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Kompetenz für die Wasserstraßen

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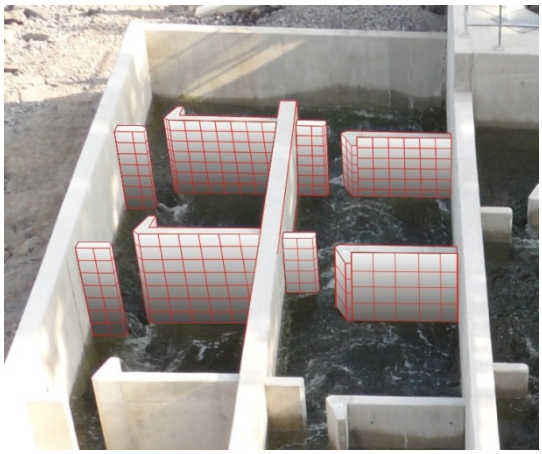
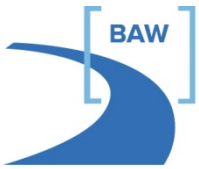


Guideline
Upstream Fishways on German Federal Waterways
(AH FAA)



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List of abbreviations

ADCP	Acoustic Doppler Current Profiler, refer to glossary
ADV	Acoustic Doppler Velocimeter, refer to glossary
AH FAA	Short title for this Guideline (also referred to as „AH FAA Guideline“)
BAW	Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau)
BfG	Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde)
BMVBS	Federal Ministry of Transport, Building and Urban Development (until 16/12/2013)
BMVI	Federal Ministry of Transport and Digital Infrastructure (since 17/12/2013)
BWaStr	German federal waterway(s) (Bundeswasserstraßen)
DWA	German Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V.)
DWA-M 509	DWA Code of Practice no. 509, last updated May 2014, see References
Entwurf-AU	Execution document for the draft/design pursuant to Section 54 of the BHO (Federal Budgetary Regulations)
Entwurf-HU	Budgetary framework for the draft/design pursuant to Section 24 of the BHO (Federal Budgetary Regulations)
HD	European Habitats Directive; Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
GDWS	Federal Waterways and Shipping Agency (Generaldirektion Wasserstraßen und Schifffahrt)
GEP	Good ecological potential (see Glossary)
GES	Good ecological status (see Glossary)
HOAI	German Fee Scales for Architects and Engineers (Honorarordnung für Architekten und Ingenieure)
LP	Performance phase of HOAI (Leistungsphase)
MQ	Mean discharge
PF/PG	Planning approval (Planfeststellung)
PFV/PGV	Planning approval procedure (Planfeststellungsverfahren)
Q_s	Non-exceedence probability
R&D	Research and Development

TdV	Project executing agency (Träger des Vorhabens)
VHB-W	Vergabehandbuch für Bauleistungen - Wasserbau (Manual for the awarding of construction work contracts - waterways engineering) (VV-WSV 2102)
VV-WSV 1401	Verwaltungsvorschrift der WSV „Bundeswasserstraßenrecht“ (Administrative Regulation of the Federal Waterways and Shipping Authority “Law governing Germany’s federal waterways”)
VV-WSV 2101	Verwaltungsvorschrift der WSV „Bauwerksinspektion“ (Administrative Regulation of the Federal Waterways and Shipping Authority “Structural inspection”)
VV-WSV 2107	Verwaltungsvorschrift der WSV „Aufstellen und Prüfen von Entwürfen“ (Administrative Regulation of the Federal Waterways and Shipping Authority “Concept design and verification”)
WaStrG	German Federal Waterways Act (Bundeswasserstraßengesetz)
WHG	Act on the Regulation of Matters Relating to Water (German Federal Water Act) (Gesetz zur Ordnung des Wasserhaushalts)
WFD	European Water Framework Directive, Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy
WSA	Waterways and Shipping Office (Wasserstraßen- und Schifffahrtsamt)
WSV	Federal Waterways and Shipping Administration (Wasser- und Schifffahrtsverwaltung des Bundes)
ZTV-W	Supplementary Technical Contract Conditions – Hydraulic Engineering (Zusätzliche Technische Vertragsbedingungen – Wasserbau)

1 Initiative for and purpose of the Guideline

1.1 Initiative

The version of the German Water Resources Management Act (WHG) which has been in force since 1 March 2010 imposes a duty on the Federal Waterways and Shipping Administration (WSV) to preserve or restore ecological continuity across the damming structures built or operated by it to the extent necessary to meet the objectives laid down in the European Water Framework Directive (WFD). Under WHG Section 34 (Continuity of surface waters) the construction and operation of damming structures, or substantial alterations to these structures, require appropriate facilities and modes of operation which preserve or restore flow continuity. Existing structures must be refurbished. The WSV, which builds and operates inland waterways in Germany and the accompanying regulatory structures, is responsible for implementing the required measures as one of its statutory tasks under the Federal Waterways Act (WaStrG).

A key objective in efforts to establish ecological connectivity is ensuring that fish, lampreys and benthic invertebrates are able to migrate along federal waterways appropriately[1]. On the basis of current scientific knowledge the behaviour of these species differs depending on whether they are migrating upstream or downstream and this must be taken into account in all measures taken. As the vast majority of Federal Waterways and Shipping Administration damming structures impede or almost completely prevent fish migration, upstream fishways need to be newly built or improved at a number of sites. Basically all barrages, which can in turn consist of several damming structures, need to have at least one functioning fishway.

To the extent required to fulfil the goals of the Water Framework Directive all damming structures must also ensure that downstream fish passage is possible. Operators of hydropower plants are also required to adopt applicable fish protection (cf. Section 35 of the WHG) and downstream migration measures which comply with criteria stipulated by federal state authorities.

This Guideline on Upstream Fishways on German Federal Waterways (AH FAA) deals primarily with issues relevant to upstream migration[2] (Chapter 4). Information on downstream migration which is relevant to the construction of upstream fishways as well as measures

[1] The definition of "fish" for this purpose, depending on the actual context, is that used in fishing laws of the federal states and includes cyclostomes and benthic invertebrates.

[2] The term upstream fishway is used in this document to refer to a structure which is mainly designed to assist the upstream passage of the relevant migratory fish but which at the same time should be designed in a way which enables ground-based organisms and macrobenthos to pass upstream as well. Synonyms frequently used in the literature include “fish pass”, “fish steps”, “fish passage”, “fish ladder” or “fish migration facility”.

relating to downstream migration at WSV weirs is provided in Chapter 5. This document does not address the issue of sediment continuity.

1.2 Current state of knowledge concerning the dimensioning of upstream fishways

The current state of knowledge in this field must be taken into account in the planning of fishways. This is currently available in a large number of publications. The German Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V., DWA) has issued DWA-M 509 (*Code of Practice 509: Fishways and fish passable buildings: design, dimension and quality assurance*) (DWA, 2014). This code largely reflects the current state of knowledge and is consequently used as the planning base for upstream fishways. However, it is important to bear in mind that the lessons learned in Germany to date mainly relate to the construction of fishways on small and medium-sized rivers. The conditions prevailing on Germany's federal waterways may, however, differ considerably in a number of respects. This applies in particular to the issue of the attraction capabilities of upstream fishways. The relevant BfG and BAW planning recommendations are discussed in detail in Chapters 4.4.2 and 4.5.2. **It should be noted that the purpose of this Guideline is not to present an exhaustive discussion of the state of the art, but rather to outline diverging or supplementary issues which are relevant to the particular circumstances prevailing in Germany's federal waterways.**

The lessons learned from planning and construction projects at both the federal and state levels, as well as the new insights continually emerging from international and national research and development are all sources of continuing development. This leads to ideas or even solutions being produced for certain unresolved questions before they have found their way into generally accepted technical standards (such as revised DWA codes of practice). Knowledge which is relevant to the planning and construction of upstream fishways on important federal waterways is integrated in the latest version of the AH FAA Guideline. In this respect the Guideline provides recommendations for the planning and construction of upstream fishways on federal waterways which must be updated on an ongoing basis.

However, not even the latest state of knowledge can entirely eliminate unresolved questions which continue to entail certain planning risks or which could be optimised in the future as new knowledge is acquired. It is therefore desirable for **structural components to be designed flexibly**, particularly where there are significant planning risks or potential for optimisation. This approach allows changes to be made at a later stage based on the knowledge gained from assessments of effectiveness or the current state of knowledge (refer to Chapter 4.4.2). This will also involve weighing up the additional costs of flexible structure components against the benefits of risk reduction.

Planners, the Federal Waterways and Shipping Administration (WSV), the Federal Institute of Hydrology (BfG) and the Federal Waterways Engineering and Research Institute (BAW) will need to meet and discuss ideas on a regular basis in order to pool and use the knowledge they have gained from the planning and new construction or rebuilding of upstream fishways and assessments of their effectiveness. These meetings will take place in the form of regular colloquia and workshops.

1.3 Research and development

Despite the well documented state of the art there are still gaps in our knowledge about the dimensioning of upstream and downstream fishways. The BfG and BAW response is to run various research and development projects which aim at developing implementation proposals for specific construction projects as well as producing fundamental recommendations for configurations, orientations, dimensions, modes of operation and assessment of upstream fishways on Germany's federal waterways. R&D projects on the attraction capabilities of an upstream fishway include studies of the migratory behaviour of fish in the tailwater of damming structures, the discharge of a sufficient auxiliary flow volume or the design of entrances. In the context of passability, consideration is given to factors such as the influence of special construction methods on upstream migration or responses to fluctuating downstream water levels. These R&D projects are undertaken on the basis of biological studies in the field and in the laboratory and make use of physical and numerical modelling and field investigations (hydraulic measurements, etc.).

An essential component of the R&D concept are studies at pilot locations referred to in the prioritisation concept proposed by the Federal Ministry of Transport, Building and Urban Development (BMVBS, 2012a) for the establishment of ecological connectivity. Suitable pilot locations were selected and assessed according to technical, planning and organisational criteria. Selection and assessment take into account fish ecological aspects, relevance for attraction and passability, synergies with planned measures, the potential for transferring results to other locations, the possible use of specific measurement methods and other organisational aspects.

Information concerning the status of research and development projects is available on the BfG and BAW websites (www.bafg.de/durchgaengigkeit, www.baw.de).

1.4 Application of the Guideline

This document is intended to provide the WSV with a tool for planning, building and assessing the effectiveness of fishways. This also applies to structures for which the WSV is

not the project executing agency (TdV). The Guideline can also be used by outside bodies, such as engineering firms, public authorities and the general public.

The Guideline does not replace the information or computational approaches in Code of Practice DWA-M 509 (2014). **The DWA-M 509 must therefore be generally used as the basis for planning fishways. Any requirements concerning fishways on German federal waterways which differ from or go beyond those in the Code of Practice are explained in this Guideline (cf. in particular Chapters 4.3.2, 4.4.2 and 4.5.2).**

In order to avoid duplication of work, the TdV must comply with the work steps outlined in the Upstream Fishways Guideline (cf. Annex 1). The TdV is responsible for planning and constructing the fishway according to the state of the art criteria in science and technology. In this respect it may also draw on the services of third parties (engineering firms) in compliance with the relevant regulations. The BfG and BAW provide the WSV with technical advice rather than planning services. Unless the relevant WSV-office prefers alternative communications channels, contacts with engineering firms assigned with planning the fishway are made through the WSV, thereby reflecting the fundamental tasks of the BfG and BAW. Contractual agreements must be made which ensure that engineering firms or other third parties apply the latest editions of this Guideline and DWA-M 509. The relevant administrative regulations issued by the WSV (VV-WSVs), the Technical Codes for Waterways (TR-W) and generally accepted technical standards applicable to construction projects must be complied with.

This Guideline basically describes the specific steps involved in planning and building fishways (cf. Chapter 4), it provides information about the construction of fishways in or at damming structures (cf. Chapter 5) and stipulates the related fundamental technical requirements. The Guideline defines the stages at which, for quality assurance reasons, the TdV and the BfG/BAW must cooperate. The TdV may also ask the BfG and the BAW for support if this is required at other stages in the planning and implementation process.

1.5 Statements by the BfG/BAW

The participation of the BfG/BAW results in the issue of joint statements by both authorities. These always relate to the current plans presented by the TdV and also contain technically based information relating to planning. They should be understood as recommendations. Financial aspects are not usually taken into account. Statements by the BfG/BAW are aimed at technical solutions to restore or improve the continuity of federal waterways. These statements also identify uncertainties pertaining to specific projects (e.g. special building structures) and draw attention to the need to carry out monitoring. Statements made by BfG/BAW are only ultimately authoritative if they are made in writing.

At its own discretion, the TdV may include these statements in the required approval procedure, although the BfG and the BAW must be informed if the TdV chooses to do this.

Deadlines and response times for comments must be discussed and agreed at an early stage by the TdV and BfG/BAW and included in the project schedule in accordance with the project phases.

If the recommendations made in statements are not complied with in full, the biological control tests which must be performed every time a structure is completed must, as a rule, be supplemented by technical and hydraulic assessments to ensure effective functionality. In these cases facilities which are required for additional assessments must be taken into account during planning.

2 Fish ecological objectives in the construction and improvement of fishways

Constructive requirements of fishways result from fish ecological objectives and the relevant legal framework: The WHG requires the re-establishment of river continuity to the extent necessary in order to achieve the management objectives laid down in the European Water Framework Directive (WFD). The purpose of the WFD is to achieve a good ecological status/potential as a minimum (GES or GEP). In the major rivers, to which most of the federal waterways in Germany belong, migratory fish make up a large proportion of the fish communities which originally existed in or which need to be restored to these waters. For this reason, continuity in these rivers in particular is a key requirement for achieving GES/GEP.

What is more, Article 3 (4) of the WFD stipulates that the protection objectives defined in the Directive on the Conservation of natural habitats and of wild fauna and flora (Habitats Directive) for designated aquatic areas in the relevant river basins must be taken into account and included in the management plans of the federal states. Protective goals which envisage the conservation and development of stocks of (migratory) fish and lampreys must be integrated in river continuity planning.

The eel management plans which must be drawn up under the European Eel Regulation (EC, 2007) establishing measures for the recovery of the stock of European eel outline the objectives and measures to ensure protection and sustainable use of the population of European eel. These plans must be taken into consideration, where appropriate, when building upstream and downstream fishways.

To the extent necessary for the purpose of achieving the management objectives of the Water Framework Directive, with reference to the requirements referred to above, the fish species which are relevant for the dimensioning of fishways must be defined by the BfG in consultation with the federal states and communicated to the TdV as the technical basis of planning. This information is then used to determine the hydraulic design and geometric parameters of a fishway in compliance with DWA-M 509.

The maximum flow velocities in fishways are contingent on riverine zoning (or the fish region). Contrary to DWA-M 509, each river section is assigned to the riverine zones by the federal states when implementing the WFD. This process has not yet been completed. The riverine zone to be referred to is determined by the BfG in agreement with the federal states and then notified to the TdV as the technical basis of planning.

Both experience and theoretical considerations show that it is only possible to maintain and develop stocks of fish and lampreys which have to pass one or several damming structures at regular intervals if fishways can be guaranteed to attract and allow as much fish wishing to move upstream as possible to find their way through such passages with as little delay as

possible, regardless of their age or size. These criteria must be guaranteed on at least 300 days a year (for all discharges between Q_{30} and Q_{330}) in order to facilitate the migratory patterns of different species at different times of the year (DWA, 2014). This means that a fishway must achieve more than generally attract and enable the relevant species or individual fish to continue their journeys up or downriver. Circumstances may arise in which requirements must be met for certain target fish species which go beyond the conditions referred to above.

3 Monitoring, assessments of effectiveness and quality assurance

Establishing ecological continuity through bodies of flowing water promotes the achievement of a good ecological status and good ecological potential according to the management objectives laid down in the WHG. The ecological status of surface waters is evaluated according to specific biological quality components. For flowing water bodies these quality components are the composition and abundance of aquatic flora, benthic invertebrate fauna and fish fauna as well as their age structure. Actual performance is verified with the aid of a differentiated programme and certain fixed test locations in the individual water bodies of a river.

Assessments of this nature, which are carried out at regular intervals and which evaluate the status of a system (e.g. of fish fauna in a body of water) in relation to a stipulated standard or reference, are referred to as monitoring. In addition to monitoring in accordance with the WFD, action is also taken to determine the conservation status of populations of fish species as part of monitoring undertaken in line with the Habitats Directive. Both monitoring programmes are the territorial responsibility of Germany's Federal States. At this point it is therefore recommended that the term "monitoring" be applied to these regular recurrent evaluative assessments which are undertaken according to a uniform method and which relate to the status of a system.

In contrast, other assessments concerning, for example, the function and effectiveness of a fishway are undertaken separately within a defined time period. Differential assessments of how well a structure is functioning can be made by carrying out separate technical hydraulic performance tests (cf. Chapter 4.10) and biological control tests (cf. Chapter 4.11).

Hydraulic/technical assessments of effectiveness and biological control tests are key aspects of technical quality assurance. Quality assurance comprises all requirements, measures and processes which promote sufficient quality of fishways by adequate planning, construction and control phases. These requirements and measures are discussed in the Guideline for each planning stage (cf. Chapter 4).

Assessments of effectiveness are dealt with in different ways in various publications. In DWA (2006), for example, hydraulic/technical and biological tests are both referred to as assessments of effectiveness. Chapter 9 of DWA-M 509 "quality assurance" refers solely to hydraulic/technical assessments of dimensions and their evaluation in terms of fishway functionality. As the state of the art is still incomplete as regards

- the number of fishways or fishway entrances on large rivers,
- the impact of several fishways in series on upstream migration,
- the way fish behave in, e.g., changing water conditions (impoundments interrupted by fishways), etc.,

the DWA-M 509 (Chapter 10) requires that biological assessments are undertaken on at least some fishways. For clarity, both issues - hydraulic/technical and biological assessments of effectiveness - are discussed separately in the Guideline (see Chapter 4.10 and Chapter 4.11). The R&D projects described in Chapter 1.3 also provide further insights into these issues and contribute to quality assurance in the years ahead.

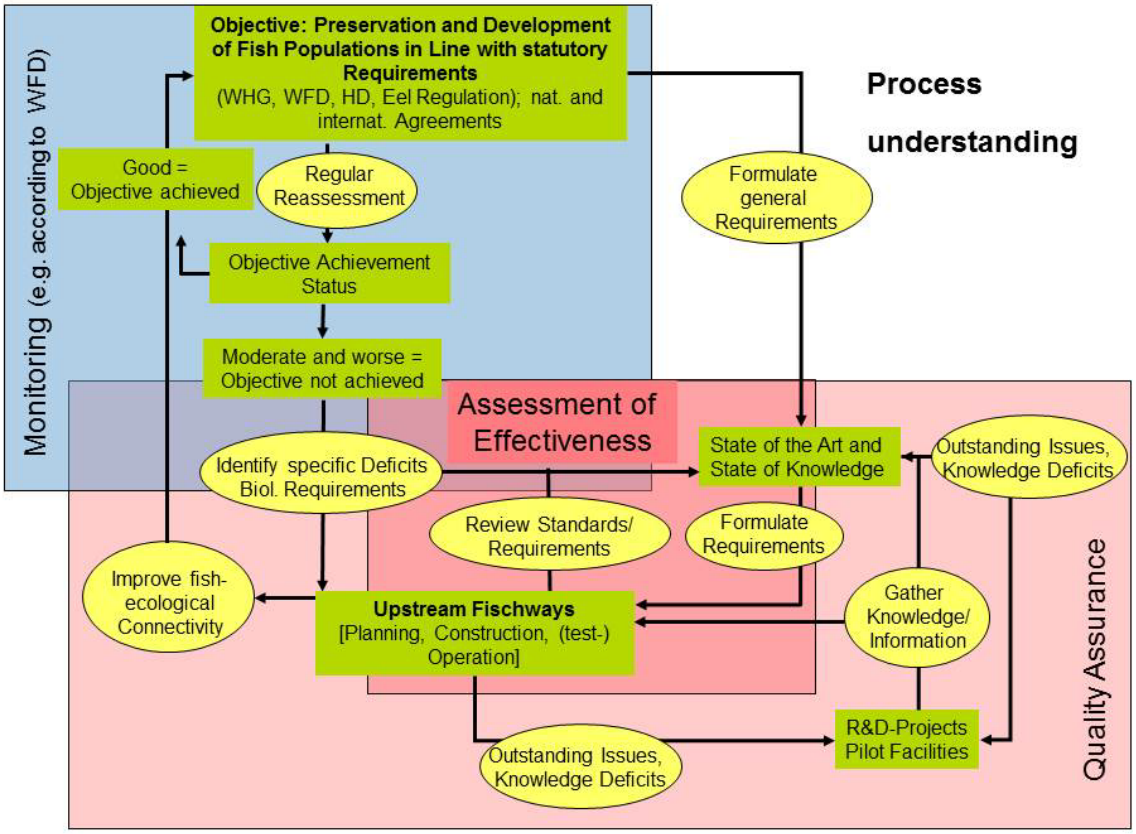

Figure 1: Definition and differentiation of monitoring, effectiveness assessments and quality assurance. Responsibility for federal waterways and their fishways[3]: Blue = Laender/State responsibility, Red = Federal responsibility (WSV)

The diagram above (Figure 1) shows the relationship between these various processes. The Federal States are responsible for monitoring within as defined by the European WFD and HD. Quality assurance related tasks, on the other hand, are closely linked to the WSV's responsibility for the restoration of ecological continuity at damming structures along federal waterways and are consequently the responsibility of the federal administration (as the TdV). Close cooperation between state and national authorities during the process is essential and can generate synergies.

[3] Fishways which are required in order to meet the objectives of the WFD where ecological connectivity is interrupted by WSV damming structures.

4 Upstream fishways

4.1 Project Phases

This chapter describes some of the important steps necessarily involved in assessing existing fishways and in planning and building new fishways. The focus of this description is on the presentation of those technical aspects of fishway construction which deviate from DWA-M 509 and the issue as to when and how BfG and BAW should be involved in this process (new insights, quality assurance). Annex 1 shows the workflow process in addition to the description provided here. In most cases the actual work is undertaken by the organisational units (waterways and shipping offices, waterway construction offices, i.e. TdVs) which also hold local responsibility for the management, development or construction of federal waterways and for building new structures. At some locations, agreements have also been reached between the WSV, the federal states and power plant or dam/weir operators. These agreements must be taken into account in the planning process. The contents of the AH FAA Guideline are equally applicable when WSV organisational units work on fishway projects in which the TdV is a third party. In these cases the WSV must ensure - by means of agreements, statements (made in the context of planning approval procedures, for instance), in contracts of use or waterway and right of way regulations and licenses (“SSG” as defined in Section 31 of the German Federal Waterways Act, WaStrG) - that the generally accepted technical standards in this Guideline are applied. As a rule, it is recommended that third party planning for WSV damming structures (Section 34(3) WHG) should also meet the technical requirements set out in this Guideline. Owing to the legal issues involved it is advisable to coordinate with the Federal Waterways and Shipping Agency (GDWS).

Planning work on fishways undertaken by the WSV is based on VV-WSV 2107. Generally the WSV does not have sufficient personnel capacities to plan fishways and, in most cases, freelance professionals[4] have to be hired (refer to Manual for the awarding of public service contracts VHF BVBS, Chapter 0 (24)).

[4] The applicable statutory and administrative regulations must be complied with whenever the services of freelance professionals are used. Information for the WSV is available on the WSV intranet. Contracts concluded in line with the HOAI must be drawn up with care and in a transparent manner to ensure that the planning task is completed as intended. It may be helpful to draw on the lessons learned by other administrative units.

Table 1: Project phases in the planning and construction of fishways

Project phases in this Guideline	**Assignment to VV-WSV 2107/ VV-WSV 2102/ VV-WSV 2108**	**Performance phases defined in Section 43[5] HOAI (refer also to Section 51) (with reference to VV-WSV 2108)**	**Project phases defined in the WSV PM Manual**
Assessment of existing upstream fishways, where appropriate (Chapter 4.2)			0 Preparation
Collection of basic information (Chapter 4.3)[6]	Preliminary study (VV-WSV 2107 Sec. 6(1)) Collection of basic information (VV-WSV 2107 Sec. 6(2))	Collection of basic information (LP 1)	1 Preliminary planning and preparation of Entwurf-HU
Preliminary study (Chapter 4.4)[6]	Preliminary study Concept (VV-WSV 2107 Section 6(3)	Preliminary planning (LP 2)	
	Concept		
Creation of Entwurf-HU/AU (Chapter 4.5)[6]	Budgetary framework (Entwurf-HU) (VV-WSV 2107 Section 7)	Design process (LP 3)	
	Execution document (Entwurf-AU) (VV-WSV 2107 Section 8)		(4 Creation of Entwurf-AU)
Approval procedure (Chapter 4.6)		Planning approval (LP 4)	2 Creation of planning approval documents
			3 Planning approval procedures

[5] Fishways are engineering structures according to HOAI.

[6] The collection of basic information, the preliminary study and the design process must take account of the outcomes of the nationwide prioritisation concept and the model concept proposed by the Federal Ministry of Transport and Digital Infrastructure (BMVI).

Preparation of contract documents/ contract award procedure for building works (Chapter 4.7)	Execution document (Entwurf-AU)[7] (VV-WSV 2107 Section 8) Contracting of parts 1+2 VV-WSV 2102	Final planning (LP 5) Where applicable, preparation and involvement in contracting process (LP 6, 7)	4 Creation of Entwurf-AU 5 Tendering and contracting
Construction and acceptance (Chapter 4.8)	Construction part 3 VV-WSV 2102	Overall construction management (LP 8) Project follow-up and documentation (LP 9)	6 Construction work
Hydraulic/technical assessment of effectiveness (Chapter 4.10)	Part 1-3 VV-WSV 2108		7 Finishing Work
Biological control tests (Chapter 4.11)	Part 1-3 VV-WSV 2108		
Operation and maintenance (Chapter 4.12)			

[7] If planning approval procedures are necessary, it will only be possible to prepare, review and approve the Entwurf-AU after a planning approval decision has been made.

Since payment for planning and other services for the construction project has to accord with the German Fee Scales for Architects and Engineers (HOAI, 2013), Table 1 shows how the terms used in this Guideline for each phase of the work may be aligned with the corresponding performance phases defined in HOAI, VV-WSV 2107 and the Manual for the Awarding of Construction Work Contracts - Waterways Engineering VHB-W (BMVBS, 2010). The phases of the WSV project management manual (WSV, 2010) are also shown.

It is important to emphasise at this point that the project phases referred to in this document are assigned to the performance phases in the HOAI and VV-WSV 2107 merely by way of example. As previously referred to in Chapter 1 this Guideline is intended to assure the quality of the project phases which typically occur when planning, constructing or improving fishways. The projection of these individual project phases to the work steps outlined in VV-WSV 2107 is contingent on the specific side constraints to which each individual project is subject. In this respect the project phases defined in the Guideline must be flexibly assigned to the work steps in VV-WSV 2107 and the VHB-W.

Various work steps which are carried out by either the TdV, external planners or the BfG/BAW, can be defined in each of the project phases. The TdV, which is usually the authority which holds responsibility for the structure, takes on the management of the project and also awards contracts to external planners for this purpose. It is up to the TdV to decide in which cases and for which performance phases or work steps it wishes to engage external planners. Although this Guideline structures these different activities under different chapter headings, this does not mean that separate contract grant procedures are necessary for each work step involved.

The AH FAA Guideline focuses primarily on the work steps which are necessary to ensure quality assurance in respect of attraction and passability of a fishway. The TdV is also responsible for the standard tasks arising during project implementation.

4.2 Assessment of existing upstream fishways

This work step is only relevant if one or several fishways are already in place at the relevant location. If there is no existing fishway, the first step is to collect basic information (Chapter 4.3).

The initial evaluation of the urgency of measures from a fish ecological perspective undertaken by the BfG has already provided a rough assessment and taken account of the effectiveness of most existing fishways (BfG, 2010). Not all fishways have yet been assessed for effectiveness. This assessment will be performed by BfG and BAW.

At locations where there are currently no plans for new fishways or where none are currently being built, the working status of existing fishways should be maintained or achieved to guarantee at least restricted connectivity. In some circumstances modifications (on their own or in addition to a new fishway) may improve upstream fish passage. This does not entail foregoing a new fishway, which may in fact be necessary, but provides for a temporary solution until the new fishway can be completed.

Agreements on specific locations may need to be made with the BAW/BfG depending on regional requirements. Existing fishways should be retained at least until ongoing BfG/BAW R&D projects have been completed. These R&D projects (at several pilot locations) also address issues such as whether wide rivers require more than one fishway, whether a fishway requires more than one entrance and whether additional measures can improve attraction or rates of upstream passage. Where old and new fishways are operated in parallel the concerns of affected hydropower plant operators, if appropriate, must be taken into account.

4.3 Collection of basic information

The collection of basic information is part of the preliminary study undertaken under Section 6 VV-WSV 2107. It is used to prepare planning for the new construction or extension and modification of existing structures.

A number of constraints and influencing parameters must be taken into account in the planning and construction of fishways (Annex 2).

4.3.1 Work steps

The collection of basic information deals with the following issues:

- **Task clarification:** While the basic objective itself is clear (establishing connectivity), a common understanding still needs to be reached with the federal state authorities regarding the relevant fish fauna and the state of the art of fishways.
- **Assessment of dismantling:** Assessment of whether ecological continuity can be ensured by removing or dismantling the weir or the entire barrage. This would be the best solution as regards fish ecology and may also entail significantly lower maintenance cost, or indeed none at all.
- **Clarification of legal conditions:** Agreements, contracts and permits granted must be collated, e.g. regarding ownership of the land in the area of the damming structure, agreements between the WSV/federal government and the state/local authority, agreements concluded between the WSV and hydropower plant operators, agreements with nature protection organisations, sports associations or similar organisations.

- **Consideration of third party concerns:** Acceptance of the measure will be enhanced and any local knowledge available can be integrated from the very start of the planning process if all stakeholders are involved as early on in the process as possible. Involvement of this kind will speed up the entire process. This involves gathering information about the interests of the stakeholders, i.e. the WSV, operators of hydropower plants, federal state authorities, organisations/authorities engaged in fishing or water sports or responsible for nature conservation and the protection of monuments, munitions clearing services, the BfG/BAW and any other stakeholders with regard to the objectives to be attained by the construction of the fishway. It also involves finding out which designs are possible and how to proceed with planning, the execution of construction work and the assessment of the fishway's effectiveness.
- **Identifying additional side constraints:** Key issues which need to be clarified include physical conditions (e.g. space, available land), existing structures (e.g. service line routes) or ecological aspects (existing protected areas). It is essential for the planning process to have information about and take account of such side constraints and such knowledge may, for instance, result in pre-selection of the relevant types of fishways.
- **Project launch meeting and local inspection:** Project launch meetings must always be held with all those directly involved in planning (TdV, BfG/BAW, GDWS, or the engineering firm responsible for planning). This will clarify the task (see above) and should be combined with a local inspection wherever possible.
- **Gathering and evaluating documents:** The relevant planning documents must be compiled and checked for their completeness. Chapter 4.3.2 lists the documents required for planning work on upstream fishways.
- **Documenting results:** Listing the documents available and, where appropriate, the documents still to be furnished, including short comments, if necessary.

4.3.2 Required specialised information

The following specialised information must be gathered when basic information is collected:

- **Relevant fish species:** The relevant fish species include the spectrum of fish species typically found in the respective body of water based on references in the applicable federal states. With reference to these requirements and in consultation with the federal states, the types of fish which are relevant for the design of fishways are then defined and communicated to the TdV as the technical basis of planning. Depending on location, the applicable data is already held by and available at the BfG.
- **Other species:** There is very little information in the literature about the dimensioning of fishways for the needs of benthic invertebrates. It is generally assumed that the conditions created when the valid design criteria are fulfilled are also beneficial for upstream migrating macrobenthic organisms. It is particularly relevant how the bottom of the fish

pass is designed and how it is connected to the bottom of the downstream and upstream areas (see Chapter 4.4.2). The migration needs of species which move along river banks, such as otters, may also play an important role in the planning of fishways.

- **Hydrology/hydraulic engineering:** For the purpose of designing fishways verified data on the following are required:
  - relevant discharge conditions in the fishway operating range between Q_{30} and Q_{330} with reference to the underlying time series;
  - the flow duration curve, including the maximum design water level;
  - normal (target) water levels with impoundment tolerances;
  - water levels near the barrage between Q_{30} and Q_{330} (with the same height reference as in structure data, e.g. DHHN 92); and
  - discharge management, i.e. the different loads on barrage components at various discharge levels (regulation of normal water levels, weir systems, design discharge of turbines).

  Where water is discharged through more than one channel, the large-scale discharge distribution must be determined for the entire duration curve, i.e. the strength of specific discharge in each channel must be identified (where applicable taking account of several scenarios for different discharges). If no information about large-scale discharge distribution is available, the TdV and the BfG will need to consult with each other and determine the need for additional measurements/research. The hydrological service of the relevant WSA holds fundamental responsibility for providing the data and carrying out measurements.

  Duration curves from long-term time series and trends, where these exist, must be taken into account when determining the water levels and discharges which are relevant for dimensioning purposes. It may be appropriate to calculate the envelope curve in order to assess the reliability of the data. It may also be necessary to take into account the variation of the hydrographs of neighbouring water level gauges in conjunction with the surface slope. This will be at the discretion of the hydrological service.
- **Barrage:** Relevant planning documents must be compiled concerning the structure (aerial images, location plans, longitudinal and cross sections), the layout of barrage components (lock, weir, power plant, existing downstream/upstream fish passage facilities, moles/islands, etc.) and information about the weir body (number of weir fields, types of gates, modes of operation). If there is a power plant, relevant information also includes turbine data (number and type of turbines, design discharge, rotation direction, mode of operation and, where relevant, eel management measures). Where fishways are already in place documented status plans or, as a minimum, as much information as possible about the type of construction and the dimensions (e.g. gradient, water depths; drops between pools; the length, width and height of pools; widths of vertical slots; inclination of

river bottom ramp) is required (see also Annex 3). Any studies available of the basic structure must be collated.

- **Other data:** Further data, such as surveying information about the land and ground investigations may also be required depending on the situation in each case. Under certain circumstances, data may be collected in conjunction with corresponding activities undertaken or contracted out for other projects (e.g. extension of a lock). The geological conditions and the space available for the structure must be defined before the project commences. Furthermore, the substantial interests of third parties (ownership situation, occupancy of the land, water rights, etc.) must be clarified.

This basic information must be collated and also communicated to BfG/BAW as early as possible, at the latest in time for the first meeting.

4.3.3 Involvement of the BfG/BAW

To ensure consulting and quality assurance the BfG and the BAW need to be involved in the process as early as possible. The TdV must therefore inform both federal institutes before the project commences. The BfG will then make the updated version of the relevant fact file on the relevant barrage available to the TdV. The TdV checks the contents of the fact file against the facts on the ground. The TdV completes the preliminary information (Annex 3) accordingly and, if necessary, adds further information about the planning project. Attention must be drawn to the need to update the BfG fact file if new information has become available. The preliminary information may be sent by post or e-mail to the BfG and the BAW (durchgaengigkeit@bafg.de, durchgaengigkeit@baw.de).

The completed fact file or the preliminary information must be sent to the BfG and the BAW in good time prior to the date of the project launch meeting. As a rule, the project launch meeting should be accompanied by a field inspection by the BfG/BAW to determine local conditions.

BfG and BAW then verify whether there is any additional substantial information on the barrage and whether some of the above basic specialised information is already available at the BfG/BAW. In particular, this review includes a comparison with the lessons learned from similar types of dams. It may be apparent even before planning begins that, owing to the special situation at a barrage, the preliminary study will have to include numerical or laboratory modelling studies. The earlier the parties involved agree on this, the better this will be for the project. Agreement must also be reached with the BfG at an early stage on the need for a fish ecological study.

4.4 Preliminary study

According to Section 6 VV-WSV 2107 this work step includes describing possible options and cost evaluations in the preliminary study. The concept to be drafted in the framework of the preliminary study outlines the side constraints, possible realisation options and the option finally chosen on which binding agreement must be reached by all responsible parties (TdV, parties which will later be responsible for maintenance (e.g. the Waterways and Shipping Office (WSA)), Federal Waterways and Shipping Agency (GDWS), Federal Ministry of Transport and Digital Infrastructure (BMVI), the BAW/BfG, federal state authorities, or the operator of a hydropower plant, if appropriate, and parties with whom agreements on river continuity have been concluded, e.g. agreements between the federal government and the federal states) (Section 6 (3) VV-WSV 2107).

Conducting a high-quality preliminary study is an important step towards identifying the option which is most compatible with local conditions. Often the integration - close to the transverse structure - of a fishway in the downstream area and the routing to the upstream side of the barrage create specific technical and organisational difficulties (e.g. accessibility, ownership rights, etc.), because flowing bodies of water are used for various purposes and the space available is limited. This makes it all the more important to consider different options in the preliminary study which make allowance for these difficulties and the individual interests. Chapter 4.4.2 describes areas where there may be conflicts. The work steps of the preliminary study phase of a fishway project are defined and discussed in the following.

The sheer diversity of federal waterways and the structures existing on them mean that every single fishway needs to be planned individually. Generally applicable standardisation is not possible at the present time.

4.4.1 Work steps

- **Analysis of basics:** At this stage the basic information (cf. Chapter 4.4) must be used to specify the technical requirements for planning and to define the planning limits. This concerns hydraulic and geometric dimensioning as well as the need for an auxiliary water supply. For this purpose the basic data must be complete, understandable and clear; where this is not the case, additional information may be called for.
- **Consultation with hydropower plant operators:** Agreement must be reached with hydropower plant operators concerning auxiliary water supplies (refer also to Annex 5) and maybe an auxiliary water turbine obtained. Operators may also need to be involved in the planning process for the fishway/fish protection (e.g. space required).
- **Examining alternative planning options**: This work step is the core task of the preliminary study, i.e. examining various alternative solutions while taking account of their re-

spective influence on the available land, design and construction, fish ecological effectiveness and suitability, maintenance (in this particular case accessibility, avoidance of clogging and maintenance outlay in particular), economic efficiency (cost estimate), acceptance and environmental compatibility. The main criterion for the construction of a fishway is its effectiveness in terms of attraction and passability. The various solutions which might be feasible (including proposals made by other users) must be discussed and the variants which may be relevant for a particular location must be described in detail in an explanatory report together with an assessment of their feasibility.

- **Evaluation of alternative planning options:** Once the different planning alternatives have been developed, the results are subject to a quality control review and evaluation (where appropriate in matrix form). An assessment by the TdV is supported by a written statement by the BfG/BAW in which one preferred option is recommended (cf. Chapter 4.4.3).
- **Selection of the preferred option:** The TdV makes the final selection of the variant which will be implemented. At this point the decision-makers in the federal state authorities may be involved (see above) to ensure that the groundwork for a common understanding is created at the earliest possible stage.
- **Concept:** The TdV is required by official decision to produce a fishway **concept**. The contents of this concept are based on VV-WSV 2107 and the relevant official decision.

4.4.2 Required specialised information

The aim of the preliminary study phase is to ensure at an early project stage that different alternatives which meet the above fish ecological and/or legal requirements can be compared.

- **Choice of measure:** All the structures referred to in DWA-M 509 as well as dismantling are possible options. From a fish ecological perspective, and with reference to DWA-M 509, the choice of measure no longer includes any qualitative distinction between "technical" or "nature-like" designs as, assuming they are implemented professionally, both are suitable for achieving ecological continuity. Nonetheless, provided that structures are passable, a qualitative array of continuity measures may be implemented on the basis of attraction:
  1) Dismantling of the damming structure.
  2) The measure is connected to whole or large parts of the river bottom and the body of water (e.g. rock ramp fishways which extend across parts of or entire bodies of water).
  3) The measure is only connected to small sections of the river bottom (e.g. by-pass channels, pool-type fishways, etc., usually with significantly smaller dimensions and

discharges than the body of water itself. This also includes upstream fishways in the middle of a body of water.)

On 1) Dismantling: Full dismantling of the damming structure will restore full upstream and downstream continuity. This alternative should always be considered first, including with regard to significant reductions in subsequent and maintenance costs. A reduction in the top water level can also result in shorter structures and, as a result, lower costs. The impact on navigation, groundwater, hydraulics, sedimentation, channel morphology, ecology, etc. must be taken into account.

On 2) The measure usually completely or partly replaces a damming structure and, owing to its position in the cross section of the waterway and the width of the entrance, usually guarantees very good attraction. Depending on the design it can also be used for downstream migration and serve as a habitat (feeding grounds, habitat of young fish, spawning grounds) and thus improve the fish ecological status of a body of water according to the WFD (example: rock ramp fishway).

On 3) The measure usually bypasses the damming structure and for this reason particular attention must be paid to the correct positioning of the entrance. This is particularly the case in very wide bodies of flowing water, i.e. in many of Germany's federal waterways. Attention is drawn to the following special design features:

- **Artificial river channel:** Consideration should always be given to the alternative possibility of building a bypass channel. Depending on their design and dimensioning, bypass channels not only improve river continuity but can also offer further benefits by, for example, serving as habitats (feeding grounds, habitat of young fish, spawning grounds) and thus improve the fish ecological status of a body of water according to the WFD. However, for space and control reasons, a bypass channel may require an (additional) entrance structure (such as a vertical slot fishway design) on the downstream side of the barrage to ensure that migrating fish are able to find the entrance when they are near to it.
- As regards the upstream passage function, the **vertical slot fishway** is, quite apart from its habitat function, much the same as the bypass channel. It offers certain advantages where the available space is limited and is also suitable for strongly fluctuating downstream water levels. Uniform vertical slot designs are currently preferable to alternating designs[8] as there is as yet insufficient dimensioning experience for this latter design.

  Vertical slot fishways can usually be combined with bypass channels.

[8] Analogous to DWA-M 509 (see Chapter 8.2.4.5.2) "alternating designs" are those in which the pools are arranged offset from each other so that fish heading upstream are constantly forced to change direction.

- **Other structural designs** (meander fish pass, brush-furnished fishway, Denil pass, rhomboid pass, fish lock, fish elevators or similar) are to some extent the object of ongoing research projects and are used far less often. Currently these types of fishpass require much more coordination and inspection work given that the dimensions and limits for these structures are still uncertain. Not all these structures are equally suitable for all target species.
- **Type studies**: As part of the preliminary study, measures must first be selected and reasons given for their selection. The dismantling of the damming structure/fixed sill and construction of a fishway in the main cross section of the water body (rock ramp fishway across a part of or the entire body of water) must be discussed and, if necessary, counterarguments developed.

  The different types of structures are to be identified and discussed, along with their individual alignments which can be realised on site. The cost of each of the different structures must be estimated. A realistic preferred solution must then be identified based on the fish ecological requirements, local conditions and the costs and agreed between the TdV, the BfG/BAW and the technical planners. If type studies are not performed, the solutions and rationale for choosing a particular structure will be less robust and there will be delays in planning and approval as a result.
- **Large-scale location of fishway(s) in the body of flowing water**: Where a barrage has several discharge branches, it is assumed - in line with the current state of knowledge - that fish will migrate upstream into the various river branches up to the respective damming structure more or less in accordance with the discharge distribution. The channels on which upstream fishways must be constructed in order to meet the WFD objectives must therefore be identified. Since fishways in river branches with the highest discharges usually show the best fish ecological efficiency, they should have priority (i.e. they should be built first). These considerations take into account all the relevant conditions, with and without discharge over the weir. Where a barrage consists of several damming structures, which may in turn be run by different operators, an assessment must be made to determine whether the WSV is responsible for restoring continuity at the location which would be most suitable for the upstream fishway or whether an upstream fishway needs to be constructed by the WSV in a particular channel of water in order to meet the WFD objectives.

  An assessment must be made of the need for more than one upstream fishway in locations where the tailwater is very wide or where there are numerous weir spills. Large-scale constellations at sites where there is no hydropower plant are discussed in detail in DWA-M 509. At locations where there are hydropower plants the current BfG/BAW recommendation is first to construct a fishway near the bank adjacent to the hydropower plant with the option of adding further fishways or additional entrances or retaining existing entrances or fishways. This should allow older structures to continue to be used as

secondary fishways, where appropriate. The need for further structures is to be determined in R&D projects run by the BfG/BAW at pilot locations.

- **Flexible approach to construction:** As it is still difficult to predict fish behaviour in relation to hydraulic conditions and given that the application of existing regulations to conditions on federal waterways still requires clarification in certain respects, the BfG/BAW recommend designing fishways as flexibly as possible so that modifications can be made as cost effectively as possible at a later time when more knowledge becomes available.

  At the present time it would appear particularly important to allow sufficient flexibilty for the adaptation and/or optimisation of the design and location of the slots, especially at the start of a series of pools, as well as of auxiliary flows, their discharge and the connected structural elements of a fishway, and the design of the fishway entrance or entrances in the downstream area of the fishway. These issues must be taken into account in planning and the costs of flexible design weighed up against the risks of waiving such flexibility.

- **Special pools (e.g. resting pools, turning pools, diversion canals etc.)**: Owing to the uncertain impact they may have on the passability of upstream fishways the BfG/BAW currently recommend doing without special pools whenever possible.

  According to DWA-M 509 resting pools are not necessary if the maximum permitted flow velocities in relation to the length of the fishway are not exceeded.

  Turning pools are often used to overcome relatively high heads on many federal waterways as compactly and therefore cost effectively as possible. Too little is known to date about the dimensioning of turning pools; in particular, there is still uncertainty as regards their impact on hydraulic conditions in the fishway. For this reason the first slot below a turning pool in particular should be flexibly designed to allow the hydraulic conditions to be influenced by changes in slot geometry.

  The lower rated velocities for diversion canals and similar structures specified in DWA-M 509 (compared, for example, to the slot velocity of a vertical slot pass) must be taken into account (cf. DWA, 2014, Chapter 4.6.4.2.3).

- **Position of the downstream entrance**: The location and design of the downstream entrance to a fishway are decisive factors in attracting fish and thus in ensuring that the fishway fulfils its function. This is particularly true for conditions on federal waterways (discharges over the weir and/or the power plant are high in relation to the discharge from the fishway). The interplay between attraction flow, flow from the power plant and weir flow as well as the geometry and shape of the entrance are of crucial importance here. The aim is to create a flow coming from the fishway's entrance that is perceived by the fish despite the strong turbulence at the exit of the draft tube of a power plant or at a weir spillway.

  To avoid a dead-end effect, the fishway entrance in the downstream area must usually be placed next to the power plant outflow and/or the weir field with the highest load, even if this entails considerable construction work.

- **Entrance design/ connection to the river bottom:** The entrance or entrances must be positioned and designed in a way which guarantees that they attract both surface swimming and benthic species of fish. If the fishway is not flush with the river bed, a connection to the riverbed can be realised by a rock ramp, for example. If, for structural or hydraulic reasons, the fishway cannot be constructed flush with the river bed at an entrance near the power plant, the connection to the riverbed must be carried out in another area in compliance with the requirements of DWA-M 509.

  If it is possible to construct entrance flush with the riverbed near the power plant, gates can be used to reduce the flow where the vertical slots have a considerable water depth. The cross section of the entrance must not be narrowed to such an extent that the minimum dimensions for the slots are no longer met. The geometry and alignment of the entrance cross section are contingent on the required attraction flow velocity. The attraction flow must be parallel to the current (usually parallel to the bank).

  It must be possible to reach the entrance to carry out maintenance and operational work, later optimisation or any inspections which may be required.

- **Number of entrances in the upstream fishway:** The number of entrances which is needed is currently the subject of studies being undertaken at pilot locations. At present, therefore, planning is currently focused on just one entrance if it is flush with the river bed. The option of adding further entrances should, however, be taken into account on larger federal waterways where their construction would be financially and practically feasible.

- **Hydraulic pre-design/geometry of the fishway**: The hydraulic limits for fishways are defined in DWA-M 509 (see Chapter 4.6). The minimum and maximum flow velocities, the required orifice sizes/slot widths and water depths for the types of fish which are relevant for the dimensioning must be met by all structures for the relevant operating conditions (Q_{30} to Q_{330}).

  The minimum geometrical requirements, such as pool sizes and slot or orifice widths in a fishway, are not only dependent on the dimensions for the relevant fish species, but also on the prevalence of schooling fish (cf. DWA-M 509 Chapters 4.6.3.2 and 4.6.3.4).

- **Dimensions of rock ramp fishways:** The dimensioning of rock ramp fishways (without friction blocks but with perturbation boulders or with a boulder sill) has not yet been clarified. The use of natural, usually irregular, construction materials results in greater monitoring and optimisation work.

  The dimensioning and operation of rock ramp fishways and rock ramps are challenging tasks. It is essential to ensure that the necessary minimum water depths and flow velocity thresholds are kept to for all design situations. Structured profiles may also be needed. In addition, the structural stability of all the elements must be ensured as settlement or scouring may result in excessive differences in height which could impact passability and

jeopardise the structural stability of the fishway. See DWA (2009) and Minor (2007) on the dimensioning of ramps.

- **Discharging auxiliary water to produce sufficient flow in the fishway:** In certain cases it may be necessary to discharge additional water at one or more places in the fishway (e.g. where water builds up in the tailrace area of the fishway) to produce sufficient rheotactically effective flow velocities in the fishway. The BfG/BAW should be consulted in each case.
- **Discharging auxiliary water to produce an attraction flow in the tailwater (cf. also Annex 5):** Where fishways only extend across a small part of the watercourse, it is often necessary to discharge additional water (auxiliary water) to produce an attraction flow in the tailwater which ensures that the fishway can be located. In these cases the total water supply required by the fishway is the operating flow plus the auxiliary water supply. The amount of auxiliary water required and the place at which it is discharged (see below) are determined in a preliminary study. In this case the auxiliary water design will affect both the amount of space needed for the fishway and negotiations with hydropower plant operators. The BfG/BAW must be consulted before final decisions are made.

  As conditions differ considerably from location to location as regards discharge, weir and power plant design as well as the design of the fishway itself, there is no standard auxiliary water supply which would apply to all locations. This means that local conditions will need to be considered individually.

  Annex 5 contains recommendations for the auxiliary water supply which are derived from studies undertaken by the BfG/BAW at Lauffen on the Neckar. These recommendations apply to fishways where the entrance is located directly on the transverse structure. Decisions must be made on a case-by-case basis where fishways have several/remote entrances (cf. BAW, 2013). Separate numerical or physical modelling will be required, in consultation with the BfG/BAW, for those locations where the model findings from Lauffen are not applicable.

  At present there are no dimensioning recommendations for locations which do not have a hydropower plant. For this reason the parties involved must decide themselves on the amount of water which is needed. The BfG and the BAW do not consider it appropriate to determine the amount of water required solely in relation to a mean discharge (MQ) as is sometimes suggested. It is preferable for the water supply required to reflect the varying hydraulic conditions at each of the design water levels (W_{30}/W_{330}).

  Auxiliary water conduits must be protected at the entrance against debris and passage of fish, e.g. by using fine mesh screens.
- **Discharge location for auxiliary water and structural design**:

  As a rule auxiliary water is discharged near the fishway entrance. In some cases the auxiliary water may also be distributed and discharged into several pools in the fishway if there is a problem with water building up in the structure and flow velocities being re-

duced as a result. The structural design for discharging auxiliary water must ensure that the auxiliary water does not destroy the migratory corridor in the fishway and that fish are not able to swim into the stilling basin (auxiliary water pool).

The downstream water levels are rarely constant and usually fluctuate strongly in impounded rivers. This means that the extra flow must be effective for different downstream water levels. The BfG and the BAW recommend planning systems that allow modifications to be made at subsequent planning stages or even later when the facility is already in operation. If the auxiliary water is introduced to the fishway through an auxiliary water conduit, this must be designed for a range of different discharge conditions (and for various water levels in the downstream area) and it must also be possible to direct the auxiliary water flow to the particular fishway entrance area which is to be used in the respective conditions. The entrance opening(s) in these areas must be planned to ensure that the rated velocities are not exceeded even at a higher attraction flow. The design for the energy conversion (power dissipation) before the auxiliary water enters the entrance area of the fishway is described in DWA-M 509 (Chapter 4.5.3.5). Depending on the situation it may be possible to offset the energy loss of a hydropower plant from the withdrawal of auxiliary water by installing an auxiliary water turbine. Steps must be taken whenever possible to ensure that water can be introduced through the auxiliary water conduit or an alternative route even without an auxiliary water turbine, in order to be able to carry out inspection works (at the turbine), if necessary.

- **Monitoring equipment (cf. Chapters 4.10 and 4.11):** Any monitoring equipment which may be required for hydraulic/technical or biological studies of the facility must be taken into account at this planning stage. The BfG advises on the requirements which must be met when installing biological assessment equipment, e.g. lifting mechanisms for fish traps, power supply for video systems, etc. (cf. also Annex 6). All parts of the facility must be accessible.

4.4.3 Involvement of the BfG/BAW

To avoid unnecessary redundancy of alternative proposals in the preliminary study it is useful to involve the BfG/BAW, and where applicable the administrative authorities at the federal state level, in the decision-making process regarding the alternatives that are eligible for further consideration in the preliminary study.

If the preliminary study is contracted out by the TdV to an external planner, the former will then perform a first quality control check after conclusion of the preliminary study. For this purpose an approval note must be added to specify whether the technical aspects in DWA-M 509 and in Chapter 4.4.2 have been complied with. Any deficiencies must be revised in the planning concept by the contractor.

After the preliminary check by the TdV the preliminary study report is submitted for technical assessment to the BfG/BAW for quality assurance purposes. These institutions will comment on the preliminary study and the type studies and will discuss the preferred solutions (cf. Chapter 1.5). In some cases this may require subsequent revision of the planning concept.

The TdV identifies a preferred solution on the basis of technical and financial considerations which is analysed more closely in the subsequent planning stages.

The dimensions recommended in DWA-M 509 may not be met where overall conditions are complex (lack of space, strongly fluctuating channel flows in different river branches, strongly fluctuating upstream and downstream water levels, special layout of the fishway, etc.). At the end of this preliminary study phase the TdV will therefore consult with the BfG and the BAW and decide whether further attraction or passability studies (e.g. numerical or physical modelling, fishery biological studies) are required and whether this is a task for the BfG/BAW, for universities or external planners. As a rule the TdV and the BfG/BAW will need to cooperate closely on this issue which involves both technical and scheduling aspects.

If modelling is thought to be necessary, but cannot be undertaken by the BAW, this may need to be contracted out. Where numerical models are developed, the computation methods must always be agreed with the BfG and the BAW. The models must be validated for the case to be simulated. The next step is to merge the results of numerical modelling with ecological data to be able to draw eco-hydraulic conclusions for subsequent planning steps. All numerical simulations and related fish ecological assessments performed by external parties must be coordinated with the BfG/BAW.
If measurements are required (because physical or numerical models are used or to evaluate the transferability of lessons learned from similar projects) agreement must then be reached with the BfG/BAW on how such measurements should be made by and which standards are to be complied with.

4.5 Creation of Entwurf-HU/AU

This chapter deals with work steps that need to be continuously intensified at each stage of the procedure. The TdV clarifies with the superior authorities and the planning approval authority the documents required in each case (e.g. Entwurf-HU/budgetary framework and Entwurf-AU/execution documents, documents required for public approval procedures).

The following sections only deal with the work which needs to be done when planning fishways. The documents for the public works planning approval procedures must be prepared in accordance with the administrative regulation VV-WSV 1401 (including Chapter 4.3). De-

pending on requirements, the work steps from the preliminary study, the creation of drafts and approval procedures must be undertaken in parallel.

The budgetary framework is used to obtain funding within the WSV. The required documents are detailed in administrative regulation VV-WSV 2107, Section 7. As a rule, the budgetary frameworks for drafts for upstream fishways must be agreed with the BfG/BAW before they are submitted to the BMVI.

The following explanations mainly relate to the preparation of the execution document and the documents for the required approval procedure. These are usually processed in parallel. However, stipulations made in the approval procedure can have an impact on planning and thus on the execution documents.

4.5.1 Work steps

The administrative regulation VV-WSV 1401 stipulates the required content and form of the budgetary frameworks and the execution documents. As the focus of this Guideline is on fishways, the following issues are focused on, especially when dealing with the execution documents: information about building construction, duration of the construction work, construction process (location of the construction site, concept for serving the site, impoundment concept, separate construction stages, limitations during construction period, duration of construction work, etc.). The results obtained during the planning approval procedures must be incorporated in the execution documents. Further, data are needed on the impact of the construction work and operation on the flood situation, nature and landscape, public safety and traffic, adjacent owners, adjacent land, etc. Moreover, the documents must contain detailed information on the hydraulic design and geometric dimensioning of the fishway. In addition, structural analyses, verifications of stability (e.g. for rock ramp fishways) and ground investigations must be submitted.

4.5.2 Required specialised information

In principle, the DWA-M 509 standard applies, according to the qualifications set forth in Chapter 1 as well as the requirements defined for the preliminary study. To ensure an increasing level of detail, attention must be paid to the following issues:

- **Dimensions of the facility:** While the preliminary study only requires pre-dimensioning to determine the space required for a fishway, the complete geometrical and hydraulic design of the facility must be carried out and described in the design process.

  Detailed and understandable hydraulic calculations (e.g. table, longitudinal view) for the entire fishway to which the BfG and the BAW can respond must be provided. These cal-

culations must be made available in good time before the approval procedure begins in order to make the required changes, if appropriate. Hydraulic calculations must contain the following information as a minimum (in other cases the BfG/BAW must be consulted):

- Watercourse zone, fish species which are relevant for dimensioning and derived design specifications
- Upstream and downstream water levels for Q_{30} and Q_{330}
- Bottom heights from the inlet and outlet and within the structure
- Safety factors according to DWA-M 509
- Flow velocities (where applicable in each pool) at Q_{30} and Q_{330}
- Water depth (where applicable in each pool) at Q_{30} and Q_{330}
- Power density
- Pool dimensions where applicable (pool width, pool length)
- Width of vertical slots/size of orifice (if applicable) and, where appropriate, more detailed description of configuration (baffles, offset, deflection element, wall width, etc.). It is expedient to include a drawing with this information.
- Where applicable, number of pools and separation walls
- Supply of auxiliary water and place at which it is introduced (e.g. pool number) in relation to the river discharge
- Other geometrical or hydraulic variables according to DWA-M 509 (depending on the fishway design)

Compliance with applicable limits (e.g. maximum slot velocity, minimum velocity in the migratory corridor, minimum water depth and power density) must be demonstrated across the entire design discharge spectrum, including pondage of the fishway by the tailwater.

- **Attraction/auxiliary water supply:** Numerical or physical model tests may be required in order to study attraction near the entrance area (cf. Chapter 4.4.3) if previous recommendations on auxiliary water are not applicable owing to the spatial conditions (cf. Annex 5).
- **Measurements:** If modelling is required (cf. Chapter 4.4.3) it is advisable, in order to improve model validity, to use an ADCP to measure the real flow field at selected discharges between Q_{30} and Q_{330} in the tailwater of the damming structure. The ADCP measurements must either be made by or in close cooperation with the BfG/BAW. Where special conditions apply, fish ecological data must also be collected in consultation with the BfG.
- **Technical checks (see also Chapter 4.12):** The fishway must be planned in a way that allows the facility to be drained (stop log gates, sluice gates) when inspection, maintenance and revision work needs to be carried out. Components which are subject to wear

and tear must be easily accessible. It must also be possible to carry out visual inspections while the fishway is in operation. The relevant information must be provided (accessibility by foot/vehicle, transport of heavy tools/material, occupational safety, electricity/water connections). In general it is expedient with regard to all these issues to involve the responsible WSA maintenance office in the planning of the fishway (cf. VV-WSV 2107 Section 17).

- **Maintenance (see also Chapter 4.12):** To prevent fishway blockage as far as possible suitable trash deflectors must be provided at the fishway exit (e.g. trash rakes and scum boards). Where sedimentation is to be expected (for instance in low turbulence areas or with a large degree of suspended particulate matter, etc.) it must be assessed whether this can be countered by avoiding corners and niches in the design (e.g. with vertical slot passes) or by using structured profiles (e.g. for ramps).
  The TdV must draw up a service plan which describes the maintenance and operation of the fishway and which names the responsible organisational unit (accessibility to all parts of the fishway, responsibilities, control and cleaning periods, instructions on the removal of floating debris/depositions, and rules for fish trapping, where appropriate). Maintenance intervals may be altered at a later time if the operation of the fishway so requires (for instance due to special seasonal conditions, floods, increased levels of log jams, clogging or silting). The relevant information on accessibility by foot/vehicle, transport of heavy tools/material, occupational safety and electricity/water connections, etc. must be provided in order to assess the feasibility of inspection, maintenance and revision work. In this context the aspects referred to in Chapter 4.12 must be taken into account in the design process. In this case, too, it is expedient to involve the responsible WSA maintenance office.

4.5.3 Involvement of the BfG/BAW

The approval documents for further assessment of compliance with hydraulic and ecological standards must be submitted to the BfG/BAW after the minimum standards have been verified by the TdV in accordance with Chapter 4.5.2. The statement on the drafts/plans made by the BfG/BAW also addresses deviations which may be required from the provisions of DWA-M 509.

Depending on the type and scope of any hydraulic/technical and/or biological assessments of effectiveness, the required features, such as electricity and water connections, anchor points for measuring equipment, etc. must be discussed and agreed with the BfG and the BAW.

4.6 Approval procedure

This Guideline does not address the approval procedures or the associated documents which are required before a federally owned fishway can be built. The requirements which apply to specific approval procedures must be complied with in each case. As an example, for planning approval procedures under the German Federal Waterways Act (WaStrG) reference is made to Section 4.3 of the Administrative Regulation of the Federal Waterways and Shipping Authority No. 1401 (VV-WSV 1401), “Richtlinien für das Planfeststellungsverfahren zum Ausbau oder Neubau von Bundeswasserstraßen“ ("Administrative Guidelines concerning planning approval procedures for the development or construction of German federal waterways”). It is recommended that authorities at the federal state level are involved in the planning process as soon as possible (see also Chapter 4.3) and that a sufficiently long time buffer is planned for.

Fishways are subject to the usual statutory rules for hydraulic structures. The approval authority for fishways which are planned by the WSV as part of its tasks relating to federal waterways (under the WaStrG) is the GDWS (and its external offices) and in other cases the federal state authorities. To some extent contracts exist between federal states and the WSV which provide for special solutions.

The written comments given by the BfG and the BAW and the various planning phases have the character of recommendations (cf. Chapter 1.5). They may be used in their written form in the applicable approval procedure.

The locally responsible WSA or GDWS external office must, as a participant in the approval procedures for third parties, ensure that the requirements which must be met by fishways as set forth in the AH FAA Guideline are also complied with by third parties as far as possible. The requirements may need to be set down in detail and substantiated in the approval procedure (cf. Chapter 4.1).

4.7 Preparation of contract documents/ contract award procedure for building works

4.7.1 Work steps

The required work steps are detailed in the relevant regulations.
The contract award procedure pursuant to VV-WSV 2102 is applied.

4.7.2 Required specialised information

The main technical information is dealt with in the preceding planning phases. The design specification must also specify that materials with sharp edges which might injure fish must be avoided in the building construction.

As even small deviations from planning specifications can cause significant changes in the hydraulic conditions of a fishway, it is essential that the permissible deviations of construction elements are complied with precisely in the specifications. If irregularly shaped building materials (e.g. uncut stone) are used, and if it is not possible to make a precise hydraulic calculation in advance, an additional post-construction optimisation phase should be planned for or contracted out.

Monitoring of permissible deviations of construction elements during the construction phase, the subsequent qualified surveying of key structural elements and an optimisation phase, where applicable, must be included in the appropriate parts of the specifications.

4.7.3 Involvement of the BfG/BAW

The BfG/BAW are only involved in the "Contracting" work stages where equipment for hydraulic/technical or biological studies are integrated or where significant changes need to be made to the execution planning which deviate from the draft planning.

4.8 Construction and acceptance

Monitoring of the building construction and acceptance is the responsibility of the TdV and must comply with relevant codes and regulations.

4.8.1 Technical requirements

In addition to general acceptance requirements, the acceptance of construction work at fishways especially requires that geometric planning requirements are met (e.g. pool length and width, the distance between sills, perturbation boulders or baffles, the bottom height/head differential, water depths, etc.). The substrate of the river bottom and the controllability of the fishway must also be assessed. The verification must include all components; random sampling is not sufficient.

- Width of narrow parts/slots: The width and the location of narrow parts/slots must be verified before acceptance. Tolerances are based on the ZTV-W and/or analogous to DIN 1045. When planning pool-type fishways it is important to ensure that verifications in this field are performed with particular care because even minor geometric deviations in the area of the wall (arrangement of slots) can result in major deviations in the flow field.
- Permanent stability of the substrate of the river bottom must be ensured. In the area of the slots in particular, the accumulation of bottom substrate has an adverse effect as it can significantly reduce the size of the slots through which the water flows and thus negatively impact the pool's hydraulics. The system must include gaps where microorganisms and weak swimmers can rest. In the field of weir gates no bed substrate may be used in order to ensure tight closing of the gates.
- When the construction work is completed a test run must be performed according to DWA-M 509 Code of Practice (refer to Chapter 9.5).
- Auxiliary water supply: As a rule, there is no constant value for the supply of auxiliary water as it depends on the tailwater level. Availability of the auxiliary water supply specified in the plans must be ensured. Controlling the water quantity and ensuring that the required quantity is available is therefore part of the planning task. Checks must be made during the test run for acceptance to assess the extent to which the planned water volume is identical with the actual volume of water and whether the regulatory elements function properly.

  An operating instruction which includes at least the aspects referred to in Chapter 4.12 must be drawn up in addition to the maintenance concept.

4.8.2 Involvement of BfG/BAW

The BfG and the BAW only need to be involved in the execution of construction work if specific unexpected issues arise. The date determined for acceptance and/or the trial run must be communicated to the BfG/BAW to enable their participation if required. If the trial run shows that some alteration to the fishway is required, the BfG and the BAW must be informed of any projected measures beforehand.

4.9 Final information

When the construction work is completed the TdV must prepare a final information document as specified in Annex 4 which must be submitted to the Federal Ministry of Transport and Digital Infrastructure, the GDWS and BfG/BAW for information purposes and further use no later than six months after acceptance of the construction work. The final information document is part of the final evaluation.

4.10 Hydraulic/technical assessment of effectiveness

However, not even the latest state of knowledge can entirely eliminate unresolved questions which continue to entail certain risks when planning fishways. These planning risks mean that there is a need for a hydraulic/technical assessment of effectiveness after completion or modification of a fishway.

It should be noted that the hydraulic assessment of effectiveness becomes necessary if the state-of-the-art design has to be deviated from as early as in the planning phase (for instance, when smaller pool dimensions must be chosen due to space limits). In their statements regarding the planning, the BfG and the BAW usually define the items for which control in the respective project is required or recommended.

Biological control tests which are described in more detail in Chapter 4.11 are required for the final assessment and evaluation of fish ecological effectiveness and efficiency of a fishway.

Generally, the TdV is responsible for any hydraulic/technical assessment of effectiveness and resulting optimization measures that may be required. However, in the case of rock ramp fishways this may be a task for the planner of the fishway until it is possible to prove that the respective defined limits are met. With third party construction projects, the WSV is required to demand in the approval procedure that assessments of effectiveness are carried out, if needed (see Chapter 4.6).

4.10.1 Work steps

The hydraulic/technical assessment of effectiveness essentially consists of a verification of geometric and hydraulic design values which are specified in the planning process and usually follow the guidance provided in the DWA-M 509 Code of Practice and the statements by the BfG/BAW. While controlling the geometric dimensions is a necessary part of the construction work and acceptance, the need for a hydraulic assessment of effectiveness is decided in each individual case. The BfG and the BAW consult with the TdV on the work steps required for the respective facility.

The hydraulic measurements may relate to both the overall conditions in the fishway (issue of passability) and the conditions in the tailwater of the damming structure (issue of attraction). It should be noted that in some cases more than one measurement campaign will be necessary as the proper functioning of the fishway must be ensured for the entire design range of water levels (W_{30} to W_{330}).

4.10.2 Technical requirements

The technical, i.e. geometric assessment of effectiveness is mainly based on DWA-M 509 (Chapter 9) in conjunction with DWA (2006).

Since there are different requirements regarding the hydraulic assessment of effectiveness for the different parts of the structure on the one hand (related to the topics of attraction and passability) and the different construction types on the other, the following recommendations focus on the issues which are frequently addressed.

Attraction

- **Entrance design:** The acceptance procedure includes verifications of the entrance dimensions (see Chapter 4.8).
- **Attraction flow in the near field around the fishway entrance:** The attraction flow is of crucial importance in enabling fish to locate the entrance to the fishway. Research is currently being undertaken on the characteristics of the attraction flow and their dependence on parameters like power plant design, configuration of the entrance area and auxiliary water supply. In addition, to determine the characteristics of the attraction flow hydraulic measurements are necessary, which require some methodological effort and also involve occupational safety measures.

  Based on model tests the BfG and BAW elaborated a design recommendation for the auxiliary water supply needed to create an attraction flow (cf. Annex 5). When applying this design recommendation it is indispensable to evaluate the potential for transferring the recommendation to the different locations according to the boundary conditions in the

preliminary study (Chapter 4.4). On the basis of these principles the following recommendations can be derived for a hydraulic assessment of effectiveness:

- If the boundary conditions are sufficiently similar or if the auxiliary water supply is modelled and designed specifically for the site in question, no hydraulic measurements need to be taken after construction of the fishway. The reader's attention is explicitly drawn to the fact that it is not possible to conclude from the recommendations that a modelled flow field always corresponds to the natural flow field. The issue of the reliability of forecasts based on numerical or physical models is a fundamental question that has to be investigated in R&D projects rather than being considered in the assessment of a structure's effectiveness.
- Where it is impossible to transfer the design recommendations and no modelling is planned, hydraulic measurements must be carried out in the tailwater of the fishway. The use of ADCPs is recommended for these measurements. Some first insights regarding the performance of such measurements are provided by Sokoray-Varga et al. (2011), for example.

Passability

- **Vertical slot fish pass:** While the hydraulic conditions in vertical slot passes have been investigated quite thoroughly there are still some unanswered questions regarding the state of the art, which are discussed in current national and international studies. Since these issues are of fundamental character, a hydraulic assessment of effectiveness should not include the evaluation of hydraulic conditions in vertical slot passes, provided that the provisions of DWA-M 509 are observed during construction. However, if the planning or construction of the fishway deviates from the dimensions stipulated by DWA-M 509 (if pools are elongated, for example, to bridge specific areas), hydraulic measurements must be undertaken to verify that the pools meet the requirements regarding
  - maximum velocities in and below the slot,
  - minimum water depths and
  - minimum as well a maximum velocities in a continuous migratory corridor

  The measurements must cover the range of discharge between the upstream and downstream water levels (W_{30} to W_{330}) which are relevant for the design. Since the measurement of flow rates (e.g. in or immediately behind the slot) presents certain difficulties, it is recommended that, whenever possible, ADV probes are used rather than hydrometric vanes.
- **Rock ramp fishways:** The different designs of this type of fishway are mainly distinguished according to the configurations and arrangements of large rocks or boulders which are relevant for the flow (random arrangement of rocks or rock sills). Given the natural irregularity of rock it is more or less impossible to implement geometric planning measures precisely. It is therefore advisable to take measurements at the slots in the

fishway to verify whether the maximum velocity requirements are met. In addition, the hydraulic assessment of effectiveness must ensure that the major hydraulic criteria are observed overall across the structure. Where the fishway fails to meet the hydraulic criteria either over the area at large or at the slots/narrow places, the rocks must be rearranged to adapt the ramp to the requirements. The methods to be used are identical to those described for the vertical slot pass.

- **Other fishway types:** Other fishway types are rarely considered by planners at present as there is only limited knowledge about their hydraulic characteristics. One example is the meander fish pass, which has some advantages over the vertical slot pass regarding feasible head drops as well as water and space requirements. However, there are some unresolved questions regarding the hydraulic and biological functioning, especially under the conditions prevailing on Germany's federal waterways (where the required slot sizes are often comparatively large). These questions are of such fundamental importance that the uncertainties associated with this type of fishway are considered as substantial and currently investigated in R&D projects. If certain boundary conditions nevertheless require the construction of a meander fish pass or some other type of fishway for which only scarce research findings are available, a hydraulic assessment of effectiveness must be conducted to verify, for all discharge conditions relevant for design, that the limit values are observed. The methods to be used are identical to those described for the vertical slot pass.

If the need for certain measurements and investigations after construction of the fishway is already established in the pre-project phase, the required measuring equipment and safety installations (e.g. fall protections, provision of walking paths) must be taken into account in the construction phase.

4.10.3 Involvement of the BfG/BAW

The BfG/BAW must be consulted regarding the necessity and scope of hydraulic/technical assessments of effectiveness. As a rule, the statements by the BfG and the BAW contain information about the controls that may be required.

4.11 Biological control tests

The construction of a state-of-the-art fishway or optimisation of an existing non-effective fishway - successfully tested for effectiveness by hydraulic/technical assessments where necessary (see Chapter 4.10) - is an essential requirement for restoring ecological continuity. However, the evaluation of the continuity of large rivers and/or inland waterways in particular is still characterised by uncertainties: to date, these water bodies are not equipped with any facilities according to the state of the art as defined by DWA-M 509 and hence there is no

experience from such projects and, moreover, there is no evidence that limits and recommendations can be transferred to the conditions prevailing on Germany's federal waterways. Biological control tests are required for the final assessment and evaluation of fish ecological effectiveness and efficiency of a fishway. Following consultation with the BfG, such tests must therefore be performed for all new fishways.

When planning and carrying out biological tests, intensive communication with the authorities of the federal states is advisable to take their knowledge and study results into consideration. Thus it may be possible to produce synergistic effects by jointly conducting or at least aligning study programmes.
Given the deficits in the current state of scientific knowledge, shortcomings of methods and complex biological interrelationships involved, it is very difficult to provide a definition of the appropriate degree of continuity based on quantities of ascending fish. There are a number of problems associated with biological tests:

- It is only possible to make statements about the fish fauna present at the time the test is conducted. This means that biological tests do not provide any information about species for which continuity is to be provided but which have not yet reached the respective barrage (perhaps because downstream damming structures fail to ensure continuity).
- In view of the fact that different species migrate at different times of the year and day, robust results will only be produced by controls which cover longer periods of time (e.g. twelve months). Surveys may need to be repeated to effectively account for year-on-year changes in conditions for upstream migration, for example, which depend on different weather conditions, the fish stocks in the area, etc.
- Different methods (electric fishing or netting, for example) are used to record the number and species of the fish accumulating in the tailwater and needing to continue their migration route. Given daily and yearly fluctuations or avoidance behaviour of the fish, it is not possible to obtain a comprehensive picture in larger water bodies.

In some cases it is also possible to use the findings obtained at other fishways to analyse and indirectly evaluate the results of biological surveys. The same applies to the results obtained in several years' monitoring studies conducted by third parties on the development of stocks of species covered by the Habitats Directive. Additional research into factors influencing the stocks of species (e.g. fry numbers and losses due to predators, fishing, etc.) made by or in cooperation with third parties may be useful for developing targeted optimisation strategies for individual stocks, but also for demonstrating the limitations of continuity improvements with regard to promoting species.
Biological control tests are used to determine the effectiveness of fishways in the migratory route of individual fish stocks, to compare them in terms of usage intensity of migrating fish and to identify their potential for improvement.

4.11.1 Work steps

Where new fishways are constructed it may be necessary to define a concept for the biological surveys aligned to local boundary conditions (e.g. type of fishway, type of water body, fish stock) in consultation and cooperation with the BfG.
The federal state authorities must be involved accordingly. The TdV is responsible for conducting the surveys and as a rule outsources this task to experts.

4.11.2 Technical requirements

Currently there are different proposals regarding the methods to be applied in biological tests (Ebel 2006; DWA 2006, 2014). However, especially regarding their application to the conditions of large German federal waterways they are still subject to some limitations. It is therefore advisable to consult experts and cooperate with the BfG, where appropriate, and consider the recommendations in the current literature when developing a concept for the required biological control tests.

Especially fish counters or traps are suitable methods for surveillance of fish passing through fishways. In addition, telemetry can be used to track movements over a larger area and sonar cameras to obtain data on movement patterns in the tailwater and fishway entrance areas. The movements within fishways can be tracked with transponders. The above test methods and resulting (construction-related) requirements for fishways are described in more detail in Annex 6.

4.11.3 Involvement of the BfG/BAW

Biological tests – like the hydraulic/technical assessment of effectiveness – are usually a mandatory part of planning or the provisions of planning approval procedures relating to the construction of fishways. Close cooperation with the BfG and, where appropriate, with other stakeholders is required when decisions are made on the need for such tests, the way they are conducted and their scope.

4.12 Operation and maintenance

As is the case with all structures and facilities owned by the WSV, the operation of fishways must comply with safety and functional requirements. This is due to statutory provisions (WFD, Water Resources Management Act (WHG) and Federal Waterways Act (WaStrG)) on the one hand, and the considerable financial and human resources needed for the construction of the facilities on the other. See Federal Ministry of Transport, Building and Urban Development (BMVBS, 2012b as amended) for the legal context. The structural inspection processes pursuant to administrative regulation VV-WSV 1401 and the operating instructions under the Germany Occupational Health and Safety Act must be complied with.

Since the adequate maintenance of fishways presents a new challenge for many waterways maintenance offices and their staff, the associated tasks and requirements must be outlined in detail. Where appropriate, maintenance work may be outsourced.

As a rule, fishways must operate throughout the year and this means they are required to function for the discharge range between Q_{30} and Q_{330}.

A maintenance concept and an operating instruction based on the former must be set up for each fishway at the stage of preparing the budgetary framework and execution document (see Chapter 4.5). The following aspects must be taken into consideration:

- Competent bodies/persons responsible
- The affected parts of the structure (the fishway itself, gates/valves, etc. including the measuring and control systems, control devices, tools, shut-off devices, protection against predators, if necessary)
- Maintenance intervals, periods and scopes - depending on events, when appropriate (e.g. after floods, during periods of ice), visual inspection of hydraulic conditions, measurement intervals
- Instructions for the removal of floating debris/depositions and for drainage and cleaning of the fishway
- Occupational safety measures covering all tasks involved (railings, fall protection, anchors, personal safety equipment if required): To safeguard occupational safety, safe access to all areas of the facility must be ensured to enable maintenance activities and functional controls.
- Requirements regarding the control of the individual components of the fishway as a function of different boundary conditions (management as a function of discharge, management in the event of ongoing maintenance work at the fishway or the auxiliary water turbine or in the event of failure of individual components)

- Reporting duties, exchange of information/ communication with stakeholders (power plant operators, federal state authorities and third parties, where appropriate)
- Duty of the "fishway observer"[9] to report extraordinary events (e.g. recurrent malfunctions, accumulation of large numbers of fish, etc.) to the competent maintenance office or WSA
- Fishing regulations, where appropriate

All necessary planning documents indicating the planned status specified for the structure must be added to the operating instruction.

In consultation with the competent state authorities and fishing associations, zones closed to fishing throughout the year must be established in the headwater and tailwater of the fishway.

The operation and maintenance schedule must be determined in cooperation with the specialised agencies of the federal states accounting for the main migration periods of fish and providing for increased inspections and maintenance work during these periods if required. Drainage of the fishway in these periods must be avoided. Relevant information in this context is provided in the Guideline for environmental aspects relevant for the maintenance of Germany's federal waterways ("Leitfaden Umweltbelange bei der Unterhaltung von Bundeswasserstraßen").

Where tasks such as catching fish for control purposes are assigned to third parties they must be informed about the requirements for the safe and continuous operation of the fishway (no unauthorised changes) and pertinent occupational safety regulations. Instructions must be in writing.

It may be necessary to adjust maintenance intervals at a later stage if the operation of the fishway so requires (for instance due to special seasonal conditions, floods, increased levels of log jams, clogging or sedimentation).

4.12.1 Specific operation and maintenance issues

The following problems were observed at existing fishways on German federal waterways and call for increased attention during inspections and maintenance and may require structural adaptations under certain circumstances:

- **Log jams due to floating debris and river flotsam, especially in the upper part of the fishway:** Especially in front of the entrance and in the areas between pools (in the

[9] Similar to the "gauge observer"

case of pool-type fishways) this can significantly impair the effectiveness of fishways. The clogging up of channels or vertical slots causes water in the upstream area to accumulate, thereby increasing flow rates and head losses. It is therefore essential to ensure easy access to the fishway, including for (heavy) equipment for the removal of river flotsam. Experience shows that scum boards provide more efficient protection from waterborne debris than debris booms. Trash racks or other devices for preventing blockage with debris must be easy to clean and enable automatic cleaning; an automatic deflection of floating debris is recommended.

- **Insufficient accessibility of different structural elements and parts of the fishway** (especially structural elements in pipes, culverts, gates, etc.). Access for maintenance work must be ensured and sufficiently dimensioned (e.g. access routes, accessibility for staff wearing protective clothing and, if required, for heavy equipment). Depending on the maintenance process, adequate space must be provided for the installation of mobile or fixed cranes and their slewing range.
- **Damage/manipulations and/or changes affecting the planned status of components** (walls, bottom, joints, substrate of the river bed, perturbation boulders, slots/notches, friction blocks, etc.) or the structure as a whole. All operators must be instructed to refrain from undertaking any unauthorised changes regarding the structure. Where maintenance staff point out potential optimisation measures these should be taken up by the facility operator and considered, in consultation with the planning body or the BfG/BAW, where appropriate.
- **Depositions of fines** Where sedimentation is to be expected (for instance in low turbulence areas or with a large degree of suspended particulate matter, etc.) it must be assessed whether they can be countered by avoiding corners and niches in the design (e.g. with vertical slot passes) or by structured profiles (e.g. rock ramp fishways). This has been observed in tidal areas in particular. Electrical and water connections must be provided, if necessary.
- **Failure of control elements,** e.g. gate controls, etc. Automatic malfunction detectors may be installed and control data stored via data transmission, if required.
- **Derogations from agreements** on the operation of turbines, downstream passage facilities and/or weirs (failure of auxiliary water turbines etc.)

5 Procedure for downstream migration of fish/fish protection

Besides upstream migration, effective ecological continuity also includes downstream migration of fish. Many fish actively travel down rivers and brooks to reach important feeding grounds or winter habitats in the sea or floodplains, for example. Moreover, weak swimmers or juvenile fish in particular are also subject to passive drifting, for example due to floods.

When analysing downstream migration it is important to consider all the migratory corridors which are relevant for the specific site. According to the current state of knowledge, fish follow the current and use the complete water column - with some differences according to species - for their downstream migration. For the purpose of a distribution of the discharge the initial general assumption therefore is that downstream migration is proportional to the discharge distribution (Ebel, 2013). In addition to the rate of flow, flow characteristics and morphological properties of the water body, for example, have an influence on the choice of the migratory corridor. More research in this field is needed, especially on potamodromous species.

At barrages without hydropower generation facilities, fish pass over/under the weir and only suffer injury under certain conditions. However, at sites with hydropower plants damage to descending fish must be expected with the damage rates differing across power plant types and fish species. Additional protection measures and migration facilities are therefore required at such sites. For instance, facilities for safe downstream migration (e.g. bypass pipes) may be combined with protective elements (e.g. screen systems) to prevent or reduce the number of fish entering the turbines of the power plant. It should be noted that a fishway designed for upstream migration generally fails to enable downstream passage effectively. This is due, amongst other factors, to the location of the upstream exit of the fishway which must be at a relatively long distance from the transverse structure to ensure upstream passage. As a result it is difficult or impossible to locate for fish that intend to move downstream and swim in the direction of the transverse structure.

5.1 Work steps

1. Identify relevant migratory corridors
2. Assess relevant migratory corridors for potential negative impacts on downstream migration
3. Identify necessary measures
4. Examine need for action by the WSV

5.2 Technical information required

1. **Identify migratory corridors at the site that are relevant for downstream migration:** Given the current state of knowledge the identification of relevant migratory corridors at a barrage can only amount to a first general assessment based on the large-scale distribution of discharge. The BfG is presently working on identifying suitable methods for quantifying large-scale discharge distributions over separate channels of water. Other factors such as the hydromorphology of the body of water, location of the discharge channels and hydraulic conditions can also affect the function as migratory corridor.

   A method developed at the BAW (BAW, 2013b) can be used to analyse the discharge distributions of the different damming structures (weir, power plant, lock, etc.) located in the same channel. The estimated discharge quantity can be assumed to be proportional to the probability of fish passing downstream over the damming structure under study. This provides initial insights into the potential significance of the different migratory routes. To determine the relevance of the individual corridors for downstream migration the data obtained must be completed with further information (see above).

2. **Assess relevant migratory corridors for potential negative impacts on downstream migration:** In a second step, the potential negative impact on the fish must be estimated, differentiated according to the type of structure:
   - The potential damage due to hydropower generation is at first estimated based on the turbine data, degree of utilisation and protection system currently in place. Relevant information is available from extensive studies (cf. e.g. Ebel, 2013). Estimating the damage is the responsibility of the operator of the power plant.
   - No damage need be expected at overshot weir gates with heads of less than 13 m (this applies to all weirs of this type on Germany's federal waterways) and a sufficient water cushion in the tailwater (cf. DWA, 2005).
   - At undershot gates, however, high velocity gradients, shear forces or sudden changes of pressure can occur.
   - Most of the undershot weir types have flaps to permit fine control: when the flaps are opened, the fish can first use the free falling water for its descend. The weir gates are only lifted when the hydraulic capacity of the flap gates is reached. Therefore, when water flows under the gates, the tailwater level will already have risen due to the higher discharge, resulting in smaller heads and pressure changes and therefore causing less damage. Hence, potentially higher mortalities are confined to a small part of the discharge range.
   - Friction blocks in stilling basins can cause injury to fish because they increase the damaging potential of various factors (direct physical impact, shear stress, pressure variations, energy dissipation rate and turbulence).

While conventional stilling basins (without friction blocks) have fewer physical impacts on descending fish, there is less scope for reducing the energy dissipation rate in the stilling basin. In line with DIN 19700 the design of stilling basins must ensure that the high kinetic energy of the water is reduced to a level that can be tolerated by the river bed connected to the basin. Any failure of a damming structure must be excluded at a sufficient level of confidence. Some damaging effects on the fish result from the hydraulic jump itself - a natural phenomenon, the sudden transition from subcritical to supercritical flow - and cannot be influenced by the design of the stilling basin.

- Injuries or behavioural changes can increase the fish's vulnerability to disease and exposition to predators. This is also the case when the fish do not descend via the weir.
- Downstream passage via locks has not been sufficiently investigated so far. Therefore, their importance can only be roughly estimated based on the quantity of water passing through the lock. However, technical aspects of the lock filling process need to be taken into consideration.

3. **Identify necessary measures:** Following the method outlined above it is possible to obtain a very rough estimate for a specific site regarding the potential significance of the individual migratory corridors and possible impacts on the descending fish. If downstream fish migration in the relevant migratory corridors is adversely affected or if such impacts are to be expected, suitable measures must be identified. These depend both on the type of transverse structure and the specific conditions of construction and hydrological side constraints. To identify the measures required, more detailed investigations are required.

4. **Need for action by the WSV:** The need for action by the WSV is determined by technical and legal considerations. According to the BMVI the polluter-pays principle is generally applicable to fish protection and fish migration facilities on Germany's federal waterways. Responsibility for fish protection and migration facilities at sites with hydropower plants lies with the WSV if it is the operator of the power plant or if the passage over the weir has a high risk of injury to fish. Where there are no power plants at damming structures on German federal waterways erected or operated by the WSV, downstream fish passage falls under the responsibility of the WSV.

   If the WSV is responsible for downstream migration and if by performing the work steps 1 to 3 a need for action is identified, appropriate solutions must be developed in a next step.

   Overshot weir gates are generally beneficial to descending fish, provided that there is a sufficient water cushion in the tailwater. At undershot gates injuries can occur due to collisions, shear forces or sudden changes of pressure. Weir gates should therefore have sufficiently wide openings in order to minimise the risk of injury to fish (Ebel, 2013). The

need for weir rebuilding measures to reduce the injury rate among descending fish depends on the situation in each case. Generally, possible measures include modifications of weir gates and stilling basins or changes of the weir programme control.

When planning the construction of a new weir and/or weir replacement measures, conditions for downstream migration via the weir must be optimised.

Where the operator of an existing hydropower plant is responsible for downstream migration in the area of the power plant, this will be accounted for by the WSV in the planning and construction of the fishway. If the fishway is built at the bank near the power plant, less space will be available for providing a downstream passage facility. It is therefore the duty of the TdV responsible for the structure to inform the power plant operator of current planning activities and opportunities to contribute to the planning.

5.3 Involvement of the BfG/BAW

Steps 1 to 3 in particular, which are discussed under the required technical information section, and the concrete planning of actions require the involvement of the BfG/BAW. However, it should be first examined whether the WSV is responsible for the sites in question.

6 Glossary

Term	Definition
Abundance	In the context of ecology, abundance refers to the number of individuals of a species per area unit or volume unit.
ADCP	Acoustic Doppler Current Profiler - a device used to make ultrasonic measurements of velocity, such as measurements in water bodies. The device uses four beams which are oriented at an angle and which provide velocity values for the measurement directions across a spectrum of heights. As rule, the results obtained from each measurement volume are averaged into a single value.
ADV	Acoustic Doppler Velocimeter - a device used to make ultrasonic measurements of flow velocities. ADVs are smaller than ADCPs and are used both for field and laboratory measurements. Contrary to ADCPs the measuring beams concentrate on a single spot (i.e. a very small measurement volume), thus immediately delivering results for this particular spot.
Assessment of effectiveness	Assessments of effectiveness are conducted to verify whether or to what extent a fishway attains the projected degree of effectiveness. A distinction can be made between hydraulic/technical assessments of effectiveness (for instance, the measuring of flow velocities) and biological tests assessing attraction and passability.
Attraction, large-scale/small-scale	Whether fish find the entrance to a fishway depends on the structure's overall location in the water body and on their ability to perceive the entrance when close to the structure. Attraction is differentiated according to the boundary conditions. – For large-scale attraction these are: the location of the fishway in the (main) migratory route of the fish which are expected to ascend to the facility (e.g. in relation to discharge distributions or the banks) – For smale-scale attraction: siting of the entrances in relation to the transverse structure, the adjoining bank, water depth, etc. as well as a perceptible attraction flow from the fishway into the main channel

Attraction flow	The attraction flow is used to create a continuous corridor for migration between the tailwater of a damming structure and the fishway. Fish that want to ascend a river need a perceptible flow in the area where, due to their orientation, they meet with a transverse structure and where they are naturally looking for routes further upstream. From this point the attraction flow leads them into the fishway, which means that the effectiveness of the attraction flow is confined to the area of the fishway entrance. (DWA-M 509)
Auxiliary attraction flow, auxiliary water, auxiliary water flow, auxiliary water supply	The water injected into the fishway in addition to the operating flow. Auxiliary water is supplied for the purpose of – maintaining the appropriate attraction flow in the tailwater and thus the fish's ability to find the entrances to the fishway and/or – ensuring passability (and/or velocity threshold for rheotactic behaviour in the lower pools with increasing downstream water level.
Auxiliary water conduit	Conduit for directing the auxiliary water, generally from the headwater, to the auxiliary water basin.
Bypass	In most cases a pipe- or channel-like structure which enables fish that want to descend to bypass hydropower plants and rake facilities.
Bypass channel	This structure enables fish to pass widely around a transverse structure but has no impact on the water management function of the damming structure. There are different types, from facilities very much like natural flowing water bodies to wooden or concrete channels with a highly geometric structure. In most bypass channels there are reaches which are built as rock ramps. In some cases bypass channels are combined with other fishway designs. (According to DWA-M 509)
Concept	Internal WSV definition: Prior to any work undertaken on budgetary frameworks, a concept serves as a basis for a general decision on the need for construction and further planning. It defines the planning principles, possible realization options, the option which may be finally chosen and the side constraints (schedules/deadlines, organizational effort and human resources required, estimation of budgetary needs, type and extent of tenders, etc.) (Administrative regulation VV-WSV 2107).

Connection to the bottom	Connection of the bottom of the water body to the bottom of the fishway (in the entrance and exit areas) through rock fill consisting of bottom substrate with a maximum inclination of 1:2.
Continuity, ecological	Here: Linear continuity enabling fish, lampreys and macrobenthic organisms to migrate along a flowing body of water.
Dead-end effect	During their upstream migration fish follow the direction of the flow until they meet an obstacle at which point they normally try to seek a path around the obstruction. If they fail to find another path upstream or any other route, this is a migratory dead end.
Downstream fishway/ downstream fish migration facility	A facility for enabling fish to travel downstream (bypassing hydropower plants and rake facilities, if necessary).
Effectiveness	As a rule, a fishway is effective if it attracts all the fish species which are relevant for the dimensioning of the fishway and enables them to continue their journey. It should also serve as a habitat for and allow macrobenthic organisms to pass through. Further definitions are required, for instance regarding the proportion of fish that want to migrate upstream and should be attracted to the fishway within a given period for the structure to be fully effective. However, such definitions have not yet been elaborated and agreed in the context of restoration of ecological continuity according to the WFD.
Energy dissipation	The power/energy input into a pool can be perceived as a turbulence of the flow. In fishways, a complete dissipation (conversion) of the kinetic energy resulting from the reduction in heads is aimed at in order to prevent a continuous increase in flow velocity and resulting hydraulic overload in the upstream pools. Highly turbulent flow patterns also make it difficult for fish to orientate themselves and force them to use more energy when travelling against the current. It is therefore essential to minimise turbulence as much as possible. (According to DWA-M 509)
Entrance	Downstream connection of a fishway to the main channel. The entrance must be found and passed by the fish to enter the facility.
Exit, fishway exit	Upstream end of a fishway which determines the operating flow of the fishway and through which the ascending fish leave the pass to reach the headwater.

Fish lift	A mechanical transport facility by which fish are transported in tanks from the tailwater to the headwater. (DWA-M 509)
Fish region, riverine zone	In fisheries science, flowing water bodies in the temperate zones of Europe are traditionally divided into fish regions, each of which is characterised by a predominant fish species and a typical range of associated species. The riverine zone concept, on the other hand, can be applied to all climate zones and continents. It is based on abiotic factors and distinguishes brooks (rhithral rivers) from rivers (potamal rivers), dividing the two into three additional zones respectively (ILLIES, 1961). For central European water bodies, however, this nomenclature is synonymous with the classification according to fish regions.
Fish lock	In a fish lock the fish swim into the holding chamber at downstream water level. The chamber is then filled until the water level equilibrates with the upstream level and the fish can leave the chamber (DWA-M 509).
Fish protection	Any installations and measures implemented to protect fish against potential injuries during their downstream migration, caused, for example, by hydropower plants.
Gate / vertical lift gate	Device to control the inflow/outflow of water through openings. (DIN 4054)
Generally accepted technical standards / generally accepted rules of technology	Rules and standards which are proven in practice and represent concepts and ideas generally accepted by experts in the relevant discipline. (refer also to “State of the art”)
Germany's federal waterways	The inland and coastal waterways of the Federal Republic of Germany which are intended for transportation of persons and goods (pursuant to administrative regulation VV-WSV 11 02).
Good ecological status	The status of a surface water body which is at least “good” according to the classification provided in Annex V of the WFD (EU WFD). The quality components of a good ecological status are defined in the German Ordinance on the Protection of Surface Waters (Oberflächengewässerverordnung, OGewV).

Good ecological potential	The desired status of a heavily modified or an artificial body of water, derived from the relevant provisions of Annex V of the WFD or from the German OGewV.
HDX	Half Duplex Transponder: a transponder implanted in the fish. It is passive (i.e. it does not contain an internal energy source) and obtains power inductively from an antenna when the fish pass through the electromagnetic field produced by the antenna.
Hydraulic/technical assessment of effectiveness	Here: Assessment of effectiveness through verification of hydraulic parameters (flow velocities, heads, etc.)
Limit	A limit describes the conditions which are just about tolerable from the perspective of fish ecology. It is therefore essential to ensure that limits are respected in all fishways across the overall migratory corridor. This means that values must neither exceed nor fall below the maximum or minimum limit respectively. Limit values may only acceptably be reached in a few instances, for example under unfavourable operating conditions, etc. When building and operating fishways, minor deviations from the specified geometric and hydraulic conditions cannot be avoided. To account for this in planning and construction, so-called safety factors must be added to all limits.
Macrobenthic organisms	All invertebrates living on or in the bottom of bodies of water which are visible to the eye (> 1 mm).
Migratory corridor	The migratory corridor at a transverse structure is a reach of the waterway which is not interrupted by obstructions and which fish are able to find and pass through. It extends over the entire water column, from the bottom to the water surface, and connects the tailwater and headwater of a migration obstacle. In the migratory corridor all geometric and hydraulic limits at discharges ranging from Q_{30} to Q_{330} are respected. (According to DWA-M 509)

Monitoring	Scheduled (regular), targeted survey, evaluation, assessment and documentation of changes of the status of a water body or a specific reach. Monitoring is based on previously selected criteria and relates to a defined standard or reference. In this Guideline, the term monitoring refers to the regular examinations carried out by the federal states to assess whether the targets stipulated by the WFD, the Habitats Directive and the European Eel Regulation are met. Thus a distinction is made between monitoring on the one hand and verification of the functioning and effectiveness of individual fishways (assessment of effectiveness) on the other.
Operating flow	The water flowing through the slot and the entire length of the structure contingent on the slot width and the upstream and downstream water levels.
Passability	Passability refers to the unhindered passage of fish and benthic invertebrates from the entrance to the exit of a fishway. This should take place without any delay if possible.
Pool-type fishways	Fishways which consist of a series of pools. Due to the layout of the pools, the total head drop is divided into many small water level differences which the fish are able to negotiate.
Quality assurance	All scheduled and systematic activities realised within the system and documented to create confidence that the unit in question will meet the quality requirements. Quality assurance is the sum of all measures to ensure consistent product quality. (DIN EN ISO 8402, 1995-08, Section 3.5) In this Guideline, quality assurance is understood to comprise all measures and processes which ensure sufficient quality of the future fishway during the planning, construction and control phases.
Resting pool	Special pool where the flow is considerably less than in the other areas of the fishway and where fish can rest during their migration. According to DWA-M 509 resting pools are not necessary if the maximum permitted flow velocities in relation to the length of the fishway are not exceeded.

Rheotaxis	Rheotaxis is the orientation of an organism in response to a current. The velocity threshold for rheotactic behaviour consequently is the velocity at which fish change direction, not randomly but orienting their long axis in parallel with the direction of flow to swim against the current. According to DWA-M 509, depending on the species and stage of development the velocity threshold for rheotactic behaviour is in the range of 0.1 - > 0.3 m/s.
Rock ramp fishway	Fish passable structures, bypass channels or channel-type fishways where either the entire channel or only the bottom has a very rough surface. Rock ramp fishways can be designed without friction blocks or with perturbation boulders or pool structures. (DWA-M 509)
Rock ramp with pool structures	A nature-like design of the vertical slot pass. Between the pools there are sills of rocks which are spaced at different intervals. (DWA-M 509)
Safety factor	Coefficient which, by multiplication with the limit, yields the hydraulic or geometric design value of the fishway. The safety factor ensures that limits are respected even where there are minor discrepancies between structural or operational elements and the fishway plans or when such nonconformities cannot be avoided or only at unreasonable expense.
Sonar	Sonar is a method that uses sound waves and their reflections to distinguish and detect objects under water. Sonar cameras can, for example, be used to observe the behaviour of fish near transverse structures.
State of the art	The latest technological standards as defined in this Act mean the stage of development reached in progressive procedures, facilities and/or ways of operation that appear to ensure the practical suitability of a measure to restrict emissions into the air, water or the soil, to guarantee installation safety, to guarantee environmentally friendly waste disposal or otherwise to avoid or reduce effects on the environment in order to achieve a generally high degree of protection for the environment as a whole. (Section 3 WHG) In contrast to the benchmark of (generally accepted) technical standards, the state of the art is not based on many years of testing.

Telemetry	Telemetry refers to the surgically implanting of animals (e.g. fish) with battery-operated acoustic or radio transmitters. After release of the tagged animals into the water body of their origin the individual signals sent out by the transmitters are tracked by means of hydrophones or antennas. The tagged fish can thus be located and their migration route followed. (DWA, 2005)
Turning pool	Special pool in a pool-type fishway where the direction is changed.
Vertical slot pass	The vertical slot pass is a particular type of pool pass where the partition cross-walls have vertical slots extending from the top to the bottom of the cross-walls. (DWA-M 509)

The Code of Practice DWA-M 509 provides more definitions of terms generally used in the context of fishways (esp. Chapter 2.1 and Annex A).

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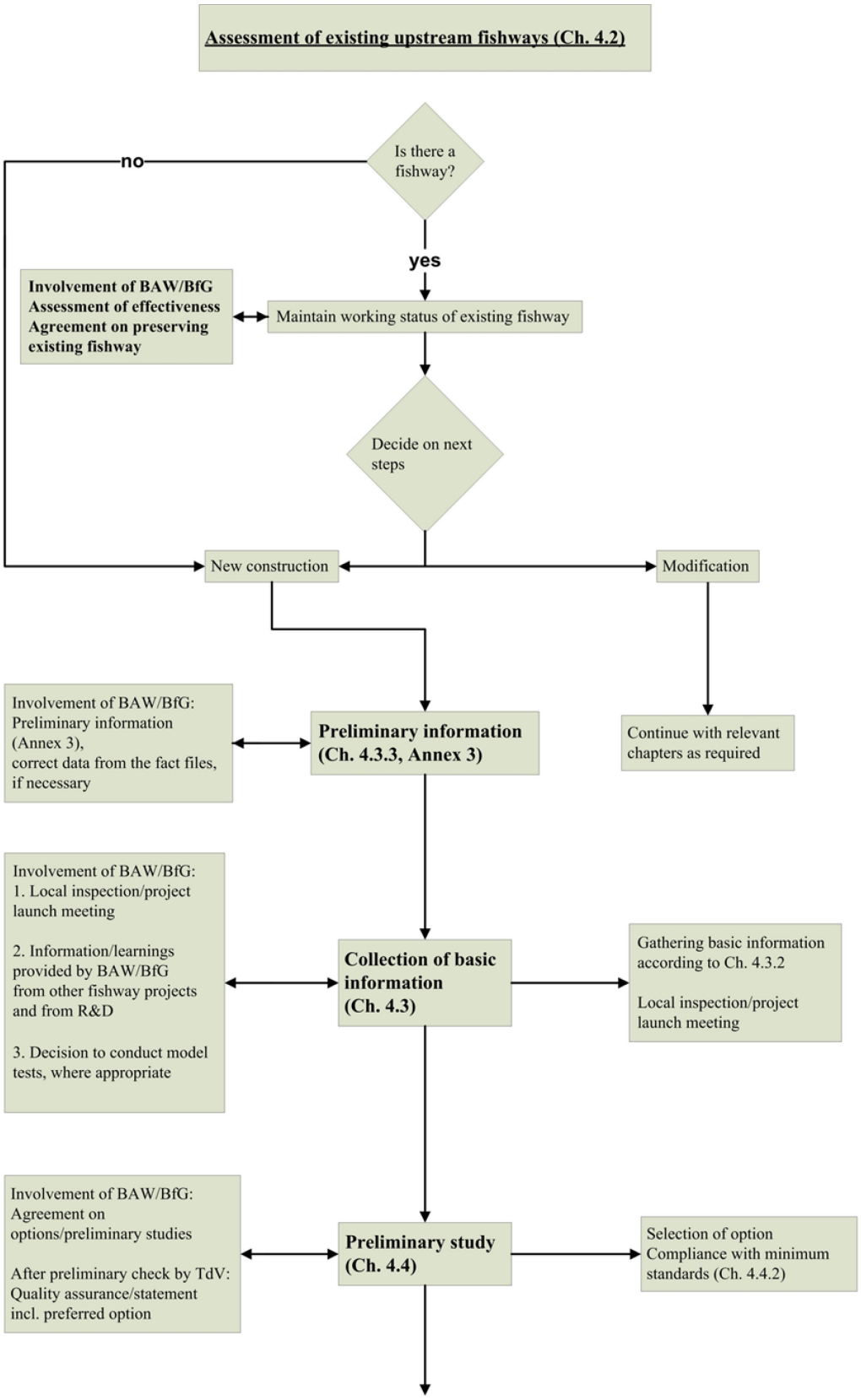
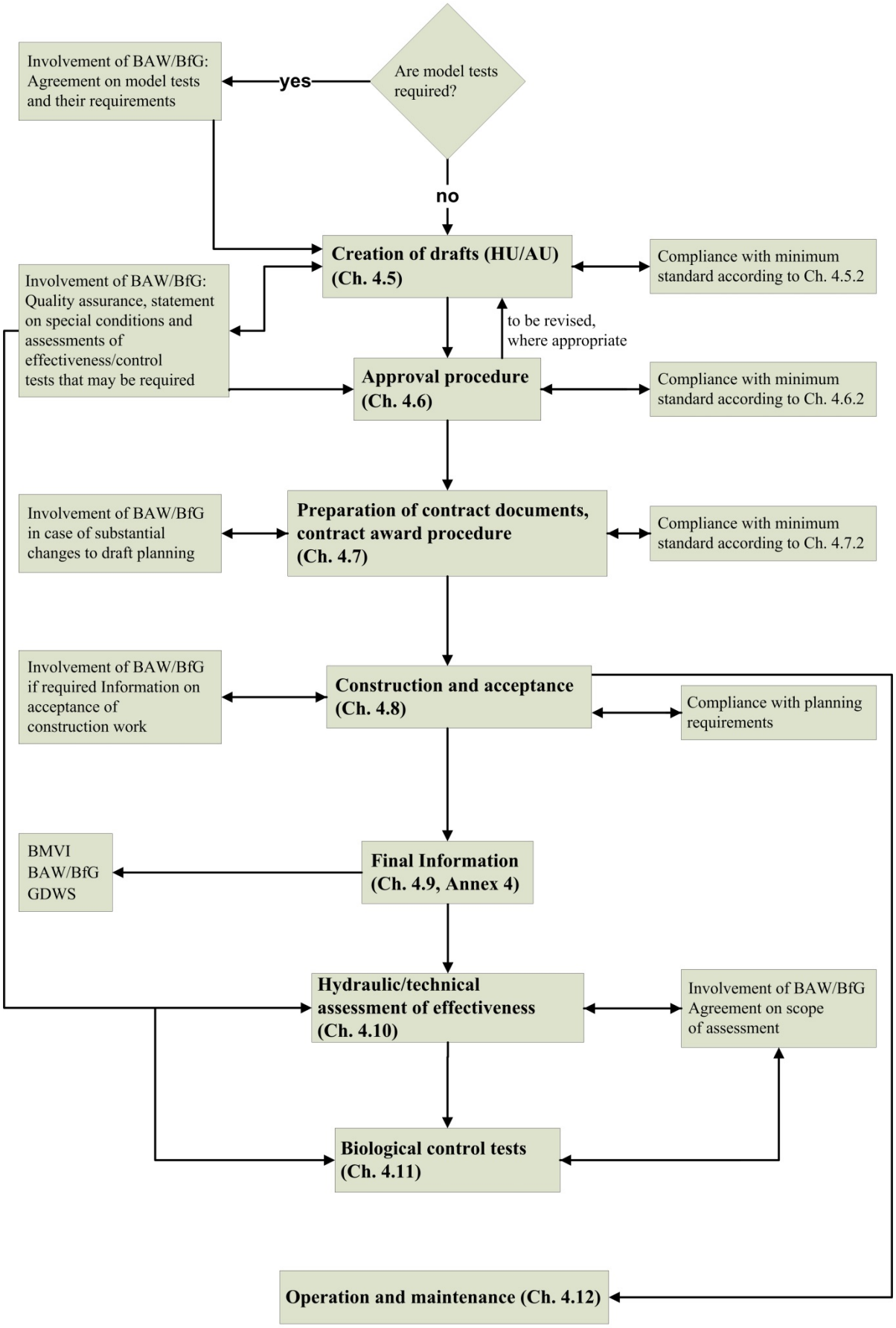
8 Annexes

Annex 1: Flow Chart for Chapter 4




Are model tests required?
yes
Involvement of BAW/BfG: Agreement on model tests and their requirements
no
Creation of drafts (HU/AU) (Ch. 4.5)
Compliance with minimum standard according to Ch. 4.5.2
Involvement of BAW/BfG: Quality assurance, statement on special conditions and assessments of effectiveness/control tests that may be required
to be revised, where appropriate
Approval procedure (Ch. 4.6)
Compliance with minimum standard according to Ch. 4.6.2
Involvement of BAW/BfG in case of substantial changes to draft planning
Preparation of contract documents, contract award procedure (Ch. 4.7)
Compliance with minimum standard according to Ch. 4.7.2
Involvement of BAW/BfG if required Information on acceptance of construction work
Construction and acceptance (Ch. 4.8)
Compliance with planning requirements
BMVI
BAW/BfG
GDWS
Final Information (Ch. 4.9, Annex 4)
Hydraulic/technical assessment of effectiveness (Ch. 4.10)
Involvement of BAW/BfG Agreement on scope of assessment
Biological control tests (Ch. 4.11)
Operation and maintenance (Ch. 4.12)

Annex 2: Side constraints and influencing parameters to be taken into account in the planning and construction of fishways

- Riverine zone
- Range of relevant fish species
- Discharge distribution across rivers branches (Q_{30} to Q_{330})
- Upstream and downstream water levels (W_{30} to W_{330})
- MQ, Q_{30}, Q_{330}, HHQ
- With/without hydropower plant
- Number of turbines, type of turbines, rotation direction
- Design discharge
- Turbine control
- Configuration of draft tube
- Information about the body of the weir (number of weir fields, gates, weir control)
- Driftwood and debris flow deposits, sediments
- Structures in place
- Space available/accessibility/safety rules
- Ground conditions
- Ownership situation
- Uses
- Contracts
- Species and nature conservation conditions, HD areas, nature/landscape protection areas biotopes, water protection areas

Annex 3: Preliminary information on fishways

The purpose of this document is to provide information to the WSA, GDWS, BfG and BAW when fishways are actually planned or inspected. The preliminary information form must be completed for each facility.

How to fill out the form:

- This document contains the data which are needed to provide sufficient information to the BfG and the BAW.
- Cross out any non-applicable information.
- The document also contains the data for each barrage which are listed in the fact files (*fields). These must be verified before submission of the document. Any uncertainties/changes must be highlighted.
- The preliminary information document must be completed to the best possible degree before it is sent. Depending on how short the timeline is (e.g. deadlines) the information should be submitted to the BfG and BAW no later than four weeks prior to a joint site inspection.
  The document will then be available as a template on the intranet. If any changes are requested please contact
  durchgaengigkeit@bafg.de and durchgaengigkeit@baw.de.
- All data are verified and, if necessary, completed by the BfG and BAW. There are also some issues which can only be solved during the planning processes.

Federal Waterways and Shipping Administration

Preliminary information on fishways

Status of this preliminary information document:
Change history (previous versions):

Address of the organizational unit in charge (usually the WSA, construction office or joint body):

Contact person, e-mail and phone:

Alternative project executing agency (TdV), if applicable:

Important data (verify data from the fact files):

1. *Administrative information:*

	Data from fact files	Changes as compared to the data from the fact files
*Designation of the barrage:		
*German federal waterway:		
*Km:		
*River basin district:		
*GDWS branch:		
*Federal state:		
*WSA:		
Branch office with address:		
Municipality:		

2. *Required specialized information:*

	Data from fact files	Changes as compared to the data from the fact files
*Assessment of level of urgency by the BfG:		
*Assessment of effectiveness by the BfG:		

Documents on effectiveness (measurements, investigations by water authorities, etc.), if available:		
Existing documents:		
Remarks:		

3. Data from management plans:

	Data from fact files	Changes as compared to the data from the fact files
*WK number (water body):		
*Fish ecological status:		
*Type of water body		
*Good ecological status/potential:		
*Priority water bodies:		
HMBW/AWB:		
*Target species:		
*Related management plan:		
Contact person for management plan in the federal state:		

4. Hydrologic characteristics:

	Data from fact files	Changes as compared to the data from the fact files
*Upstream water level (from to, where appropriate):		
*Downstream water level (from to, where appropriate):		
*Discharges MQ/Q_{30}/Q_{330}: Gauge:		
Distribution of discharge over the different facilities/components, separately for MQ/ Q_{30}/Q_{330}:		
Are there several channels of water or is there a diversion channel?		
Existing flow measurements:		

5. Overview of barrage and structures:

	Data from fact files	Changes as compared to the data from the fact files
*Types of structures/ geometry:		
*Position:		
*Type of transverse structure/ construction year:		
*Type(s) of weir(s)/ construction year:		
*Lock(s)/ construction year:		
Is there a boat lock/channel?		
*Hydropower plant/ construction year:		
Operator of hydropower plant, address, contact person:		
*Number of turbines/ types of turbines/ construction year/ rotation direction:		
*Design discharge of hydropower plant/turbines:		
*Is there an upstream passage facility for fish?/ construction year:		
Is there a downstream passage facility?/ construction year:		
Relevant Entwurf- HU:		
Relevant Entwurf- AU:		
Titles of existing documents (aerial images, location plans, longitudinal and cross sections), place where they are kept:		
Missing planning documents, if applicable:		

6. Data on the location:

Land situation (as drawing, where appropriate):	
Land use contracts (as drawing, where appropriate):	
Permits and holders of permits (as drawing, where appropriate):	

Contracts/agreements with the respective federal state/authorities for water management/nature conservation:	
Contracts/agreements with the operator of the hydropower plant/electricity supplier:	
Contracts/agreements with the municipality:	
Contracts/agreements with associations (sports, nature conservation, etc.):	
Other stakeholders and their representatives (fishing, protection of monuments, land owners):	
Existing protected areas and species (Habitats Directive, Natura2000, etc.):	

7. *Planned building works:*

8. *Facilities (plans, expert opinions, planning):*

9. *Planned deadlines:*

Date, time	Site	Planned participants

Please send this preliminary information to
Durchgaengigkeit@bafg.de
and
Durchgaengigkeit@baw.de

Sent on:

Distribution list:

By order

Name of person responsible

Annex 4: Final information on fishways

Notice:

- The * fields correspond to the fields specified in the fact files for each barrage.
- Complete the basic data (sections 1 to 3), based on the preliminary information on fishways. Any changes must be noted. Under section 4, specify the fishway which has been realised.
- The purpose of the final information document is to inform the Federal Ministry of Transport and Digital Infrastructure and the GDWS on measures undertaken (fishways). It also serves as a project completion report for the BfG and BAW.

Federal Waterways and Shipping Administration

Final information on fishways

Status of this final information document:
Change history (previous versions):

Address of the organizational unit in charge (usually the WSA, construction office or joint body):

Contact person, e-mail and phone:

Alternative project executing agency, if applicable:

Important data (use data from preliminary information on fishways):

1. *Administrative information*

	Data from preliminary information	Changes as compared to data from preliminary information
*Designation of the barrage:		
*German federal waterway:		
*Km:		
*River basin district:		
*GDWS branch		
*Federal state:		
*WSA:		
Branch office with address:		
Municipality:		

2. *Required specialized information:*

	Data from fact files	Changes as compared to the data from the fact files
*Assessment of level of urgency by the BfG:		
*Assessment of effectiveness by the BfG:		

Existing documents on effectiveness (measurements, investigations by water authorities, etc.):		
Existing documents:		
Remarks:		

3. Data from management plans:

	Data from preliminary information	Changes as compared to data from preliminary information
*WK number (water body):		
*Fish ecological status:		
*Type of water body:		
*Good ecological status/potential:		
*Priority water bodies:		
HWBW/AWB:		
*Target species:		
*Related management plan:		
Contact person for management plan in the federal state:		

4. Hydrologic characteristics:

	Data from preliminary information	Changes as compared to data from preliminary information
*Upstream water level (from to, where appropriate):		
*Downstream water level (from to, where appropriate):		
*Discharges MQ/Q_{30}/Q_{330}: Gauge:		
Distribution of discharge over the different facilities/components, separately for MQ/ Q_{30}/Q_{330}:		
Are there several channels of water or is there a diversion channel?		
Existing flow measurements:		

5. Overview of barrage and structures:

	Data from preliminary information	Changes as compared to data from preliminary information due to construction of new fishway(s)
*Types of structures/ geometry:		
*Position:		
*Type of transverse structure/ construction year:		
*Type(s) of weir(s)/ construction year:		
*Lock(s)/ construction year:		
Is there a boat lock/channel?		
*Hydropower plant/ construction year:		
Operator of hydropower plant, address, contact person:		
*Number of turbines /types of turbines / construction year/ rotation direction:		
*Design discharge of hydropower plant/turbines:		
*Is there an upstream passage facility for fish?/ construction year:		
Is there a downstream passage facility?/ construction year::		
Relevant Entwurf- HU:		
Relevant Entwurf- AU:		
Titles of existing documents (aerial images, location plans, longitudinal and cross sections), place where they are kept:		
Operation and maintenance data		

6. Data on the location:

Land situation (as drawing, where appropriate):	
Land use contracts (as drawing, where appropriate):	

Permits and holders of permits (as drawing, where appropriate):	
Contracts/agreements with the respective federal state/authorities for water management/nature conservation:	
Contracts/agreements with the operator of the hydropower plant/electricity supplier:	
Contracts/agreements with the municipality:	
Contracts/agreements with associations (sports, nature conservation, etc.):	
Other stakeholders and their representatives (fishing, protection of monuments, land owners):	
Existing protected areas and species (Habitats Directive, Natura2000, etc.):	

7. *Information on fishways which are already built and on additional fishways, where appropriate:*

	Data from fact files	Changes as compared to the data from the fact files
*Types of structures/ geometry:		
Existing documents on effectiveness (measurements, investigations by water authorities, etc.):		
Existing documents:		
Remarks:		

8. *Construction work completed (with date of completion):*

9. *Information about status of hydraulic/technical assessments of effectiveness, biological tests, etc.:*

10. Comparison of cost:

Draft total	
Expenditure to date (date when final information document is prepared):	
Unsettled claims:	

11. Remarks, learnings, notices:

Please send this final information to all of the following recipients:
ref-ws14@bmvi.bund.de
ref-ws11@bmvi.bund.de
gdws@wsv.bund.de
Durchgaengigkeit@bafg.de
Durchgaengigkeit@baw.de

Sent on:

Distribution list:

By order
Name of person responsible

Annex 5: Information on determining the required auxiliary water supply

Information on determining the required auxiliary water supply provided by the Federal Waterways Engineering and Research Institute (BAW) and Federal Institute of Hydrology (BfG), last updated 21 July 2014

When dimensioning the entrance opening of a fishway, information is needed on the geometry of the entrance, the configuration and design of the auxiliary water supply, the flow velocity at the exit cross section and the total discharge (discharge fishway plus auxiliary water supply). While the minimum requirements for the geometric design of a fishway entrance are defined for the current state of the art in the applicable version of DWA-M 509 (2014), there is more scope for discretion with respect to the required flow velocity and discharge. In this context it is the long-term objective of BfG and BAW to achieve a higher level of detail of the design rules than has been provided in the literature so far. To reach this objective, the research results of both institutes and of third parties serve as a continuous update for the further development of the current state of the art. Although this process is still in its beginnings, the studies conducted at the fishway on the river Neckar in Lauffen support the following initial conclusions. It must be emphasised that, strictly speaking, these conclusions only apply to the boundary conditions prevailing in Lauffen on the River Neckar (transverse structure with hydropower plant, etc.). The greater the difference between the boundary conditions of different sites, the more it is advisable to review the recommendations provided below for their suitability at a particular site. The planning for the Lauffen fishway, for example, provides for an entrance immediately at the transverse structure. The attraction flow of this entrance interacts with the water quantity resulting from additional fishway entrances further downstream. Current studies also discuss the auxiliary water supply required for the entrances sited at a distance from the transverse structure. For the time being, the amount of water required for an additional entrance further downstream must therefore be decided in each individual case.

Accounting for these restrictions, the BfG and BAW currently recommend the following approach for the design of the auxiliary water supply:

- The dimensions of the entrance cross section must be such that the total discharge in the fishway (for design case Q_{330}) is 5% of the design discharge of the turbine near the fishway. The flow velocity in the entrance cross section must correspond to the design velocity specified for slots in a fishway as provided by DWA-M 509. In this context the dimensions of the entrance cross section must always be examined to determine whether they fall below the minimum widths defined for the fishways based on the fish ecological requirements. This could be relevant in particular where the entrance cross section is

very deep. In this case, the geometric requirements must be weighed up against the hydraulic requirements (flow velocity and discharge).

- The design flow velocity of the fishway also determines the flow velocity in the entrance cross section for the other relevant discharge conditions. Based on the previously defined entrance geometry (width of the opening) it is possible to determine the area subject to the flow as a function of tailwater level and thus the corresponding total discharge of the fishway for the respective design event.
- It is advisable to give priority to the operation of the turbine in the vicinity of the fishway to improve attraction.
- It is generally possible that the required total discharge may increase or decrease as the state of the art evolves. In the event of an increase in the required total discharge there is the risk of subsequent adaptations of the fishway leading to significant additional costs. It is therefore recommended that planners examine whether a flexible design of the structural elements needed for the auxiliary water supply (pipe, control elements, stilling basin, entrance geometry) or an increase in the amount of auxiliary water without incurring considerable additional costs is possible. An evaluation must be undertaken in each case to determine the extent to which it may be useful to anticipate a higher total discharge value in the design of the auxiliary water supply and to include the respective components in the present construction (for instance installing a larger pipe which would entail only minor additional costs).
- The auxiliary water can be generally used for power generation. Plant operators must prevent any injury to fish, however, and ensure that the fishway with the auxiliary water supply continue to function even in the event of a turbine failure.
- Measures must always be taken to protect the inlet of the auxiliary water conduit against debris and to prevent fish or other organisms entering the conduit.

Annex 6: Requirements for the surveillance of fish in fishways

(BfG, last updated on 28/07/2014)

This annex provides an overview of the requirements regarding the methods currently applied by the BfG to perform biological quality controls in fishways. The specific tests to be carried out in the respective fishway are defined by the BfG according to Chapter 4.11 in consultation with the TdV and, where appropriate, the state authorities. Which method is suitable is contingent on the respective structure.

General requirements

At each facility, the mandatory occupational safety measures must be considered at the planning stage itself.

Live parts must be adequately protected against precipitation, floods, etc. An easy-to-reach 220 VAC external socket outlet must always be provided to allow the temporary connection of additional equipment. The location of the socket(s) depends on local conditions and must be determined in the planning stage in consultation with the BfG and BAW.

All equipment must be fixed and protected against theft and vandalism.

When planning the tests it must be assessed whether and to what extent a notification of and/or approval by the fishing and animal protection agencies may be necessary. As a rule, owners of fishing rights must be informed about the tests.

Requirements for the use of fish traps

Either fyke nets or box traps are used.

- To monitor the number of ascending fish, a fyke net is installed upstream of the fishway exit in the free-flowing water, after prior examination of the local conditions.
- Staff must wade through the water or use a boat in order to empty the net.
- The detailed planning of the fyke net must be agreed with the BfG.
- A box trap is ideally used at the upper end (topmost basin/ upstream of the exit) or in the inlet channel of a fishway in order to determine the number of ascending fish.
- It may be necessary to use one or several additional box traps further downstream, for example at pilot sites. This requires consultation with the BfG during the planning process.
- The detailed planning of a fish trap must be agreed with the BfG and BAW.
- Turbulence and flow velocities in a fish trap should be as low as possible to minimise the risk of injury to fish. Fish traps must not be located immediately below a slot/orifice; the minimum distance required is therefore 2 m. The use of fish traps

consequently means that a reach (straight section) with a length of at least 5 m or, better, 7 m must be available.

- A lifting device is needed for emptying the traps and hauling them onto land. The crane must be equipped with a winch and/or a pulley. It is also possible to use two small mobile gantry cranes. Electric operation of the winch is advisable; the corresponding cable (three-phase current) must be laid.
- Rails must be mounted on both sides of the fishway for vertically moving the fish trap. Alternatively it is possible to provide for appropriate recesses in the concrete during the planning process.
- The junction between the fish trap and the bottom or sill in the bottom substrate and the walls must be sealed. If necessary, screens or other attachments to the fish trap can be used for this purpose.
- There must be sufficient space for emptying the fish trap (into a temporary holding tank) and for counting and measuring the fish caught (at least 10 m²). The practicalities of emptying the fish trap should be considered before construction work begins.
- If necessary, larger holding tanks where fish can be kept for several days must be provided at pilot sites.
- The headwater must be at the appropriate distance from the site of the fish trap to ensure that fish can reach it when they are released from the holding tank. If feasible, a fish chute should lead from the counting site into the headwater.
- The fish trap must be easily accessible (e.g. pathways/walk-on gratings on the fishway).

Requirements for a trap chamber

- Where available space permits it, a separate trap chamber can be attached to the fishway as an alternative to the traditional fish trap. Due to its size and hydraulic conditions, a trap chamber must generally be considered as more beneficial to fish than fish traps.
- For operation of a trap chamber (cf. Gebler, 2010 for example) a bulkhead is lowered into a slot of the fishway and the water impounded. The spill is like a waterfall and flows into a parallel basin which can be connected to the fishway by opening a bulkhead at the bottom. At this connection point there is an entrance funnel. The ascending fish are guided into the trap chamber, but cannot pass the waterfall.
- By closing the connection to the trap chamber and opening the fishway, normal operation is resumed.
- After the water has been released from the chamber through a bottom outlet impassable for fish, the fish can be taken from the chamber.
- The dimensions of the trap chamber must be at least 2 x 10 m.

- A grill door may be installed to enable separate trapping of ascending and descending fish.
- It must be possible to access the trap chamber via stairs. The stairs must lead from the headwater into the trap chamber so that fish which are not to be examined can be released into the headwater and no transport is necessary.
- Contrary to a fish trap, a trap chamber has no “back end” to prevent debris from entering it. This must be taken into consideration when choosing the entrance funnel. Simple bars are less susceptible to the accumulation of debris but are less effective for preventing fish from leaving the chamber.

Requirements for the use of automated fish counters

After conducting some trials the BfG concluded that a mobile fish counter is not yet a full substitute for fish traps. (The BfG tested the Riverwatcher Fish Counter by Vaki; it may be necessary to adapt the following information where devices by other manufacturers are concerned.) However, by combining various approaches it is conceivable that a satisfactory system will be developed in the near future, making the use of a fish counter indeed probable.

- For counting the number of ascending fish a fish counter is ideally used in one of the top basins and/or in the inlet channel of a fishway.
- In addition, at pilot sites it may be necessary to use one or several fish counters in the vicinity of the bottom. This requires consultation with the BfG.
- The dimensions of the Riverwatcher Fish Counter are approximately 1.7 x 1 x 1.1 m (LWH). The fish counter must be installed inside a frame which has inclined grids on both sides used to guide the fish through the scanner. The system therefore has an overall length of up to 3 metres.
- In the counter, the amount of air bubbles in the water must be reduced as much as possible, hence a sufficient distance (at least two metres or even three metres) to “sources of bubbles” at the top (i.e. the slot) must be ensured. This means that the basin or pool must have a length of at least 7 metres.
- The counter must not be installed directly above of a slot; a minimum distance of 1.5 metres must be kept.
- Given the total weight of the Riverwatcher Fish Counter (depending on the design approximately
  200 - 600 kg including the grids and the frame) a lifting device is needed for hauling the counter onto land. The crane must be equipped with a winch and/or a pulley. It is also possible to use a mobile gantry crane. If the winch or pulley is electrically operated a cable (three-phase current) must be laid.

- Rails must be mounted on both sides of the fishway for vertically moving the fish counter and the frame. Which type of rails and dimensions are required depends on the guiding grids and the frame around the fish counter.
- When in position at the bottom, the counter and/or the grids must be positioned as close as possible to the bottom or the sill in the bottom substrate.
- The main connector box which houses the control computer must be connected to a 220 VAC power system. Although it is impervious to rain it should be placed in a location safe from floods and direct sunlight. The counter itself is connected to the connector box via a waterproof cable for power supply.
- The cable between the counter and the connector box must be securely fastened for trip prevention. Maximum distance: 100 metres.
- If possible, a high-speed internet connection or stable high-speed mobile phone connection (LTE) must be provided for the connector box.
- For cleaning purposes the fish counter must be easily accessible (e.g. pathways/walk-on gratings on the fishway).

Requirements for the use of transponder antennas (HDX)

- It must be possible to use a fish trap or trap chamber at the respective site to enable handling of the fish for tagging them.
- At the entrances and at each slot/orifice of the pools/structures a loop antenna (with a diameter of the frame of 5 x 5 cm) must be installed.
- The antennas must not come in direct contact with metal; a distance of at least 10 cm is required.
- The maximum slot width that can be reliably monitored with HDX antennas is approximately 1 metre.
- 220 VAC external socket outlets must be provided at different places in the fishway. The placing of the outlets must be discussed with the BfG during the planning process. The socket outlets serve as voltage sources for the BfG's data loggers for the HDX system.

Requirements for the use of a sonar camera

The BfG uses a DIDSON sonar camera; it may be necessary to adapt the following information where devices by other manufacturers are concerned.

- A vertical metal rail must be installed at approximately 10 metres from the structure to be observed. Prior to installation the BfG must be consulted regarding the design and type of rail used. During surveillance, the DIDSON is lowered down along the rail into the water.
- If the DIDSON is to be used at an existing fishway a scaffold is needed on which staff can work safely and where the rail can be installed. Where there is a bank wall, a suspended

scaffold may be used and where the bank is made of riprap a foot-bridge may be more suitable. However, this depends on the situation in each case.

- If the bank wall is very even and steep it may be possible to mount mobile rails. However, this must also be evaluated in each case.
- A voltage supply of 220 VAC is needed.
- Anchors must be provided close to the metal rails in order to ensure safe working conditions during surveillance.