WP6.1 MIF definition and use for hydropower production

Report

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Summary

SHORT DESCRIPTION
This document intends to describe the various methods used in the participating countries of SHARE to define Minimum Instream Flow (MIF) and possible methods to use it for hydropower production.

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Introduction

Damming or diversion of water bodies leads to locally smaller quantities of water beneath the water catchment. Any water withdrawal interferes with the complex ecological balance of watercourses, since natural biological communities are adapted to the existing runoff regime of the respective river. It is important to ensure that the specific conditions of natural environment and water body have always to be taking into account.

Every power plant interferes with the rivers natural ecosystem by retaining or diverting water for power production and reducing the rivers downstream runoff. The demands of the acquatic habitat, recreation, wetlands, riparian vegetation and water quality have to be met additionally to humans need for drinking water and power production.

Small hydro power plants can be easier integrated in the local ecosystem than conventional hydro power plants, which require flooding of large areas, but many small hydro power plants are diversion types, which lead to a reduction of flow in the streambed between the point of diversion and the tailrace downstream of the power house. The reduced runoff has negative impacts on the ecosystem, especially on the natural occurring fish species. It affects spawning, incubation, rearing, and the passage of fish down- and upstream the river. To minimize the negative consequences a certain minimum instream flow (MIF) has to be specified.

The residual flow should be specified taking into account the continuity of the water body, sediment management and the demands of the fish species in different life stages. Its determination is affected by the conflicting demands of hydropower production and the water body as natural habitat.

A dynamic minimum flow, depending on the natural run-off, is favourable. The natural river run-off depends on the seasons and climate conditions (flood events).

The methods for assessing the MIF are based on hydrographic-statistical or hydraulic data, simple models or the water body as natural habitat. Simple formulas do not consider hydro-morphological aspects and the impact on the habitat and they provide a constant value instead of a dynamic discharge. The use of habitat models is favourable, since they analyse abiotic (flow regime, hydraulic factors,…) and biotic (resident species, flora,…) factors and relate them to the habitat quality, but more input data is needed.

Due to the required minimum instream flow, the available discharge for power production is reduced. The MIF is not available to power production and especially for plants with one turbine, the non-operation periods are longer. The minimum instream flow is often determined after a trial period. In this case a prior dimensioning of the turbines is not possible and in case of turndown they often run at a low degree of efficiency.

The respective legislation regulates how much water has to stay in the residual flow stretch and hydropower producers are searching for solutions taking account of the tensions between electricity production and river conservation. This report will set down possible opportunities to both use the MIF and preserve the river environment.

MIF release obliged on WFD

This part of the report deals with the legal aspects concerning MIF release in the various countries within the SHARE program. For each PP region/country the definition of the legal aspects concerning MIF release are given, with a. description of the national implementation of WFD and other national set of laws in each country, illustrated by examples.

Italy

Introduction – Water and the WFD in Italian Legislation

The European Directive WFD 2000/60/CE has been implemented in the Italian legislative set by the Legislative Decree 152/2006. One of the basic targets of D. Lgs. n. 152/2006 is to pursue the sustainable and durable use of water resources, prioritizing drinking water services. This target has to be reached through the integrated protection of qualitative and quantitative aspects inside every hydrographic district, and through the identification of measures aimed at conserving, saving, reuse and recycling of water resources.

The decree does not expressly provide quantitative targets, as it does for quality standards, but merely lays down some general rule for the protection of the resource quantity and water saving, leaving to the Protection Plan (Piano di Tutela), the indication of the quantitative measures for the protection of the water system.

However, D. Lgs. n. 152/2006 recalls the planning of the water balance: Art. 95 says that the resources quantitative protection contributes to the reaching of quality targets, through a planning of water uses directed to protect quality and to allow sustainable water uses. Protection Plans contain measures dedicated to ensure the equilibrium of water balance, as it is defined by The River Basin Management Authority, respecting the priorities defined by law and taking into account different needs, availabilities, minimum instream flow, groundwater recharge capacity and water uses consistent with the qualitative and quantitative features of the water resource.

Protection Plans have therefore two main targets:

- the reaching of the water balance
- the minimum instream flow in respect of the superficial hydrographic network

These two targets are strictly related, especially because of the frequent connection between superficial and underground water, which together contribute to the target reaching.

MIF in Italian Laws

The Legislative Decree 152/2006 refers to MIF at the Art. 95, paragraph 4, stating that all water abstractions in exercise by the date at which the third part of the decree becomes effective, are regulated by the conceding authority through the minimum vital flow definition. The MIF value is recalled also at the Art. 145, paragraph 3 (ex L. 36/94, Art. 3): water abstractions are regulated so that the flow level necessary to preserve life in the abstracted reaches is guaranteed and the ecosystems equilibrium is not damaged.

The MIF respect was already present in the Law n. 183/1989 (Art. 3, paragraph 1), in the following D. Lgs. n. 275/1993 (modifying the Royal Decree n.1775 of 1993 – Single Text for Public Water and Hydropower Plants), and in the D. Lgs. n. 152/1999. The R.D. n. 1775/1933 was introduced in the period between the two world wars with the aim of promoting the modernization of the country, which then passed on to the production of hydroelectric power. Therefore its approach was aimed at encouraging the almost total use of water resources technically and economically available. Moreover, even the R.D. n. 1775/1933, by Art. 43, paragraph 4, had envisaged the possibility of intervention of the Public Administration (formerly the Minister of Public Works, now the Regions) to restrict the use of the derivation "for special reasons of public interest or exceptional deficiency of the available water occur".

In the time the approach has changed and evolved thanks to an increased environmental awareness and culture, leading to the more modern definition, contained in the D.M. 28/07/2004 "Guidelines for the preparation of river basin water balance, including the criteria for the census of active uses and to define the minimum vital flow, as stated in Article 22, paragraph 4, of the Legislative Decree of May 11, 1999, No 152 ": MIF is the flow rate to be determined for each homogeneous reach of the water body, in order to ensure the preservation of the physical characteristics, of chemical and physical properties of water, and the maintenance of biological communities typical of natural local conditions.
To achieve the objective of waterways ecological sustainability, the quantitative requirements cannot be separated from those of environmental quality. In fact, the decrease of the available flow and the alteration of the hydrologic system caused the unbalancing in the self-purification process, and in the development of aquatic life. On the other hand, the Ministerial Decree 28/07/2004 provides that the MIF can also be determined based on the needs of protection induced by the anthropic presence, i.e. taking into account the effects of human activities in pursuing quality objectives under the Water Protection Plan.

The Ministerial Decree 28/07/2004 indicates that the MIF discharge has to be regulated by the Protection Plan, because it is both a useful indicator for the needs of protection and a fundamental tool for regulating abstractions and waste discharges. Moreover it states that waiting for Protection Plans implementation and for waterways which are not concerned by Plans elaboration, the DMV can be defined according to the criteria and formulas already adopted by the River basin Authority or by Regions.

Implementation

This is an extremely complex activity, which requires a careful evaluation of natural and anthropic factors for each stream, divided into reaches according to the geomorphological, hydrological, hydraulic and biological characteristics and according to the presence and amount of discharges and withdrawals. Such an analysis requires a prior acquisition for each considered reach and for a period of time large enough, of a number of cognitive elements. At now in the Veneto Region, only the Po River Basin Authority and the High Adriatic Basin Authority have adopted special planning tools according to L. No 183/1989 for the rivers Piave and Tagliamento.

Moreover, the two authorities have considered a reference value, which represents the minimum flow to be ensured immediately downstream of water abstractions. Therefore, in Veneto the MIF value and how to determine the volume of water, necessary to ensure the life of aquatic biological communities, have not been defined for all streams.

According to the Ministerial Decree 28/07/2004, The Protection Plan must establish the MIF value for each reach of the watercourse, even as a first guidance estimate, based on regional or experimental methods, using available data. Further studies and insights will have to follow this first definition in order to reach an evaluation according to the natural and anthropic features of every single stream.

The MIF should be considered in a dynamic way, due to its close relationship with the development of monitoring and biophysical knowledge of the environment, with the temporal evolution of the anthropic impact and of the dynamics of the socio-economic and environmental policies. In addition, its application, even if it is a first definition, represents a useful base knowledge for a possible upgrade or redefinition.

In case of water abstractions from surface water bodies, the withdrawal management has to guarantee a minimum value of the instream discharge nearby and downstream the abstractions, not less than the value of minimum vital flow. If the natural flow is less than the minimum vital flow, and there is no dam upstream, downstream the abstraction a discharge equal to the upstream incoming one must be guaranteed, that means no abstraction is permitted. If the natural flow arriving is less than the minimum vital flow and there is a dam with a reservoir upstream, the discharge which has to be guarantee downstream the abstraction is equal to the incoming discharge plus half the difference between the MIF value and the incoming discharge.

In Veneto the River Po Basin Authority and the High Adriatic Basin Authority, the latter just for the River Piave, have already furnished a MIF quantification with ad hoc studies and evaluations, adopted with legislative measures based on public participation, following the Law n. 183/1989.

In particular, for the River Po basin, the MIF quantification in a determined cross section is based on the following formula (unless specific local studies are available):

$$DMV = k \cdot q_{medium} \cdot S \cdot M \cdot Z \cdot A \cdot T \qquad [l/s]$$

Where:

- k is an experimental parameter determined for single geographic areas
- q_{medium} is the specific medium annual discharge per basin unit surface (l/s km^2)
- S is the basin surface upstream the selected cross-section (km^2)
- M is a morphological parameter
- Z is the maximum value among three parameters separately evaluated:
  - N = naturalistic parameter
  - F = fruition parameter
  - Q = water quality parameter
- A = parameter concerning the link between surface and underground water bodies
- T = parameter concerning the temporal modulation of MIF

The term $k \cdot q_{medium} \cdot S$ represents the hydrologic component of MIF, which has to be defined for every abstraction present in the natural hydrographic network, while the other parameters represent possible correction factors which take into account particular local conditions.

Is it a regional duty to define the q_{medium} computing procedure inside the Protection Plans and the definition of the parameter k. Moreover the regions have to indicate the water courses to which the parameters M, A, Z, T have to be applied, and the correspondent values.

This formula applies to all rivers in the River Po Basin, except the River Po itself, for which the MIF value is directly established for some cross-sections. Moreover, for river basins larger than 50 km^2 the k parameter value has been already defined.

The Water Protection Plan of the Veneto Region defines the following parameters for the streams reaches included in its territory:

- q_{medium} = 30 l/s/km^2
- k = 0.14

Concerning the river Piave, the High Adriatic River Basin Authority has defined that, temporarily, while waiting for the conclusion of last experimental field surveys dedicated to the definition of the effective functional dependence between minimum flows and water co-system protection, the MIF has to be evaluated with the following formula:

$$Q_{MDR} = (K_{biol} + K_{nat}) \cdot 177 \cdot S^{0.85} \cdot q_{medium} \cdot 10^{-6}$$

Where:

- Q_{MDR} is the minimum respect flow, expressed in m^3/s
- K_{biol} is the biologic critic index
- K_{nat} is the naturalistic critic index
- S is the hydrographic river basin surface upstream the selected cross-section (km^2)
- q_{medium} is the specific mean discharge (l/s km^2)

For all the other rivers, for which specific studies haven't still been defined, the Water Protection Plan of the Veneto Region proposes a first value based on the basin area upstream the investigated cross-section:

- 4 $l/s/km^2$ for upstream basins less than 100 km^2
- 3 $l/s/km^2$ for upstream basins larger than 1000 km^2
- a value obtained by linear interpolation between the former two, for basins from 100 to 1000 km^2.

For the river basins of Adige, Brenta and Piave, in relation to the hydrologic characteristics and to the uses present on the basin, if an exceptional drought situation occurs, exceptional dispensations could be granted, but for limited periods.

In case of interregional river basins, if the MIF value computed by the Veneto region results to be in some cross-section located on the regional boundary less than the one determined by the other country with similar computation rules, it has to be adequate.

Slovenia

Introduction – Water and the WFD in Slovenian Legislation

Water management is under the competency of the Ministry of the Environment and Spatial Planning. The Ministry in the area of water protection prepares and ensures the preparation and implementation of programming documents for the achievement of goals of the Water Framework Directive (Directive 2000/60/EC), the Bathing Water Directive (2006/7/EC, 76/160/EEC), the Nitrates Directive (91/676/EEC) and the Marine Strategy Framework Directive (2008/56/EC) and the preparation and implementation of regulations concerning protection areas as regards the Water Act: water protection areas, bathing water protection areas.

First step in WFD implementation is the transposition phase. Table 1 shows considered legislations, which were adopted or amended.

Table 1: Slovenian Legislation concerning WFD at national level

LEGISLATION CONCERNING WFD AT NATIONAL LEVEL
National legislation concerning WFD and the year of transposition: **o The Environment Protection Act (2004)** **o Water Act (2002)** **o Nature Conservation Act (2004)** **o Public Administration Act (2004)** **o Decree on the chemical status of surface waters (2002)** **o Decree on the quality of underground water (2002)** **o Decree on the emission of substances and heat in the discharge of waste water from pollution sources (1996)** **o Decree on the quality of underground water (2002)** **o Two Act Ratifying the Conventions**

In July 2011 a Decree on River Basin Management Plans for Adriatic Sea and Danube Basin was adopted. With the Decree River Basin Management Plan for Adriatic Sea and Danube Basin 2009-2015 (RBMP) plans of measures were elaborated and adopted. The mentioned documentation is in Slovenian language and is available at: http://www.mop.gov.si/si/delovna_podrocja/voda/nacrt_upravljanja_voda_za_vodni_obmocji_donave_in_jadranskega_morja_2009_2015/

RBMP consists of a textual and a map part. Figure 1: Map of mean flow trends of rivers on Slovenian territory shows one of the maps, representing trends of mean flows of Slovenian rivers. Red colour assigns rivers and their tributaries where a future decrease of mean flow is expected, yellow colour assigns the areas with no changes expected and green colour where an increase of mean flow is expected. Dotted areas assign tributaries with no adequate data available.

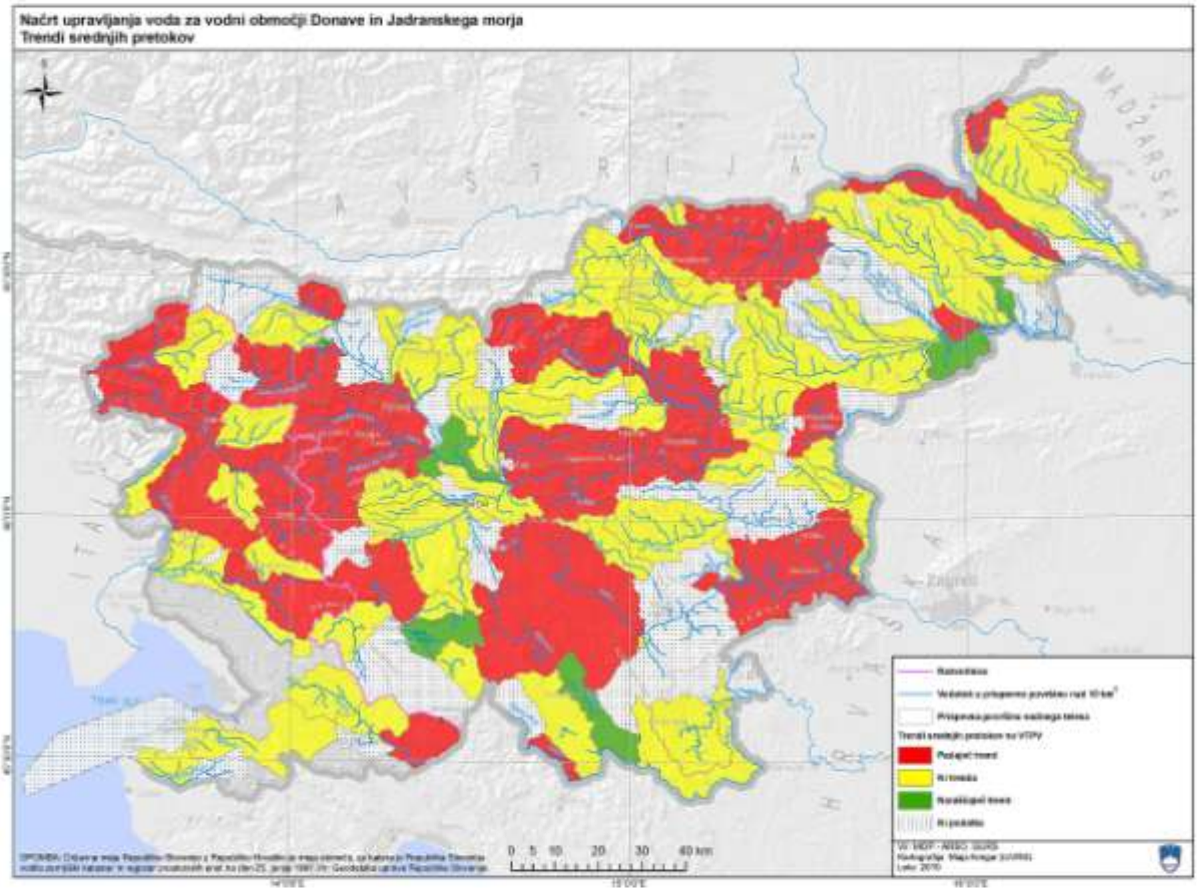

Figure 1: Map of mean flow trends of rivers on Slovenian territory

Slovenian legislations concerning and governing determination of Minimum Instream Flow are presented in Table 2. In Slovenia MIF is defined (and named) as Ecologically Acceptable Flow.

Table 2: Slovenian legislation concerning MIF

NATIONAL LEGISLATION GOVERNING THE MIF DETERMINATION IN SLOVENIA
Water Act (Official Journal No. 67/2002 and 57/2008) Environment Protection Act (Official Journal No. 41/2004) Decree on criteria for determination and on the mode of monitoring and reporting of ecologically acceptable flow (Official Journal No. 97/2009)
NATIONAL LEGISLATION THAT IS INDIRECTLY CONNECTED TO THE MIF DETERMINATION IN SLOVENIA
Construction Act (Official Journal No. 110/2002 and 102/2004 and 14/2005) Nature Conservation Act ((Official Journal No. 56/1999, 31/2000 and 96/2004) Freshwater Fishery Act (Official Journal No. 61/2006)

The main national legislation concerning WFD implementation is the Water Act. The Water Act was harmonized with WFD in 2002.

Article 71 of the Waters Act (OG RS No. 67/2002, amended by Nos. 110/2002-GZO-1, 2/2004-ZZdrI-A, 41/2004.ZVO-1, 57/2008) refers to ecologically acceptable flow as follows:

- For use of surface waters or the emission of substances and heat into surface waters that might reduce flow, lower the water level or degrade the condition of water, an ecologically acceptable flow or surface water level (hereinafter called ecologically acceptable flow) must be ensured at all times of the year.

- Ecologically acceptable flow shall be a quantity of water, which, in the case of permitted use or permitted pollution, does not degrade the ecological condition of surface waters or does not prevent its improvement.
- Ecologically acceptable flow shall be specified in the water permit referred to in Article 125 of this Act, in the concession contract referred to in Article 141 of this Act or in the water approval referred to in Article 150 of this Act, on the basis of an expert opinion formulated by an authorised person at the expense of the investor.
- The expert opinion referred to in the preceding paragraph shall be formulated by an authorised person on the basis of a methodology prescribed by the minister in agreement with the minister responsible for nature conservation.
- The authorised person must have appropriate higher education and appropriate work experience.
- The regulation referred to in the fourth paragraph of this article shall also prescribe more detailed conditions that must be fulfilled by an authorised person, and the method of acquisition and revocation of authorisation.
- The minister shall prescribe the types of use and encroachment referred to in the first paragraph of this Article.

On the basis of hydrological, hydraulic, morphological and ecological criteria appropriate for different river types, separate hydrological-based and ecological-based methods were developed to undertake MIF assessments in Slovenia (i.e. those developed in the research project sponsored by the Ministry of the Environment and Spatial Planning). In the following years, the methods underpinning both the hydrological and ecological-based approaches were improved. By 2002, both methods were used in practice, though they are not legalized by Decree yet.

On the basis of Article 71 of the Waters Act the Decree on Criteria for Determination and on the Mode of Monitoring and Reporting of Ecologically Acceptable Flow (Decree; OG RS, No. 97/2009) was adopted in 2009. It consists of the following chapters:

- General provisions (application, exceptions, terms)
- Criteria for determination of ecologically acceptable flow
    - Article 5: Determination of MIF (characteristics of water abstraction, hydrological, hydro morphological and biological properties of watercourses and the information on protection arrangements)
    - Article 6: Hydrological Elements (MQ, MMF etc.)
    - Article 7: Determination of MIF on the basis of hydrological elements (formula will be given in chapter 0.)
    - Article 8: Study for the determination of MIF (study requirements)
    - Article 9: Determination of MIF in relation to the protection arrangements
    - Article 10: Exceptions to the determination of MIF
- The mode of monitoring and reporting on MIF
- Supervision
- Penal provisions
- Temporal and final provisions

Temporal provisions of the Decree state that, if MIF was defined by water permits and concession contracts before the Decree came into force (for existing water use), those values for MIF are considered as MIF. Only in the case that the value of the previously defined MIF is higher than the MIF determined according to the Decree, the MIF-calculation corresponding to the Decree is used. If MIF for existing water use (before the Decree adoption) had not been defined by water permits and concession contracts, MIF is determined according the Decree. Nevertheless, there are some mitigation measures, as for example for hydropower use a lower MIF can be determined to preserve 85% of electricity production of existing hydropower plants. To be more precise, the Decree states that a lower value for MIF can be defined to preserve 85% of current electricity production, but a study in such cases (according to the Annex 3 of the Decree) is obligatory. So, if the objectives of the WFD cannot be achieved for a certain water body, where this problem may occur, the possibility for MIF reduction will not be preceded. In this case a problem can occur, since it inflicts already granted concessions and owner rights. This can lead to compensation claims against the state because it jeopardizes the financial viability of realized investments to the SHP. But only an insignificant number of cases are expected.

The Decree on MIF is new. By 2014 MIF needs to be determined and the monitoring has to be assured. By then, it is planned to identify all discrepancies and to realize proper measures (adoption of the Decree, possibilities of compensations for reduction of electricity production etc.).

The value of ecologically acceptable flow, determined on the basis of Articles 7 and 8 of the Decree, may change to the value set in the opinion on the impact of activities on the fish status in accordance with the regulations governing freshwater fishing where necessary because of fish migration over built structures or in order to reduce the impact of activities on the fish status and to the value set in the conditions of use arising from the nature protection policies and guidelines under the nature preservation regulations, if a protected area or a valuable natural feature is consistent with the regulations governing the preservation of nature.

MIF Assessment

The first definition of minimum flows on running waters in Slovenia was defined as a quantity of water that enables the survival of water organisms. This formed the basis for granting permission, according to specific regulations, to ensure the availability of water supply for drinking and economic purposes (Official Gazette SRS, 1976).

The methodology for MIF assessment in Slovenia was developed in research projects by the Institute of Water of the Republic of Slovenia and part of this approach was used in the Decree.

In Slovenia there are a large number of proposals that have an impact on aquatic ecosystems, but the nature and/or extent of these impacts is likely to be limited. Conversely, a small number of proposals have potentially much greater significance, in terms of the length of reach affected, quantity of water abstracted and/or ecological importance. In the process of finding appropriate methods for MIF assessment from existing methods, it was recognized that approaches based solely on hydrological indices are not suitable because they are not site specific. As a consequence, the “rapid assessment method” was established with the aim of quick application, based on the use of basic hydrological data and site information including an inventory of habitats and ecological and morphological information. The “detailed assessment method” utilizes similar information, but in addition requires the sampling of zoobenthos and periphyton in different aquatic habitats of the relevant sections of river. The rapid assessment method is used unless the proposal is influenced by any of the factors given in the list below:

- If the running water is in a preserved or legally protected area.
- If there are rare, endangered or protected species of flora and fauna in the running water or in the riparian zone.
- If the spawning grounds are threatened by water use.
- If the river reach is affected by the water use over a long river section (i.e. for rivers with a catchment area more than 100km^2 a ‘long river section’ is deemed to be more than 200m).
- If the water abstraction is not returned to the river further downstream and is larger than 20% of mean annual minimum flow.
- If the public interest demands multi-designation use of the water
- If the inventory of habitats, the fieldwork or ecological survey, work carried out during the application of the rapid assessment method, raise any of the issues outlined above and hence require the application of detailed assessment method (Smolar-Žvanut et al., 2006).

MIF Calculation

Ecologically Acceptable Flow (Minimum Instream Flow or Environmental Flow – MIF) determination in Slovenia is exactly defined and beside depending on mean low water flow (sQnp) also depends on:

- type of water withdrawal/ abstraction (reversible or irreversible),
- length of reversible water withdrawal (point, short or long),
- size of catchment area (__<10 – 100 – 1000 – 2500 km^2 < __),
- group of ecological type of rivers (1 to 4),
- ratio between mean water flow (sQs) and sQnp (sQs/sQnp <> 20),
- amount of withdrawal compared to mean water flow (sQs <> 50 m^3/s when catch. area > 1000 km^2)

The above mentioned criteria are the basis for the determination of factor *f*, which is a multiplier of sQnp

$$MIF = f \cdot sQnp .$$

To support water users to define MIF for certain water use, the Ministry of the Environment and Spatial Planning prepared a data layer with ecological types of rivers and the size of catchment area, which is presented in Figure 2.

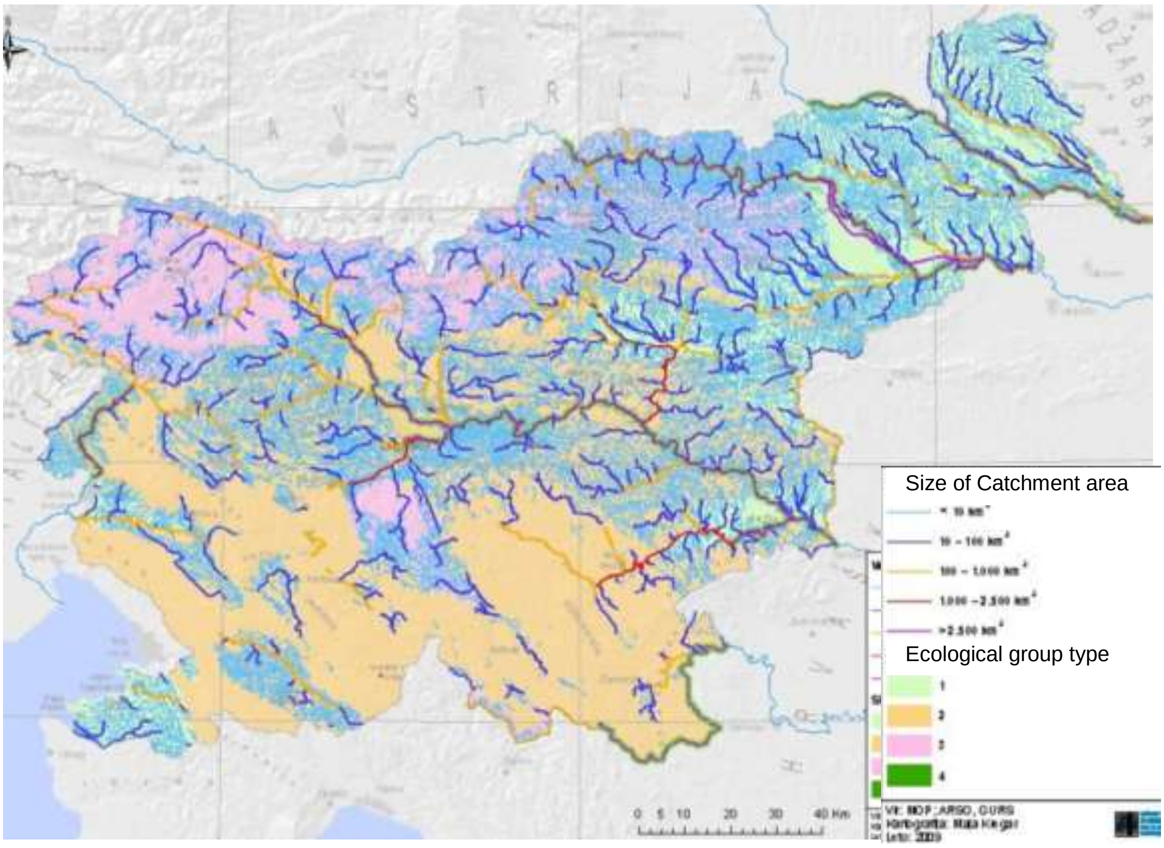

Figure 2: Map of ecological types of rivers with size of catchment area

(http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/zakonodaja/okolje/voda/skupine_ekoloskih_tipov_vodotokov.jpg)

Table 3 shows the values of the multiplication factor f for calculation of MIF in the case of reversible withdrawal (case for hydropower water use), where the first step is to read the size of the catchment area and ecological group type from the previous figure.

Table 3: Factor f determination for reversible water withdrawals

Ecological group type	Size of catchment area				
	<10 km^2	10 - 100 km^2	100 - 1000 km^2	1000 - 2500 km^2 and sQs < 50 m^3/s	> 2500 km^2 or sQs > 50 m^3/s
Point abstraction					
1 (1)	0.7	0.7	0.5	0.4	
2 (1)	0.7	0.5	0.4	0.4	
3	0.5	0.4	0.3		
4					0.3
Short abstraction all year or long withdrawal in dry period					
1 (1)	1.2	1.2	1.0	0.8	
2 (1)	1.2	1.0	0.8	0.8	
3	1.0	0.8	0.7		
4					0.7
Long abstraction in wet period					
1 (1)	1.9	1.9	1.6	1.3	
2 (1)	1.9	1.6	1.3	1.3	
3	1.6	1.3	1.1		
4					1.1

(1) *Factor **f** is multiplied by 1.6, if the ratio between sQs and sQnp at the withdrawal location is more then 20*

For structural length (river distance from water intake and water release) > 100 m and catchment size <= 100 km^2 and for length > 500 m and catchment size > 100 km^2 wet and dry periods are defined. Table 4 presents dry and wet periods according to Slovenian methodology.

Table 4: Wet and dry periods definition depending on ecological group type

Ecological group type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	wet	wet	wet	wet	wet	dry	dry	dry	dry	wet	wet	wet
2,3,4	dry	dry	wet	wet	wet	dry	dry	dry	dry	wet	wet	dry

It is important to stress that MIF determination can differ,

- when MIF was determined before the mentioned determination was adopted by the Decree on criteria for determination and on the mode of monitoring and reporting of ecologically acceptable flow (Published in *OG of RS , no. 97/09;* Decree is an act which is adopted by the Government) MIF can sustain the same
- when an additional study for MIF determination is carried out. The study must be carried out according to the Annex 3 of the mentioned Decree, in which minimum requirements for this study are stated.

EF is an important issue for the preservation of the good status of water bodies and must be ensured.

The Water Act and the Decree on the detailed content and method of drawing up a water management plans transposed the WFD into national legislation. The Aim of the WFD is to achieve and to maintain the “good status of water bodies”. To achieve this goal there is a special emphasis on reducing the burden on water bodies and on improving the chemical, ecological and quantitative condition of water bodies. As the main legislation, the Water Act and the Decree (OG RS, no. 26/2006 and 5/2009) consider the good ecological status of water bodies as main objective.

Austria

Introduction – Water and the WFD in Austrian Legislation

The Water Frame Directive (WFD) proposes an integrated approach which includes the protection, the improvement and sustainable use of water bodies. This directive was implemented into Austrian law with the legal amendment of the Austrian Water Act in 2003. One of the focal points was the problem of minimum instream flow in connection with fish migration barriers.

According to the objectives of the WFD, all water bodies, except the "heavily modified ones", should reach the good ecological as well as the good chemical status stepwise up to 2015/2021/2027.
The heavily modified ones should reach a good ecological potential. The stepwise procedure is defined as follows:

- For rivers larger than 100 km^2 basin area: meeting of objectives by 2015.
- For rivers between 100-10 km^2 basin area: meeting of objectives by 2021.
- For rivers smaller than 10 km^2 basin area: meeting of objectives by 2027.

Implementation

Austria reformed its water protection totally in 1959 resulting in a new water law. The term of Environmental Flow assessment was partially integrated in the Water act 1985. The legal base of development of a national water plan (in original "Nationaler Gewässerbewirtschaftungsplan – NGP") was set in place 2009 and will be adapted and maintained periodically (every six years). This document becomes the future basis for the coordination of all uses and impacts on the rivers in Austria. Under the premises of an improvement of the condition of water bodies, an increase of minimum residual flow and better fish migration at transverse structures is required.

- In 2003 the Water Framework directive was implemented into national law (http://www.ris.bka.gv.at/Dokumente/BgblPdf/2003_82_1/2003_82_1.pdf) later replaced by some amendments; the consolidated version of 2011 (http://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10010290).
- Since 2006 regulations concerning quality objectives as well for surface waters and as for groundwater were published (http://www.lebensministerium.at/wasser/wasser-oesterreich/wasserrecht_national/planung.html)
- In 2009 the National Water Management Plan was published (http://wisa.lebensministerium.at/article/archive/29367) and amended later by the regulation concerning the Articles 5 and 6 of the Water Management Plan.
- By 2015 almost 150 of the main water courses are to meet the objectives set by the WFD including Environmental Flows Assessment. Even for the heavily modified water bodies there has to be a minimum instream flow which allows free fish passage for the whole "eco-region-typical"-fish fauna.

In some cases reduced flow conditions at diversion plants cause migration problems all the year. For example the majority of native fish species do not migrate in river sections that are characterized by a "low set" minimum instream flow, minimum flow velocity and minimum depth and eutrophication. A reduced water amount may cause a deposition of sediments, a change of temperature and - in some cases - a deficit of oxygen as well.

Short introduction concerning environmental flow (EF) in Austria:

Environmental flow assessment in Austria bases on the “Austrian regulation for ecological quality objectives of surface waters” - Federal Law Gazette II No. 99/2010 (in German “*Qualitätszielverordnung Ökologie*” - BGBI.II NR. 99/2010). The document can be found here: http://www.lebensministerium.at/wasser/wasser-oesterreich/wasserrecht_national/planung/QZVOekologieOG.html.

The additional important legal acts have been mentioned already above.

This regulation does not only concern environmental flow, but all biological quality components demanded by the WFD (e.g. Phytoplankton, Macrophytes, Phytobenthos, Benthic invertebrate fauna and Fish fauna).

Ecological parameters and natural processes of aquatic ecosystems (e.g. spawning seasons of the eco typical fish fauna, sediment transport and maintenance of the abiotic habitat conditions like oxygen or temperature) are described in this regulation. Also the dynamic discharges including the natural flow dynamics are taken into account.

In Austria it is possible to use following methods to fulfil the provisions:

- To keep the good ecological status of river sections it is recommended to release at least 20% of the actual natural flow as a value for EF.

- If the EF should be below these defined thresholds detailed habitat modelling has to be performed to prove the suitability.

- For smaller rivers there are two methods for fulfilling the recommendations of the regulation. This regulation was done just for smaller rivers where the first method is a simple approach:

  The regulation is part of “Attachment G” (in original “Anlage G”) and can be used for small rivers with natural mean annual flow < 1 m3/s**:

  - First method deals with a minimum endowment of 50% of the mean annual low flow. In this case the compliance of set values for minimum depths and minimum flow velocity (values see below) is granted with a “high amount of certainty” and additional measurements concerning depth and flow velocity can be omitted (plausibility check through experts has to be done before).

  - Second method is based on the local target values (different from Epirhithral, Metarhirthral, etc.) which have to be proved for each single case by measurements to preserve the minimum values.

**Please note: Just suitable for rivers with minimum water flow < 1m^3/sec and natural minimal daily minimum flow < than the half of the natural medium minimum instream flow/ year and in natural fish areas.

Referring the “Attachment G” the following minimum values (=guiding values for the “good ecological status”) have to be met (with the method “minimum endowment of 50% of the mean annual low flow” or through measurements).

Table 5: Minimum values according to “attachment G”

REGION	MINIMUM WATER DEPTH TMIN [M]	Ø MINIMUM DEPTH TLR [M]
Epirhithral (> 10% slope)	0.1	0.15
Epirhithral (3-10% slope)	0.15	0.20
Epirhithral (≤3% slope)	0.20	0.25
Metarhithral	0.20	0.30
Hyporhithral	0.20 (0.30)	0.30 (0.40)
Epipotamal	0.30	0.40

- Minimum water depth applies in the specific spawning and developmental stages of the respective site-related dominant and sub-dominant fish species.
- Hyporhithral values in brackets are to keep in case of presence of Danube Salmon *(Hucho hucho)*.
- Ø Minimum depth TLR: Measurements have to be set for a 200m-stretch which is characteristic of the water body, the maximum water depths in the thalweg (at minimum flow) or the residual-flow , respectively shall be determined in the five most distinct riffles or rapids and in the five most distinct scours. This is to serve as a basis for the calculation of the respective depth in the thalweg for this stretch of water body at a certain discharge level of residual flow. The arithmetic mean made up of the ten values accounts for the respective mean depth in the thalweg in this stretch of water body in the event of discharge at the time of the depth measurement.
- Hyporhithral and Epipotamal: higher minimum water depths can be required during spawning seasons. This has to be taken into account individually according to the site-related dominant and sub-dominant species of fish, e.g. for rivers with presence of Bream *(Abramis brama)* or Nase *(Chondrostoma nasus)*.

In addition to the water depth values the flow velocity values have to be kept as well. Mean velocity in the cross-section is to keep ≥0.3 m/s. The principal current in the migration corridor serves the purpose of rheotactic orientation of fish and has to be kept at the same value (≥0.3 m/s)

Monitoring programs

Monitoring programs are executed by the Federal Government – *Lebensministerium* (=Federal Ministry of Agriculture and Forestry, Environment and Water Management) in cooperation with the 9 Regional Governments. Surveillance and operative control is done by the Federal Government and its administration units in cooperation with the Regional Governments.

Monitoring is executed by the various regulations concerning the status of waters (see above); coordination is done by the ministry. The competent authorities are district administrative legal authorities, provincial governor and Federal ministry. Central data management for Austria is in most cases done by the Federal Environmental Agency.

The monitoring program in general is executed in close cooperation of Federal Government, Regional Governments and Federal Environmental Agency. Survey and operative control is an assignment of the federal government. The monitoring is regulated by the legal act called regulation of monitoring of Water Status (GZÜV) and coordinated by the *Lebensministerium*. The responsible regional authorities for the accomplishment of monitoring are the regional governments, in the case of Styria it is the Regional Government of Styria. Data management and processing is made by the Federal Environmental Agency in cooperation with the Regional Governments.

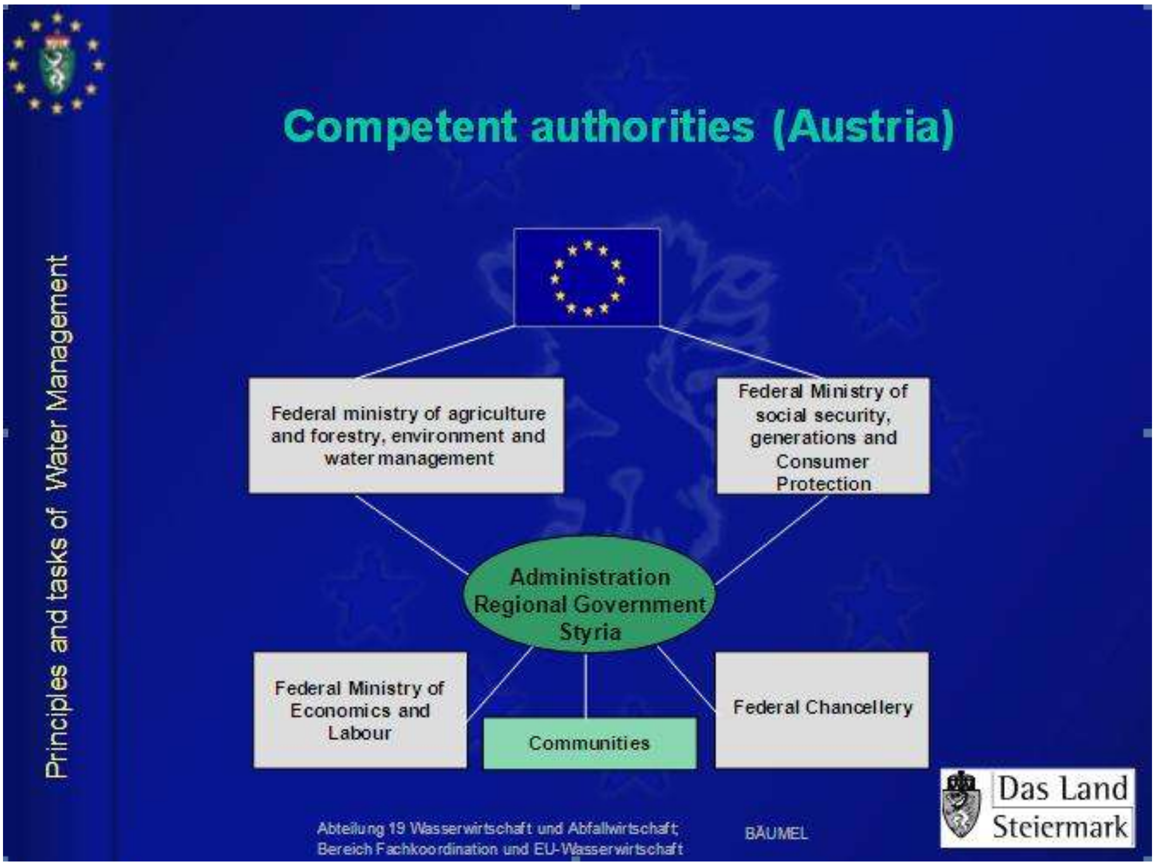

Figure 3: Competent authorities for execution of the National Water Act (Regional Government of Styria)

France

Introduction – Water and the WFD in French Legislation

Prior to the WFD, the French legislation on water was composed of two main texts:

- The law of 1964 relative to the water regime and repartition and to the fight against pollution: This law organized water management in France, in particular by dividing the territory into 6 main basins, and creating the Water Agencies responsible from water management until today.
- The law of 1992 on Water: this law complements the previous one, reinforcing the aspects of respect of the environment, and of integrated water management with consultation between all stakeholders. This law also establishes water as "Nation shared patrimony." This law also created the SDAGE (Master Plan of Water Management) and SAGE (Plan of Water Management), the main texts used for implementing the law in terms of water.

However, the principle and modalities of a minimum instream flow (MIF) (*débit réservé* or *débit écologique minimum* in French) was defined in a separate law from 1984, related to fishing in freshwaters.

The transcription of the WFD into French legislation was realized through two laws:

- The law of 2004 relative to the Water Framework Directive (n°2004-338): This law explicitly transcribes the WFD into French legislation
- The law of 2006 on water and aquatic environments: This law is a complement to the former law. It gives tools to improve the state of aquatic ecosystem and to gain a better match between water resources and water needs. This law modifies the MIF requirements.

MIF in French laws

The concept of MIF entered the French legislation as soon as 1919. This law outlines the fundamental principle of MIF, reiterated in each law on MIF since then: It is necessary to guarantee the life, movement and reproduction of aquatic species at all times.

In 1984, the *loi pêche* (fishing law, n°84-512) reiterates this principle and defines the MIF normatively as:

- 1/10 of the mean annual flow for all new structure
- 1/20 of the mean annual flow when this mean flow is above 80 m^3/s
- 1/40 of the mean annual flow for the existing structures.

The mean annual flow is computed over a period of at least 5 years.

Following the WFD, the Law on aquatic environments includes an article on MIF. This law reiterates the fundamental principle of the previous laws on MIF: all structures in a river bed, no matter their use, must maintain a minimal flow to guarantee the life, movement and reproduction of aquatic species in streams downstream of these structures.
The MIF is established for three groups of structures:

- In general, the MIF must not be less than 1/10 of the mean annual flow of the river, computed over at least five years, immediately downstream of the dam, or immediately upstream if the mean annual flow is inferior.
- For streams whose mean annual flow is more than $80m^3/s$, or for streams that contribute to the production of hydropower in high energy demand periods (listed by a decree), the MIF must not be less than 1/20 of the mean annual flow of the river.
- For streams or reaches which present an atypical pattern, which makes the attribution of a minimal flow prescribed as above irrelevant, the MIF can be set at a lower level.

Moreover, it is possible to set different MIF values depending on the season, as long as the annual mean of these values is not less than the MIF set as above. Moreover, the lowest MIF must remain superior to half of the set MIF.
In exceptionally dry periods, it is possible to set a temporary MIF inferior to the MIF described above.

Implementation of the Law

Respecting this law implies that:

- MIF is multiplied by 2 for structures previously having a MIF of 1/40 (existing before 1984), on a river of more than $80m^3/s$, or structures that furnish energy in high demand periods, to reach an MIF of 1/20 of the mean flow,
- MIF is multiplied by 4 for other structures previously having a MIF of 1/40

After a rough estimation realized by ONEMA, around 50 000 structures across a minor bed are concerned in France, of which 2000 are used for hydropower. 400 of them are on the official list of structure furnishing hydropower during high demand energy periods. This number gives an indication of the magnitude of work needed to implement the legislation. Moreover, the respect of this law may necessitate more or less important civil engineering work in the case of a certain structure.

In this context, a circular letter from 2009 gives indications about how to implement this law: *the Circulaire DGALN/DEB/SDEN/EN4 du 21/10/09 relative à la mise en oeuvre du relèvement au 1er janvier 2014 des debits reservés des ouvrages existants* (Circular letter regarding the implementation of the increase of MIF of existing structures by January 1st 2014).

This documents first limits the structures on which the implementation should focus: Because some old structures have no legal managers and many structures already respect the prescribed MIF, because they are deteriorated or not used, the implementation effort must focus in particular on the 10% to 20% of structures that have an official manager and that are in use.

This document then establishes pragmatic rules to reach the objectives of the law. The implementation has to be developed in the following parts:

1. Preparatory stage, in consultation with the structure managers

- 2009

First the document and the details of the legislation must be made widely known.
Second, all services involved in the implementation of this legislation must meet: the basin services, the services in charge of water and aquatic environments, the services that control concessions of the DRIRE (Regional Research Direction of Industry, Research and Development) or the DREAL (Regional Directions of Environment, Territory planning and Accommodation), the services of water police, and representatives of the ONEMA (national office for water and aquatic environments) and the Water Agencies.

These meetings are aimed at gathering the available information related to MIF (previous studies, current experiments, local knowledge from fishing associations or structure managers…). The aim of this data compilation is to simplify and harmonize the effective implementation of the law, by giving all relevant information to the managers so that they know which rules are applicable to them.

- 2010

Following the work of the previous year, the services must inform the managers individually of the structures. They also fix a deadline for the managers to propose their MIF regime, when this could not be done by the services themselves with the available information.
In the meantime, the services must find out from the managers the technical consequences that the MIF increase may have on the existing structure, and especially if construction work is necessary.
In the case of conflict, the MIF is to be determined at the national level by the MEEDDM (sustainable development ministry).

- 2010 and following year

The following years will be used to determine which structures will be the object of a monitoring program or of an assessment of the effects of the MIF after 2014.
After 2014 the implementation of monitoring programs, assessments, and when relevant, the revision of the MIF depending on the obtained results, is planned.

2. Rule for setting MIF and criteria for implementing a monitoring program and for revising the MIF.

- Rule for setting the MIF

The rule of thumb, used in most cases, is to multiply the MIF by 2 or 4 for structures that were previously under the 1/40 of the mean flow regime, to reach 1/10 or 1/20 of the mean annual flow. However this simple rule can be applied only in case were the MIF of 1/40 has been officially set on the basis of a mean flow validated after 1975. In all other cases, the current MIF must be recalculated over 5 years of recent data.
In the cases where water withdrawals change substantially the discharge upstream of a dam, the natural flow must be reconstructed by incorporating the value of the withdrawal and by establishing coherence with the other data of the basin.
In all cases, the principle of preserving the life, movement and reproduction of aquatic species is more important than the exact numbers.

A monitoring procedure must be applied to the most important structures, and over a limited time. The structures that will be the object of a monitoring program will, between other legal considerations, be chosen based on:

- The information from the SDAGE 2010-2015 (Master Water Management Plan) about the high stake streams, the migratory axes, the presence of habitat for fish reproduction, the presence of species of high patrimonial value, and the objectives of the Good Status by 2015.
- The results of the preparatory works realized by the ONEMA (national office of water and aquatic environments) with the aim of classifying the structure that can have an IMF of 1/20 of the mean Flow
- Data availability

- Criteria to be taken into consideration to revise the set MIF

The following criteria should be taken into consideration for revising the MIF:

- A principle of only one revision
- The cost vs. benefits of this revision
- The revision does not lead to new expensive construction work on structures that have already realized some construction work to reach the 2014 MIF
- Assessments of attainment of the objectives of good status

The necessary engineering works must be realized under existing legal frameworks chosen depending on the type of structure.

Germany

Assessment of Minimum Instream Flow

The assessment of MIF is individually regulated in every province of Germany. The Länderarbeitsgemeinschaft Wasser (LAWA) publicized a guideline based on hydraulic factors and simple formulas, but for every hydropower plant an ecological investigation according to the size and extent of the project has to be completed in the course of the approval process.
Based on experience the assessment of the minimum instream flow is usually carried out according to the following steps:

- Determination of the current state with consideration of biozenosis, hydrology,…
- Determination of the consequences of different discharges
- Technical implementation of the gained knowledge under consideration of hydropower production and other uses
- Operation requirements
- After a few years control of the results of the taken measures and where required adaption

Influence of minimum instream flow on the power production in hydropower plants

Due to the required minimum instream flow the available discharge for power production is reduced. Other consequences are:

- The minimum instream flow is not available for power production , except if the natural discharge > design discharge
- Especially for plants with one turbine the non-operation periods are longer
- By turndown the turbines often run with a low degree of efficiency
- If the minimum instream flow is assessed after a trial period a prior dimensioning of the turbine is not possible
- Depending on the kind of minimum residual discharge a greater effort for the controlling system is needed

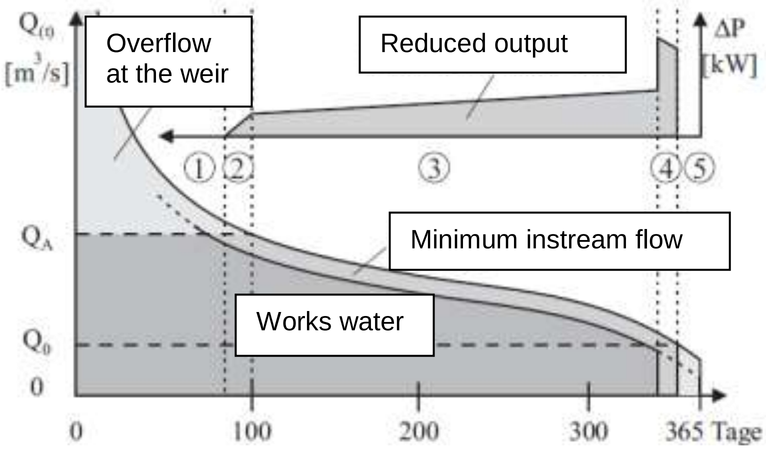

Figure 4: Impact of minimum residual flow on energy production (Giesecke, Mosonyi 1998, modified)

How to produce hydropower from MIF release

This chapter specifies the possible ways of using MIF to produce energy and it gives some considerations on the best turbine typology to install at a MIF energy plant.

It is a difficult balance between the purpose of a hydropower plant and the needs of downstream ecosystems. The decision to process the environmental flow at the weir is an efficient solution to use available potential and to increase power generation.

Another advantage of MIF use is the possibility to use the MIF plant as an operating reserve. During maintenance works at the main turbines it is therefore no longer necessary to reduce or cease the operation of the plant.

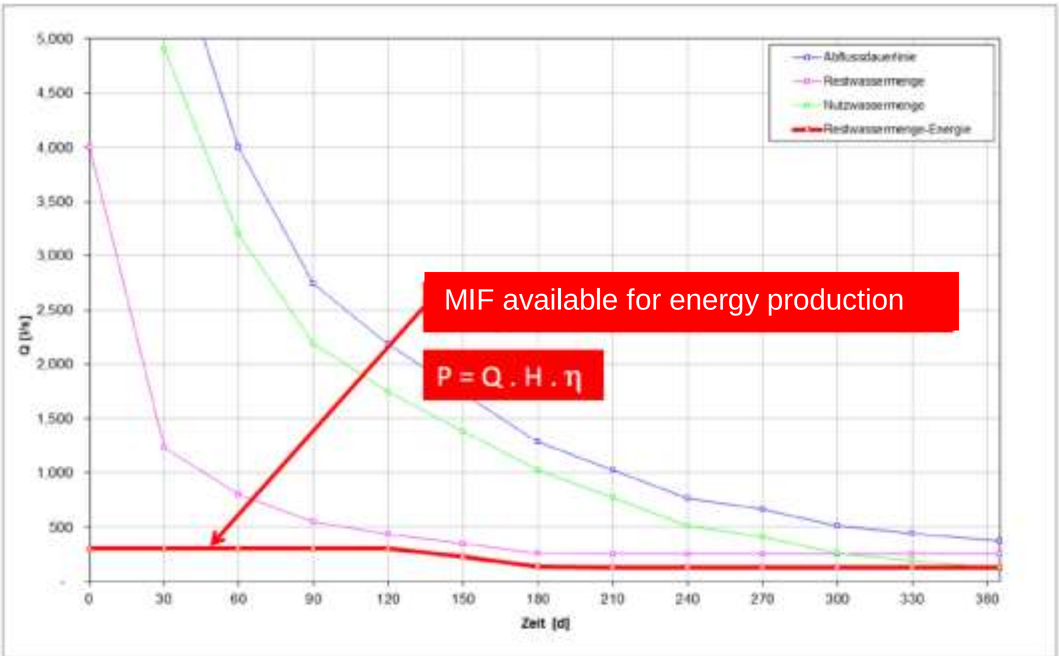

Figure 5: Minimum instream flow available for energy production (PI Mitterfellner GmbH)

Power machines using minimum instream flow can be situated at the water inlet or at the diverted reach. Hydraulic screws, propeller-spiral turbine, water weels, Kaplan, Francis and Pelton turbines can be used to asses MIF for power production.

Examples of different turbine typologies used for power production from MIF release:

- HPP Rosegg – St. Jakob at the river Drau in Carinthia: propeller-spiral-turbine with asynchronous generator at the water inlet
  - Q = 5 m³/s
  - H = 17 m
  - P= 760 kW
  - Energy = 6.6 GWh
- Peltonturbine at diverted reach (Effective water law for fish ponds):
  - Q = 10 l/s
  - H = 120 m
  - P= 10 kW
  - Energy = 80,000 kWh

- HPP Kindberg und Niklasdorf: Hydrodynamic screws at the water inlet

Table 6: Technical data of hydrodynamic screws at PP Kindberg and Niklasdorf (Sonnweber, 2009)

	KINDBERG	NIKLASDORF 1	NIKLASDORF 2
Usable flow (l/s)	5000	3600 (4000)	3600 (4000)
Height (m)	3.7	3.9	3.9
Length of the hydrodynamic screw (m)	19	10.24	10.63
Slope of the hydrodynamic screw (°)	21	22	22
Diameter of the hydrodynamic screw (m)	3.6	3.2	3.2
Number of revolutions	variable	constant	constant
Number of revolutions (U/min)	21 (16-26)	22	22
Capacity : calculated (kW)	142	132	132
Capacity : actually (kW)	142	132	132
Year of installation	2008 (august)	2008 (spring)	2008 (spring)
Total cost of the plant (EUR)	400,000	200,000 + 600,000	200,000 + 600,000

Hydrodynamic screws

Hydrodynamic screws provide an efficient use of hydraulic power, even in the case of small flow rates and low head. Minimal potential for hydropower can thus be exploited and therefore the screws are a good method to utilize residual water in weir systems.

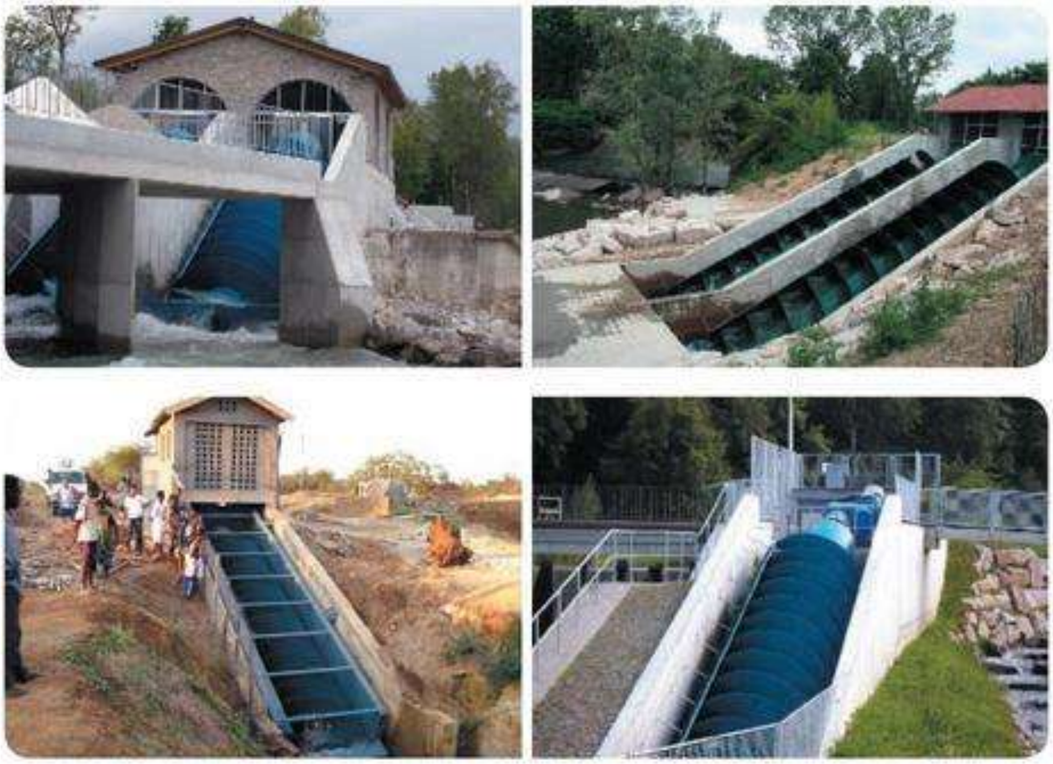

Figure 6: Various examples for hydrodynamic screws (Ritz Atro)

Hydrodynamic screws feature a flat and stable efficiency chart. They are characterized by large chamber volume, large diameter and low rotational speed. The nominal rotation speed is indicated at 20 rpm with peak-load range reaches values up to 25 rpm. Further characteristics are a low mechanical wear; they are extremely rugged and therefore need low maintenance.

As shown in Figure 7 and Figure 8, especially when operating with partial loads, the efficiency of hydrodynamic screws is significantly better than turbines and conventional water wheels.

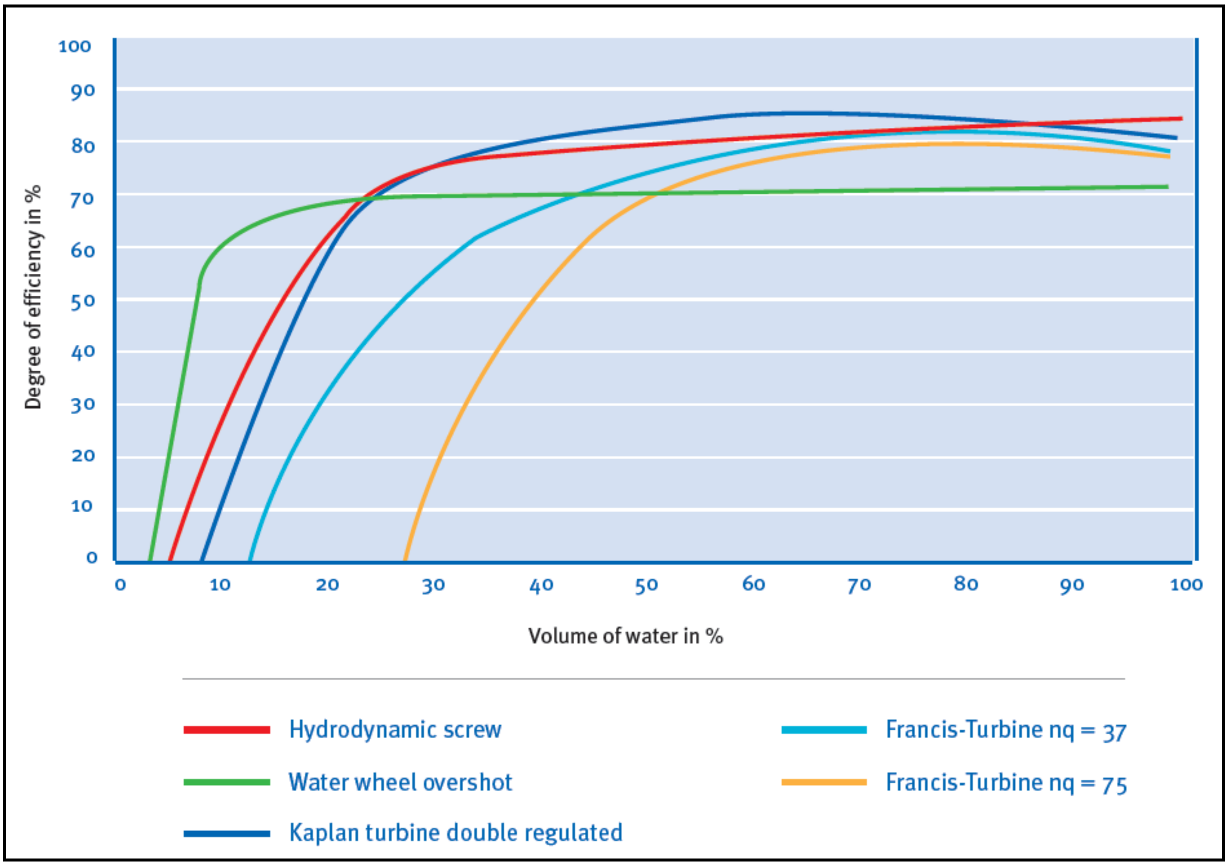

Figure 7: Efficiency factor for hydrodynamic screws compared to turbines (Ritz-Atro GmbH, 2010)

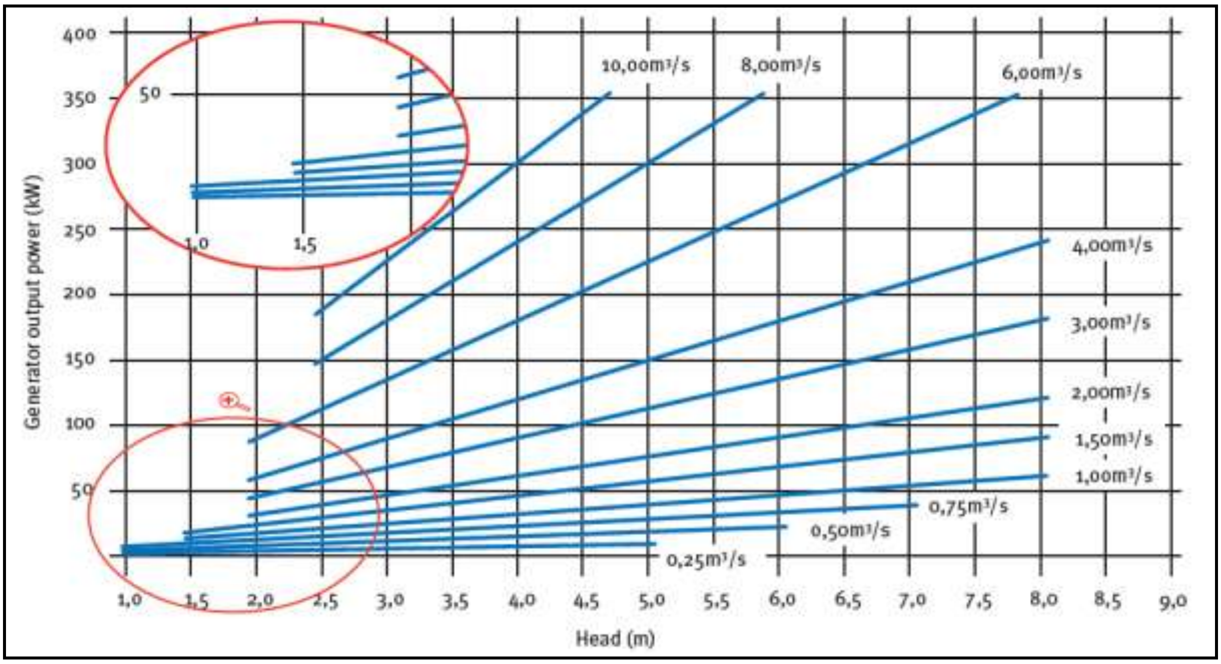

Figure 8: Output power of hydrodynamic screws with different heads and flows. (Ritz-Atro GmbH, 2010)

No complex excavations are needed compared to turbines. A further advantage is that a fine screen to filter floating materials is not required and no cleaning is necessary.

This form of hydropower production is also highly compatible with fish because it is almost completely riskless to pass for fishes in the downstream direction. They can use the waterway between the spiral blades to overcome height difference at the weir.

The screw is installed on a slant on the river bed, downwards in direction of the water. The water then forces the screw into a rotational movement, whilst it flows down the thread. Since the slope of the screw is rather small, the screw rotates relatively slow, with 20 to 80 rounds per minute. At the top end of the screw an electric generator is situated, optionally with an interconnected transmission.

The world`s largest hydrodynamic screw is installed at a power plant at the town of Kindberg, Austria and will be described in the best practice section of this report. The world's first hydrodynamic screw was tested at Prague Technical University in 1995 and then deployed by the foundation for wind and water energy Ostalb. It is running since 1997 at the Oberen Schlägweidmühle in Bopfingen-Aufhausen, Germany.

If hydrodynamic screws are installed care has to be taken concerning noise emissions. Probably noise protection measures have to be installed.

Table 7: Technical key data of Obere Schrägmühle, Bopfingen-Aufhausen, Germany

TECHNICAL KEY DATA	
Head	2m
Power	max. 4 kW
Screw diameter	1m

Figure 9: World's first hydrodynamic screw, situated at *Obere Schlägweidmühle.* (Förderverein Wind- und Wasserkraft Ostalb e.V.)

Conventional turbines

Besides hydrodynamic screws, conventional turbines are used for the production of hydro-electric energy at weirs for water diversion as well. Because of the low head, mainly the Kaplan Turbines are used. Kaplan turbines work at a head range from 2 to 40 meters. Francis and Pelton turbines are usually used for higher heads.

A distinction is made between “double regulated” and “single regulated” Kaplan turbines. The first one has adjustable runner blades and adjustable guide-vanes, while the latter has fixed guide-vanes and is less flexible in the case of head variation and works between 30% and 100% of the maximum design discharge.

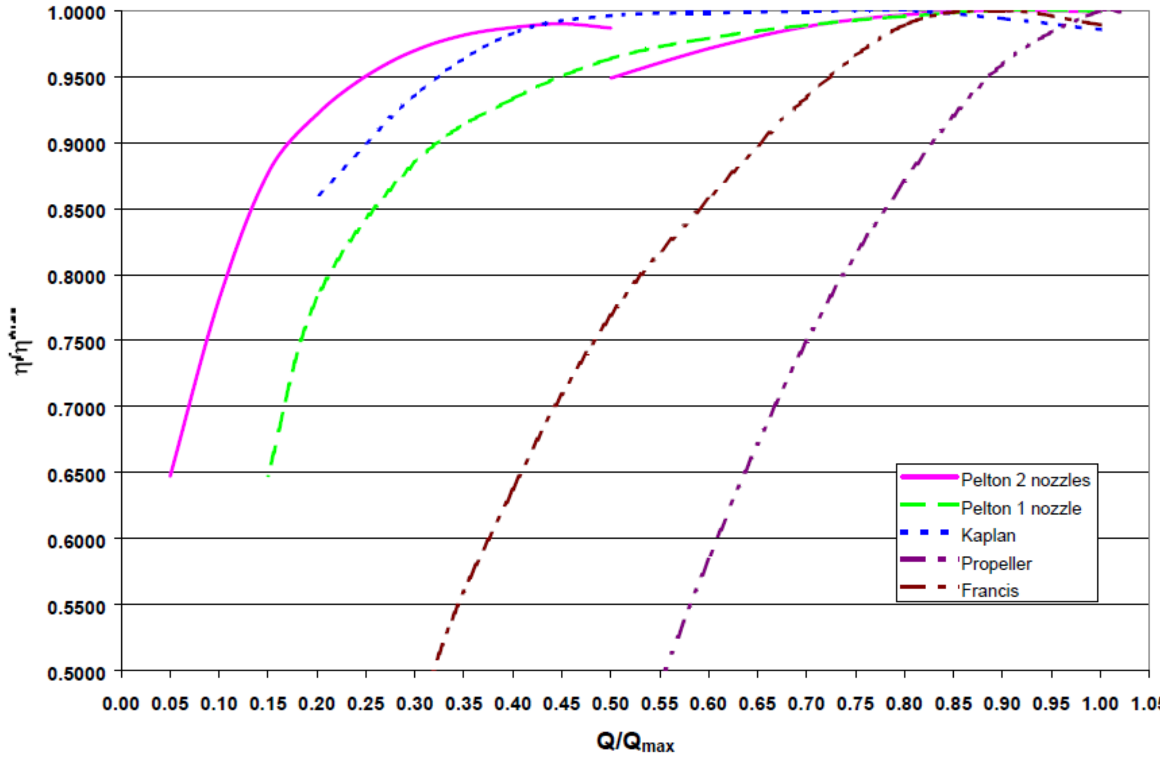

Figure 10: Typical small hydro-power turbines efficiencies

Kaplan turbines are more fish-friendly than Francis turbines, due to their construction characteristics. The mortality rate is influenced by the elevation of the runner above the tail water and the efficiency rate of the turbine.

Turbines of overflow and underflow type

The electrical supply company Mittelbaden Wasserkraft GmbH & Co.KG (EWM WKA) operates two hydro power plants at the river Kinzig in Gegenbach and Offenbrug. The Kinzig is one of the most important rivers for the re-introduction of the salmon on the Upper-Rhine region. Therefore the passability for fish was an important condition for construction. The realized innovative movable hydro power plant of overflow and underflow type was for the first time in this scale integrated into the existing weirs on each location without additional water diversion. Rather the diverted water in the canals is reduced and more water remains in the river, leading to an ecological improvement.

In Offenburg up to 7 m³/s are diverted into the canal due to a water rights permit and cannot be used in the new plant. It can be assumed that with the implementation of the new WFD, the minimum residual flow in the Kinzig will be increased (the water rights permit will be curtailed) and therefore a higher water use at the weir will be achieved.

The over- and underflow of the power plant in combination with additional fish ladders improve the passability for fish. In high water situations, the power plant can be rotated, which clears an opening below the turbine housing and is used for the control of the backwater level. The deposited sediments can also be removed in the same way.

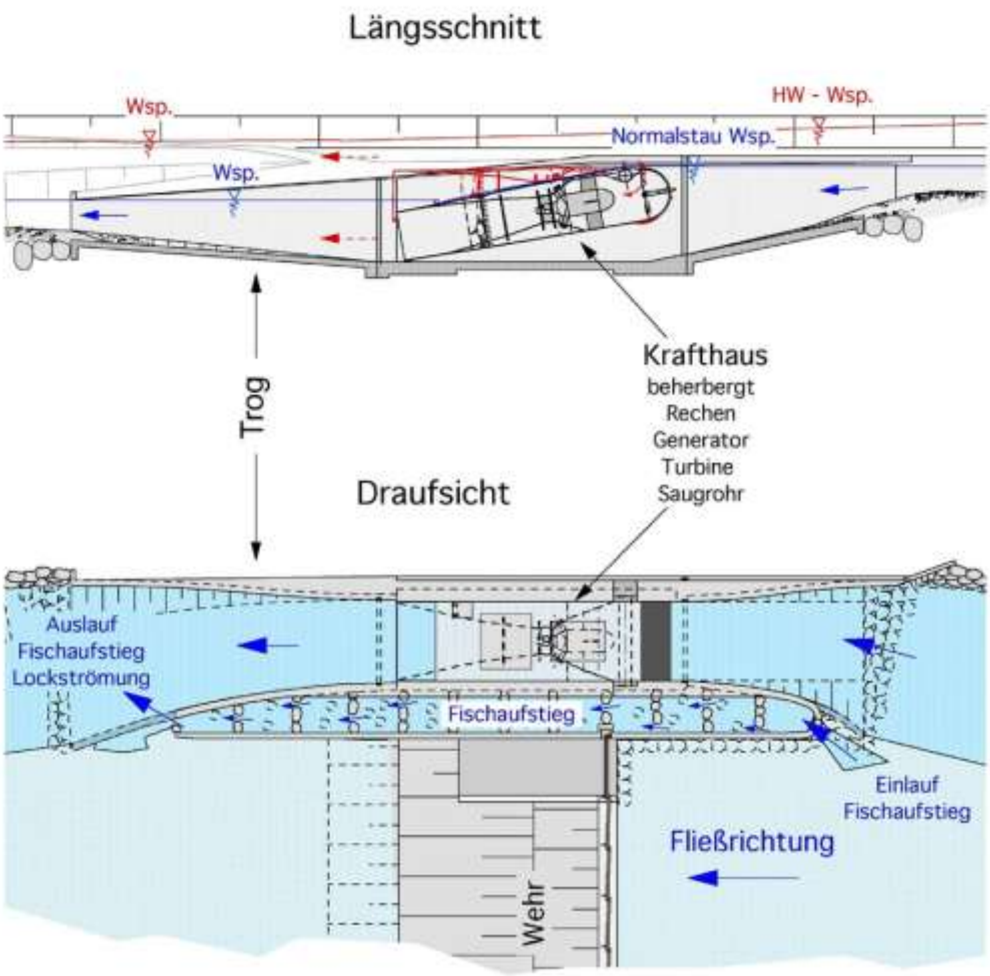

Figure 11: Schema of movable power plant of overflow and underflow type (source: http://www.moveable-hepp.com/)

Figure 12: Power plant Gengenbach (source: http://www.moveable-hepp.com/)

Literature summaries

In this summary some recommended examples, selected from the current literature are listed, which are useable for further research and background information on this topic. It offers readers the chance to gain more in-depth knowledge on this particular issue.

K. Angermann, G. Egger, H. A. Steiner (2005): DSS RiverSmart: Optimierte Lösungen im Spannungsfeld von Wasserkraft und Ökologie Fallstudie Ausleitungsstrecke KW Rosegg/ St. Jakob, Drau, PRAXISTHEMA, Heft 9–10 Sep/Okt 2005

At the HPP Rosegg there are problems at the residual water stream due to excessive sedimentation and insufficient minimum instream flow.

H. Cardwell, H. Jager, M. Sale (1996): Designing Instream Flows to Satisfy Fish and Human Water Needs, Journal of Water Resources Planning and management, Sep/Oct 1996

The multiple uses of river basins and the conflicting requirements of hydropower production, flood control and maintenance of ecosystem integrity make high demands on the reservoir operation plans. Minimum flow regulations have become a very important issue. The primary conflict is between releases to maintain ecosystem integrity downstream, versus the stored water for hydropower production.

The paper presents a multiobjective model to determine instream flow considering both water supply and minimal flow necessary to ensure a specie-rich fish population. By the habitat capacity measure the demands of the fish population in different life stages can be taken into account. The model also allows a minimum flow based on the hydrologic year types and the consideration of legal restrictions.

J. Giesecke, E. Mosonyi (1998): Mindestwasserregelungen, Wasserkraftanlagen. Planung, Bau und Betrieb, Seite 751-780, Springer

The water withdrawal at hydro power plants leads to a lower discharge in the actual river bed. By providing a minimum instream flow the preservation of the ecosystem integrity should be ensured. The conflicting demands of hydropower and water body as natural habitat affect the determination of the required residual discharge. Considering the natural run-off (depending on seasons and flood events) a dynamic residual discharge or a modus for sediment management to prevent deposition of fine sediments are favorable. Further the demands of the occurring fish species in different life stages and the continuity of the water body should be taken into account.
The methods for assessing the minimum instream flow are based on hydrographic-statistical or hydraulic data, simple models or the habitat.

Parameters:
Simple formulas considering hydrographic-statistical data for certain types of waterbodies, catchment areas or even countries provide a constant value instead of an ecological substantiable dynamic discharge. Common parameters are:

- mean water discharge and low flow discharge (MQ, MNQ, NM_xQ_n)
- specific discharge of catchment area
- limit discharges (95%-Percentile,…)
- minimum water depth
- mean flow velocity

The disadvantage of these formulas is that they don't consider the interaction of discharge and river bed morphology and its impact on the habitat. Therefor more complex models with morphological and ecohydraulic parameters are needed.

Habitat models

- PHABSIM in North America
- CASIMIR (University of Stuttgart, Germany)

The models analyze abiotic (flow regime, hydraulic factors,…) and biotic (resident spacies, flora,…) factors and relate them to the habitat quality.
The advantages of these models are:

- The ecological status of the water body is related to the living conditions of the resident species
- The influence of changes in flow and structure on fishes, invertertebrate and macrophytos can be evaluated
- Flow alterations affect water depth, flow velocities and substrate composition, which are the key factors of habitat methods
- By referring habitat to discharge a quantitative basis for comparing the ecological conditions to the requirements of other usages is created

R. Haselsteiner, B. Ersoy (2011): Die Auslegung und Wirtschaftlichkeit von Restwasserkraftanlagen bei Großprojekten in der Türkei, , 34. Dresdner Wasserbaukolloquium 2011

The legal foundation provides for a minimum instream flow as percentage of the mean annual discharge, because of ecological reasons. The design of power plants using the minimum instream flow is governed by local boundary conditions. In Turkey (unlike in Germany) they are realized together with the overall approach to save money and time and increase economic efficiency. Generally two PP-types can be distinguished:

- two completely separated systems
- a combination power plant (Kombinationskraftwerk) with generally two machine sets, one for the use of the minimum instream flow and one for the main use

Examples in Turkey:

- Söylemez: annual storage reservoir with residual flow reach and separate power plant
- Pervari: monthly storage reservoir without residual flow reach and combination power plant for generation of peak load power
- Arkun: monthly storage reservoir with power plant using the minimum instream flow and combined bottom outlet

I. G. Jowett (1997): Instream Flow Methods: A Comparison of Approaches, REGULATED RIVERS: RESEARCH & MANAGEMENT, VOL. 13, 115–127, New Zealand

The determination of the required minimum instream flow depends on different factors. It can be determined according to historical data, the hydraulic geometry or the habitat. The habitat method accounts for the requirements of the ecosystem and shows that smaller rivers are much more sensible to discharge variations.

G. Meissl (2005): Die Wasserkraftschnecke als Restwassermaschine – Ein Lösungsmodell, PRAXISTHEMA, Heft 9–10 Sep/Okt 2005

Hydrodynamic screws are based on the principle of the Archimedean screw.
They can be operated with variable speed and constant upstream water level or self-regulated with constant speed. They are very fish-friendly and have a low impact on the downstream fish migration and no narrow rakes are needed.

H. Schrofelbauer Ove (2004): Kraftwerke und die WRRL sowie andere Erschwernisse für die Wasserkraft, e&i Heft 10 Okt 2004 / 121. Jahrgang

The use of the resource water is limited by many national and European legal restrictions. The most important one may be the European Water Framework Directive (Europäische Wasserrahmenrichtlinie- WRRL), which came into force 2000. It focuses on the good ecological status of the water bodies and has a major impact on planning, construction and operation of hydropower plants:

- Ecological run-off regime (continuity of rivers, fish passes)
- Quantity and dynamics of discharge (minimum residual water, hydro-peaking)
- preventing the deterioration of the status of the surface water bodies

H. Stigler, C. Huber, C. Wulz, C. Todem (2005): Energiewirtschaftliche und ökonomische Bewertung potenzieller Auswirkungen der Umsetzung der EU-Wasserrahmenrichtlinie auf die Wasserkraft, Institut für Elektrizitätswirtschaft und Energieinnovation der Technischen Universität Graz

The new European Water Framework Directive commits all member states to reestablish the "good ecological" status of all water bodies. There has to be a reason for the application of the exemption clause (extension, lower quality).
The determination of the current situation (minimum instream flow, hydropeaking and continuity of the water body) is carried out separately for small hydro power plants (<10 MW), river power stations and storage power:

- Small hydro power plants: generation loss 10-32%; for the majority of the SPP no minimum instream flow is determined due to their age
- PP > 10 MW: restrictions for up- and downsurge are determined individually
- Diversion plants: generation loss 5-20%

C. Zaugg, H. Leutwiler (1996): Kleinwasserkraftwerke und Gewässerökologie

Natural water bodies form a unity with the surrounding riparian forest and riverbanks and provide a wide range of different living conditions for a species-rich flora and fauna. Due to river training structures the flow dynamics and sediment transport, as well as the continuity was negatively affected. The fish passability has to be provided in both directions. The mortality rate of fishes in turbines varies according to type, elevation and fish size (Travade and Larinier, 1990)

- Pelton turbines → 100%
- Francis turbines → 37%
- Kaplan turbines → 9%

At diversion plants a specified withdrawal of water is used for power production, this leads to a lower water amount in the river, which causes a lower flow velocity, deposition of suspended particles and sediments and lower water depth. To ensure a good ecological status the determination of the minimum residual discharge is very important:

- A certain discharge dynamic should be provided
- Limitation of the design discharge
- Continuity of the water body
- Short residual water reach

PROJEKTBERICHT: Optimierung von Maßnahmen an Wasserkraftanlagen Entwicklung eines Konzepts zur Kosten-Wirksamkeits-Analyse ökologischer Maßnahmen an kraftwerksbeeinflussten Fließgewässerstrecken, EFG Nr. 10.29, 2004

The DSS RiverSmart was developed to evaluate measures at watercourses and implemented at the rivers Drau and Traisen to carry out an ecological evaluation according to the WFD:

For the river Drau 4 different scenarios were evaluated and compared with a cost-effectiveness study (1- 1998, 2- implementation of the Rosegg study, 3- implementation of the Rosegg-study and increase of discharge, 4- abandonment of the power plants) and 3 for the river Traisen (1- current state, 2- implementation of the GBK and increased discharge, 3- alternative barrages) to propose required measures for the improvement of the ecological status.

Land Steiermark (2010): 23. Umweltschutzbericht, Umweltschutz in der Steiermark

Condition of the Styrian Waterbodies: National Water Management Plan [Nationaler Gewässerbewirschaftungsplan (NGP)]

The Water Frame Directive (WFD) proposes an integrated approach which includes the protection, the improvement and sustainable use of water bodies. This directive was implemented in Austrian law with the legal amendment of Austrian Water Act in 2003. The question of minimum in-stream flow in connection with fish migration barriers was one of the focal points

According to the objectives of the Water Frame Directive (WFD) all water bodies, except the “heavily modified ones”, should reach the good chemical status as well as good ecological status, the heavily modified ones should reach a good ecological potential. Depending on the different conditions of the water bodies in Austria, the National Water Management Plan 2009 (NGP) provides a gradual achievement of these goals. In the first phase the fish passability and the rehabilitation of residual water reaches for water bodies with a catchment area > 500 km² should be reached until 2015. Further measures will be defined until the end of 2011. All ground water bodies satisfy the demands of the good chemical status and no actions are needed.

Measurements of the residual water quantities at small hydro power plants:
In 2010 the Federal Land of Styria FA17C, 17B and the Hydrographic Service FA19A carried out residual water measurements at small hydropower plants in the region Ennstal, Murtal and Mürz. 15 plants were analyzed based on assessed minimum flow. For the determination of the required residual amount of water, it is not sufficient to provide a minimum flow, but also a variable discharge for the structural diversity in the residual water reach. The requirements are determined in the “Qualitätszielverordnung Ökologie Oberflächengewässer- OVZ Ökologie OG §13 (2). Generally the natural minimum basis discharge (NQ_T) must not be exceeded. Additionally the fish passability must be granted by a minimum residual flow. The study showed that 20% of the examined power plants don’t fulfil these criteria.

Land Salzburg (2005): Planungsbehelf Wasserkraftanlagen- Rahmenbedingungen für Wasserkraftanlagen aus Sicht des Gewässerschutzes

According to WRG 1959 all measures must prevent the deterioration of the status of the surface water bodies. A water withdrawal of more than 20% leads to a change of the hydromorphological quality components and a deterioration of the ecological status. To maintain the good ecological status of the surface water body and further public interests following framework requirements have to be abided (WRG 1959):

- No interference of public security
- Maintenance of public access for leisure activities and navigation
- Compliance with hydromorphological criteria for the status analysis according to §55 d, WRG 1959, BMLFUW
- Maintenance of the physical-chemical and hydromorphological characteristics of the water body

- Maintenance of the typical fish ecology (according to the fish regions by JÄGER et al, 2004)

Table 8: Impact on residual water reaches

No impact	Withdrawal < 10% MQ_{nat}
	Withdrawal < 20% MQ_{nat}
Remote impact	MQ_{Rest} > $MJNQ_{Tnat}$ oder MQ_{Rest} > MJNQ, if NQ_T is not available
Residual water assessment	Residual water> NQ_T or residual water > NNQ, if NNQ is not caused by a singular event
Significant impact	No Residual water assessment
	No year-round Residual water assessment
	MQ_{Rest} < $MJNQ_{Tnat}$ and residual water < NNQ
	Discharge in diverted reach
	low flow velocity

The efficiency of the fish pass and the residual water reach hast to be proved.

Restwasserkraftwerk und Fischaufstiegshilfe in Greinsfurth, http://www.lebensministerium.at/wasser/wasser-oesterreich/foerderungen/gewaesseroekologie/ aktuelle_projekte/RWKW.html, 17.01.2012

The installation of a residual water turbine and a fish pass and restoration works at the downside of the weir are illustrated by the example of a power plant at the river Ybbs.

Mindestabflüsse in Ausleitungsstrecken: Grundlagen, Ermittlung und Beispiele, Gewässerökologie 97, Landesanstalt für Umweltschutz Baden-Württemberg (LfU), 2005

The determination of the minimum instream flow is a multi-step selection process. From hydrological data an orientation value is determined which is adapted to the local conditions according to the present guideline based on the requirements of the occurring fish species. The fish fauna is a suitable bioindicator, because it has very specific requirements at the habitat “river” and requires the largest space of the occurring biocoenosis. The procedure is explained with 10 examples.

Archimedes Hydro Screw
http://www.archimedeshydroscrew.com/hydro-dynamic-screw-turbine/

Advantages of Hydro dynamic screws over turbines and waterwheels are:

- Hydro screw has high efficiency in a wide range of flows leading to a stable and consistent yearly output
- Efficiencies up to 90%
- The screw continues to harness power from the water even during low summer river levels, down to 20% of the design flow
- Screw turbines are simple and reliable
- Hydro dynamic screw turbines are fish friendly
- Hydro screws don’t need costly fine screening
- Hydro dynamic turbine can be installed in places with very low head: 1m up to 12m
- Hydro dynamic turbines have low installation costs

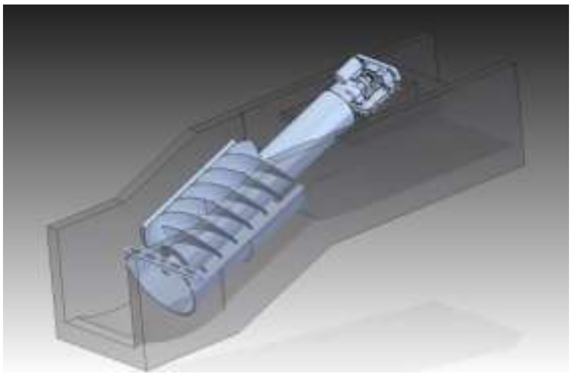

Figure 13: hydrodynamic screw (http://www.archimedeshydroscrew.com)

Ritz-Atro: Wasserkraftschnecken – Fischereibiologisches Gutachten
http://www.ritz-atro.de/2006/index.html

Hydraulic screws are very fish-friendly. Small (length> 8cm) and big (length ≤ 58 cm) fishes are able to pass through the screws without injuries.

Best practice examples for MIF use

In this chapter, the project partners describe best practice examples for hydro power plants that do already use MIF for hydro power production.

Best practice examples Italy

Best practice example power plant Mis

A new MIF HP plant project has recently been approved in Veneto. It exploits the MIF release from the Mis' dam, which has been built across the homonymous torrent. The available discharge is 0.811 m^3/s, the hydraulic head is 44.73 m and the mean power of the power plant will be 355.65 kW.

Figure 14: Present Mis' dam situation. The light blue arrow indicates the present MIF release

Figure 15: Design configuration. The light blue arrow indicates the present MIF release

Table 9: Technical key data PP Mis

Design flow	0.811 m^3/s
Head	44.73 m
Power	355.65 kW

Best practice example power plant Fener

The works for the construction of the Fener power plant began in February 2009, and were completely financed by the Piave Land Reclamation Consortium. The Fener abstraction structure withdraws from the River Piave a maximum discharge of 35.8 m^3/s and a minimum of 16.2 m^3/s for irrigation purposes, and 14 m^3/s for hydropower production by ENEL. The abstraction work is located on the right bank immediately upstream the barrage, which allows the water abstraction from a still water basin. In the same basin the restitution of the ENEL power plant of Quero flows and the Brentella irrigation channel starts.

The idea of a MIF power plant originated in 2001, when the River Basin Authority defined the MIF value at the Fener barrage. The MIF discharge value is not constant and changes during the year. It was released to the Piave by means of a moving barrage. Now it is used by the new power plant, which has been built over the barrage. The plant characteristics are shown in Table 10.

Table 10: Technical key data PP Fener

Design flow	17,800 l/s
Head	4.50 m
Power	785,29 kW
Minimum discharge allowed	6 m^3/s
Maximum discharge allowed	34 m^3/s
Machines	n. 2 by 17 m^3/s (Kaplan)
Mean annual production	5500000 kWh

Figure 16: Design location of the new power plant

Figure 17: Design location of the new power plant

Figure 18: The beginning of the construction works

Figure 19: The two Kaplan machines

Figure 20: The power plant completed (upstream point of view)

Best practice example power plant Busche

This power plant has been built in 2005 in the municipality of Cesiomaggiore (BL), in correspondence of the Busche barrage.

Table 11: Technical key data PP Busche

Design flow	10 m^3/s
Head	8.7 m
Power	856 kW
Mean Annual Power	5.6 GWh
Machine	1 Kaplan (horizontal axis)

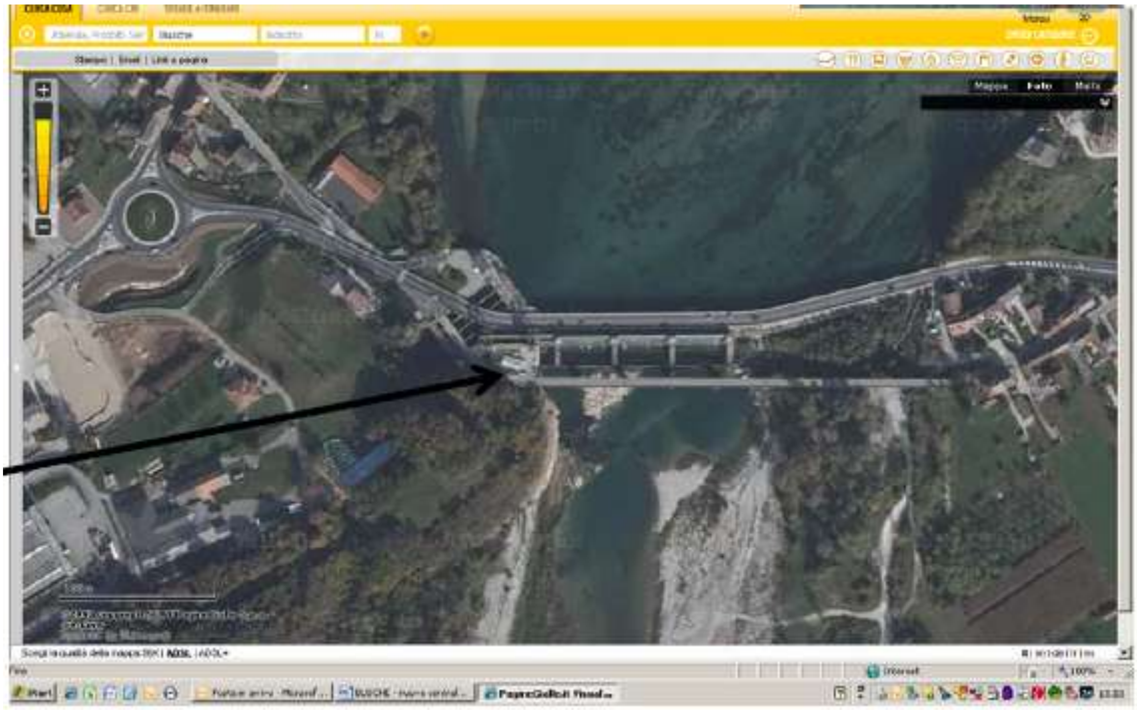

Figure 21: Busche power plant location

Figure 22: MIF release before the power plant construction

Figure 23: MIF release after the power plant construction

Figure 24: Busche power plant machine (horizontal axis Kaplan)

Best practice examples Slovenia

Best practice example power plant Melje

In the area of Drava River water course 8 hydropower plants and 1 small hydropower (Melje SHPP) plant are situated. Figure 25: Hydro power plants on Drava River (http://www.dem.si/) shows the location of hydropower plants.

Figure 25: Hydro power plants on Drava River (http://www.dem.si/)

The Melje Small HPP was constructed in the year 2003 on the Melje dam and has a unit with a net capacity of 0.68 MW. Figure 26 shows the Melje Dam, with the main purpose of providing water derivation to the Zlatoličje HPP.

Figure 26: Melje Dam with assigned location of Melje SHPP

It exploits the prescribed winter flow of the Drava riverbed, whose discharge value is 10 m^3/s. The remaining portion of the flow, which in the summer reaches 20 m^3/s, flows back into the river via the floor channel of the derivation channel. Table 12 shows the main SHPP characteristics.

Table 12: Technical key data Melje

ANNUAL GENERATION (MILLION KWH)	NET CAPACITY (MW)	NO. OF UNITS	RATED CAPACITY OF GENERATORS (MVA)	INSTALLED FLOW (M3/S)
5.1	0.680	1	1.18	10

Figure 27 and Figure 28 show the design cross-sections of Melje SHPP penstock, the turbo-generator and water release and cross-sections of the spillways of the Melje dam.

It is planned to increase the power of Melje SHPP, in that phase also a fish pass should be considered and planned. Data on economic issues of the HPP were not available.

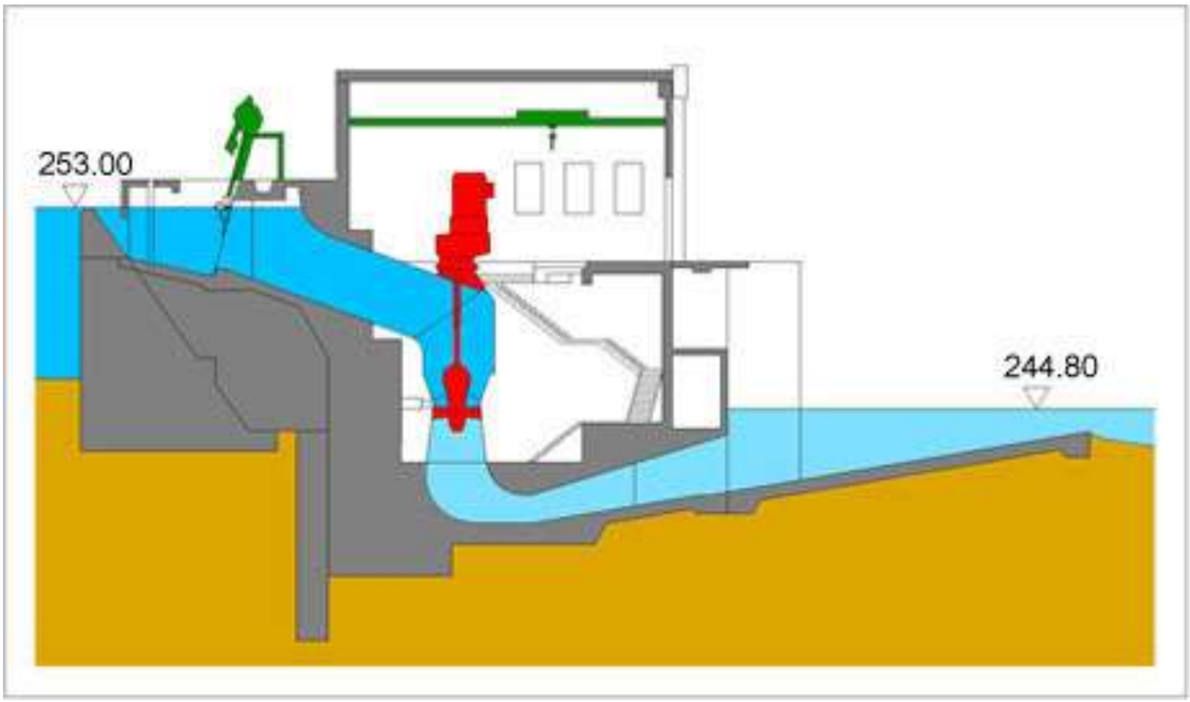

Figure 27: Cross-section of a turbine pier

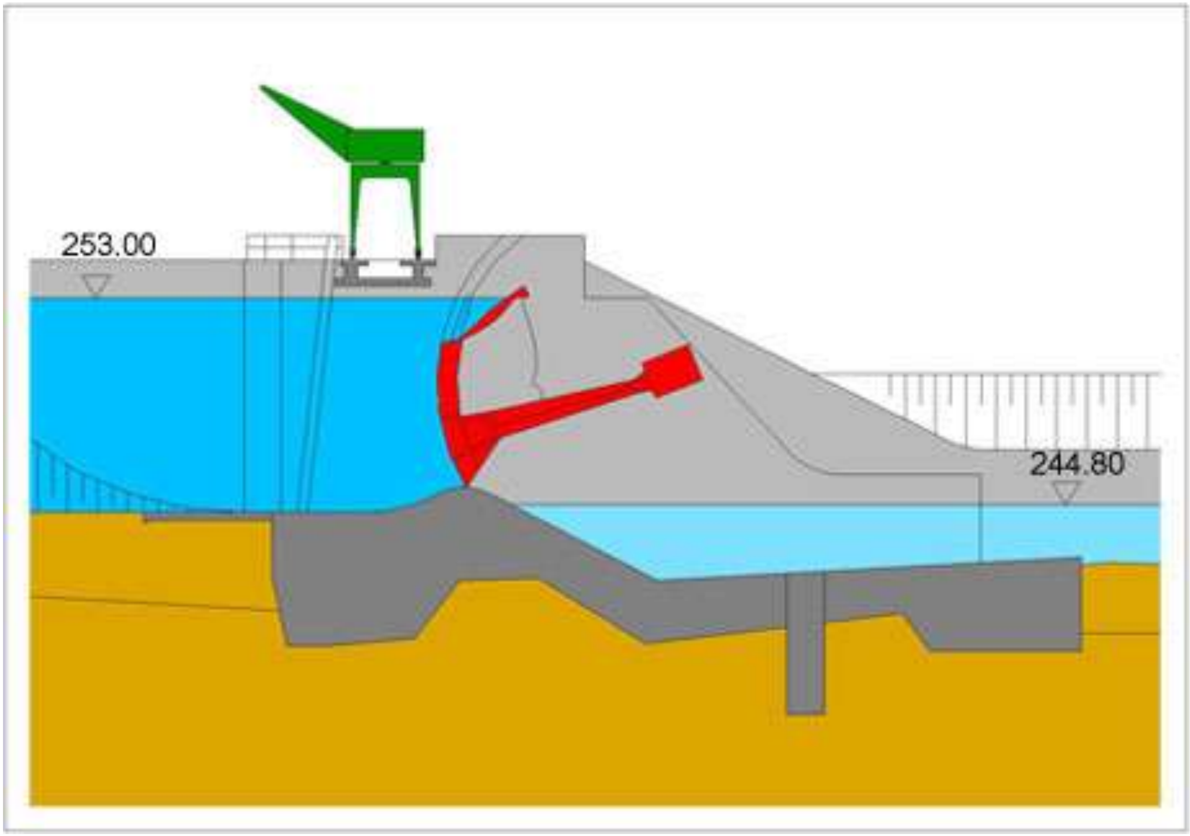

Figure 28: Melje Dam: cross-section of a spillway

Best practice examples Austria

Regarding the situation in Austria, PP6 picked two examples for MIF use located at the power plants in Kindberg and Niklasdorf. Both are situated in Upper Styria, in the northwestern half of the federal state of Styria.

Other examples for MIF use in Austria are located in Lunz, situated in the federal state of Lower Austria, as well as in in Salzburg and Amstetten, where recently (2010) the construction of a MIF plant at the weir in Greinsfurth with a power of 479 kW was completed.

In the cases of Niklasdorf and Kindberg, a hydrodynamic screw is used for MIF use. The hydrodynamic screw turns the principle of the Archimedean screw around. Instead of making water flow upstream, the hydrodynamic screw uses the power of falling water to produce energy.

Figure 29: Hydrodynamic screw in Kindberg, with a diameter of 3.6 meters currently the world's largest hydrodynamic screw (*Kindberger Gemeindenachrichten, June 2008*)

Best practice example power plant Kindberg

The Kindberg power plant site stands for a long tradition of electricity generation, the diversion hydropower plant was already commissioned in 1905. Half a century later, the facility was rebuilt and at the same time the weir system was renewed. Two Francis turbines were installed with a design flow of 12m³/s. However, the river Mürz was frequently carrying higher amounts of water, which in those cases ended up not being used. Consequently it was decided to use this water and install a hydrodynamic screw.

Figure 30: View from above of the MIF plant at Kindberg (*Schalungsbau Hager Ges.m.b.H.*)

It is currently the world's largest hydrodynamic screw with a diameter of 3.6 meters at a length of 19 meters and a weight of 24 tons. Supplementary, a fish ladder in the form of a vertical-slot-pass was installed for the upstream fish passage.

Table 13: Technical key data PP Kindberg, Austria

Design flow	5 m^3/s
Head	3.7m
Power	max. 142 kW
Nominal rotation speed	21 rpm
Generator capacity	160 kW

The installation of the generator, the transmission and the electrical equipment was carried out by the Austrian company BEA Electrics Energietechnik GmbH, initial startup of the plant was on June 11, 2008. Operator of the power plant is the electricity company of the municipality Kindberg, a regional energy provider for the middle Mürz valley.

Figure 31: Detailed view of hydrodynamic screw (*Schalungsbau Hager Ges.m.b.H.*)

A big advantage of the new hydrodynamic screw is the possibility of running it as operating reserve. During maintenance work the plant does not need to shut down operations, but processes the water with the hydrodynamic screw. In particular, because the net head at the weir is comparable to that of the main power plant.

Also positive environmental aspects can be associated with the commissioning of the new hydrodynamic screw, because its operation spares the municipal area of Kindberg 176 tons of CO_2 per year.

Figure 32: View of the MIF power plant in Kindberg (*BEA Electrics*)

The plant is regulated by variation of the speed of revolution with frequency changer technology as well as by opening the intake gate. Due to its simple controllability, the machine is optimally adapted to the operational requirements.

Aligned with the two main turbines, the MIF plant guarantees an optimum exploitation of hydraulic conditions for the whole power plant. The integration of the control system in the guidance system of the existing power plant was selected to provide remote control from the central control station.

Estimated cost of construction of the plant was ca. € 600,000 and it produces annually about 500,000 kWh of electricity.

Best practice example power plant Niklasdorf

Another example of MIF use in Styria is situated in the small town of Niklasdorf at the Brigl & Bergmeister plant. Brigl & Bergmeister GmbH is a specialized manufacturer of label papers and flexible packaging papers.

The power plant consists of two identical hydrodynamic screws, which use the otherwise idle capacity of the residual flow. The implementation of the project took place between the years 2008 and 2009, power plant *1* was built in autumn 2008, power plant *2* a year later.

One hydrodynamic screw was assembled on the left bank of the river Mur, the second one on the other side.

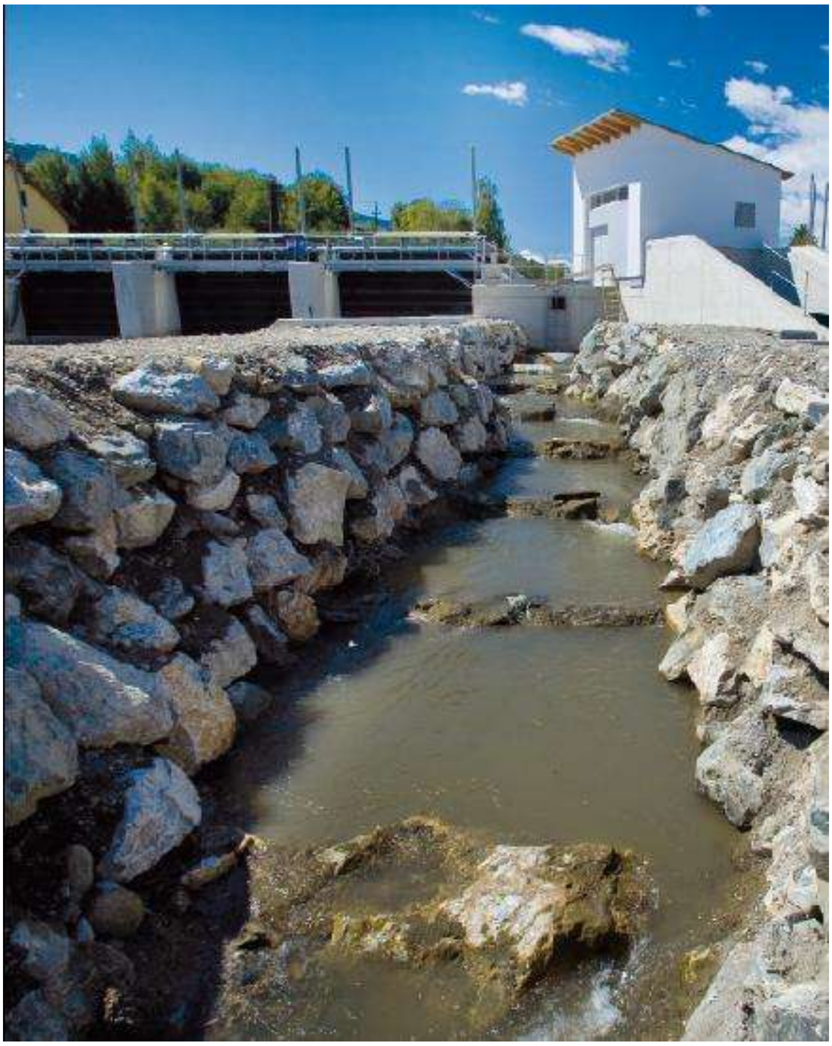

Figure 33: View of the power plant and fish ladder at Niklasdorf (*BEA Electrics*)

Together with the amount of water for the fish ladder, there is a residual flow of 8 m^3/s available at the weir. This means that a flow of 7.7 m^3/s is obtained for usage at the hydrodynamic screws, which is led over a head of 3.95 meters.

Figure 34: One of the hydrodynamic screws at Niklasdorf power plant (*BEA Electrics*)

The hydrodynamic screws are quite large with a diameter of 3.20 meters and a 17 meters long central pipe, of which about 12 meters are equipped with blades.

Table 14: Technical key data PP Niklasdorf

Design flow	7.7 m^3/s
Head	3.95m
Power	max. 2 x 125 kW
Nominal rotation speed	22 rpm
Generator capacity	2 x 132 kW

An essential point for the construction of this power plant was noise protection, because the plant is located not far from a residential area. One of the two power plants was shut down after an official noise measurement and had to be optimized. The primary insulating material was making the acoustic problems worse and was then replaced by mineral wool, like the enclosure of the second screw.

Figure 35: View of the power plant at Niklasdorf (*zek - Zukunftsenergie und Kommunaltechnik June 2008*)

Best practice examples Germany

Best practice example power plant Rappenberghalde

The MIF turbine of a HPP Rappenberghalde is a rare example of minimum flow utilization in Gemany and in particular in HP production leading States Bavaria and Baden-Württemberg. The question about installation of a MIF turbine has arisen as the diversion weir of a HP station had to be renewed. HPP Rappenberghalde was built in 1929, the originally granted minimum flow discharge before the weir renovation comprised 0.8 m³/s (0.14 MNQ) (Winkler, 2000).

HPP characteristics

HPP Rappenberghalde situates on Neckar by Tübingen in the State Baden-Württemberg at a river kilometer 251.73. It was built in 1929 and completely renovated and modernized in the years 1999. Its owner is the Stadtwerke Tübingen GmbH (SWT). The current technical state of HP is referred as very good (Renz, 2011).

The catchment area of Neckar at the diversion weir Hirschau comprises about 1900 km². The main hydrological discharges estimated linearly from both adjacent gauges Horb and Kirschentellinsfurt are:

- Mean low discharge (MNQ) = 5.6 m³/s
- Mean discharge (MQ) = 21 m³/s
- 100-year flood = 620 m³/s

HP Rappenberghalde consists of the main hydropower station with two Kaplan turbines and the MIF hydropower station. For the needs of the main HP station the Neckar is diverted on the total length of 1.7 km, the tailrace of a HPP channel comprises about 200 m. The diversion weir with a total width of 36 m and water surface difference of 4 m consists of two flap gates. On the right from a weir looking downstream the MIF power house (Q_T = 1.35 m³/s) and the fish step-pool bypass accounting for 0.3 to 0.5 m³/s depending on the season are situated, see Figure 36.

Table 15: Technical key data HPP Rappenberghalde

TECHNICAL DATA HPP RAPPENBERGHALDE	
Head	7.5 m
Turbine type	2 x Kaplan
Design discharge	22 m³/s
Installed power	1,500 kW
TECHNICAL DATA MIF TURBINE	
Head	4 m
Design discharge	1.35 m³/s
Installed power (mean power)	40 kW

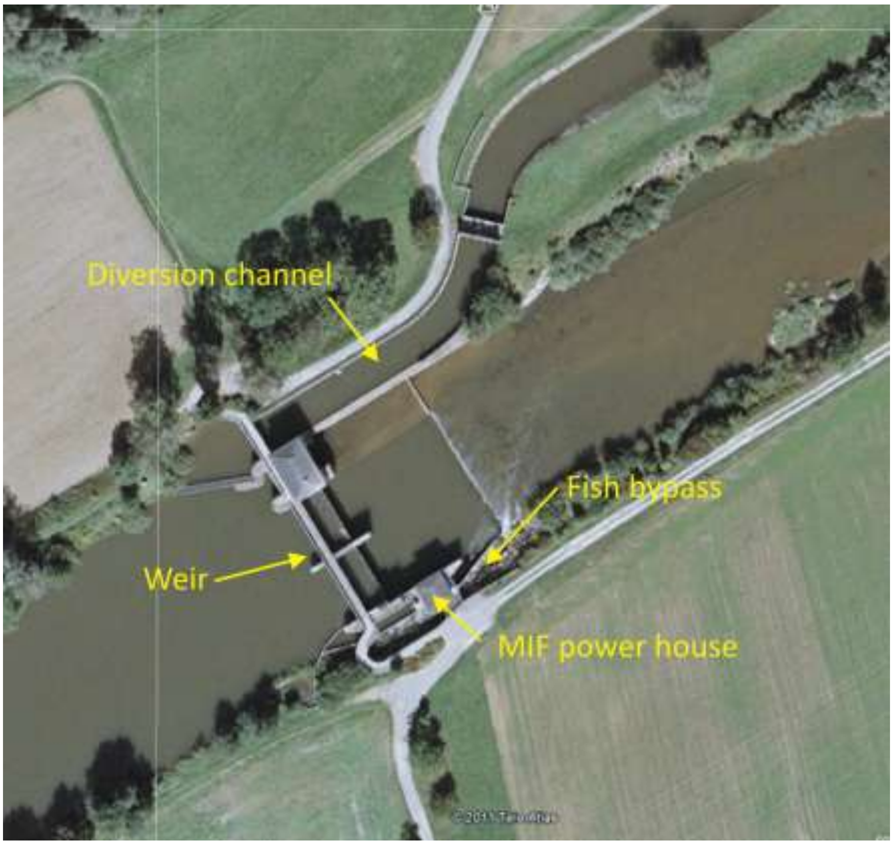

Figure 36: Diversion weir, fish bypass and MIF power house of HPP Rappenberghalde

Figure 37: Location of HPP Rappenberghalde

Figure 38: Main power house of HPP Rappenberghalde, view from tailrace channel (photo [Renz, 2011])

Figure 39: Trash rack clearing facility of main power house (photo [Renz, 2011])

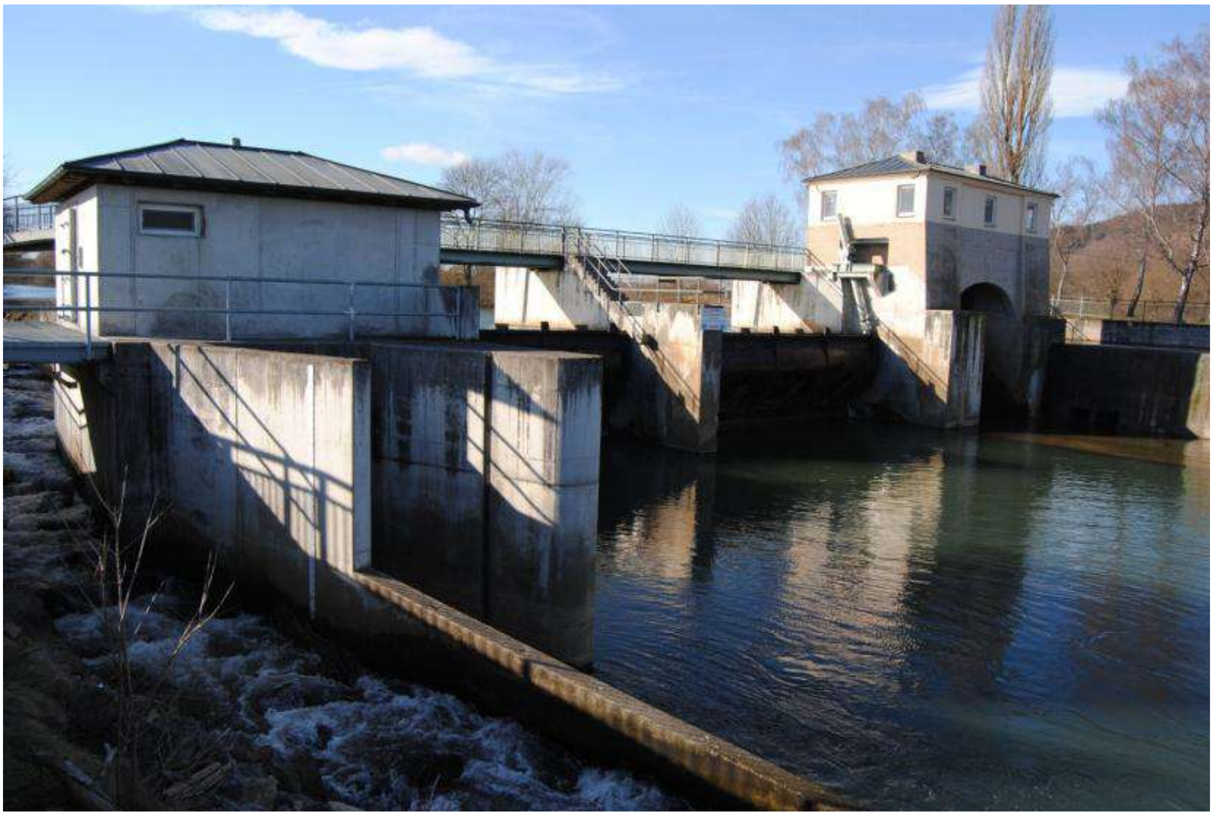

Figure 40: Diversion weir, MIF power house and fish bypass, view from downstream (photo [Renz, 2011])

Figure 41: New rock ramp instead of concrete weir in diversion reach (photo [Renz, 2011])

Ecological effects

The installation of a MIF turbine by HPP Rappenberghalde in 1999 can be considered ecologically positive for the following reasons:

- Due to the necessity of a renovation the new concept of diversion weir complex came into consideration. An important role here plaid local sport fishery and nature protection organizations insisting on the increasing of the minimum flow discharge and construction of a fish bypass.
- Installation of a MIF turbine resulted in increase of minimum flow discharge from 0.8 m³/s (0.14xMNQ) to 1.85 m³/s (0.33xMNQ). Within the framework of renovation works the fish bypass was constructed.
- The conversion of the two old concrete weirs for prevention of deep erosion within the diversion reach into the rock ramps in years 1999 and 2006 contributes positively to a passability of Neckar for upstream and downstream migrating fish species.
- The possibility to visit the HPP and its facilities is offered to public what helps to improve the public opinion about hydro power production.

Unfortunately, the catalog of positive ecological measures could be more reach as it is in the present situation. Some damages to eel population (which migrates downstream for spawning) were reported for the HPP Rappenberghalde as its rack cleaning device do not ensure the downstream passage of animals and they die in the garbage collectors.
Also the required minimum flow was estimated only using hydrological approach (proposed value = 0.33xMNQ), not taking any other ecological aspects into consideration. The minimum flow discharge for the HPP Rappenberhalde as it operates now is set according to the guidelines of the Wasserkrafterlass of Baden-Württemberg (Umweltministerium Baden-Württemberg, 2006) which regulates the minimum flow requirements for HPs with installed capacity of < 1,000 kW. An example of alternative assessment of HPP Rappenberghalde minimum flow requirements is well documented in LfU (2005). Depending on the assessment method, the required flow is ranging from 1.75 to 11 m³/s. The habitat modeling based assessment with simulation model CASiMiR which accounts for the requirements of indicator species grayling results in a flow of 2.3 m³/s (0.41 MNQ) which is well above the obliged value of 1.85 m³/s.

Economic aspects

The MIF turbine of the HPP Rappenberghalde came to operation in October 1999 and produced about 66,000 kWh till the end of January 2000 with mean power of 40 kW. The mean annual energy produced of a whole HPP complex including mean and MIF turbines comprises about 7 Mio kWh per year.

Best practice example power plant Iffezheim on Rhine

Strictly speaking this particular German example does not belong to a “MIF use” category. However it is a very singular case of innovative energy production using the flow intended for ecological compensation measures.
HPP Iffezheim is a run-of-river hydropower station situating on Rhine kilometer 334. Together with Gambsheim the construction of a barrage Iffezheim is based on the treaty of 1969 and is a German-French cooperation effort. The construction of a barrage Iffezheim lasted 4 years and it was commissioned in 1978.

Figure 42: Iffezheim barrage on Rhine, view of a double ship lock, a power house and a new fish pass. Photo (EnBW, 2009)

The Iffezheim power station which is managed and technically supervised by the Rudolf Fettweis station at Forbach is located on the right side of the Rhine in line with the weir, barrage and lock (see Figure 42). Now the station operates with four horizontally installed Kaplan turbines with the diameter of 5.80 m. The power station operates fully automatically and is monitored by the EDF control center in Kembs, as are the other nine power stations of the Upper Rhine group. The weir consists of six 20 m wide weir fields; it is designed for a maximum flood discharge of 7,500 m³/s. While the power station is owned and operated by RKI GmbH, the weir is property of the German and French governments. In summer of 2009, the expansion of the Iffezheim HPP has begun. With the fifth turbine and a total installed power of 148 MW Iffezheim will be one of the largest run-of-river power stations in Europe. The main technical data of HPP Iffezheim are given in Table 16.

Originally the barrage Iffezheim was supplied with a fish ladder and an eel collector which, unfortunately, did not function effectively. In the year of 1987, the International Commission for the Protection of the Rhine drafted an action plan to restore the Rhine's ecosystem. A visible sign of success of these measures is the return of salmon. Parallel to the action plan, the construction of new fish passes at Iffezheim and Gambsheim was decided to allow the fish to migrate upstream since the natural path is blocked by a power house and a weir. The project is financed by the two countries bordering the Rhine and the power station operators. The Iffezheim fish pass, which is one of the largest in Europe, has been in operation since June 2000. Using attraction flow the fish are guided into collector chamber from where they can migrate upstream. The power of the attraction flow is converted into electric energy by a turbine.

Table 16: Technical key data HPP Iffezheim

TECHNICAL DATA HPP IFFEZHEIM			
Average head	11 m		
Facility	**Old HPP**	**Fish pass**	**Extension HPP**
Turbines	4 Kaplan bulb turbines, wheel diameter 5.8 m	1 bevel gear bulb turbine wheel diameter 1.45 m	1 Kaplan bulb turbine, wheel diameter 6.5 m
Maximum discharge (m^3/s)	1,100	13	400
Maximum power output (MW)	108	2	38
Total average annual energy output (million kWh/a)	740	8	122
Fish pass			
Total length (m)	300		
Discharge (m^3/s)	1.2		
Total number of compartments	48		

Ecological effects

The new fish-pass taken into operation in 2000 is a major ecological improvement towards restoration of Rhine ecosystem. Providing longitudinal river continuity for long and medium-distance migratory fish species and especially salmon it helps to re-establish the natural reproduction of Rhine-native species. Now fish can reach their spawning grounds in the upper Rhine tributaries. Not only innovative technical concept of the fish-pass but also thoroughly designed monitoring framework for documenting the number, size and species stock represent valuable contributions to the restoration measures. Extensive long-term observations conducted by the international fish expert team help to gain the best-practice experience for construction of fish-passes. For example, the fish-pass of a barrage Gambsheim will be build integrating the experience obtained during operation of Iffezheim fish-pass.
The functionality of a new fish pass is confirmed by fish observations and integrative evaluation of the number of fish that passed the barrage in the upstream direction (Degel, 2010). In total, 22 fish species were found to be able to pass the barrage, including such rare and almost extinct species like may-fish and salmon. Although some percentage of species, especially those of asp, carp bream and nase experienced injuries after using the fish pass, the overall functionality of fish pass according to fish experts is higher than expected. Considerable improvement of passability for macrozoobenthos species is achieved also.

Below the details of the old and new fish-pass constructions are summarized.

Old fish pass

The old fish pass of Iffezheim of type Borland situated in the weir pier on the French side was designed mainly to insure the passability for local fish species (Figure 43). The practice showed that the fish pass was operational only during about 180 days per year and especially during spawning time it had now water. Additionally the attracting flow was not sufficient for fish to find a way to it. Fish experts believe that the only way the fish could pass a barrage was to go through the ship-lock.

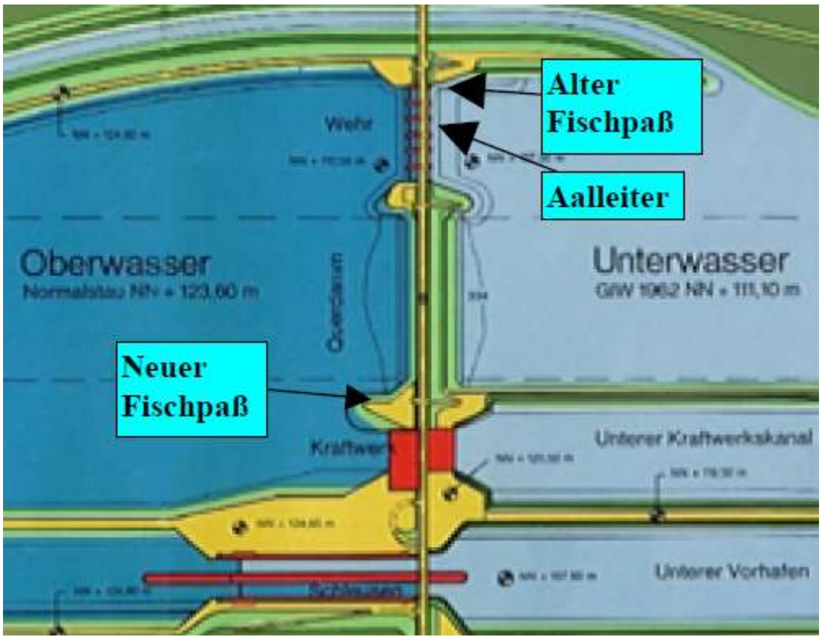

Figure 43: Positions of an old and new fish passes and eel collector

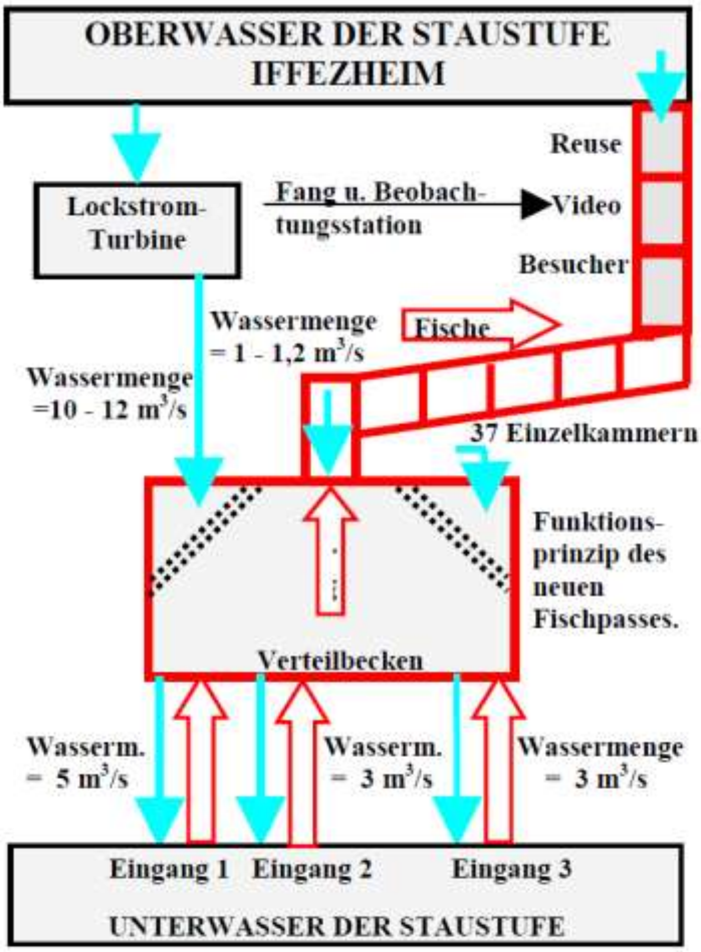

Figure 44: Construction scheme of a new fish pass

The new fish pass

In contrast to old step-wise type fish pass, the new fish pass is of the Vertical-Slot-Pass type. It insures upstream migration of fish without necessity to jump the steps. Also its construction insures that the design flow remains almost independent of the main Rhine discharge. The new fish pass was taken into operation in June of 2000.

The new fish-pass situates between a power house and a Rhine barrage and consists of the following parts (Figure 44):

- Three downstream openings with special conditions for different fish species which can be closed on demand;
- Distribution chamber with two outflow openings from attracting flow turbine;
- Main fish pass of Vertical-Slot-Pass type with 37chambers;
- Attraction flow turbine;
- Catch station (fish trap - German: Reuse), video observation and public access rooms
- Inflow regulation facility

The main fish pass consists of a concrete channel with mean slope of about 4°. The slot width is about 45 cm. Upstream migrating fish can rest in each of the 37 chambers with area of 15 m² (4.5x3.3 m), their mean depth is about 1.5 m. The bottom of every chamber is covered with large stones what is ensures favorable conditions for resting fish as well as for macrozoobenthos species.

In contrast to the old fish pass, the new one situates in the middle of the river near the main turbine outflow openings. It insures higher attraction flow to provide the best opportunity for anadromous fish species to find it.

Economic aspects

Together, the main four turbines of Iffezheim generate approximately 740 million kWh of electricity per year which corresponds to the consumption of about 465,000 individuals. When the fifth turbine will be put in operation in 2012 an additional 122 million kWh of electricity per year will be produced. That means that in total over 540,000 consumers will receive CO_2-friendly electricity from Iffezheim hydro power plant. The investments costs for a new turbine are about 100 million euro.

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