Guideline for

Determination of Environmental Flows (E-flows) for Development Projects that Result in Impounding of Water in Streams/ Rivers

Central Environmental Authority

Ministry of Mahaweli Development & Environment

1. Introduction

Water, tThe essence of life

Earth is a unique planet as it is the only planet known so far to harbour life. Life evolved in water and continued existence of life on earth depends on the availability of clean water. Nearly 96.5% of the water on our planet is used to form the oceans that cover 71% of the earth surface. Another 1%, exist as saline lakes or saline groundwater. Only the remaining 2.5% exist as freshwater. About 98.7% of the freshwater exist as either ground water (30.1%) or glaciers and ice caps (68.6%). The remaining 1.3% is classified as surface water that is available for terrestrial living organisms. Surface water can take many forms such as ice and snow (73%), standing water in the lakes (20.1%), water in the swamps and marshes (2.5%), running water in the rivers (0.5%), water in the soil (3.5%), air (0.2%) or living organisms (0.2%).

Water is an essential commodity for all living organisms. On the other hand living organisms help to maintain the quality and quantity of surface water by removing toxic material dissolved in it and helping the water cycle to operate unhindered. Of all living organisms human beings have had the greatest influence on water as many human activities have resulted in degradation of limited water resources available on the planet. These include, disrupting flow patterns by abstracting water, obstruction of water ways, point and diffused discharge of agricultural and urban pollutants, conversion of wetlands, overuse and pollution of ground water resources. Climate change driven events that are taking place on the planet and attempts to adapt to climate change further exacerbate these issues.

Impact of ever increasing human demand for water on surface water resources

As the human population increase in the world, there has been a corresponding increase in the demand for water to irrigate farm lands, generate power, satisfying the potable water needs for human beings or flood mitigation. Most countries have attempted to meet this demand by development of rivers, rivulets or streams. More than 50% of the accessible surface water sources are already utilized for this purposes, and the level of extraction is projected to increase to about 70% by 2025 (Postel et al., 1996[1] ; Postel, 1998[2]). Development of surface water resources such as impounding, temporary or permanent diversion or inter-basin water transfer have resulted in unprecedented impacts to riverine ecosystems, primarily due to alteration of the natural flow regime of the river system (Rosenberg *et al.*, 2000[3]).

The flow regime of a river, comprising of five key variables, magnitude, frequency, duration, timing and rate of change, is considered the key factor responsible for sustaining biodiversity and maintaining the integrity of the river ecosystems. Therefore, changing the flow regime of a riverine ecosystem can result in a wide range of impacts such as genetic isolation of species through habitat fragmentation, habitat alterations, changes in species distribution and abundance, loss of biodiversity, reduction in transport of silt and nutrients to sustain the activities of the river mouth, incursion of

[1] Postel S.L., Daily G.C., Ehrlich P.R. (1996). Human appropriation of renewable freshwater. *Science* **271:** 785–788.

[2] Postel S.L. (1998). Water for food production: will there be enough in 2025? *Bio Science* **48:** 629–637.

[3] Rosenberg D.M., McCully P., Pringle C.M. (2000). Global-scale environmental effects of hydrological alterations: introduction. Bio Science **50(9):** 746–751.

salinity from the sea, loss of floodplain fisheries, lack of water for downstream users, loss of aesthetic beauty due to drying of waterfalls and loss of revenue from tourism and other recreational activities.

The impacts of river/ stream diversion will vary with the type of changes the project will bring about in the upstream elements of a river. The specific impacts of river diversion will be felt immediately upstream and downstream of the project as shown in Table 1. In any event, the stretch of the river downstream of the point of diversion will be subjected to low flows resulting in both ecological and social impacts.

Table 1. Biophysical and social impacts of river diversion on the immediate vicinity

Biophysical/ Social **impact**	Upstream	Downstream	Comments
Flood control	-	+	Generally downstream floods are reduced while dam construction can lead to floods in the upstream area
Excessive sedimentation		+	Dams retain sediments and therefore downstream sedimentation is reduced while upstream sedimentation is increased
Changes in fisheries	+	-	Upstream fisheries potential is not affected or increased in case of large impoundments while downstream fisheries can be reduced due to reduction in population sizes
Aquatic weeds	+	-	Upstream impoundment can promote weed growth
Modified irrigation activities		-	Downstream irrigation activities can be impacted due to low flows especially during the dry season
Loss of biodiversity	+ f-	-	Upstream biodiversity can change due to the change in the flow regime from that of a lotic to a lentic system, since some of the riverine species require running water to trigger key biological processes such as breeding
Alteration to hydrology		-	Upstream will change into a standing system while downstream will be subjected to low flows
Modified ground water recharge	+	-	Ground water recharge will improve in the upstream while decrease in the downstream section
Bank and shoreline erosion		-	Due to changes in riverine vegetation bank stability will be reduced in the downstream section
Modified flood plain watering		-	Downstream floods will be prevented or reduced

In recent times, many have come to the realization that any change in the flow regime of a river during water resource development and management, should be done in a manner that does not compromise the integrity of the riverine ecosystem or only results in acceptable level of degradation (Rapport et al., 1998[4]). This has lead to the development of a new concept called environmental flow which attempts to define, what proportion of the original flow regime of a river should continue to flow down the river in order to maintain valued features such as biodiversity, socio-economic, aesthetic, recreational etc., of the ecosystem.

Environmental flow

The environmental flow of a river can be defined as “the flow regime that is needed to meet its socio-cultural and ecological needs”. The socio cultural needs of a river may include irrigation of farm lands, provision of water for drinking, washing or bathing, small scale power generation, subsistence or commercial scale fishing, extraction of water to support small scale industries, recreational activities, tourism and religious activities centred on theriver.

The ecological flow is a subset of instream flows that is directly tied to the ecology of the riverine ecosystem. The ecological functions of a riverine ecosystem includes providing direct habitat (depth, velocity, cover) for aquatic organisms, mitigating water quality impairment, triggering specific biological life stage responses and creating and maintaining habitat. Therefore, ***“ecological flow”*** *can be defined as the instream flow needed to sustain ecosystem functions that native fish and wildlife species depend upon to survive and flourish. These stream flows not only include base flows but can include a range of flows needed to protect habitat maintenance and other ecological functions.*

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[4] Rapport D.J., Costanza R., McMichael A.J. (1998). Assessing ecosystem health. Trends in Ecology and Evolution 13: 397–402.

Ecological flows can be classified into four groups based on the ecological functions provided by different types of stream flows (Figure 1). These functional stream flows include:

1. Subsistence flows: The flows needed to prevent direct mortality of aquatic species
2. Base flows: The flows needed to provide minimal or optimum habitat for target aquatic species such as fish and aquatic invertebrates
3. Biological triggering flows: Some key biological activities of aquatic organisms such as migration, spawning or initia tion of different life stage activities of aquatic insects is linked to changes in environmental conditions such as water temperature, turbidity, daily sunlight, or flows. If such species inhabit the river these type of flow should also be considered in the ecological flow determination.
4. Channel and habitat maintenance flows: Habitat mainte nance flows serve many functions such as moving gravel in the streambeds and allowing for "cleaning" of gravel intruded with fine sediments which improves spawning habitat and foods sources as well as providing high quality macro invertebrate habitat, scouring and filling the stream channel against encroaching riparian vegetation which allows the stream to retain its bed form rather than losing conveyance capacity and stream habitat, retaining bed configurations which support the formation of riffles and pools and other channel unit habitats and creating conditions for the replen ishment of streamside vegetation such as Kumbuk *(Termi nalia arjuna)* to maintain long-term riparian functions.

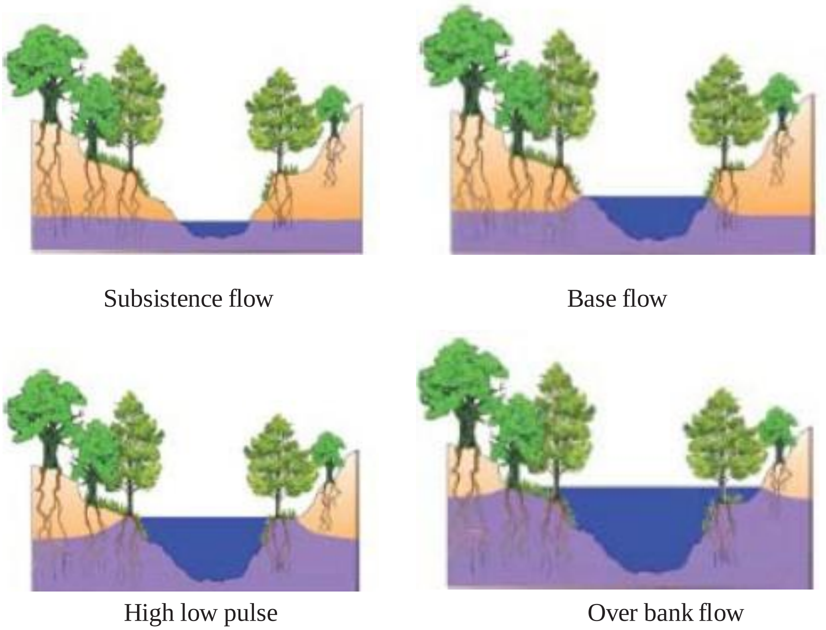


Figure 1. The four types of flows that might be required for maintaining the ecological integrity of a riparian ecosystem

Water resource development in Sri Lanka

Sri Lanka is a country rich in freshwater resources that includes 103 river basins, more than 30,000 manmade tanks, reservoirs, natural ponds (Vil) and manmade irrigation channels. Sri Lanka also has a long history of water resource development which dates back to 500 B.C. where an extensive system of tanks and irrigation channels have been developed by successive kings to store rain water and use it for agriculture during the long dry periods that prevail in the dry zone of Sri Lanka.

Water resource development continues at present where both state and private sector has embarked on a number of development projects ranging from mini hydro development to large irrigation projects. Many of these water resource development projects involve construction of a dam/ weir across a river/ stream to impound water.

Impounding and diversion of water will result in low flows in the downstream area which will have an impact on the downstream water users as well as the ecology of the downstream area affected by the project. Downstream impact can vary according to the type of diversion. Some projects will result in diversion of only part of the inflows while other projects will result in diversion of the entire inflow, especially during the dry season. The latter type of river diversions projects can be further classified as follows

1. Diversion followed by returning of all the diverted water back to the river as in the case of Major, Mini and Micro hy dro development projects. The distance between diversion and return may vary from few meters to several kilo meters. The impact of diversion in this instance will depend on the proportion of the instream flow diverted and the distance between point of diversion and point of return. However, if there are inflows into the river from other seasonal or perennial

sources, the impact can become less or negligible. This type of diversion projects can be further classified as run of the river projects (where the required water quantity will be diverted using a short weir or dam without any impounding) and storage type projects (where a large volume of water will be impounded by constructing a tall dam). In the case of the latter, downstream impact tends to be greater as very little water will flow over the dam resulting in prolonged dry spells, while in the case of the former, during the rainy season much of the water will flow over the weir that can provide the ecological requirements such as triggering and channel maintenance flows.

2. Diversion followed by returning of part of the diverted water back to the river as in the case of irrigation projects. In such projects the return flows may vary up to 50% of the diverted flow if the command area lies completely within the diverted river basin. Further, the point of return is not fixed in such a system where return flows will flow back across the length of the river and therefore will be determined by the shape of the command area as well as the distance of the command area from the point of diversion.

3. Diversion with zero return of diverted water in to the river as can be seen in drinking water projects as well as hydropower and irrigation projects that involve trans-basin diversion (where the entire quantity or part of the diverted water will be returned to a different river basin).

In order to compensate for such losses, an environmental flow (e-flow) is prescribed for all river diversion projects in Sri Lanka since 1990's to meet the downstream water demands and to ensure that the ecology of the downstream area is not adversely affected. However, to date a specific set of guidelines has not been developed as to how this release should be determined and as a result different project approving agencies have utilized different criteria to determine the e-flow requirement for a given project. This has caused much debate between developers and project approving agencies. Thus the need to develop a set of objective guidelines to aid decision making with respect to determination of e-flows for all such projects that involve water impounding and diversion has been identified as a critical need both by the implementing agencies as well as project proponents.

Thus, this guideline has been developed by the Central Environmental Authority in order to assist water sector developers to determine e-flow requirements for prescribed projects in the future.

2 Different Criteria and Guidelines used around tThe world to set e-Flows

Environmental Flow is an ecosystem based approach to Integrated Water Resources Management (IWRM). The concept of e-flow is very wide in scope and the method applied should be site specific. The general scope has to do with the hydrological, ecological and social parameters. There is no specific approach that can be taken to prescribe the required e-flow for a given project. There are several accepted guidelines for determination of environmental flow requirements for river diversion projects. Some of the key guidelines include

1. IUCN guidelines - "flow" the Essentials of Environmental Flow.
2. IWMI Global Environmental Flow Calculator
3. World Bank guidelines

Around the world, several methods are being used for the computation of e-flow for prescribed projects. These methods can be grouped into six main categories that can be broadly divided in to two main classes, prescriptive methods and interactive methods. Comprehensiveness of the method increases from category 1 to 6. A brief description of these main methods is given below.

Brief description of tThe main metThods used for computation of e-flows

Prescriptive MetThods

1. Hydrologic Index MetThods: Hydrological index methods are mainly desktop approaches, relying primarily on historical flow records to make flow recommendations for the future e.g. Percentages of Mean Annual Flow. However, there will not be any direct ecological considerations when e-flows are derived using these method although such considerations would have been included in the original studies.

Percentage Probability Flow Methods

This method is one of the popular methods used where the e-flow is derived based on the flow duration curve. Flow duration curve is a graph showing flow vs. probability of flow exceedance. Flow duration curves for a point of interest could be generated either by use of measured flow data for a gauged catchment or flow data estimated using hydrologic models for an ungauged catchment. A flow corresponds to a percentage probability of exceedance (for example 95% probability flow is the flow which is available 95% of the time). According to standard literature flows such as 90% or 95% are commonly considered as environmental flows. CEA usually specifies 90% flow as the environmental flow for minihydro projects (Figure 2).

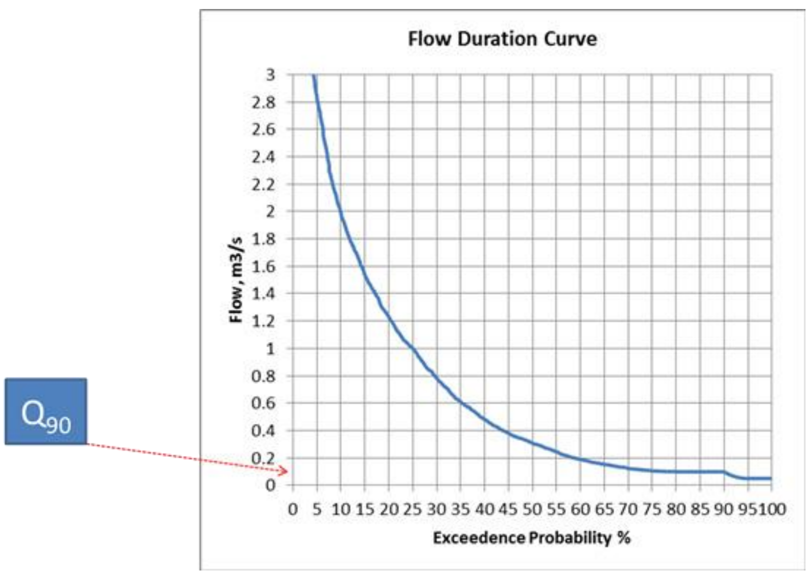


Figure 2. An example of a flow duration curve

n Day-Low Flow-Return Period (Inverse Probability of Exceedance) Method

In this method, a moving minimum flow for a certain time period is considered. These moving minimum flows will be fitted to a probability distribution and flow belong to a certain return period will be obtained. Examples are 7day10 year return period flow (Figure 3) usually termed as 7Q10. The 7Q10 flow is the most commonly used single flow index. By the early 1970's, U.S. agencies which regulated stream pollution based their stream water quality standards on the 7-day 10-year low flow condition (Singh & Stall, 1974[5]). Further examples for the the use of "7Q10 flow" method are given in table 2.

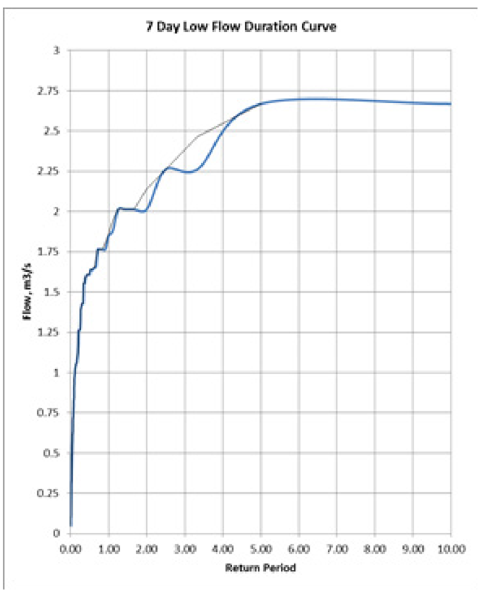


Figure 3. A typical 7 day low flow duration curve

[5]Singh, K.P., and Stall, J.B., (1974). Hydrology of 7-day 10-yr low flows. Journal of the Hydraulics Division, HY12: 1753-1771

Table 2: Some potential applications of the 7Q10 flow method.

Uses	Reference Source
Determination of minimum quantity of stream flow necessary to protect habitat during a drought situation	Delaware Water Supply (2004)
Waste load allocation for Great Lakes initiative to determine the pollutants in the absence of a total maximum daily load stream design	Minnesota Office of the Revisor of Statutes (2004)
As a chronic criteria/estimate for aquatic life/habitat maintenance or protection	Flynn(2003)
Possible indicator of potential mortality of aquatic life	Imhof and Brown (2003)
Compared to whole effluent toxicity (WET) compliance (USEPA - National Pollutant Discharge Elimination System)	Diamond and Daley (2000)
Comparing the impacts of climate change and irrigation in low surface stream flows	Eheart & Tornil (1999), Eheart *et al.* (1999)
Determination of the instream flow requirement of Atlantic salmon	Caissie *et al.* (1998)
Determination of the annual design low flows for waste water discharge and minimum flow periods and volumes	Cusimano (1992)

Although frequently used, the 7Q10 approach has been strongly criticized as lacking any scientific support for its use in setting environmental flow standards for fisheries, and could lead to severe degradation of fishery resources (Annear et al., 2004; Caissie et al., 2007). Caissie et al., (2007) carried out a rigorous statistical comparison of a variety of hydrological methods where the 7Q10 method consistently produced the lowest instream flows. Therefore, using this method for fisheries protection is not appropriate.

The Tennant (or Montana) Method

This is one of the most widely used methods worldwide. This method is a desk-top approach that is relatively inexpensive, quick, and easy to apply. The method was developed in United States and differs from other hydrological methods as it is based on a large data set including hydraulic and biological data. The approach is based on trends derived from field observations in the United States of the relationship among river condition, the amount of flow in the river, and the resultant fish habitat. These are used to recommend environmental flows for the maintenance of fish, wildlife, recreation, and related resources as a percentage of the average annual flow (Table 3). The results compare relatively well with those from data-intensive techniques.

Table 3. Percentage of Average Annual Flow (AAF) values recommended for achieving different objectives by the Tennant method (AAF is expressed as an instantaneous flow).

Objective	Recommended Percentage of AAF	
	Autumn-Winter (dry)	Spring – Summer (wet)
Flushing or maximum flows	200	200
Optimum range of AAF	60-100	60-100
Percentage of AAF required to maintain a required river condition		
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	10 - Zero flow	10 - Zero flow

Source: Tennant, 1976[6]

The use of quantitative hydrological variables to support the development of ecologically-sound environmental flow strategies is well accepted in the scientific literature (Poff and

[6] Tennant, D.L. (1976). "Instream flow regimens for fish, wildlife, recreation and related environmental resources." Fisheries 1(4): 6-10.

Zimmerman, 2010). Developed by Richter et al. (1996), the indicators of Hydrologic Alteration (IHA) represent a subset of ecologically-important hydrological parameters based on variability of the annual flow regime e.g. magnitude and frequency (Olden and Poff, 2003).

2 Hydraulic Rating Methods: Hydraulic rating methods use the relationship between the flow of the river (discharge) and simple hydraulic characteristics such as water depth, velocity, or wetted perimeter to calculate an acceptable flow. Most of the hydraulic rating methodologies were developed to recommend instream flows for economically important Salmon fisheries in the USA and have been superseded by more sophisticated habitat simulation models in recent years. These methods are an improvement on hydrological index methods, since they require measurements of the river channel, and therefore, are more sensitive than the desktop approaches to differences between rivers. However, judgment of an acceptable flow is still based more on the physical features of the river rather than the known flow-related needs of the biota.

The most commonly applied hydraulic rating methodology is the wetted perimeter method. This method assumes that river integrity can be directly related to the quantity of wetted perimeter, typically in riffles or other critically limiting biotopes. This method also assumes that preservation of such areas will ensure adequate habitat protection. An established empirical or hydraulically modelled relationship between wetted perimeter and discharge is used to determine minimum or preservation flows, usually for fish or benthic invertebrates. The R-2 cross method is another Hydraulic rating method that is been practiced in many countries. The method relies on a hydraulic model, R-2 cross to generate a relationship between flow and instream hydraulics, from which e-flows are derived using critical hydraulic parameters and expert opinion.

3 Expert Panel Methods: Expert panels use a team of experts to make judgments on the flow needs of different aquatic biota.

4 Holistic Methods: Prescriptive holistic approaches require collection of considerable river-specific data and inputs from the experts. The results compare relatively well with those from data-intensive techniques. The approach is based on trends derived from field observations in the United States of the relationship among river condition, the amount of flow in the river, and the resultant fish habitat.

These are used to recommend environmental flows for the maintenance of fish, wildlife, recreation, and related resources. Development of more complex holistic methodologies such as habitat simulation e-flow models was stimulated by the need to improve hydraulic rating methods. The building block methodology (BBM) was one of the first holistic methods to be developed in early 1990's which were followed by number of other methods. Some of the widely used holistic methods include the computer aided simulation model for instream flow requirements (CASIMIR), river system simulator (RSS), evaluation of habitat (EVHA), river hydraulics and habitat simulation program (RHYHABSIM), microhabitat modeling system (HABIOSIM) and riverine community habitat assessment and restoration concept (RCHARC).

5 **In-stream Flow Incremental MetThod (IFIM):** IFIM is the most commonly used flow assessment method worldwide and the best-documented method currently available. It was developed by the U.S. Fish and Wildlife Service's In-stream Flow Group in the late 1970s. It is founded on a basic understanding and description of the water supply and habitats within river reaches of concern. IFIM is used to evaluate the effects of incremental changes in discharge on channel structure, water quality, temperature, and availability of suitable microhabitat for selected target aquatic species. Both macrohabitats and microhabitats, as described below, are assessed for key species.

6 **Downstream Response to Imposed Flow Transformations (DRIFT):** DRIFT method was developed for the assessment of environmental flows for the Lesotho Highlands Water Project. DRIFT method requires one or more multidisciplinary workshops that are designed to produce an agreed number of biophysical and socioeconomic scenarios. Specialists use methods that are specific to different components of the flow regime to collect data and then, within the DRIFT structure, to predict the consequences of flow changes.

StrengtThs, weaknesses and data requirements of tThe different metThods used

Prescriptive MetThods

1 Hydrological metThods

If hydrological records can be obtained for a number of years, the hydrological methods are the simplest, quickest and most inexpensive way to provide information on threshold flow levels, but by themselves they do not produce credible flow regimes that mimic the natural hydrograph. They may be used with other methods, however, as part of a methodological approach to generate reasonably natural hydrographs. Hydrological methods do not necessarily require as much field work as other methods. Hydrological methods can be used at the planning level or to setup preliminary flow targets in low risk, low controversy situations but are not recommended for studies requiring a high level of detail. In the absence of any other method most countries use hydrological methods to set the most general level of flowprotection.

However, hydrological methods have been criticized for their lack of ecological validity and high uncertainty with regard to hydrology-ecology relationship. If flow-ecology relationships are not known for the type of river under consideration for flow modifications, defining the e-flow based on hydrological methods may result in significant damage to the ecology of a river or stream.

2 Hydraulic RatingMetThods

Hydraulicratingmethodsareanimprovementonhydrological index methods, since they require measurements of the river channel, and so are more sensitive than the desktop approaches to differences between rivers.

However, judgment of an acceptable flow is still based more on the physical features of the river rather than flow related needs of the biota. Like hydrological index methods, hydraulic rating methods also use the hydrological record. However, hydrology data is linked with simple cross-section data collected in the river of interest. The Wetted-Perimeter Method is a low-resolution, river-specific method that is used for determining seasonal flows required to maintain fish populations. It is relatively quick and cost-effective. The number of measurements taken and field visits made will depend on the level of confidence required for the study. It is useful as a planning method at catchment scale or greater. Because it is a widely used method, there is a great deal of expertise and experience to draw upon.

The disadvantage of the method is that the observed relationships between wetted-perimeter and discharge used to recommend suitable habitat for fish are based on general principles, and are not proven to be relevant to the fish of a particular river. To remedy this, detailed studies have to be undertaken on the relationship between wetted perimeter and the survival and reproduction of particular fish species. Although these studies increase the reliability of the results, they also add considerably to the time required and the costs of the method.

3 Expert Panel MetThods

Here the collective experience of the panel members is used in the absence of reliable, predictive flow-ecology models. By putting these experts on a panel, rather than employing them independently, it is expected that an integrated assessment of flow needs will emerge. The advantages of this method include rapidity, ability to effectively capture and integrate the knowledge of different experts, and its flexibility. However, the results are site-specific, influenced by personal bias and non-reproducible. Therefore, the outcome of this method is more open to challenge than traditional data intensive modelling approaches.

4 Holistic MetThods

Holistic methods are based on flow-related data and prior knowledge. They often incorporate some of the methods described above, particularly the expert panel methods. Holistic methods can be better described as a methodological approach that links several distinct methods to produce an output that none could have produced alone. These methods have the advantage of focussing not only one or few target species but the health of the entire river ecosystem. One of the Holistic Method used in Australia as well as South Africa, the Building Block Method (BBM) is based on early identification of the future desired condition of the river. An environmental flow regime is then constructed on a month-by-month basis, through separate consideration of different components of the flow regime to achieve and maintain this condition. Each flow component is intended to achieve a particular ecological, geomorphological, or water-quality objective.

Interactive MetThods

5 In-stream Flow Incremental MetThod (IFIM)

IFIM is used to evaluate the effects of incremental changes in discharge on channel structure, water quality, temperature, and availability of suitable microhabitat for selected target aquatic species. In this method, both macro-habitat and micro-habitat are assessed against key species. These species are chosen either because they are the major species of concern, or because they are deemed to represent the species and the general river condition desired. The availability of suitable microhabitat, over a range of flows is modelled using PHABSIM II (Physical Habitat Simulation Model). This model predicts how the water depth, water velocity, and riverbed features change with changing flow, and thereby the change in suitability for a chosen species. The model was designed for, and is usually applied to, fish habitat. The model requires extensive field data and considerable understanding to apply. It also requires a fairly detailed understanding of the habitat preferences of the chosen species during their different life stages. IFIM has been subjected to extensive scientific critique, but this is more a product of its widespread use in flow assessments than an indication of its merits relative to other methods. The main disadvantages of this method include its complexity, difficulty of use, its extensive field data demands, requirements for good understanding of target species needs, and questionable applicability outside its area of development. The method has a strong scientific basis and therefore is appropriate for e-flow determination of controversial projects.

6 Downstream Response to Imposed Flow Transformations (DRIFT)

This method could be ideal to model changes in fish habitats arising from medium level floods that affect in-stream fish habitat. DRIFT also uses data on cultural and subsistence use of the river to predict the socioeconomic implications of river change. DRIFT is essentially a system for managing data and knowledge in a structured way, following five main steps.

1 Identification and isolation of wet-season and dry-season low flows, and small and large floods from the long-term hydrological record.

2 Description of the consequences for the river of partial or complete removal of each of these flow components.

3 Creation of a biophysical database detailing the consequences of flow alterations.

4 Use of the database to describe how river condition will change with any future combination of high and low flows.

5. Description of the socioeconomic implications of the changes in river condition. This, together with the previous step, constitutes the creation of environmental flow scenarios.

The time and resource requirements vary for each of the above mentioned six methods. A comparison of the six methods with respect to time and resource needs is shown in table 4.

Table 4. Estimated time and resource requirements for the six EF determination methods

Method	Type	Date and Time Requirement	Duration of Assessment	Relative Confidence in Results	Level of Experience
Tennant	Hydrographic	Moderate - low	2 weeks	Low	USA
Wetted perimeter	Hydraulic rating	Moderate	2 - 4 months	Low	USA
Expert Panel	Holistic	Moderate - low	1 - 2 months	Medium	Australia, South Africa
Holistic	Holistic	Moderate - high	6 - 18 months	Medium – high	Australia, South Africa
IFIM	Habitat simulation	Very high	2 - 5 years	High	USA, UK
DRIFT	Holistic	High – Very High	1 - 3 years	High	Lesotho, South Africa, Tanzania

Source: Davis and Hirji 2003[7]

[7]Davis, R. and R. Hirji (2003). Water resources and environment technical note C. Washington, D.C., World Bank, Environment Department

Criteria Adopted by Different Project Approving Agencies in Sri Lanka

The subject of determination of environmental flow requirement is new and in it's formative stages in Sri Lanka. Environmental flow requirements for Attanagalu Oya and Maha Oya were determined in a preliminary way under the Western River Basin Project way back in 1990. However this flow determination criterion was mainly water quality related. At present, there is no specific method applied in Sri Lanka for e-flow determination. However, the Central Environmental Authority and other project approving agencies have been prescribing e-flow mainly based on the flow duration curve (Hydrological Index Method). The method that is being used in most instances is the Q90 (i.e. the flow occurring 90% of the time during the regular flow cycle) or the minimum flow method. Therefore, CEA has developed the guideline described below in consultation with other project approving agencies as well as project investors in order to fill the existing gap.

3. MetThod for determination of e-Flows for projects involving impounding and diversion

Overview of tThe metThod:

The type of river diversions that are encountered in Sri Lanka and data and expertise available for determination of environmental flows, does not allow adoption of any of the available methods (see table 5 for an analysis as to why none of the methods that are being used at present is not applicable for Sri Lanka), which are currently being used elsewhere in the world.

Table 5: Reasons for disregarding the currently used methods for environmental flow determination in Sri Lanka.

Method	Reason
Hydrologic index method	Does not take into account the ecology of the affected river/stream. Derived based on flow data that are extrapolated from rainfall and catchment area in most cases due to lack of gauging data which may result in erroneous interpretation of inflows.
Hydraulic rating method	This method although an improvement of the above method does not take into consideration ecology of the affected river/stream
Expert panel method	This method is based on subjective interpretation of a panel of experts, which is not repeatable or applied over a wider set of scenarios. Therefore, cannot be adopted as a general guideline
Holistic methods	Even though these methods provide a much better way to assess the e-flow requirement for a prescribed project, it requires more extensive data sets regarding the flow regime, river functions and goals of river management. As such this method cannot be applied for most diversion projects in Sri Lanka
In-stream flow incremental method	This method requires extensive data sets and an explicit knowledge about the river/ stream affected and therefore will be difficult to apply under the Sri Lankan conditions
Downstream response to imposed flow transformation	This method too requires extensive data sets regarding structural and functional changes in the affected river under a range of flow regimes which makes it difficult to use under the Sri Lankan conditions

Therefore, it has been decided to develop a new robust method that can be applied for a variety of diversion scenarios without being adversely affected by available limitations in flow data. Thus, the method given in this guideline can be described as a combination of some of the existing methods such as the Hydrological flow method, Hydraulic rating method and expert panel method. Some usable elements from all these methods have been combined to develop a multi-criterion based method for the determination of e-flows for river diversion projects that takes into account the impact of the flow regime change on ecological and social environment of the diverted river/stream. According to this method, the environment flow will be expressed as a percentage of the mean annual flow of the river. The percentage value will be derived using a scoring system based on 9 criteria that focus on the critical ecological and social aspects that will be affected due to the changes in the downstream water regime upon diversion.

In this method the environmental flow is defined, as the *flow regime that is required to meet the socio-cultural and ecological needs of section of the river/stream that will be subjected to low flows due to diversion of* water. Therefore, the environmental flow is further sub divided in to two sub sets of instream flows, ecological flow and sociological flow.

The sociological flow is further subdivided in to two categories, namely

- **Non-consumptive demands:** the flow required to support activities such as bathing, drinking, washing, subsistence fishing, cultural uses etc., in the stretch of the river/stream that is subjected to low flows, which cannot be quantified exactly

- Sectoral demands: the flow required to support activities such as micro-hydro projects, small scale irrigation schemes, community drinking water schemes, small industries, farms etc., that extract a measurable quantity of water from the stretch of the river/ stream that is subjected to low flows

The ecological flow includes the flow required to

- Provide minimal or optimum habitat for target aquatic species
- Support key biological activities of aquatic organisms such as migration, spawning or triggering different life stage activities
- Prevent stream bed from losing its conveyance capacity and bed configuration
- Support long-term riparian functions.

Out of the three subsets of instream flows mentioned above, non-consumptive uses, and sectoral demands can be easily estimated using a questionnaire survey. However, the ecological demands are more complex and therefore a point scale based on nine criteria will be used to determine the ecological flow, which will take into consideration the changes in the flow regime, sensitivity of the habitat as well as species.

Parameters to be considered in The proposed meThod

The following set of parameters was identified as the key variables that should be taken into consideration in defining the environmental flow for a river diversion project.

1. he stretch of the river that is affected
2. Percentage of the mean annual flow diverted
3. Nature of impounding – whether permanent or temporary
4 Natu.re of diversion – whether there is return to the river basin and the percentagereturned
5 Whe.ther it is a standalone project or a single project in a cascade of diversions
6. Presence of critical aquatic fauna and flora in the stretch of river that will be affected by low flows (refer table 6 for the critical aquatic fauna and flora present in river/ stream ecosystems in Sri Lanka)

Table 6. Critical fauna and flora inhabiting river/stream ecosystems

Family	Scientific name	Common Name	TS	CS
Alismataceae	*Caldesia oligococca*		N	CR
Aponogetonaceae	*Aponogeton jacobsenii*	Kekatiya	E	CR
Araceae	*Cryptocoryne alba*		E	CR
Araceae	*Cryptocoryne bogneri*		E	CR
Araceae	*Cryptocoryne undulate*		E	CR
Araceae	*Cryptocoryne walker*		E	CR
Araceae	*Cryptocoryne x willisii*		E	CR
Araceae	*Lagenandra erosa*		E	CR
Cyperaceae	*Mapania immerse*		E	CR
Eriocaulaceae	*Eriocaulon catopsioides*		E	CR
Eriocaulaceae	*Eriocaulon fergusonii*		E	CR(PE)
Eriocaulaceae	*Eriocaulon fluviatile*		N	CR
Eriocaulaceae	*Eriocaulon subglaucum*		E	CR(PE)

Family	Scientific name	Common Name	TS	CS
Eriocaulaceae	*Eriocaulon thysanocephalum*		E	CR
Eriocaulaceae	*Eriocaulon trimeni*		E	CR
Podostemaceae	*Polypleurum stylosum*		N	CR
Podostemaceae	*Zeylanidium lichenoides*		N	CR(PE)
Cyprinidae	*Dawkinsia srilankensis*	Dankuda pethiya	E	CR
Cyprinidae	*Devario aequipinnatus*	Dumbara salaya	E	CR
Cyprinidae	*Devario pathirana*	Pathirana saalaya	E	CR
Cyprinidae	*Labeo fisheri*	Gadaya	E	CR
Cyprinidae	*Labeo lankae*	Thambalaya	E	CR
Cyprinidae	*Laubuca insularis*	Dumbarakara-adaya	E	CR
Cyprinidae	*Laubuca varuna*	Varunakara-adaya	E	CR
Cyprinidae	***Pethia bandula****	Bandula pethiya	E	CR
Cyprinidae	*Rasbora armitage*i	Rakvana dandiya	E	CR
Cyprinidae	*Rasbora naggsi*	Belihuloya dandiya	E	CR

Family	Scientific name	Common Name	TS	CS
Cyprinidae	**_Rasboroides nigromaginata*_**	Kaluiri halmaldandiya	E	CR
Cyprinidae	**_Rasboroides rohani*_**	Rohana halmaldandiya	E	NE
Cyprinidae	*Systomus asoka*	Asoka pethiya	E	CR
Cyprinidae	*Systomus martenstyni*	Dumbara pethiya	E	CR
Cobitidae	*Lepidocephalichthys jonklaasi*	Wairan ahirava	E	CR
Gobiidae	*Sicyopterus griseus*	Maha gal weligowwa	N	CR
Gobiidae	*Sicyopterus halei*	Gal weligowwa	N	CR
Gobiidae	**_Stiphodon martenstyni*_**	Weligowwa	E	CR(PE)
Mastacembelidae	**_Macrognathus pentophthalmos*_**	Katu theliya	E	CR(PE)
Synbranchidae	*Monopterus desilvai*	Potta aandha	E	CR
Synbranchidae	*Ophisternon bengalense*	Potta aandha	N	CR
Belontidae	*Malpulutta kretseri*	Malpulutta	E	CR

Abbreviations used: TS: Taxonomic status, **CS:** Conservation Status, **E:** Endemic, **N:** Native, **CR:** Critically Endangered, **CR(PE):** Critically Endangered (Possibly Extinct), **NE:** Not evaluated as it is a new species. *** Species indicated in bold are point endemics (species is endemic to Sri Lanka and known to occur only in one location) and tTherefore are tThe most critical species in tThe list. If sucTh a species is affected, tThe project sThould not be processed furtTher (a TOR sThould not be issued).**

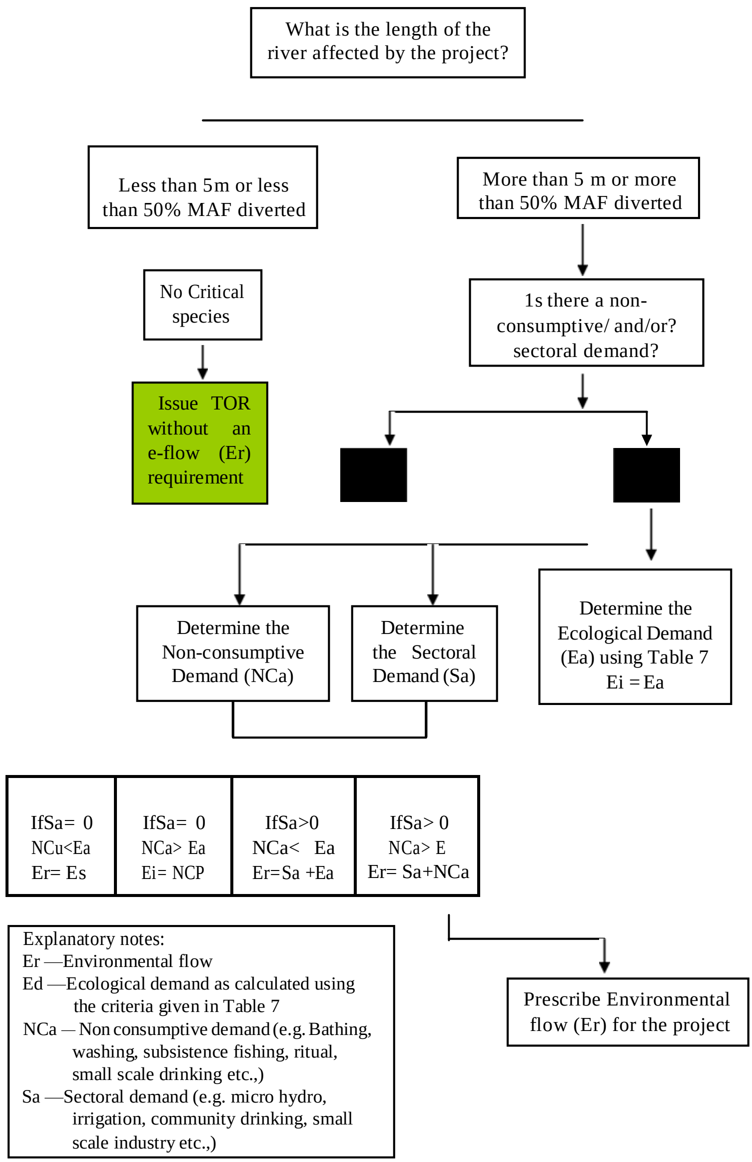
7. Sociological uses (mostly non consumptive and in some instances sectoral) in the stretch of the river affected by the diversion
8. Perennial inflows into the stretch of the river affected and distance of each inflow from the point of diversion
9. Water quality of the river/ stream
10. Changes in the wetted perimeter of the stretch of river/ stream affected by the diversion. In most instances the wetted perimeter diminishes resulting in changes of the cross section of the river. The wetted perimeter is extremely important to rivers/streams that have aquatic vegetation growing on the edges of the stream (Figure 5) or on rocky substratum of the river. Further, reduction in the wetted perimeter results in a reduction in the carrying capacity for species, especially large species of fish. Reduction in the wetted perimeter will also result in reduction of depth that will contribute to increased water temperatures and higher rates of predation, especially for fish species.

Figure 5: A stream with a rich aquatic vegetation on the edges of the stream

Different projects in Sri Lanka vary according to the parameters listed above. Therefore, it is not possible to assign a single criterion such as Q_{90} or Tennant method to determine the e-flow. Therefore, a multi criterion based decision making tool has been developed to determine the e-flow for diversion projects. The process that should be followed during the project scoping stage with respect to e-flow determination is outlined in the next section.

Decision making flow chart

The decision making flow chart to be followed during scoping in determination of environment flow requirement for a water diversion project is as follows



Methodology for calculation of ecological demand (Ed):

The ecological demand of a river/ stream should be analysed using the framework provided in table 7. This framework includes nine criteria out of which five focus on factors that can influence the flow regime of the river and the remaining four criteria assess the impact on habitat structure and critical species inhabiting the river/stream. An appropriate score (between -5 and +5) will be assigned to each of the nine criteria and finally the cumulative score will be determined by adding the score given to each of the nine criteria.

The cumulative score will then be used to determine the ecological demand of the river, which will be expressed as a percentage of the Mean annual flow of the river/ stream. Therefore, this method can be described as a mixed method that incorporates features from hydrological, hydraulic rating and expert panel methods to provide a broader assessment framework that take in to consideration not only the flow regime but both ecological and sociological demands of the river/ stream affected.

Converting cumulative scores into ecological demand: The ecological demand of the river/ stream can be derived based on the cumulative score derived using table 8 below. The ecological demand will be expressed as a % of the mean annual flow of the river. This can be used to calculate the volume (m^3) that will be released for the whole year to meet the ecological demand of the river. This value can then be converted to calculate the rate of release (m^3/sec). This can be calculated as a fixed release throughout the year or can be calculated in a manner to simulate the existing flow regime of the river. The latter is extremely important for rivers/ streams that show heavy seasonal flow variations such as rivers/ streams present in the intermediate and dry zone.

Table 7. Proposed multiple criteria based scoring system for the determination of ecological demand of a river/stream

Parameter (Negatively impacting)	0	1	2	3	4	5
Length of the river Affected (meters)	-	0-250	251-500	501-1000	1001-2000	>2000
% of the mean annual flow diverted	-	<50	51-60	61-70	71-80	>80
% return to the river	-	100	75-100	50-74	25 -49	0-24
Number of Critical species present [8]	0	1	2	3	4	> 5
Number of Threatened aquatic or aquatic associated species present [9]	0	1-3	4-6	7-10	11-15	>15
Number of Endemic aquatic or aquatic associated species present that are not listed as threatened species [10]	0	1-5	6-10	11-15	16-20	>20
% of aquatic vegetation affected due to reduction in wetted perimeter [11]	No aquatic plants	1-10	11-20	21-30	31-40	41-50
Percent reduction in wetted perimeter related to mean annual flow at the most critical point of the stretch of the river affected[12]	-	1-20	21-40	41-60	61-80	81-100

Parameter (Positively impacting)	- 5	-4	-3	-2	-1	0
Perennial inflows as a % of diverted flow	86-100	71-85	56-70	41-55	25-40	< 25
% length of the river affected supported by perennial inflows[13]	86-100	71-85	56-70	41-55	25-40	<25

8 Refer table 7 for the critical aquatic fauna and flora present in river/ stream ecosystems in Sri Lanka. If the stretch of the river affected does not contain any of the species listed in Table 7 assign a value of 0.

9 This category includes aquatic species (a species that spend at least a part of its life cycle in water) that are listed as Critically Endangered, Endangered or Vulnerable or endemic species listed as Near Threatened in the most recent Global or National list of Threatened species. Species that are listed in Table 7 should not be included in this count.

10 This category includes aquatic species (a species that spend at least a part of its life cycle in water) that are endemic to Sri Lanka but not listed as a Threatened species in the most recent Global or National list of Threatened species.

11 If the river contains aquatic plants, estimate the percentage of the plants in the stretch of the river affected by reduction in wetted perimeter.

12 Should be determined based on the river cross sections of the affected stretch. The stretch of the river affected is the distance between point of diversion to point of return or the confluence with the first major perennial tributary, whichever comes first.

13 If the value assigned for perennial inflow criterion is 0, value assigned for this criterion should also be 0

Note: Values should be brought to the closest round number.

Table 8. Framework for converting cumulative score calculated using table 7 in to ecological flows that will be expressed as a percentage of Mean annual flow of the river.

Cumulative Score	Project Classification	Recommended flow as a % of Mean Annual flow
Less than 10 points	Low impact	10
Between 11- 20 points	Moderate impact	20
Between 21 - 30 points	Medium impact	30
Between 31 - 40 points	High impact	40

Note: For projects that fall into Medium and High impact categories, the population sizes of critical species in the affected stretch of the river should be monitored during the implementation period and e-flow should be increased if the population shows a decreasing trend within three years.

Once the ecological demand (E_d) is calculated, the e-flow for the project can be defined taking into consideration the non consumptive and sectoral social demands. The following are the possible scenarios that may arise.

Scenario 1: Length of the river affected is less than 5 m or less than 50% of the Mean Annual Flow is diverted and critical species are absent in the section of the river affected. **E flow is not required ($E_f = 0$)**

Scenario 2: Length of the river affected is more than 5 m or more than 50% of the Mean Annual Flow is diverted and there is no sectoral or non consumptive demand.

E flow is needed to meet only tThe Ecological demand ($E_f = E_d$)

Scenario 3: Length of the river affected is more than 5 m or more than 50% of the Mean Annual Flow is diverted. There is no sectoral demand. However, there is a non consumptive demand that can be met by the flow released to meet the ecological demand. **E flow to meet Ecological demand is sufficient ($E_f = E_d$)**

Scenario 4: Length of the river affected is more than 5 m or more than 50% of the Mean Annual Flow is diverted. There is no sectoral demand. However there is a non consumptive demand that cannot be met by the flow released to meet the ecological demand. **E flow to meet non consumptive demand is sufficient ($E_f = NC_d$)**

Scenario 5: Length of the river affected is more than 5 m or more than 50% of the Mean Annual Flow is diverted. There is a sectoral demand and a non consumptive demand. The Non Consumptive demand can be met by the flow released to meet the ecological demand. **E flow sThould be realised to meet tThe Sectoral demand and tThe Ecological demand ($E_f = S_d + E_d$)**

Scenario 6: Length of the river affected is more than 5 m or more than 50% of the Mean Annual Flow is diverted. There is a sectoral demand and a non consumptive demand. The Non Consumptive demand is greater than the flow released to meet the ecological demand. **E flow sThould be realised to meet tThe Sectoral demand and tThe Non Consumptive demand ($E_f = S_d + NC_d$)**

Data requirement for application of tThe proposed system

It is expected to obtain the information required to apply this system in advance through the Basic Information Questionnaire (BIQ), which is submitted to CEA by project proponents. Once the BIQ is obtained, with this information CEA could apply the scoring system and determine the potential environmental flow requirements for the project prima facie and indicate the potential e-flow requirement to the client before issuing the Terms of Reference (ToR) for the project. The client in turn can decide whether they wish to continue the project under the potential e-flow requirement. However, it should be noted that the actual environmental flow requirement is determined based on the findings of the environmental assessment which will provide the detailed information required for application of the criteria outlined in the sections 3.3 and 3.4 above.

The project team has developed the potential BIQ items that will provide the necessary information to make a predetermination of the potential e-flow requirement for a prescribed project.

1. **LengtTh of tThe river/stream affected –** This can be calculated based on point of extraction and point of return (e.g. the distance between the weir and the tail race). However, for trans basin diversions and water extraction projects where there is no return, length affected can be calculated based on the distance from point of extraction to the next largest tributary. For irrigation projects point of return can be determined based on return flow scenarios predicted.

2. **Nature of Diversion –** It has to be stated whether the impounding will be permanent or temporary in nature. Further, the proportion of the instream flow that will be extracted has to be indicated. Also, the project proponent must indicate whether the extracted water will be returned to the river and if so what proportion will be returned and at what distance(s) from the point of diversion. If there will be overflow from the dam/weir, the proportion of water that will enter the river due to such overflows and period of the year during which such overflows are expected to occur should also be indicated. It is best that this information can be submitted in the form of a flow diagram.

3. **WThetTher it is a standalone project or one of a cascade of projects -** The number of diversion projects that are ongoing or proposed, either upstream/ downstream of the proposed project must be indicated and if there are such projects, a schematic map drawn to scale of the layout of those projects showing point of extraction and point of return must be included.

4. **Fauna and Flora**

    a) Are there any point endemics in the stretch of the river/ stream affected

    b) Are any of the species listed in Table 6 found in the stretch of the river/ stream affected by the project

    c) Are there any endemic species that are listed as Globally or Nationally Endangered or Vulnerable

d) Does the stretch of the river/ stream affected by the project contain unique or critical aquatic habitats

e) Are there any protected areas within or nearby the stretch of the river/ stream affected by the project

5. **Inflows –** Whether there are any inflows from tribu taries below the diversion point and point of return. Further, whether these are perennial or seasonal sources. Also the distance from the diversion point to the confluence of each of the listed sources must be provided.

6. **Sociological and OtTher Water Uses–** Whether there are any irrigation/ service/ commercial oriented water intakes present in the stretch of the river/ stream affected by the project

a) Whether the extraction is regular or intermittent

b) The quantity extracted as a proportion of the inflows at the point of extraction

c) If seasonal, for how many months of the year the ex traction will be done and for each month the pro portion extracted with respect to total inflow:

d) Details regarding non consumptive demands on the stretch of the river/stream affected by the project such as bathing, drinking, washing, recreation (tourism), rituals, subsistence fishing or any other domestic usage

7. **Water Quality -** Basic water quality parameters at the weir location

8. **Nature of tThe River Bed-** Rocky, sandy muddy or any other status

Case Study 1: A major hydropower project

A 40 MW hydropower project is planned to be built in the Kandy District. A 40 m high concrete gravity dam will be built across the Mahaweli River to create a reservoir with a capacity of 1.98 MCM and a spread area of 39 ha, at Full Supply Level (FSL). Approximately 80% of the river flow will be diverted through a 3 km underground tunnel to a powerhouse located on the left bank of the river. After power generation water will be released back to the Mahaweli River approximately 3 km downstream of the dam site. Between the dam site and the tail race, one perennial stream and several seasonal streams release into the river. The perennial stream releases into the river at a point about 300 m downstream from the dam site and its annual flow is estimated to be around 15 MCM (approximately 2% of the diverted flow). The reservoir is expected to overflow during the rainy season and annual overflow is estimated to be around 70 MCM. Mean annual flow of the river at the dam site is 21.95 m^3s^{-1}. During dry years monthly mean flow reduce to about 4.68 m^3s^{-1}. The lowest flows recorded are 3.20 m^3s^{-1}. The base flow in the river is estimated to be around 3.0 m^3s^{-1}.

The stretch of the Mahaweli River affected by the project has an average width of around 20 m and consists of shallow or deep cascades where the flow becomes rapid and turbulent. The river also has deep pools, which are frequented by globally endangered fish species *Tor khudree* (Marsheer; Lehella) and *Labeo fisheri* (Mountain Labeo; Gadaya). The river has fairly high fish diversity including several species that are endemic and listed as threatened species such as the Critically Endangered *Labeo fisheri* (Mountain Labeo; Gadaya), Endangered Pethia nigrofasciatus (Black Ruby Barb; Bulath Hapaya) and *Pethia reval* (Red-fin two banded carplet; Rathu waral depulliya). Further, *Belontia signata* (Comb tail; Pulutta) listed as a near threatened species in Sri Lanka is also recorded here. In addition, 10 species of endemic aquatic fauna that is not listed as threatened was recorded in the stretch of the river that will be affected by the project. Only a few aquatic plant species were recorded here, none of which are listed as endemic or threatened species in Sri Lanka. A minor irrigation scheme (extent 54 ha) cultivated with irrigation water fed from the Mahaweli River is located downstream of the proposed dam. The water requirement of the irrigation scheme fed by the irrigation canal is 0.3 m^3s^{-1}. The poultry meat processing factory is also located downstream of the dam sites, which extracts 220000 litres (0.003 m^3s^{-1}) of water per day via an intake located downstream of the proposed dam site. In addition, the 3 km stretch of the river that will be subjected to low flows contains several locations that are used for bathing and washing.

Parameter (Negatively impacting)	Value	Score
Length of the river affected (meters)	3000	5
% of the mean annual flow diverted	>80	5
% return to the river	100	1
Number of Critical species present[1]	1	1
Number of Threatened aquatic or aquatic associated species present[2]	4	2
Number of Endemic aquatic or aquatic associated species present that are not listed as threatened species	10	2
% of aquatic vegetation affected due to reduction in wetted perimeter	0	0
Percent reduction in wetted perimeter related to mean annual flow at the most critical point of the stretch of the river affected	>80	5
Parameter (Positively impacting)		
Perennial inflows as a % of diverted flow	5%	0
% length of the river affected supported by perennial inflows	90%	0
	TOTAL	**21**

[1]Labeo fisheri; [2]Tor khudree, Labeo fisheri, Pethia nigrofasciatus and Pethia reval

Environmental flow prescribed for tThe project:

E_d = 30% of the mean annual flow = (MAF x 0.3) = (21.95 x 0.3) = 6.585 m^3s^{-1}

$S_d = 0.3 + 0.003\ m^3s^{-1} = 0.303\ m^3s^{-1}$

Relationship between NC_d and E_d = $NC_d < E_d$

$E_f = Ed+Sd = 6.585 + 0.303 = 6.88\ m^3s^{-1}$

Case Study 2: A mini Thydropower project

A private company plans to develop a 10 MW mini hydropower project at Kithulgala. This will involve construction of a 2 m high concrete weir across the Kelani River that will create a reservoir that extends 600 m upstream of the weir location. About 80% of the river flow will be diverted using an open channel to a powerhouse located on the right bank of the river approximately 1 km from the weir. Water after power generation will be released back to Kelani River approximately 1 km downstream of the diversion point. Between the dam site and the release site there are no perennial inflows to the river. The reservoir is expected to overflow during the wet season. Mean annual flow of the river at the dam site is 49.19 m^3s^{-1}. The base flow in the river is estimated to be around 2.5 m^3s^{-1}.

The stretch of the Kelani River affected by the project has an average width of around 30 m and can be described as a large perennial river with substratum made out of sand, pebbles and bed rock. In most places it flows gently except at places where it forms shallow or deep cascades where the flow becomes rapid and turbulent. Nineteen species of fish were recorded in the river including eight species that are endemic to Sri Lanka. Only a few aquatic plant species were recorded. The deep pools, are frequented by globally endangered fish species *Systomus asoka* (Asoka Barb; Asoka Pethiya) and Tor khudree (Marsheer; Lehella). The river has fairly high fish diversity including endemic fish species *Pethia nigrofasciatus* (Black ruby barb; Bulath Hapaya), *Garra ceylonensis* (Stone Sucker; Gal Pandiya) and *Puntius kelumi* (Kelums long snouted barb) listed as Nationally Threatened species. Also the stretch of the river also includes the habitat of *Systomus asoka* (Asoka Barb; Asoka Pethiya) listed as a Nationally Critically Endangered species. In addition, 10 species of endemic aquatic fauna that is not listed as threatened was recorded in the stretch of the river that will be affected by the project. Only a few aquatic plant species were recorded here, none of which are listed as endemic or threatened species in Sri Lanka. The stretch of the river that will be subjected to low flows does not have any sectoral water demands. The non consumptive demands include bathing and washing.

Parameter (Negatively impacting)	Value	Score
Length of the river affected (meters)	1000	3
% of the mean annual flow diverted	>80	5
% return to the river	100	1
Number of Critical species present[1]	1	1
Number of Threatened aquatic or aquatic associated species present[2]	5	2
Number of Endemic aquatic or aquatic associated species present that are not listed as threatened species	10	2
% of aquatic vegetation affected due to reduction in wetted perimeter	0	0
Percent reduction in wetted perimeter related to mean annual flow at the most critical point of the stretch of the river affected	>80	5
Parameter (Positively impacting)		
Perennial inflows as a % of diverted flow	5%	0
% length of the river affected supported by perennial inflows	90%	0
	TOTAL	**19**

1 Systomus asoka; 2Tor khudree, Systomus asoka, Pethia nigrofasciatus, Garra ceylonensis and Puntius kelumi

Environmental flow prescribed for the project:

E_d = 20% of the mean annual flow = (MAF x 0.2) = (49.19 x 0.2) = 9.838 m^3s^{-1}

$S_d = 0\ m^3s^{-1}$

Relationship between NC_d and E_d = $NC_d < E_d$

E_f = Ed = 9.838 m^3s^{-1}