitation. Other opportunities should also be taken if they arise. It may be appropriate to undertake construction of fish passage at the same time as a barrier is being refurbished, even if the barrier is not the highest priority. Funding may also influence the order in which barriers are rehabilitated, as the highest priority structure may be beyond the scope of the funding available for rehabilitation.

In addition to the results of the remote assessments and field appraisal, factors to be considered for selecting a site for rehabilitation include:

- if it is within the rehabilitation budget;
- if support is available from local officials;
- if support is available from local people;
- if the construction site is accessible;
- If the impact on water flow and environment of the stream and on other water users during fishway construction is acceptable;
- if it is a good site to demonstrate fishways to the public.

If a site has these features and is a significant level of priority, then the design and construction should be undertaken. The success of the project will then depend on the application of the MRC *Guidelines on Fishway Design, Construction, Operation, Maintenance, and Adjustment.*
GLOSSARY

Annual exceedance probabilities: The probability (expressed as a percentage) of a flood event occurring in any year.

ArcMap: The main component of Esri's ArcGIS suite of geospatial processing programs, it is used primarily to view, edit, create, and analyse geospatial data.

Barrier: Any structure across a waterway that inhibits the movement of fish up and down a waterway.

Dam: A barrier across a waterway that has a separate spillway structure, they are large structures, usually over 5 m high.

Dipterocarp forest: A forest largely dominated by tropical hardwood trees that are long-lived and can grow to exceptional sizes.

Fish-friendly: A structure that provides easy access for fish to upstream habitats through the design of the structure or inclusion of a fishway.

Fish migration: Movement of fish from their home habitat range to another habitat mainly for feeding or reproducing.

Fish passage: The movement of fish in both upstream and downstream directions past an obstruction in the waterway.

Fishway/fish ladder: An engineered structure that provides fish passage past a barrier.

Floodgate: A structure that prevents floodwaters from entering the floodplain, usually consists of steel flaps that can let water out of the floodplain, but not let water in.

Georeferenced: Geographic/spatial data that identify a specific location on earth.

Geospatial: Relating to or denoting data that are associated with a particular location.

Google Earth: A virtual globe, map, and geographical information program that maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe.

Naiban: Village leader.

Orifice: An opening such as a vent, mouth, or hole through which something may pass. Orifice controls water flow in a fishway, and fish pass it to move from a pool to the next.
**Oziexplorer:** A raster navigation and mapping software for Windows. It is very popular among off-road drivers and adventure travellers as it allows to use and create custom maps for remote locations that are not fully covered by major map providers.

**Potamodromous:** Fish species whose migrations occur wholly within freshwater for breeding and other purposes.

**Proxy:** Substitute.

**Regulator:** A gated structure that regulates the flow of water, usually into off-stream channels.

**Rehabilitation:** The process of restoring a structure, habitat, or stream back to a condition of good condition or operation.

**Road crossing:** Any structure that crosses a waterway to enable traffic to cross the waterway.

**Shapefile:** A popular geospatial vector data format for geographic information system software. It is developed and regulated by Esri as a open specification for data interoperability among Esri and other GIS software products.

**Spillway:** A structure on a barrier that conveys water past the barrier.

**Stream order:** A method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries.

**Vector data:** A data model based on the representation of geographical objects by Cartesian co-ordinates, commonly used to represent linear features. Each feature is represented by a series of co-ordinates which define its shape, and which can have linked information.

**Waterway:** A river, stream, creek or channel.

**Waypoint:** A set of coordinates that identify a point in physical space.

**Weir:** A barrier across a waterway that incorporates the spillway into the main body of the structure.
REFERENCES


ANNEX 1: Types of barriers against fish migration

*Fixed crest weirs*

Fixed crest weirs are defined as a low dam or wall built across a stream to raise the upstream water level. During the wet season, unregulated flow is discharged over the crest, while during the dry season, the weir holds back stored water for use by local communities. A wide variety of weirs have been constructed throughout the LMB, with most located in streams and rivers. They generally consist of a fixed crest structure that stores water for delivery off-stream via irrigation canals (Figure 27). Some weirs are also constructed at the outlet of wetlands; in association with bund walls, these structures usually increase the storage area of the wetland from its natural state (Figure 28). Fixed crest weirs are generally considered to be partial barriers to fish migration, depending on their height and drown-out characteristics. If they are high and drown out infrequently, their impacts on fish communities can be very large. However, low structures that are easily drowned out by flood flows may have only a minor impact on fish communities.

*Figure 27.* Typical run of the river weir located on an upland stream that is too high for fish to ascend
Gated weirs
gated weirs do not have a fixed crest, but instead have a series of gates that can be raised or lowered to store water upstream. Flow is usually discharged under the gates, with the gates raised during high flows so as to not get damaged, and lowered during lower flows to hold water upstream. The gates are then operated during low flows to provide water to downstream consumers. Gates may be radial (Figure 29) or vertical (Figure 30), with radial gates preferred on the larger structures. Gated weirs generally have high velocities under the gates that can negatively impact the movement of fish in both an upstream and downstream direction.
Dams

Dams are larger structures that create an extensive reservoir to supply water for hydroelectricity, flood mitigation, and potable water, or to provide permanent water for irrigation schemes. They are generally over 10 m high. A significant number of reservoirs have been built in the LMB, usually higher up in the catchment, where they are used to deliver water to the downstream irrigation area via irrigation canals (Figure 31) or to generate electricity (Figure 32). Dams form impassable barriers to fish migrations unless they have a fish transfer device installed, because they are never drowned out by river flows.
Regulators

A regulator is a type of impounding structure able to release water downstream from gates. Regulators are similar to gated weirs but are generally smaller and not primarily maintained to create a storage. Regulators are operated either to alter downstream discharge, or to manipulate upstream water level to gravitate water into irrigation systems. Regulators can also be used to store water for dry season needs. These systems may be located downstream of a weir, or off-stream. The gate structures range from complex steel lift gates, occasionally motorized, to simple dropboard structures. A wide variety of regulators have been constructed throughout the LMB and are one of the most common types of irrigation structures affecting fish passage (Figures 33 and 34). The highwater velocities at the gates can negatively impact the fish movement in both an upstream and downstream direction.

Figure 31. Large dam constructed to provide hydroelectricity

Figure 32. Large irrigation dam located in the upper Xe Champhone catchment
Flood gates

Elevated water levels in the Mekong River and other major tributaries during the wet season can threaten floodplain rice crops. To protect floodplain infrastructure and agriculture, floodgate structures have been constructed in the lower reaches of many river systems. The floodgates aim to protect floodplain areas from excessive inundation when river levels exceed critical heights of rice fields. These structures consist of culverts set into levee banks along the river, usually at floodplain drainage points such as stream or wetland outlets (Figure 35). They have a series of flap gates that are forced closed if the water level downstream is greater than upstream. This prevents river water flooding onto the floodplain when there is limited local rainfall. The floodgate systems are common in areas that are affected by the Mekong River or other major tributaries such as the Nam Ngum. They form partial barriers for the most part of the year, but are complete barriers when they are closed, which often coincides with significant fish migration periods.

Figure 34. Steel regulator gates controlling water on a wetland outlet

Figure 33. Another steel regulator gate controlling water from a wetland under a road crossing
Bridges

Bridges are not generally considered to be barriers to fish migrations if they maintain the original cross section of the stream beneath them. However, during their construction, many bridges have further structures such as weirs and regulators built beneath them. These structures, rather than the bridge itself, become the barrier to migration (Figure 36).

It is important to record the presence of bridges from the imagery because they can conceal other barriers beneath them (Figure 37).
Culverts

Culverts are tunnels or pipes that transport water under roads, bridges, or rail. If incorrectly designed, they can become barriers to fish migration due to several factors:

- Placement above ground level;
- High gradient;
- Inadequate flow;
- Lack of resting areas.

Figure 37. A weir hidden beneath a bridge

Figure 38. Culvert with shallow water flow and high drop
**Fords**

A ford is a shallow place with good footing where a river or stream may be crossed by wading, or in a vehicle. A ford may occur naturally or be constructed. Fords may be impassable during high water. A low water crossing is a low bridge that allows crossing over a river or stream when water is low but may be covered by deep water when the river is high (DOF, 2020).

![Ford in Thailand](source: DOF, 2020)

**Temporary weir**

This is a small, non-permanent dam or weir that uses local materials such as boughs and stones to block the stream to reduce water flow. These structures store water to restore degraded forest areas, or to maintain high-water levels in canals during the dry season (DOF, 2020).

![An earth weir in Lao PDR](Source: DOF, 2020)

![A check dam in Thailand](Figure 40. A check dam in Thailand)
Annex 2: Field appraisal sheet

Name of an inspector:

Site information

<table>
<thead>
<tr>
<th>Barrier Reference No.</th>
<th>Date of Visit</th>
<th>Actual Barrier?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Structure Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Video File Times</th>
<th>To</th>
<th>Photo File Times</th>
<th>to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Structure Measurements

<table>
<thead>
<tr>
<th>Barrier Description</th>
<th>Weir or Dam</th>
<th>Road Crossing</th>
<th>Gated Regulator</th>
<th>Water Drop</th>
<th>Tailwater</th>
<th>Headwater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Flow R.L.</td>
<td>1.0m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High Flow R.L.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maximum Water Drop (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Minimum Water Drop (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bank Full Height (m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Cross Channel Width (m) | Structure Width | Individual Culvert/ Pipe/Gate Width | | |
|-------------------------|-----------------|-------------------------------------|---|
|                         |                 |                                     |   |

| U/S/D/S Length (m) | Structure Length | Individual Culvert/ Pipe/Gate Length | | |
|--------------------|-----------------|-------------------------------------|---|
|                     |                 |                                     |   |

<table>
<thead>
<tr>
<th>Apron</th>
<th>Apron Length (m)</th>
<th>Apron Drop (m)</th>
<th>Total Number of Culverts/Pipes/Gates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observation

**Fish species and migration period** (Know/observed, any accumulations below the barrier, and migration timing including downstream migration)

**Upstream changes** (Has the fishery upstream changed due to the barrier?)

**Structure use** (Describe structure operation. Is it used? Can it be removed?)

**Construction access** (Describe access conditions to the site, roads, bank, etc.)

**Local community** (Identify local community associated with structure and their interests in a fishway.)
### Field Appraisal Sheet (five scoring questions)

<table>
<thead>
<tr>
<th>Barrier Reference No.</th>
<th>Date of Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1. Existing Barrier Type

<table>
<thead>
<tr>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dam or Weir</strong></td>
<td><strong>Weir, Dam or Reg</strong></td>
<td><strong>Weir or Dam or Reg</strong></td>
<td><strong>Weir or Causeway</strong></td>
<td><strong>Causeway or Ford</strong></td>
</tr>
<tr>
<td>Greater than 4 m high</td>
<td>Between 2.0 m and 4.0 m high</td>
<td>Between 1.0 m and 2.0 m high</td>
<td>less than 1.0 m high</td>
<td>less than 0.3 m high</td>
</tr>
</tbody>
</table>

#### 2. Catchment Condition Upstream of Barrier

<table>
<thead>
<tr>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Good</strong></td>
<td><strong>Good</strong></td>
<td><strong>OK</strong></td>
<td><strong>Poor</strong></td>
<td><strong>Very Poor</strong></td>
</tr>
<tr>
<td>No clearing upstream, banks fully vegetated</td>
<td>Some clearing upstream. Banks have most of its riparian vegetation</td>
<td>25–50% of vegetation upstream removed and banks partially cleared</td>
<td>51–75% of vegetation upstream removed and banks mostly cleared</td>
<td>Little vegetation upstream and banks fully cleared</td>
</tr>
</tbody>
</table>

#### 3. Stream Flow

<table>
<thead>
<tr>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural permanent flow</strong></td>
<td><strong>Regulated permanent flow</strong> (via supplemented flow)</td>
<td>Stream stops most years Pools remain at all times</td>
<td>Stream stops flowing every year. Pools remain at all times (drought refuge)</td>
<td>Streams cease to flow every year. There are no permanent pools</td>
</tr>
</tbody>
</table>

#### 4. Instream Habitat

<table>
<thead>
<tr>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Good</strong></td>
<td><strong>Good</strong></td>
<td><strong>OK</strong></td>
<td><strong>Poor</strong></td>
<td><strong>Very Poor</strong></td>
</tr>
<tr>
<td>Large quantities of suitable habitat for all migratory fish</td>
<td>Moderate instream habitat suitable for all migratory fish</td>
<td>Little instream habitat suitable for all migratory fish</td>
<td>Poor instream habitat for all migratory fish</td>
<td>Fish cannot live there</td>
</tr>
</tbody>
</table>

#### 5. Importance of Fishing at Barrier

<table>
<thead>
<tr>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very High</strong></td>
<td><strong>High</strong></td>
<td><strong>Moderate</strong></td>
<td><strong>Poor</strong></td>
<td><strong>Very Poor</strong></td>
</tr>
<tr>
<td>Most important fishing location for villagers (villagers fish at the site more than 180 days per year.)</td>
<td>Regularly fish, second most important fishing location for villagers (villagers fish at the site for more than 90 days and less than 179 days per year.)</td>
<td>Occasionally fished by villagers (Villagers fish at the site for more than 30 days and less than 89 days per year)</td>
<td>Occasionally fished by villagers (villagers fish at the site for more than 30 days and less than 89 days per year)</td>
<td>Never fished by villagers</td>
</tr>
</tbody>
</table>

Comments
Annex 3: Detailed information for the Field Appraisal Sheet (Marsden, 2018)

Site information

Information that should be recorded in the Site information section is as follows:

- Date of visit: Site inspection date;
- Actual barrier: Check if the potential barrier identified on the GIS mapping is an actual barrier to fish migration or not;
- Yes – all other remaining data are to be collected for the site;
- No – take a photo and record photo times on the datasheet. No other data are required.

- Barrier name: A local name used by Irrigation officials or the community. Leave blank if there is no name used locally.
- GPS: Record the latitude and longitude of the barrier using the GPS.
- Stream name: Record the stream name on which the barrier is located. Local official records are preferred.
- Structure owner: Record the owner of the structure if known. The owner is the individual or organization who is responsible for the structure and able to give permission for any modifications. The owner is usually a local irrigation department or road department. If contact details are available, please record these in the comments section.
- Video file times: Record the start and finish time of all videos taken at the site. The camera app on the tablet records the date and time of all photos in the file name and this allows matching of photos.
- Photo file times: Record the start and finish time of all photos taken at the site. The camera app on the tablet records the date and time of all photos in the file name and this allows matching of photos.
Structure measurement

Structure measurements are necessary to prioritize barriers for rehabilitation. The physical characteristics of each barrier helps the team to estimate the rehabilitation cost, select fishway types, and design fishways. Structure measurement data are utilized for Step 5, “Socio-economic assessment”. In particular, “Barrier Description” can be vital information for the team to decide on the type and size of a fishway on the barrier.

The physical characteristics should be recorded in the section “Structure measurement” of the Questionnaires. Key data of the physical characteristics should be measured are as follows:

- Headwater and tailwater levels;
- Height, width, and length of the barrier;
- Apron length and drop;
- Maximum water drop and minimum water drop.

All measurements during the field appraisal should be as accurate as possible. When the team cannot physically measure the structure, e.g. the height of a high bank, it should estimate the scale. When a team cannot access a far bank due to water levels, for example, it is advisable for them to use a 100 m laser measurer. To estimate the height, a digital height meter could also be used if available.

Height

The height of a barrier significantly affects fish migration, fishway design and its construction cost. It is difficult for fish to pass a high barrier. In addition, fishway design in a high barrier is more complicated than that in a low barrier. The construction cost of a fishway in a high barrier is also generally higher than at a low barrier. Table 1 indicates measurement points of structure height.

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Total height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam and weir</td>
<td>From the downstream bed level to the full supply water level of the structure</td>
</tr>
<tr>
<td>Regulator</td>
<td>From the downstream bed level to the full supply water level of the structure</td>
</tr>
<tr>
<td>Road crossing</td>
<td>From the total height to the road surface above the downstream bed</td>
</tr>
<tr>
<td>Culvert and pipe</td>
<td>From the floor of an individual culvert and pipe to the roof of the same culver and pipe</td>
</tr>
<tr>
<td>Gate</td>
<td>Height of gate</td>
</tr>
</tbody>
</table>
**Width**

The width of a barrier affects the fishway design and its construction cost. The narrower the width, the simpler its design and the lower its construction cost. Table 2 shows measurement points of width for each structure.

**Table 3.2.** Width of each structure type

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam, weir, road crossing, and regulator</td>
<td>The total width of the structure from bank to bank</td>
</tr>
<tr>
<td>Culvert and pipe</td>
<td>The total width from the right to the left wall of a single culvert and pipe</td>
</tr>
<tr>
<td>Gate</td>
<td>The cross-channel width of each gate in the structure</td>
</tr>
</tbody>
</table>

**Length of the barrier**

The length of the barrier also affects fishway design and its construction cost. The longer the length of a barrier, the more complicated its design and the higher its construction cost. Table 3 shows measurement points for length of each structure.

**Table 3.3.** Length of each structure type

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam and weir</td>
<td>The total length of the structure from upstream to downstream, not including the apron</td>
</tr>
<tr>
<td>Culvert and pile</td>
<td>The total length of a culvert and pipe from upstream to downstream, not including the apron</td>
</tr>
<tr>
<td>Regulator</td>
<td>The total length of a structure from upstream to downstream, not including the apron</td>
</tr>
<tr>
<td>Gate</td>
<td>The total length of a gate from upstream to downstream</td>
</tr>
</tbody>
</table>
**Length and drop of an apron**

An apron is a dissipation floor downstream of a structure that helps to prevent erosion and undercutting of the structure. Table 4 shows ways of measurement of length of an apron.

**Table 3.4. Length of an apron**

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Length</th>
<th>Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam, weir, road crossing, and regulator</td>
<td>Total length of an apron from the base of the main structure to the edge of the apron</td>
<td>Total vertical drop of the apron from the base of the main structure to the downstream bed of the apron</td>
</tr>
</tbody>
</table>

**Hydrological measurements**

If the team cannot obtain comprehensive hydrological data to determine suitable headwater and tailwater levels for a fishway, they need to collect these basic hydrological data from the knowledge of local officials or villagers, and identify signs at the site such as water level tide lines (Figure 44). The team also needs to interview local officials and villagers, and confirm if the physical signs at the site (tide lines) are accurate. It is important to gain local knowledge of the barrier for accuracy.

![Figure 44. Tide line of a weir](image)

**The water drop**
The water drop is the difference between the upstream and downstream water levels across the barrier (Figure 45). The water drop impacts fish migration and affects the fishway design and its construction cost. It is difficult for fish to pass a barrier with a high water drop. In addition, fishway design at a high barrier is more complicated than that at a low barrier. The construction cost of a fishway at a high barrier is also higher than at a low barrier.

To calculate the maximum and minimum height of the fishway entrance and exit, the team needs to know the flow range at the barrier so that they can design a fishway where fish can easily find the fishway entrance on most flows and which fish can pass on a range of flows throughout the year.

*“Tailwater” is water level downstream of the barrier, and “Headwater” is water level upstream of the barrier.

![Figure 45. Tailwater, headwater, and waterdrop of a weir](image)

“Low flow R.L.” is the water level at a weir during low flows, which can be considered the base flow at the end of the wet season (Figure 46). Two low tail water flows should be estimated:

- **Tailwater low flow relative level (R.L.)** is the water level downstream of the structure during low flows and is standardized at 1.0 m regardless of the altitude of the weir. This allows all other measurements to be recorded regardless of whether or not information on altitude is known.
- **Headwater low flow relative level (R.L.)** is the water level on the upstream side of a barrier during low flows.
“High flow R.L.” is the water level at the weir during high flows, often considered the flood flow recorded at the peak of the wet season (Figure 45). Two high flows should be estimated:

- **Tailwater high flow R.L.** is the water level downstream of the structure during higher flows;
- **Headwater low flow R.L.** is the water level on the upstream side of the structure during low flows.

“Maximum water drop (m)” is the maximum difference in the water level between headwater and tailwater levels, which usually occurs during low flows outside of the wet season.
“Minimum water drop (m)” is the minimum difference in the water level between headwater and tailwater levels, which usually occurs during high flows during the wet season.

“Bank full height (m)” is the water level where water overfloods from a channel to floodplains (Figure 47). The height is one of indicators to show the barrier’s impacts on fish migration. A barrier that covers a greater proportion of the bank full height blocks more fish migration throughout the year.

![Figure 48. Bank full height (an overflood level from a channel to floodplains)](image)

**Existing fishways**

The “existing fishway” section in the Sheet is to record the characteristics of a fishway i.e., fishway type, length/width of the entire fishway and pools and height/slope of drops between pools. The recorded information in this section is important for the team to consider the effectiveness of an existing fishway.

The team must take photos of the existing fishway and record its type under the heading “Fishway type” and length, and width under the heading “Entire fishway” in the Sheet. In addition, the team needs to measure the length and width of individual pools and record them in the blanks of “Fishway pools” (Figure 49).
In the “Drops between pools” section, the team records the height of a drop in water level between individual pools and the slope gradient of the fishway as a ratio of height to length (Figure 49). For example, 1 m height for 20 m of length (1:20) for a fishway is 20 m long and rises over 1 m.

**Figure 49.** Length and width of a pool

In the “Site observation” section, the team will score the barrier that will be observed in Step 4. The data recorded in this section is general observational data on the barrier that the team can inspect at the site or interview local officials, operators or villagers.

**Site observation**

The “Site observation” section provides information on the barrier that will be scored in Step 4. The data recorded in this section is general observational data on the barrier that the team can inspect at the site or interview local officials, operators or villagers.
To record the observational data, the following points should be noted:

**Fish species and migration period**: Record any known or observed fish species and their migration timing at or around the barrier, especially migratory fish species which may be impeded in their upstream movements by the barrier. If downstream migration is a concern, it should be listed here as well.

**Upstream changes**: Record information on anecdotal changes that have occurred to the fish communities upstream of the barrier since its construction. Local fishermen are useful for the information on the changes and can often detail the decline in migratory fish communities due to the barrier.

**Structure use**: Record information on what the structure is used for (e.g. a water storage dam, a road for access to local fields or an irrigation gate for downstream rice), and how often the barrier is used. Consider if the barrier could be removed to improve fish migration.

**Construction access**: Record how to access the site. Does new fishway construction require access for trucks and machinery? Can materials for the construction be easily carried to the site?

**Local community**: Record information on the local community that is associated with the barrier. Which local community uses the structure? Who is the owner of the structure? Which local community is interested in improving the fish passage? Dealing with communities that are interested in improving the fish passage is easier than trying to force communities to be build a fishway.

**Five scoring questions**

The “Five scoring questions” section provides information related to the barrier that will be scored in Steps 4 and 5. The team can obtain the date recorded in this section by inspecting the site and interviewing local officials, operators or villagers. Each question has multiple choices with a score. The team should circle one selection in each of the questions based on how closely the barrier matches categories a. to e.

1. **Existing barrier type**

   Record how closely the barrier matches one of the categories in the question based on the type of structure, height of the barrier, or how much of the stream the barrier covers.

2. **Stream condition**

   Record the condition of the stream banks and catchment in the reach where the barrier is found. Streams that have less clearing of the catchment and better riparian vegetation have better fish communities and score higher for this question. The level of clearing is subjective, but the team should assess the stream condition based on site observations and satellite imagery at the catchment.
3. **Stream flow**

Record the flow characteristics of the stream at the barrier site. Streams that maintain permanent flow provide long-term habitat for fish in the area. The team should consult with local officials and villagers to determine if the stream flows all year round, if the stream dries up or if flows are maintained by releases from dams upstream.

4. **Instream habitat**

Record the habitat within the stream upstream of the structure. Streams that contain a variety of good quality habitats, such as large pools, deep waterholes, and rock and timber cover provide better habitat for migratory fish communities. If specific spawning or rearing habitats are present upstream, migratory fish numbers will be improved by accessing these habitats. The team should assess the habitats upstream by inspecting the site or interviewing local officials, operators or villagers.

5. **The importance of fishing at barriers**

This section provides a clear indicator of the impact that the barrier has on migratory fish. The team should interview local officials and villagers to determine if the community collects fish below the barrier. It is likely that there are large fishing sites with large fish accumulations below the barrier where they can be caught, indicating migrations that are significantly blocked.