EAWAG

Green Electricity Certification for Hydropower Plants

Concept, Procedure, Criteria

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CONTENTS

THE AIM OF THIS DOCUMENT

greenhydro

A certification for electricity produced in an environmentally responsible way needs to rely on credible and objective assessment criteria. This also applies to “green hydropower”. Therefore, the report presented in this document sets out the technical basis of a uniform and scientific certification process for green hydropower plants. A power station can use the *greenhydro* procedure to prove that its operations are managed and its facilities are designed in such a way that they safeguard basic features of the ecological integrity of the river system it uses. The report’s basic principles were developed as part of EAWAG’s “Ökostrom aus Wasserkraft” green hydropower project, and are the result of collaborative work with international experts and a range of different stakeholder groups. The report covers both general concepts for certifying hydropower plants and procedural proposals as well as criteria for assessing green hydropower facilities. This procedure has already been applied with initial success during pilot certification tests conducted jointly with the Swiss Association for Environmentally Sound Electricity (VUE in German and hereafter).

Target audience

This document is intended for interested specialists from the fields of hydropower generation, river management and environmental protection. In practical terms, the idea is to provide information on the requirements for green electricity certification to power stations, environmental organisations, governmental agencies, environmental consultancies and marketing experts from the electricity industry. The procedure was adapted with VUE’s help in order to conform to the specific regulatory conditions existing in Switzerland. However, its concepts and criteria are valid independently of the Swiss law requirements and can therefore be applied in principle to other countries without fundamental difficulties.

The procedure’s scope and degree of detail

The following key dilemma became apparent while the procedure was developed: local environmental criteria used to define ecologically sustainable hydropower utilisation would have to satisfy two conflicting requirements; on one hand, they are supposed to establish a set of generally applicable and comparable standards, which need therefore to be based on transferable guidelines and metrics. On the other hand, they are also supposed to consider the specific disparities among individual power stations that reflect the huge diversity of technical approaches and river ecosystems. In order to resolve this dilemma, the EAWAG procedure combines an extensive range of generally applicable assessment criteria on one side, with a specified procedural sequence on the other. This, however, restricts inspection of specific facilities solely to relevant criteria and thus keeps the process within manageable bounds. In addition, certain criteria are formulated in a way that means they can be matched to the particular conditions of various power plants. Prior experience has shown that sensible ecological solutions are frequently possible by having the comprehensive range of criteria counterbalanced by procedural flexibility on an individual basis.

Protection for the EAWAG procedure

The EAWAG procedure for green electricity certification is a public one, and the information it contains is freely available to anyone interested. In regard to the use of the procedure, however, EAWAG has registered the word/picture symbol

greenhydro ●●

This symbol protects EAWAG against improper use by third parties, who might use the procedure unprofessionally, or use only parts of it, while still citing EAWAG. The use of the *greenhydro* symbol is governed by an explicit symbol utilisation contract (or an equivalent agreement) between EAWAG and the user.

Report format

This report is divided into the following five sections:

- **Section I: Green hydropower** analyses the requirements for establishing a scientific and credible way for power plant operators to communicate with green electricity customers. These are the source for the basic principles and plans of the certification procedure described in the subsequent section. Finally it outlines how these plans are implemented as part of the Swiss *naturemade* ***star*** eco-label.

- **Section II: Procedure for green electricity certification** describes the actual auditing and certification process and outlines the specific steps that make up the procedure.

- **Section III: Aims and requirements of the management program** gives a detailed list of aims and criteria for use within the scope of a green electricity certification program.

- **Section IV: Annotated bibliography** provides an overview of available methodologies for fulfilling the aims and basic requirements of green electricity production. The bibliography has been compiled with a view to implementing these requirements in practice and is designed to indicate the level at which green electricity inspections should be carried out. Therefore, it is also a form of quality control.

- **Section V: Appendix** comprises a glossary, bibliographical references, a brief system overview and background information on VUE.

ACKNOWLEDGEMENTS

Conceptual development and procedural implementation

The procedure described in this document was developed as part of a multi-disciplinary research project at EAWAG. A large number of people and institutions participated in creating the procedure's structure, in selecting criteria and assisting with its practical implementation. It is therefore very difficult to acknowledge retrospectively every individual contribution. However, we would like to mention that we liaised closely with VUE in holding discussions with affected stakeholder groups and carrying out the first pilot certifications of actual facilities.

Conceptual formulation of report contents

This report is based on the work of the EAWAG project's "assessment group". The group was directed by Christine Bratrich (07/1997-09/1999), Barbara Känel (09/1999-03/2000) and Stefan Vollenweider (04/2000-09/2000). Alongside the report's authors, other EAWAG staff who took part in developing the procedure are: Jürg Bloesch, Matthias Brunke, Ueli Bundi, Andreas Frutiger, Mark Gessner, Tom Gonser, Edi Hoehn, Werner Meier, Armin Peter, Manuela Saballus, Christoph Sutter, Bernhard Wehrli, Carlo Wiegand and Johny Wüest.

Steering committee

An external steering committee advised and oversaw the entire project. The following people sat on the steering committee while the project was under development: Ueli Bundi (Chairperson, EAWAG), Jörg Aeberhard and Kurt Baumgartner (both ATEL Olten), Roland B. Bischof (IBA – Ingenieurbüro für bauliche Anlagen Zürich), Mathias Jungwirth (Universität für Bodenkultur Wien), Josef Rohrer (contact person for Swiss environmental organisations), Samuele Szpiro (OFIMA/OFIBLE S.A. Locarno), Antonio M. Taormina (former director of OFIMA/OFIBLE S.A. Locarno).

External experts

In April 2000, EAWAG organised an international workshop to establish the basic requirements for green electricity production. External experts at the workshop reviewed thoroughly these criteria, contributing their comments and revisions. Those taking part in the workshop were: Peter Ergenzinger (Free University Berlin), Ursula Grasser (University for Soil Cultivation, Vienna), Klaus Jorde (Stuttgart University) Mathias Jungwirth (University for Soil Cultivation, Vienna), Christian Moritz (Limnology Study Group, Innsbruck), Andreas Stalder (BUWAL Bern) and Thomas Wohlgemuth (WSL Birmensdorf).

Additional expert support

The project team received further expert support from people working for the following private consultancies, university institutes and specialist environmental agencies:

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Comments from other specialists

We would like to thank members of the following organisations for their many helpful comments and useful critiques which helped improving this report: Fachkommission Wasserkraft des VUE (Hydropower Expert Commission of the VUE), AG Gewässerschutz der Umweltorganisationen (River Protection Group of the Environmental Organisations), IG Wasserkraft des Verbands der Schweizerischen Elektrizitätswerke (VSE), Interessenverband der Schweizer Kleinkraftwerkbesitzer (Interest Group of the Swiss Small Power Plant Owners - ISKB), as well as the operators of the power plants taking part in our pilot certification procedures.

Financial support

The project received additional financial support to supplement EAWAG's own resources from various electricity companies involved in working with VUE. This ensured that funding was guaranteed for tasks such as developing basic requirements and establishing management goals for green electricity production.

Finally, we would like to extend once more our heartfelt thanks to everyone who took part in the project. The responsibility for the content of this report rests with the authors, in spite of the support received from experts.

Christine Bratrich and Bernhard Truffer
Kastanienbaum, June 2001

Part I:

Green hydropower

1 INTRODUCTION

1.1 Background

Deregulation

The deregulation of electricity markets is steadily accentuating the importance of supplying end consumers with differentiated forms of electricity. Previous experience with deregulated markets in the USA, the UK, Scandinavia and Germany has highlighted the intensity of ensuing competition in terms of electricity prices. Using environmental criteria to compare different ways of generating electricity opens up the possibility for companies to escape some of this pricing pressure.

Demand for renewable electricity sources

Since the beginning of the 90s, private customers have also been able to switch to electricity products that are differentiated according to environmental criteria, i.e. green electricity[1]. This option, which was initially available only in the USA and Canada, but was later also introduced in Europe and Switzerland, has met with a popular response right from the outset. Studies carried out to estimate its market potential have concluded that about 20 % of private households and around the same proportion of service companies are prepared to pay a premium of approx. 20 % for green electricity (Wüstenhagen 2000).

Eco-labels reinforce credibility

However, since customers are unable to verify directly the quality of green electricity products, the market success of those being offered depends crucially on how much credibility they can establish. Prior experience has shown that simply touting electricity as being eco-friendly provokes a sceptical reaction among some groups of customers. Such products generally have limited market success (Markard 1998). There are various methods of reinforcing credibility. In the green electricity product sector, one of the most important strategies on an international level involves developing scientifically based eco-labels with the support of a wide range of specialists (Markard & Truffer 1999).

Criteria for developing an eco-label for green electricity

A green electricity eco-label has to consider and assess the environmental effects at all levels of producing, distributing and utilising electricity as objectively as possible. The criteria employed to do this should be simple to apply and straightforward to explain to customers. Since this is not an easy proposition when it comes to electricity generation and distribution, credible institutions are needed to vouch for the fact that the right criteria have been chosen and that transparent procedures are in place. When it comes to evaluating environmental impact, this particularly means involving environmental organisations and independent research institutes.

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[1] "Ökostrom" or "green electricity" means electricity that is generated and distributed in a way that minimises the environmental damage caused.

Aim of green electricity certification

A certification procedure for green electricity pursues both economic and environmental aims. From a commercial point of view, the purpose of objectively labelling green products is mainly to win the confidence of customers. On the other hand, however, it also protects serious providers from unscrupulous competition. From an ecological point of view, green electricity certification supports an environmentally more sustainable power supply. This takes into account both global and local environmental factors. Unlike regulatory targets, the decision to meet a required standard or not is voluntarily taken and is ultimately motivated by commercial considerations.

1.2 Green hydropower

What is eco-friendly hydropower?

If green electricity is taken to mean a label for electricity that is generated in a way that minimises environmental damage, how is one then to evaluate hydropower? Depending on what one's standpoint is, assessing hydropower gives rise to a certain dilemma (Fig. 1). Hydropower is a largely emission-free[2] and renewable energy source. Overall, it scores very high in terms of power output and low in CO_2 emissions, particularly when compared with other power generation systems, and from a global perspective is therefore one of the most meritorious energy systems in ecological terms. No other renewable method of production can match its high efficiency or can produce electricity to meet demand in similarly large quantities at a relatively low price. On the other hand, to a certain degree hydropower plants involve sizeable disruptions to local and regional river ecosystems and riverine landscapes. In countries like Switzerland, where the technical and economic potential for harnessing hydropower resources has been largely exhausted, almost all large, free flowing rivers today are already affected either by water diversion and/or by hydropeaking. This means that unlike practically any other energy source, there are conflicting arguments "for" or "against" integrating hydropower into a holistic concept for green electricity.

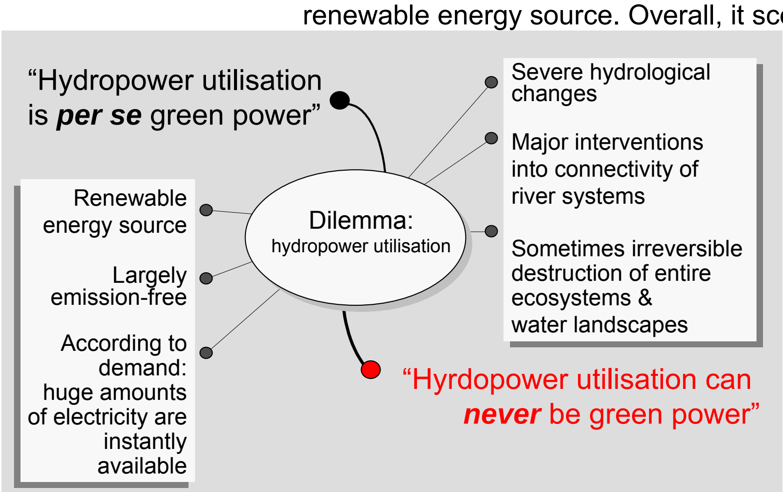


Fig. 1: Arguments for and against "Green hydropower"

[2] The qualification "largely emission-free" takes into account figures recently issued by the "World Commission on Dams", which estimate that greenhouse gases released from large reservoirs throughout the world can make a significant contribution to global climate change (WCD 2000). The extent of this contribution varies considerably. It depends principally on how much organic matter was submerged when the reservoir basin was originally impounded and how intensively this matter produces greenhouse gases (CO_2, methane, etc.) as it is broken down over time. In Switzerland, this emission problem is negligible.

Integrating hydropower into provision of green electricity

Hydropower can be integrated effectively into offers to supply green electricity mainly if it is combined with other renewable energy sources to create joint electricity products. The ability to make relatively large quantities of electricity available on demand, allied to tried-and-tested production technology, make it possible to establish an attractive pricing structure. This in turn is the basis for providing competitive alternatives to conventional mixtures of electricity and is thus also a launch pad for the successful market presence of green electricity products.

2 THE *greenhydro* CERTIFICATION CONCEPT

2.1 Rationale

Existing international certification procedures

So far there is no international certification procedure for hydropower facilities allowing the uniform labelling of green electricity production on an integrated basis. Impacts on the local river systems in particular pose a problem that has not been satisfactorily resolved (Truffer et al. 2001). Existing procedures often ignore the local environmental impacts of hydropower plants completely or assess them poorly. The few procedures that already integrate local river aspects are strictly based on national legislation, thus are only of limited applicability in other countries (Bratrich 2000).

Aim of EAWAG's "Green Electricity" project

The aim of EAWAG's "Green Electricity" project was therefore to develop an environmentally credible, scientific and practicable certification procedure for hydropower facilities. This was designed for implementation as part of a comprehensive eco-labelling scheme for green electricity [3] to facilitate communication with electricity customers.

The certification level

The procedure described here focuses on the certification process for hydropower plants. However, environmentally aware customers will generally purchase their electricity via a utility company and thus generally from a range of different production facilities. Therefore, the supply of green electricity must also be certified, not just the power plants. The VUE's eco-label concept is designed to cover the certification of both power plants and supply offers.

[3] In cooperation with the Swiss eco-label *naturemade* ***star***, that has been launched by VUE.

2.2 Requirements for green electricity certification

Hydropower plants can be certified as "green hydropower facilities" if they operate and are designed in such a way as to protect the environment. This means that the plant voluntarily meets the following two conditions:

Requirement 1: Basic requirements for green electricity

The hydropower plant has to fulfil general "basic requirements" for green electricity. In doing so it has to meet an ecological standard based on the standards imposed by Switzerland's relicencing rules, thus taking into account the revised Swiss Water Conservation Act and all other laws (NHG, BFG, RPG, etc. ➢ Glossary). This standard is based on generally formulated, local criteria. These criteria apply to all hydropower facilities.

Requirement 2: Eco-investments

In addition, the power plant invests a fixed payment per kilowatt-hour of green electricity sold, for restoring, protecting or upgrading the environment in the catchment area used by the plant in question. These eco-investments, as they are called, ensure that measures are undertaken to improve the local ecological conditions. These mitigation measures are intentionally designed to go beyond the level established by the basic requirements, while their implementation can be linked specifically to the sale of green electricity and be explained to customers accordingly. Fig. 2 shows the principle of green hydropower plant certification. Ecological integrity here is a measure for evaluating basic ecological standards.

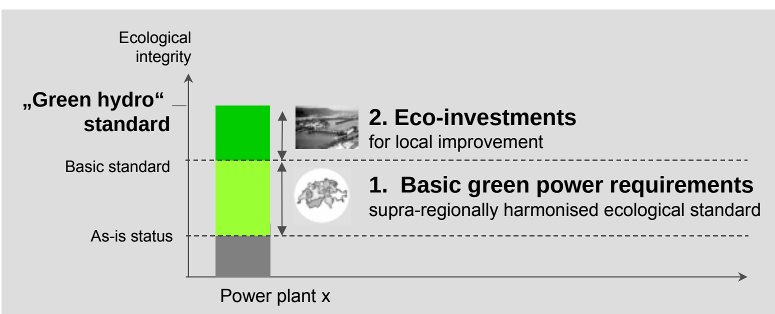


Fig. 2: Schematic depiction of the two requirements for green hydropower plant certification

2.3 Basic ecological standards for certified facilities

Aim and function of basic standards

Scientifically based criteria are used to determine basic ecological standards for green hydropower plants. These criteria are chosen in order to ensure that the river system's principal ecological functions are preserved even when they are affected by hydropower generation. Establishing a uniform set of basic green electricity standards allows supra-regional comparable certification of different power plants, regardless of their age, size or how they are built or operated. It thus defines a general benchmark for assessing different types of installations in different catchment areas.

Determining basic standards

Determining the basic ecological standards for green electricity involves estimating the direct impact of power generation on the river ecosystem and its riverine landscapes. In order to determine more easily these highly complex relationships, the criteria were structured using what is called an environmental management matrix (see Fig. 3).

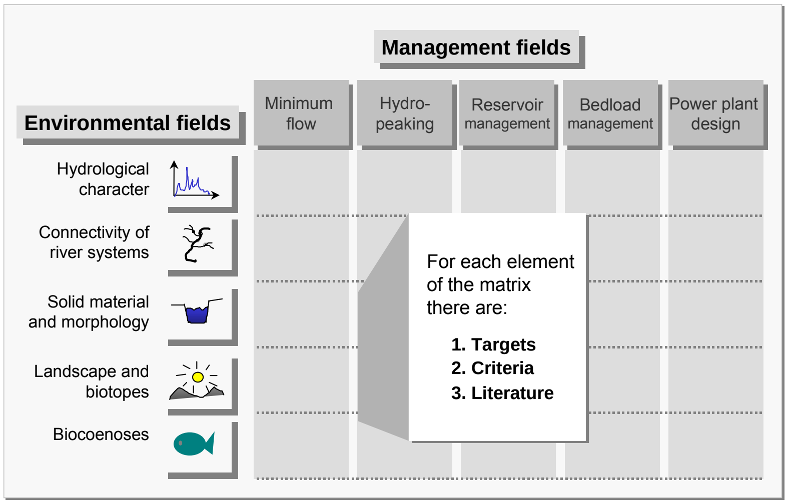


Fig. 3: Environmental management matrix with the relevant management and environmental fields

Specific aims and requirements are formulated for every element within the matrix. These are designed to be universally applicable to all types of power plants in different catchment areas. Annotated bibliographical references and assessment tools are available to assist the practical data collection and ensure its quality (see Section IV, annotated bibliography).

Five management fields

Five management fields describe operational issues or aspects of construction relating to hydropower generation. These should be organised and structured in order to allow the power plant to be run in a sustainable and ecologically optimised manner, taking into account various conservation and usage needs. The following management fields need to meet ecological requirements:

- Minimum flow regulations
- Hydropeaking
- Reservoir management
- Bedload management
- Power plant design

Five environmental fields

The following five environmental fields were selected to cover the most important aspects relevant to ensuring the ecological viability of a river ecosystem. They comprise the following areas:

- Hydrological character
- Connectivity of river systems
- Solid material budget and morphology
- Landscape and biotopes
- Biocoenoses

Level of basic standards

The basic requirements for green electricity are derived from general environmental criteria and are based on the international state-of-the-art technology and research. In Switzerland, this corresponds with maintaining the river environment in the condition roughly equivalent to that prescribed by relicensing regulations in conformance with the revised Water Conservation Protection Act of 1991 and with other laws (NHG, BFG, RPG ➢ Glossary). Fulfilling the basic requirements is not a part of any relicensing process, however, nor is it a substitute for mandatory environmental impact analysis.

2.4 Eco-investments

Aim and function of eco-investments

Eco-investments are used to finance targeted mitigation measures within the affected ecosystems. After a power plant is certified, it invests a fixed payment per kWh sold in projects to improve the local environment. (This payment has been fixed at 1 Rp./kWh for facilities accredited with the *naturemade* ***star*** eco-label ➢ Glossary). The eco-investments thus ensure that environmental mitigation is tailored to the specific circumstances involved. Unlike the basic requirements, this does not call for power plants to reach comparability with other facilities.

Eco-investments can be made in all management fields to fund mitigation measures in any environmental field. They may also be used to remedy environmental shortfalls that have not been caused primarily by the power plant. The only selection criterion required is that the measures have an optimal cost-benefit ratio. Eco-investments are particularly well suited as a way to communicate with end customers. The power plant can use them as means of documenting how the premiums that consumers are willing to pay, feedback to create environmental benefits.

Selection procedure for additional improvement measures

Part of the procedure involves determining what kind of mitigation measures should be implemented using eco-investments. These measures should be agreed upon in consultation with representatives of relevant local and regional stakeholders. The inclusion of local authorities, environmental organisations and other interest groups enables projects to gain wider acceptance. This means that potential conflicts are more easily minimised, and permits early recognition of synergies with other environmental initiatives in the catchment area.

2.5 Applicability and individual flexibility

Demarcation of basic requirements

The basic requirements for a green hydropower plant apply to the facility's zone of influence. This includes all catchment regions affected by intakes, reservoirs, river impoundments, power plant buildings, etc. Only in certain cases the impact on further areas should be considered as well (e.g. if hydropeaking is involved). Furthermore, the basic requirements only concern environmental problems caused by the power plant itself. However, when measures are implemented, planners are required to take into account the existence of possible synergies with other measures in river management (e.g. measures for flood protection, agriculture, tourism, etc.). Efforts should be made wherever possible to tackle the environmental effects caused by several power plants working simultaneously as an integrated project (because of chains of reservoirs, hydropeaking overlaps, etc.).

Demarcation of eco-investments

The facility's zone of influence also essentially constitutes the relevant area for implementing the measures funded by eco-investments. However, it should also be possible to boost the cost-benefit ratio by using eco-investments to support mitigation measures whose scope extends beyond the region affected directly by the power plants concerned. Nevertheless, for all projects it is required to ensure that, under any circumstance, they are beneficial to the local environment.

Flexibility

The basic requirements for green electricity apply in general to all green hydropower plants. However, an exception may possibly be made for ecological reasons set out in Chapter 8. There is an ecological reason for making the exception when it has been determined that doing so would prove more beneficial to the local or regional environment than adhering strictly to the basic requirements. The relative benefits of either option are assessed based on the natural conditions prevailing in the pristine ecosystem. (In practice, this means that mitigation measures do not necessarily have a beneficial ecological impact even when they lead to an absolute increase in the number of species living in the ecosystem, if this involves fundamentally altering the natural habitat. A significant example would be the increase in species numbers in formerly free-flowing river sections, where the building of weirs has led to an influx of lentic (➢ Glossary) species.

3 IMPLEMENTING THE *greenhydro* PROCEDURE IN SWITZERLAND

Association for Environmentally Sound Electricity (VUE)

An isolated green electricity certification program for hydropower plants would be neither desirable for the environment nor credible on a long-term basis. EAWAG has therefore worked on its procedure in collaboration with a private institution and developed an eco-label for green electricity to cover Switzerland. This institution is the Association for Environmentally Sound Electricity (VUE), which was created in October 1999 and is run by representatives of renewable energy producers (solar, wind, hydropower), electricity companies, environmental and consumer associations and a commercial bulk purchaser.

Adoption of the GREENHYDRO procedure

VUE uses the EAWAG procedure as the basis for its certification program for green hydropower plants. Further information on the certification of other renewable energy sources can be found at the Internet address www.naturemade.org. What follows is a brief description of just those aspects that are directly relevant to the certification of hydropower facilities for green electricity.

Difference between eco-label and product declaration

VUE accreditation program provides for a two-tiered *naturemade* eco-label. Green electricity proper is indicated by the *naturemade* ***star*** label, which is assigned to leading environmentally sound power plants and products. In contrast to this, *naturemade basic* identifies electricity that comes from a renewable source. For hydropower, the *naturemade basic* label is thus mainly a product declaration, although it is linked to the promotion of other *naturemade* ***star*** facilities (which generate at least 5 % of the amount of certified electricity that is sold).

The EAWAG procedure exclusively concerns those hydropower plants aiming to reach the *naturemade* ***star*** level.

VUE basic criteria for naturemade ***star*** *hydropower*

VUE developed basic criteria for the certification of *naturemade* ***star*** facilities, which supplement the adopted EAWAG procedure in the following points:

- Hydropower plants that have been relicensed according to the new Swiss environmental legislation, i.e. in conformance with the revised Water Conservation Act and with regard to other applicable laws, should undergo a simplified certification procedure.

- In addition, VUE has fixed the extra costs for eco-investments as follows (see also Ch. 2.4): a green hydropower plant is to pay 0.1 Rp for every certified kilowatt hour of *naturemade* ***star*** electricity produced and another 0.9 Rp for every kilowatt-hour of green electricity sold.

- Extensions to power plants and new constructions can be certified as *naturemade* ***star*** if they do not cause any additional degradation to natural or near-natural habitats, biocoenoses and riverine landscapes.

- As a rule, hydropower plants can be certified only at their transformer terminals (➢ Glossary). It means that green electricity certification can be awarded solely to an entire hydropower facility, but not, for example, to a plant's individual turbines. (For all special regulations see VUE guidelines at www.naturemade.org).

- VUE set up a simplified procedure for small hydropower facilities. However, this also means that the plant has to fulfill the fundamental green electricity requirements and implement them on a viable basis as a precondition of *naturemade* ***star*** certification.

- *Naturemade* ***star*** facilities have also to fulfil all criteria as *naturemade basic* facilities. In particular, this means that only net production may be certified. To this end, the plant has to keep energy accounts as a record of how much net power it produces. Facilities with a capacity of more than 10 MW are also required to phase in a certified environmental management system (ISO 140001 system) within 5 years.

Part II

Procedure for green electricity certification

4 Procedural format

Naturemade ***star*** certification is based on carrying out a series of studies to establish a hydroelectric power plant's suitability. On one hand, this involves determining which basic requirements for green electricity must be met, and on the other hand, it involves conducting appraisals on how to use eco-investments. Four procedural steps are important in this respect (see Fig. 4 and VUE's certification process for *naturemade* ***star*** hydroelectric power plants in the Appendix, section V):

- Step one: preliminary study → see Ch. 5
- Step two: management program→ see Ch. 6
- Step three: audit and certification → see Ch. 7
- Step four: control audit → see Ch. 8

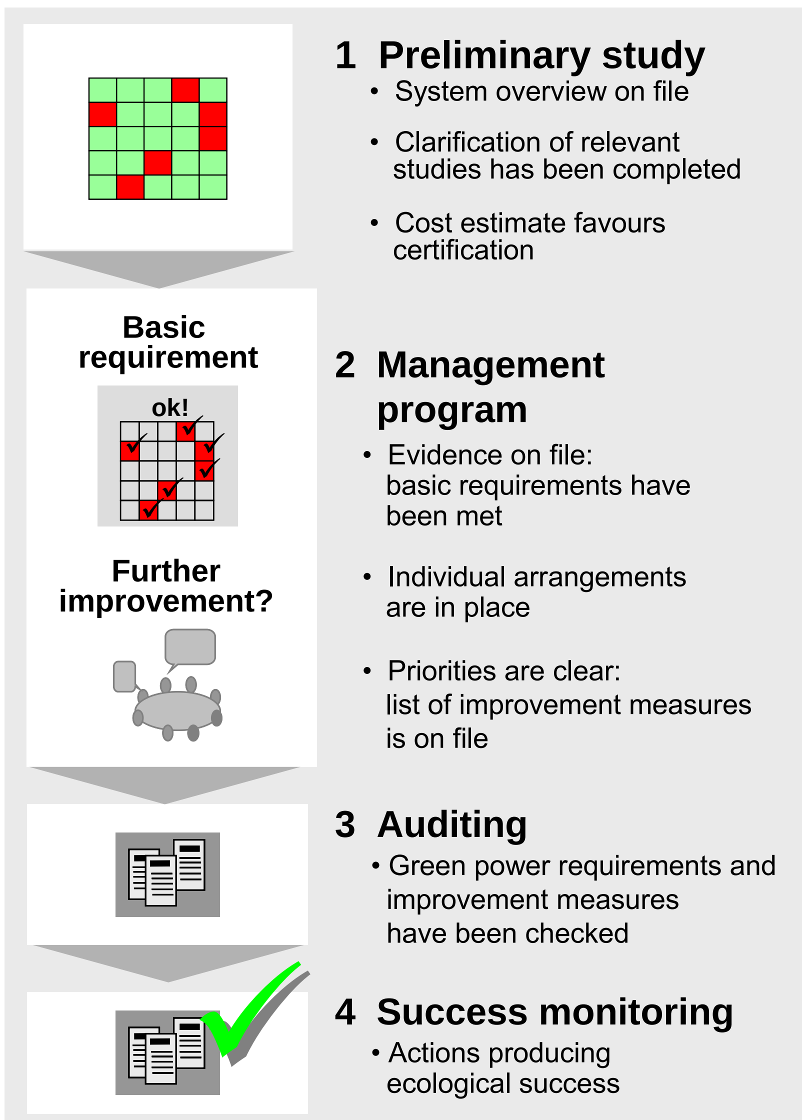


Fig. 4: Procedural format for certifying green hydroelectric power plants. This ensures that a naturemade **star** facility meets the basic requirements for green electricity and undertakes to use eco-investments to implement more extensive mitigation measures in the local environment (for details see Ch.5-7).

5 PRELIMINARY STUDY

5.1 Aim and function of the preliminary study

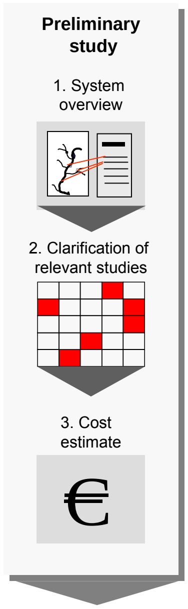


Fig.5:
Format of preliminary study

The aim of the preliminary study is to identify possible ecological deficits in the catchment area affected by the hydroelectric power plant. This principally means establishing which of the basic requirements are in fact relevant to a specific facility. The preliminary study allows for a cost estimate, which facilitates the decision as to whether it makes commercial sense to adopt the certification procedure for green electricity.

The preliminary study involves carrying out the following three-step analysis (see Fig. 5):

- Step one: system overview → see Ch. 5.2 and Appendix, section V
- Step two: clarification of relevant studies for the specific facility → see Ch. 5.3
- Step three: individual cost estimate → see Ch. 5.4

5.2 System overview

Function

The system overview allows the ecological condition of the river ecosystem within a used or affected catchment area to be characterised. It provides an overview of the extent of environmental degradation under a range of ecological aspects. At the same time, it gives an indication of what types of human usage might be responsible for the observed degradation of the river.

Source of information

The data used to compile the system overview are obtained as much as possible from existing information on hydroelectric power plants and the environment, through consultations with local stakeholders and an examination of the study area. The work is based on the environmental management matrix mentioned in Chapter 2, which is also used to establish the fundamental requirements for green electricity. The procedure normally involves carrying out an inspection of the hydroelectric power plant and identifying the most important ecological deficits in the facility's catchment area. The Appendix (Part V) contains methodological guidelines for performing the system overview. These are illustrated using examples of alpine storage power plants.

Boundaries of the study area

The studies carried out as part of the system overview should cover all river sections influenced by hydropower generation. That means that it is the impact of hydropower utilisation rather than the natural borders of the hydrological catchment area that determines the boundaries of the study area. This involves considering valleys, for example, which in a specific case are affected by diversion. On the other hand, the study should disregard river reaches that are located in the same hydrological catchment area, but which are mainly influenced by the activities of another power plant. Appraisals can thus be restricted to relevant parts of the river system in order to prevent their cost from escalating. However, at the very least this involves examining the main channel and representative secondary tributaries. There will usually be sufficient information obtainable from the hydroelectric power plant, local authorities, environmental associations and interest groups in order to determine the relevant river reaches. Expert auditors must establish and propose the precise definition of where the study area's boundaries lie. Any outstanding questions or problems that arise from transferring small-scale examinations to the overall catchment area will be resolved by coordinating the input of expert auditors (see Ch. 8).

5.3 Clarification of relevant tasks to be conducted

After available environmental data have been gathered and the results of the system overview are present, the second step of the preliminary study is carried out. It involves determining what further examinations are relevant for going ahead with a specific certification for green electricity, which basic requirements have already been met, or in which areas, if any, additional clarification might be needed. The environmental management matrix (Fig. 3) serves as the basis for decision-making. It should be established for all elements in the matrix whether they require further work to be conducted in the subsequently developed management program. After these issues have been dealt with, the results are placed in a relevance matrix (table 1). This shows which studies must be carried out in order to produce the management program and which are not necessary. The classification scheme illustrated here (Fig. 6) proved a practical and helpful tool while conducting pilot certifications. The first distinction involves determining whether a particular problem area is relevant for the management program. Should it prove relevant, it must be established whether the facility in question already meets the basic requirements for green electricity in this respect. If this is not the case, further studies are necessary and these are to be identified in the relevance matrix. The matrix should also show those elements in which eco-investments might conceivably be successfully used to promote ecological mitigation measures. For illustration purposes, some examples are given below.

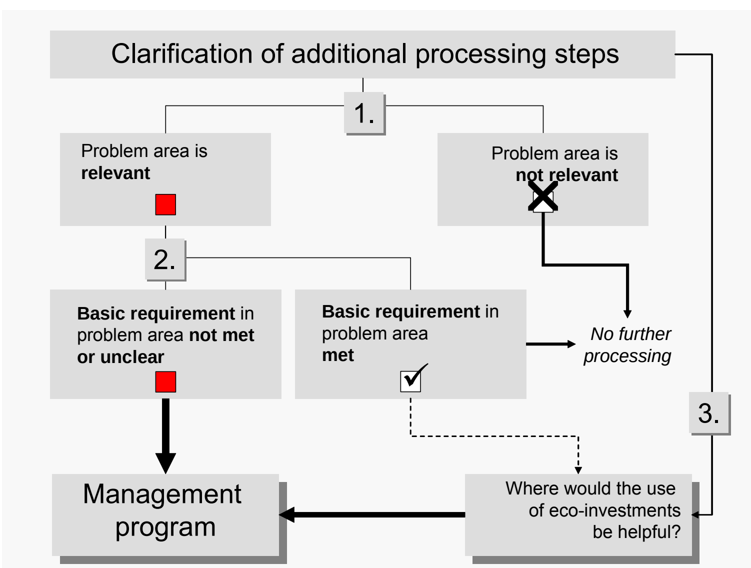


Fig.6: Establishing relevant tasks to carry out in order to produce the management program.

First distinction: The problem area is **relevant** or **not relevant** for the subsequent management program based on the assumption that, essentially, all problem areas in the environmental management matrix are relevant, unless qualifications (a) or (b) apply.

(a) It can be proved that the problem area does not exist and is therefore not relevant.
e.g.*: The power plant does not run a hydropeaking operation. This means that the hydropeaking management field does not require any further analysis.*

(b) The identified deficit is not caused primarily by the power plant and concurrently there is no potential for eco-investments to fund ecological mitigation measures.
e.g.*: The banks in a hydroelectric power plant's catchment area are regarded as not being in their natural state, but this condition cannot verifiably be improved through any alternative means (including mitigation efforts promoted by eco-investments) due to technical reasons related to flood protection or safety considerations.*

Second distinction: For all relevant problem areas it must be determined whether the power plant **meets** or **does not meet the basic requirements for green electricity.**

- It can be shown that the ecological status quo maintained by the power plant in this problem area meets the basic requirements for green electricity.
  e.g.*: The plant has installed a well-documented and demonstrably effective system for safeguarding the passage of fish*
  or:
  e.g.: The power plant operates an ecologically optimised flushing procedure that can be shown to satisfy the stipulated requirements, thus rendering further work in this problem area unnecessary.

- The basic requirements for green electricity have not been met
  e.g.: There is no system at all to allow the passage of fish.

- It is unclear whether the power plant meets the basic requirements for green electricity. Further studies are necessary.
  e.g.: although a fish ladder is in place, it is not clear whether it works properly.

Third distinction: Points where **eco-investments might be used** to promote additional ecological mitigation work are to be noted for all relevant problem areas.

The facility meets the basic requirements for green electricity, but there is potential for eco-investments to support further mitigation measures.
E.g.: although a working fish ladder has been installed, an existing branch of the river is suitable for conversion into a detour channel. This would enable extra improvements to fish passage and habitat quality.

Result of preliminary study: relevance matrix

Table 1 shows what a hypothetical relevance matrix might look like after completion of the preliminary study. It sets out the respective basic requirements, along with an assessment of which criteria are deemed irrelevant or already fulfilled. This sorts out the basic requirements for which further studies or action plan proposals must be formulated.

	Management fields									
	Minimum flow		Hydropeaking		Reservoir		Bedload		Power plant	
Environmental fields	BR	EI	BR	EI	BR	EI	BR	EI	BR	EI
Hydrological character	MF1 MF3				RM1		BM1	BM3		PD1
Connectivity of river systems	MF5 MF6 MF7				RM3 RM4				PD3	PD4
Solid transport & morphology	MF8						BM4 BM5 BM8	BM7		PD5 PD6
Landscape & biotopes	MF9 MF10				RM6 RM7			BM9	PD7	
Biocoenoses	MF11						BM10	BM11	PD8	

Legend:

BR Basic requirement

EI Eco-investments

MF7 Problem area is relevant and not met or unclear

BM7 Potential for eco-investments to support further mitigation measures

Problem area is not relevant

Problem area is coverd by another area

Basic requirement in problem area met

Table 1: Schematic depiction of a hypothetical relevance matrix showing the results of the preliminary study. (Entries such as MF1, RM6, BM7, etc. refer to examples of individual requirements taken from chapters 9 - 13; the format is based on a proposal by P. Baumann, Limnex AG Zürich).

5.4 Cost estimate

After the relevance matrix has established which studies are required (table 1), step three of the preliminary study involves estimating the cost of producing the management program. These costs consist of:

- completing a definitive study to confirm what needs to be done to meet the basic requirements for green electricity
- formulating the mitigation measures to be supported by eco-investments
- creating the basic auditing process.

Cost module

The Appendix (A4) contains a sample cost estimate used to calculate the overall cost of any certification process. Other than procedural expenses and the potential cost of in-depth studies, this also includes auditing and licensing fees, the cost of meeting the basic requirements and the additional payment for eco-investments. VUE has specific tools available to help produce a real-life cost estimate.

6 MANAGEMENT PROGRAM

6.1 Aim and function of the management program

Aim

The aim of the management program is to develop a mitigation strategy comprising a binding action plan tailored to the specific situation of the hydroelectric power plants concerned, and designed to ensure eco-compatible operation and plant design.

Function

The action plan formulated in the management program is designed to ensure that a hydroelectric power plant meets the basic requirements for green electricity. Ecologically acceptable arrangements are formulated for each of the five management fields, unless they are not already in place (e.g. in EIA reports). These arrangements firstly guarantee the plant's compliance with the basic requirements for green electricity and, secondly, they determine ecological mitigation initiatives to be implemented within the framework of the eco-investments scheme. The completed management program serves the lead auditor as a basis for the audit. The management program is outlined in three investigatory stages (cf. Fig. 7):

- Outlined individual arrangements for the management fields → cf. Section 6.2
- Consulting interest groups on mitigation measures to be implemented within the framework of eco-investments → cf. Ch. 6.3
- Formulating an action plan specifying the measures already taken and the measures still to be implemented → see Ch. 6.4

6.2 Individual arrangements for management fields

Function and scope

The individual arrangements presented in the management program describe how ecologically compatible operations and plant designs can be assured specifically for every power plant. They are drawn up only for those management fields that in the preliminary study have been classified as relevant. Each of the arrangements is designed to show whether the green electricity basic requirements have been met within the purview of the management field concerned, and/or which measures are still required to be taken *before* certification. Also, the individual regulations describe the further measures that can be taken within the framework of the eco-investments for ecological upgrading.

Proposed action listing

For each relevant management field, action plans are then formulated. These are divided into two categories: measures for meeting the basic requirements and measures for the eco-investments. Where measures for meeting the basic requirements are involved, these should be designated as "obligatory measures". However, where further measures are involved, these should be designated as "optional proposals". In addition, measures whose implementation would require cooperation and coordination with third parties (flood protection, governmental renaturalisation projects, agriculture, tourism, etc.) are indicated.

Evaluation of measures involved

For ecological and economic optimisation, the individual measures are assessed for their upgrading potential, and reviewed in regard to synergies. Optimisation can be made:

- With regard to the ecological benefit (compared with the direct cost of the measures concerned).
- With regard to the difficulties of implementation (technical, temporal, legal, local opposition, coordination with third parties).

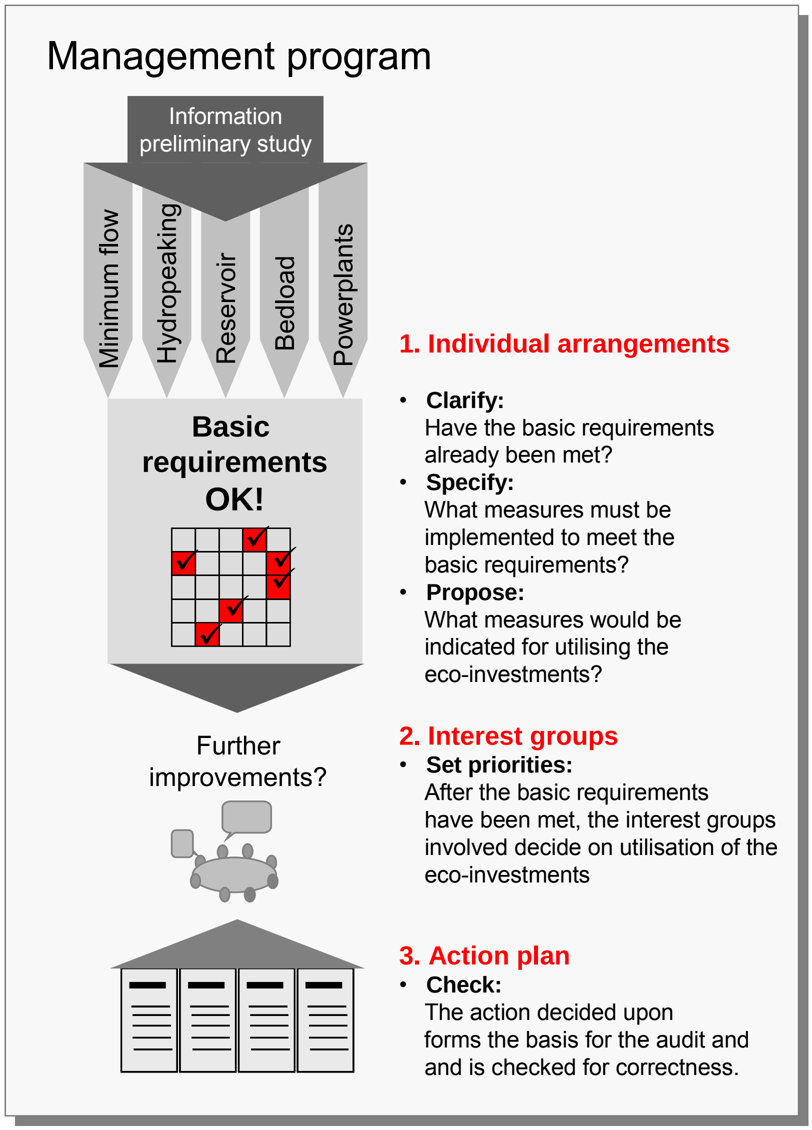


Fig. 7: Diagram showing the management program's main development stages: action listing is designed for each management field that the preliminary study has indicated to be relevant. This clarifies how the basic requirements for green electricity will be met and which improvement measures ensure that funding from eco-investments is used to optimum effect.

Procedural aids

Besides the information on methodologies and case studies contained in Part IV of this report, EAWAG is also working on additional publications specifically geared toward the individual management fields. These additional support tools are designed to assist with producing the management program and provide guidance on possible measures to deal with specific problems.

6.3 Consultation with local stakeholders

Function Environmental measures funded through eco-investments should be negotiated and prioritised on the basis of the proposed action plans and in consultation with local and regional stakeholders. This essentially means involving those interest groups that either stand to benefit from the measures in question and/or who are carrying out their own mitigation projects. This should improve the measures' ecological impact and allow funds to be used most effectively.

Process The following points should be taken into account when holding these consultations:

- Relevant stakeholders in each case should be contacted at the earliest possible stage: they might be representatives of local and/or regional bodies, active local environmentalist groups, possibly residents and people involved in other activities directly or indirectly linked to the river system (agriculture, fishing, gravel removal, tourism etc.). It is important to make sure that those people involved in the process are able to hold a serious discussion of the general issues and the actual project itself.

- The results of studies to determine whether basic requirements for green electricity have been met and what options are available for using eco-investments to fund mitigation work, should be presented in a transparent and coherent manner.

- Every effort should be made to reach a consensus on selecting and prioritising the mitigation measures to be implemented using eco-investments.

- The consultations should not be misused as an opportunity to argue out fundamental debates or disputes. A mediator should perhaps be brought in if there are outstanding conflicts from previous negotiations between the hydroelectric power plant and stakeholders.

6.4 Action plan produced by the management program

The management program is used to produce an action plan with a set of prioritised measures that are binding for the power plant concerned. The mitigation strategy is supplemented by an accompanying report commenting on these measures and explaining why they have been selected. Along with the preliminary study's results, maps and reports, the action plan constitutes the basis for the audit. Assuming that all the affected stakeholders agree, the planned measures can also be further developed on a continuing basis or at a later stage.

7 AUDITING AND SUCCESS MONITORING

Principle of audit

The audit comprises an independent inspection of the documentation and, in particular, of the action plan. The auditor determines whether the statements made in the documents are reasonable and whether the procedure has been duly carried out, and she or he issues a corresponding report. The chief auditor can call in appropriate expert auditors to advise on any specialised areas, if necessary.

Audit and licensing

If the auditor's report comes to a positive conclusion, VUE's board members decide on whether to issue the eco-label. This certification is linked to the signing of a licensing agreement. Then, the hydroelectric power plant is entitled to use the appropriate eco-label.

Re-certification, monitoring and long-term quality assurance

As part of VUE's guidelines, an auditor should verify the facility's energy sales on an annual basis (monitoring audit). If this audit finds no defects or infringements of the licensing agreement, the certificate is automatically renewed. According to current VUE criteria, the facility must undergo re-certification after five years. In order to do this, there should be a written record corroborating how effectively measures have been carried out in the relevant management areas (success monitoring). The facility must therefore ensure that it has implemented mitigation measures in a viable manner, and that it has compiled and documented (simple monitoring) important plant-related information (e.g. permanent records of water levels, operating conditions, unusual occurrences etc.). If necessary, these data should be made available for inspection. The measures in question should be subjected both to biotic and abiotic success monitoring as part of the re-certification process (VUE: 5 years, at the latest).

Part III

Aims and requirements of the management program

8 BASIC REQUIREMENTS FOR GREEN ELECTRICITY

Overview

Part III of this report deals with the definition of basic requirements for green electricity. Ecological performance targets are formulated as an evaluation tool, and specific criteria (basic requirements) are set in order to achieve each of these targets. An annotated bibliography is appended in Part IV in order to assist with this process and to provide quality assurance.

Performance targets for evaluating basic requirements for green electricity

The targets for evaluating basic requirements for green electricity define the ecological situation of a green hydroelectric power plant after certification. They are mainly concerned with the ecological integrity of the river, which should be preserved or restored despite the effects of hydropower utilisation.

Flexibility

The basic requirements for green electricity apply in general to all green hydroelectric power plants, regardless of the original ecological conditions involved. However, a deviation is permitted in ecologically justified exceptional cases. An exception may be justified on ecological grounds if it can be shown that deviating from the requirements is more beneficial for the state of the local and regional environment than adhering strictly to them. Assessment of ecological benefit is based here on the *pristine river type* and *its native riverine biocoenoses*. In such cases, the experts responsible for the appraisal should be granted an appropriate degree of professional leeway for interpreting and assessing the situation. This flexibility can be used to seek specifically tailored solutions for the affected river system, which possess an optimised cost-benefit ratio. Not the least, it must be borne in mind that all ecological or operational measures should come secondary to safety considerations.

Expert coordination to resolve outstanding issues

Expert auditors should tackle all outstanding issues collectively with EAWAG and VUE, particularly when the issues also arise from areas in which there is leeway for interpretation or assessment. If required, joint workshops can be held in order to facilitate this process.

Content overlaps

The contents of the five management fields are very closely interlinked, so that mutual interaction and overlaps are unavoidable. Individual basic requirements cannot therefore be considered as being separate from one another. Therefore, similar basic requirements can occur more than once in subject areas whose contents are highly connected. This overlapping structure was chosen deliberately in order to encourage interplay between the five management fields even if different experts or firms are carrying out the studies.

Types of power plants

The relevance of the basic requirements for green electricity varies for different types of power plants. For example, specific targets and requirements apply only to certain kinds of hydroelectric facilities and operating methods (e.g. hydropeaking). The preliminary study (see Fig. 6) checks which basic requirements for green electricity are relevant for the certification procedure, or which criteria need to be fulfilled, presenting its finding as a relevance matrix (Table 1). The procedure in this report was developed using examples of alpine storage power plants and large run-of-the-river power plants in Switzerland. It can therefore be used for power plants in alpine regions and similar areas in Europe. VUE has worked out a simplified procedure for small hydroelectric facilities. However, to receive *naturemade* ***star*** certification these plants also have to meet the basic requirements for green electricity and implement them in a sustainable manner. The underlying basis for simplifying the procedures involved can be found in Truffer et. al. (2001). Further basic scientific work would have to be conducted in order to apply the procedure to facilities operating in a catchment area with marked structural differences or located in a completely different geographical region.

Relationship between ecological requirements and commercial implementation

Ecological targets and basic requirements should be put into practice as economically and efficiently as possible. The authors are nonetheless aware that in specific cases, meeting certain requirements may come up against the limits imposed by commercial restraints. However, this factor has been taken into account because green electricity certification is undertaken voluntarily. The procedure has therefore been set up in such a way that the cost implications of certification are made transparent for the power plant at a very early stage (see Ch. 5).

Newly licensed facilities (specifically for Switzerland)

In Switzerland, basic requirements for green electricity are more or less equivalent to ecological standards that must be met by a newly licensed facility (according to the Water Conservation Act and with regard to other applicable laws e.g. NHG, BFG, RPG, etc. ➢ Glossary). It can accordingly be assumed that recently licensed facilities generally meet the basic requirements. Therefore, the individual study areas only need to be verified and existing data used to prepare a brief record of the functional viability involved. Particular efforts should be made to identify those fields in which there is significant potential for eco-investments to promote further mitigation work.

Proposed assessment techniques

Part IV (annotated bibliography) suggests some assessment methods for specific management fields along with a short commentary. An expert auditor can use these to help assess the facilities' ecological situation as well as the basic requirements for green electricity conforming to state-of-the-art methodologies. Using up-to-date techniques ensures that quality standards are maintained. The bibliography has therefore been arranged accordingly in the following categories:

- General background literature and basic information about the management field.
- Reference works on current state-of-the-art techniques that are particularly relevant to the basic requirements, along with literature covering methodological standards and assessment levels.
- Literature on selected reference systems, project reports or practical case studies (when available).
- In-depth scientific literature (only if required or useful for the management field).

To make sure that quality standards are maintained over the long term, the bibliography should be updated constantly to take into account ongoing technical advances. The list of reference literature provided here is therefore incomplete, particularly regarding the appraisal methods. The procedure should evolve continuously in order to integrate any new, scientifically based evaluation tools that are developed. The catalogue of recommended literature was primarily compiled to provide a benchmark for the level of investigation; it is by no means exhaustive. Other compatible and scientifically accepted methods can also be used in order to assess basic requirements.

Fish waters

Individual basic requirements are differentiated according to whether the affected river systems are deemed to be "fish waters", defined as:

- River systems with an original fish population capable of natural reproduction or
- River systems with a stocked fish population capable of natural reproduction or
- River systems with stocked fish capable of surviving for lengthy periods (at least one year) or
- River systems temporarily uninhabited by fish, but which are used by fish as spawning grounds

Non-fish waters are:

- River systems with no fish population
- River systems with stocked fish surviving for only short periods (i.e. less than one year).

Flood plains and other habitats and landscape features requiring special conservation

Special sets of rules deviating from the general certification concept apply in the circumstances described below. If a facility's boundary area (see Ch. 2.5) contains any inventoried flood plains or other inventoried habitats requiring special conservation, a special procedure should be followed. When certification is issued, the facility must undertake to protect the flood plain (or any other habitats identified as requiring special conservation as set out in Art. 18 NHG (➢ Glossary). This might be done, for example, by developing a floodplain conservation strategy featuring a defined series of prioritised measures. It should ensure that the floodplain environment remains in a viable state even when affected by the power plant's operation. To that effect, the plant should aim at preserving or restoring the morphological dynamics and ecological function of these habitats and biocoenoses. Furthermore, minimum flow controls should be set in order to prevent such areas from drying out in the long term and which enable the hydrological and edaphic (➢ Glossary) conditions of softwood and hardwood floodplain forests to be preserved. Implementing this strategy is a top priority for the eco-investments scheme, provided that the interests of other users of the flood plain are satisfactorily addressed.

Practical implementation of the procedure

Initial pilot certifications of various types of power plants have shown that the *greenhydro* procedure's targets and basic requirements can be used in practice at a reasonable outlay. EAWAG's collaborative work with expert auditors allowed sufficient leeway for interpretation and discretionary prerogatives while ensuring that the program's credibility was not compromised. Pilot certifications thus provided evidence that the procedure works. The first power plants have already succeeded in being awarded the *naturemade* ***star*** label.

The overview matrix below shows the basic requirements for green electricity combined in their respective management fields. The following chapters describe them in greater detail.

Overview matrix for determining basic requirements for green electricity

	Minimum flow regulations (Ch. 9)	Hydropeaking (Ch. 10)	Reservoir management (Ch. 11)	Bedload management (Ch. 12)	Power plant design (Ch. 13)
Hydrological character	MF1-MF3	HP1-HP3	RM1-RM3	BM1	PD1-PD2
Connectivity of river systems	MF4-MF6	HP4	RM4-RM6	none	PD3
Solid material & morphology	MF7	none	RM7-RM8	BM2-BM5	PD4
Landscape & biotopes	MF8-MF9	HP5-HP6	RM9-RM10	BM6	PD5-PD6
Biocoenoses	MF10-MF11	HP7	RM11-RM13	BM7	PD7

9 MINIMUM FLOW REGULATIONS

Ecologically significant aspects of minimum flows

Minimum flow can cause significant changes to the abiotic and biotic conditions in and around river systems. It is often impossible to make general statements about evaluating its impact, since many of the factors relevant to the assessment are dependent on local circumstances. Individual studies are therefore usually needed for the determination of a minimum flow regulation that optimises ecological and economic imperatives. For example, factors such as specific hydraulic characteristics (e.g. flow features of a mountain stream) and the influence of human activities (e.g. extent of flood protection measures) are relevant to the ecological impact of water abstraction. The hydropower plant's operating modes, turbine intake capacity, and the way reservoirs are managed, all play a crucial role.

It is important to know which discharge in a particular river stretch is actually significant ecologically. Nowadays, many countries use flexible guidelines instead of the old approaches to establishing minimum flows, most of which were assessed purely on the basis of hydrological statistics (flexible guidelines: see e.g. revised Swiss Water Conservation Act or guidance notes on state-of-the-art measurement techniques in Ch. 14.1).Therefore, the certification procedure for green electricity is designed to implement measures specifically aimed at affected habitats. They focus on establishing a basic discharge (based on ecological criteria) and on dynamics (tailored to the characteristics of an individual river system). They are meant to be coordinated with the goals of other management fields, something that is indispensable for certain basic requirements (See Ch. 8).

9.1 Objectives for ecologically based minimum flow

Principal objectives

The aim of ecologically compatible minimum flow is to ensure a discharge regime that closely reflects the natural characteristics of the river system involved. Apart from justified exceptional cases (see Ch. 8), minimum flow should thus exhibit near-natural discharge patterns conforming to the river type, ensure the connectivity of river systems, and preserve the native diversity of plants and animals. Individual studies should be carried out to determine minimum flow needs for ecologically important sites within the catchment area. These studies then form the basis for establishing definitive minimum flow regulation that apply to the utilised catchment area as a whole, and to all intakes. If any outstanding questions or problems arise from applying small-scale studies to the overall catchment area, they should be resolved in conjunction with expert coordination (see Ch. 8).

Ecological objectives of individual environmental fields

Hydrological character

- Minimum flow should take into account **seasonal changes** (with respect to seasonal discharge fluctuations) and **variability** (concerning the timing, frequency and extent of peak flows) to make sure that the flow regime reflects natural discharge patterns during the course of the year as closely as possible and to allow natural processes of displacement and exchange to take place.
- A **minimum, seasonally adjusted basic discharge that varies with natural flows** should ensure that current velocity and hydraulic patterns remain naturally diverse and provide a adequate range of different habitats for native riverine biocoenoses throughout the year. Minimum flow is only permitted to go below this basic discharge level in sections that would run dry naturally.

Connectivity of river systems

- Minimum flow should not sever or cause major disruption to the **interconnection** between water course, ground water and adjacent land. Drinking water supplies that are dependent on ground water should not be put at risk.
- Minimum flow regulations should be designed in order to prevent **any unnatural isolation** of tributaries and thus avoid isolating fish and invertebrate fauna from the main channel.
- **Water depth** in the entire minimum flow reach should be adequate to ensure that fish can migrate unimpeded, assuming that these river reaches are naturally populated by fish and that the original discharge enabled fish to pass through.

Solid material budget and morphology

- Minimum flow should preserve the natural **structure of the riverbed**.
- A minimum flow regime should ensure that the ongoing **solid transport** (➢ Glossary) and equilibrium levels are maintained within affected river stretches.

Landscape and biotopes

- Minimum flow regulations should be determinated in order to prevent any critical change in the hydraulic character of **free flowing river reaches**. Regulations should be put in place to preserve the natural attributes and ecological dynamics of the inventoried areas or any other riverine habitats requiring special conservation. This applies also to landscape features that rely directly or indirectly on the size and type of the river system involved.
- Special regulations (see Ch. 8) apply to the **inventoried flood plains** within the bounds of a facility.

Biocoenoses

- Minimum flow should maintain characteristic riverine habitat structures in order to preserve the **natural diversity of animal and plant species**. In particular, hydroelectric power plants should implement appropriate minimum flows to sustain the reproductive capability of **native fish species**, which also includes all types of fish that were formerly (i.e. potentially) present in the river system.
- Biocoenoses that depend directly on natural river ecosystems must not be allowed to disappear irretrievably. Hydroelectric power plants should therefore make sure that minimum flow enables **sediment deposits to reform** (pioneer and succession zones) where natural conditions appear to make this necessary.
- Minimum flow should ensure that the **temperature regime** and **dilution ratio** remain close to their natural levels to prevent biocoenoses from being harmed by critical temperature conditions and/or oxygen concentrations, and that the flows are adequate to allow natural cleaning processes in areas where wastewater outlets discharge into rivers.

9.2 Basic requirements for assessing ecologically based minimum flows

The following prescriptive formulations indicate that the specified basic requirements are binding for every green hydroelectric power plant, regardless of the original ecological conditions involved. In ecologically justified exceptional cases, however, a deviation in accordance with the guidelines in Ch. 8 is possible.

Basic requirements: hydrological attributes		*Applicable to:*
(MF1)	**Moderated, natural discharge regime** The discharge regime in minimum flow reaches (i.e. the pronounced fluctuation in discharge levels during the course of the year, including enhancement flows; ➢ Glossary) should vary on a general and seasonal basis in line with the characteristics of an unaffected river system. Run-of-the-river power plants should implement a minimum flow regime following as close as possible to naturally occurring discharge patterns.	*Storage and run-of-the-river power plants (diversion type power plants)*
(MF2)	**Minimum, seasonally adjusted base flow level varying with natural discharge conditions** Minimum flow should not fall below a minimum, seasonally adjusted basic discharge level that varies with natural stream flow. This should be dimensioned on an individual basis, so that it can be shown that the current flows and habitats are adequately wide-ranging to safeguard naturally occurring biodiversity (this of course excludes river reaches that dry out naturally).	*Run-of-the-river power plants (diversion type power plants)*
(MF3)	**Minimum, seasonally adjusted base flow level varying with natural discharge conditions** Minimum flow from water impoundments in the catchment area should not fall below a minimum, seasonally adjusted basic discharge level (varying with stream flows where possible). This should be determinated on an individual basis so that it can be shown that the current flows and habitats are sufficiently wide-ranging to safeguard naturally occurring biodiversity (this of course excludes river reaches that dry out naturally). If it is not possible to conduct a study downstream of every single water intake in a complex catchment area containing a large number of intakes, the reasons for any omissions must be documented accordingly. Representative studies should be used to extrapolate minimum flow rates for these minimum flow reaches, allowing the mitigation strategy to integrate every reach affected by diversions into an overall plan for establishing ecologically sustainable basic discharge levels. If any outstanding questions or problems arise from applying small-scale studies to the overall catchment area, these should be jointly resolved by the expert auditor and by expert coordination (see Ch. 8).	*Storage power plants*

Basic requirements: connectivity of river systems		*Applicable to:*
(MF4)	**Interconnection between water course, groundwater, riparian zone and flood plains** Minimum flow should help prevent any lasting deterioration in the interconnection of water, land- and groundwater habitats and avoid any significant reduction in the replenishment of groundwater reserves.	*Storage and run-of-the-river power plants (diversion type power plants)*

(MF5)	**Preventing unnatural isolation of tributaries** Hydroelectric power plants should quantify minimum flow rates in order to stop tributaries and secondary streams from becoming unnaturally isolated. This requirement only applies if isolation is clearly caused by the minimum flow regime and not, for example, by artificial structures that are unconnected to the power plant. If such constructions are responsible for isolating areas, this should be remedied primarily by using eco-investments to fund land reclamation measures.	*Storage and run-of-the-river power plants (diversion type power plants)*
(MF6)	**Adequate water depth for fish migration** Minimum flow rates should be adequate to maintain seasonal water depths at a sufficient level for fish both to migrate in the main channel and to reach and pass through tributaries. This requirement only applies to fish waters as defined in Ch. 8.	*Storage and run-of-the-river power plants (diversion type power plants), only fish waters*
Basic requirements: solid material budget and morphology		*Applicable to:*
(MF7)	**Preservation of the natural structure of the riverbed** The minimum flow reaches' characteristics should correspond to the natural riverbed structure. In particular, minimum flow regimes should be capable of transporting adequate material in order to avoid the formation of marshy river flow sections or fine sediment deposits over a wide area (external silting).	*Storage and run-of-the-river power plants (diversion type power plants)*
Cross reference	**Coordination with bedload management** Hydroelectric power plants should coordinate minimum flow with bedload management. Studies in both fields, particularly into aspects of ongoing bedload transport and preserving equilibrium bedload levels, should be augmented through a process of mutual consultation.	*Storage and run-of-the-river power plants (diversion type power plants)*
Basic requirements: landscape and biotopes		*Applicable to:*
(MF8)	**Preservation of habitats requiring protection and retaining function of landscape features** Minimum flow must preserve the natural attributes of inventoried habitats, landscape features or other biotopes requiring special conservation.	*Storage and run-of-the-river power plants (diversion type power plants)*
(MF9)	**Special regulations for the preservation of inventoried flood plains** Special regulations conforming to the requirements set out in Ch. 8 should apply to any inventoried flood plains lying within the bounds of a facility.	*Storage and run-of-the-river power plants, (diversion type power plants) only when inventoried flood plains are affected*

Basic requirements: biocoenoses		*Applicable to:*
(MF10)	**Preservation of natural biodiversity, particularly the native fish species as well as rare and endangered biocoenoses** Minimum flow regulations should be specifically designed to preserve a wide range of natural riverine habitats, thus providing the ecological basis for the diversity of native plants and animals. In particular, minimum flow regulations should establish the requisite conditions allowing native fish species, which also includes all formerly (i.e. potentially) occurring types of fish, to continue to reproduce on a stock-sustaining basis. Hydroelectric power plants should ensure that rare and endangered biocoenoses depending directly on river type, water quality and river size are conserved. This applies especially to pioneer and succession zones.	*Storage and run-of-the-river power plants (diversion type power plants)*
(MF11)	**No critical temperature conditions and oxygen concentrations** Power plants should be able to show that their operational modes prevent temperature conditions and oxygen concentrations within minimum flow reaches from reaching critical levels that could harm native biocoenoses. Equally, they should ensure that the dilution ratio within minimum flow reaches, particularly where wastewater outlets discharge into the river, is adequate to safeguard natural cleaning processes.	*Storage and run-of-the-river power plants (diversion type power plants)*

10 HYDROPEAKING

Aspects of hydropeaking with environmental significance

The hydropeaking aspects dealt with here concentrate on hydropeaking events of the kind occurring as a result of managing reservoirs on a daily, weekly, seasonal or annual basis (usually peak electricity production), or which arise from run-of-the-river power plants with a hydropeaking operation. As this intermittent operating method is primarily linked to the energy demand and not to ecological considerations, it often causes rapid and very strong discharge fluctuations in the affected sections of rivers, to which aquatic organisms do not have sufficient time to react. Such discharge fluctuations influence the distribution and quality of physical habitats and consequently impose huge restrictions on the living conditions of organisms: during generation-flow periods, the artificial rise in discharge levels leads to hydraulic effects such as fluvial erosion or to intensive drift and active flight behaviour of organisms. After peak generation and during reduced-flow periods, organisms can get stranded in dried-out areas of rivers or isolated in pools, where the decreasing concentration of oxygen can cause them to suffocate. This effect is particularly noticeable in river stretches whose natural morphology has extensive zones of shallow water, or in secondary streams that may be intermitted during low streamflow. This problem can also be exacerbated when the effects unleashed by a chain of power plants overlap on a single river section. The impact of hydropeaking should therefore be resolved whenever possible in the context of hydropower chains. Should this not prove possible, individual green hydropower facilities should at the very least meet the condition of minimising the local effects of their hydropeaking. On the other hand, the fact that controlling large annual storage capacities involves fundamentally altering the hydrological regime (reversing the mean discharge patterns of summer and winter) must be accepted as unavoidable as far as certifying these facilities for green electricity is concerned.

10.1 Objectives for ecologically based hydropeaking

Main objectives

The aspects mentioned above mean that inspections will focus on the **moderation** of discharge fluctuations as the main objective of ecologically based hydropeaking. Environmentally responsible operating practice should ensure that facilities control discharge fluctuations in terms of peaking frequency, peaking amplitude, and the upward and downward gradient of peak generation-flows, in such a way as to prevent any serious damage to the riverine biocoenoses or any long-term degradation in the natural diversity of plants and animals. In doing so, the hydropeaking operation should imitate more closely the slower rise and fall of natural flood events. This is of especial importance when it comes to natural or semi-natural river beds within the return flow section. In the case of power station chains operating a hydropeaking overlap, the plants should work together with each other as far as possible when implementing these measures, primarily in order to resolve or minimise the problems associated with such chains.

Ecological objectives of specific environmental fields

Hydrological character

- The **rise and fall in water levels** during hydropeaking should be slowed down sufficiently to allow aquatic organisms to migrate to safe areas.
- Unless river stretches dry out naturally, a **minimum base flow** during reduced-flow periods is required to ensure that areas of ecological significance are preserved, in order to maintain a diverse range of riverine habitats for plants and animals (see also minimum flow regulations).

Connectivity of river systems

- The discharge level during reduced-flow periods should not lead to fish and benthic fauna being left **stranded and dying** outside the main water channel.

Solid material budget and morphology

- The operation of hydropeaking should cause neither **bank** nor **riverbed erosion**; large **bedload deposits in the tailwater or return flow section** is also to be avoided.

Landscape and biotopes

- Facilities should ensure that characteristic **landscape features of the river** are preserved despite hydropeaking.
- Ecologically-based hydropeaking should allow the river to be used by the local population for **recreational activities**. However, this should not pose any safety problems.

Biocoenoses

- No long-term damage to the existing **biodiversity** represented by native fish and benthic fauna in the return flow section or tailwater reach may occur, despite hydropeaking.
- The **age class distribution** of the fish population shall be maintained despite hydropeaking, and rare and endangered species should be preserved in their reproductive state.
- The upward gradient of peak generation-flows shall be moderated in order to ensure that an irreversible **drift** of fish and macrozoobenthos does not occur.
- Facilities must ensure that the **diversity of habitats** (particularly spawning grounds, breeding areas, sensitive riparian zones, wetlands, etc.) is preserved despite hydropeaking.

10.2 Basic requirements for assessing ecologically based hydropeaking

The following prescriptive formulations indicate that the specified basic requirements are binding for every green power plant, regardless of the original ecological conditions involved. In ecologically justified exceptional cases, however, a deviation in accordance with the guidelines in Chapter 8 is possible.

Basic requirements: hydrological attributes		*Applicable to:*
(HP1)	**Attenuation of discharge fluctuations** During hydropeaking, the discharge alterations must be attenuated in regard to the frequency (this means at short notice and on a seasonal basis, particularly in the case of spawning and migration periods) and in terms of quantity, sufficiently to ensure that no lasting qualitative and quantitative damage is caused to the naturally occurring diversity of the fish and benthic fauna in the river reaches involved. In particular, care must be taken to ensure that the water level does not fall too swiftly in the reduced-flow period and does not rise abruptly in the peak generation-flow period.	*Hydropower plants with hydropeaking operation*
(HP2)	**No dry-out in the return flow section** The return flow section should never be permitted to dry up completely during low flow, so that a minimum functional habitat diversity for flora and fauna is assured (cf. also minimum flow regulations).	*Hydropower plants with hydropeaking operation*
(HP3)	**No critical effects of temperature** Critical and extreme temperature fluctuations must be avoided in the return flow section, so as to preclude any temperature-related damage to the diversity of the fish and benthic fauna.	*Hydropower plants with hydropeaking operation*
Basic requirements: connectivity of river systems		*Applicability*
(HP4)	**No isolation of fish and benthic fauna outside the main channel** The gradient of the water level change in the receding-flow phase must be attenuated adequately to ensure that wide-spread isolation of the fish and benthic fauna in their refugial habitats outside the main channel is avoided. No isolated pools should be created, in which the oxygen concentration falls below critical values.	*Hydropower plants with hydropeaking operation*
Basic requirements: landscape and biotopes		*Applicability*
(HP5)	**Preservation of habitat diversity and characteristic landscape features** Changes in discharge during hydropeaking must be moderated in terms of time and quantity as much as is necessary to preserve the accessibility and recreational function of the rivers affected, and so as not to threaten long-term damage to its natural diversity of habitats and characteristic landscape features.	*Hydropower plants with hydropeaking operation*

(HP6)	**Special regulations for the preservation of inventoried flood plains** If there are any inventoried flood plains within the influence of a facility, these should come under special regulations conforming to the requirements in Chapter 8.	*Storage and run-of-the-river hydropower plants*
Basic requirements: Biocoenoses		*Applicability*
(HP7)	**Preservation of fish habitats, particularly spawning grounds and juvenile fish habitats** No irreversible loss in the variety of fish habitats may occur, nor any serious disruption to the naturally occurring diversity and age class distribution of fish populations. Suitable spawning grounds and habitat for juvenile fish may not dry out, particularly during low flow periods.	*Hydropower plants with hydropeaking operation*

11 RESERVOIR MANAGEMENT

Significant ecological aspects of reservoir management

The guidelines on reservoir management presented here focus on river impoundments and resolving the problems associated with reservoir flushing for all types of power plants. This is why devices to remove bedload particles (sand traps) are also included in Chapter 11, although in a stricter sense this has nothing to do with managing reservoirs. Three different study fields are outlined below for various types of facilities and operating methods: (1.) flushing large annual storage reservoirs, (2.) managing storage capacity in river impoundments (incl. dam and weir design and water level fluctuations) and (3.) flushing sand traps. The development of a specific management program involves addressing the facility's potential for ecological sustainability, insofar as this is actually possible under ideal conditions, despite a particular form of utilisation. When a large storage power plant is certified, for example, it must therefore be accepted as inevitable that the banks of alpine annual storage reservoirs will dry out every year. For all three fields of study, the principle involved is the same: optimisation measures are proposed only in areas where they are made feasible by technical and operational boundary conditions, and where their ecological impact is likely to be relevant at the same time.

11.1 Objectives for ecologically based reservoir management

The categories described above were used to formulate differentiated performance targets for ecologically responsible reservoir management:

Main objectives for large annual storage reservoirs

Large (usually alpine) annual storage reservoirs run a purely demand-based operation and thus have intrinsic limitations in terms of ecological viability. Fluctuations of the reservoir levels are unavoidable as there is no other way of maintaining seasonal storage capacities. The aim of ecologically based reservoir management is therefore focused on what kind of procedures are carried out for the bottom outlet operation. If no alternatives can be found to flushing the reservoirs, these procedures should be designed and implemented so as not to endanger or cause lasting damage to fish and benthic organisms in affected river reaches.

Main objectives for river impoundments

Ecologically based storage capacity management for river impoundments focuses on measures to do with raising or lowering reservoir levels. These measures shall prevent any lasting degradation of ecologically important sections of bank and avoid major, long-term damage to the integrity of the network between reservoirs and riparian zones. Particular efforts should be made to conserve lotic water zones (➢ Glossary) in areas where they still exist.

Main objectives for sand traps

Unlike large annual storage reservoirs, sand traps are flushed much more frequently, up to several hundred times a year. This is managed in an ecologically responsible way by focusing on how the installation is built and on how flushing procedures are designed and carried out. If sudden flushing events are unavoidable because the sand traps cannot be emptied continually by a certain permanent flow, such flushing procedures should be developed in order to prevent large sand and unnatural silt deposits in downstream river sections. The power plant should control flushing operations and deposition effects in order to avert any lasting damage to fish and benthic organisms. Sudden flushing should be avoided wherever possible by appropriate structural solutions.

Ecological objectives of individual environmental fields

Hydrological character

- *Large annual storage reservoirs:*
  Hydroelectric power plants shall cause extreme changes in discharge levels due to **reservoir flushing** only during natural high water flows that are already underway in the affected stretches. During the flushing phase, facilities shall ensure that temperature conditions, oxygen concentrations and suspended-solids levels in the affected stretches do not reach a critical state for riverine biocoenoses. Flushing shall be initiated at a slow pace and gradually tapered off again.
- *River impoundments:*
  Power plants should manage river impoundments to ensure that their operations cause **no ecological degradation in tailwaters due to unnatural discharge fluctuations**.
- *Sand traps:*
  Sand traps should be flushed as continually as possible, or during natural high water flows, depending on the amount of material that is carried into the river system. Where feasible, the power plant should construct installations to implement a continuous flushing system. If sudden flushing cannot be avoided, it should be initiated slowly and gradually tapered off down to a level which will allow further transport of removed solid materials.

Connectivity of river systems

- *Large annual storage reservoirs:*
  If reservoir's inflowing streams are populated with fish, their **inlet zones** should allow fish to pass through at different water levels. Every effort should be made to turn such inlets into naturalistic features.
- *River impoundments:*
  Raising and lowering the water level in reservoirs should not cause any long-term damage or major deterioration in ecologically important riparian zones and should not cause long-term harm to the networks linking them to the reservoir. Contiguous flood plains should be flooded in accordance with the ecological criteria (see also Ch. 8).

- *Sand traps:*
  Plants must control flushing procedures to prevent deposits in the water course from causing a **barrier effect** or unwanted siltation of the top layer of sediment in areas downstream of the sand traps.

Solid material budget and morphology

- *Large annual storage reservoirs:*
  Storage reservoirs (including equalisation basins) must be flushed in a way that **avoids excessive silting or erosion of the tailwater bed**.
- *River impoundments:*
  Run-of-the-river power plants must ensure that bedload gets transported downstream over the medium term (1 - 5 years). **Gravel removal** should not take place. It is advisable to implement measures to reduce gravel removal should it be caused by third parties, i.e. not by the power plant itself. These initiatives can be undertaken using funds made available through eco-investments (see Ch. 2.4). Power plants should implement special, ecologically enhanced arrangements to deal with specific cases of contaminated sediment.
- *Sand traps:*
  Power plants must take steps to prevent **large sand deposits** in downstream areas below the sand trap, or to ensure that they are transported away within a reasonable period in ecological terms (generally within a few hours).

Landscape and biotopes

- *Large annual storage reservoirs and river impoundments:*
  Reservoirs must be managed to ensure that banks (both in the reservoir and in tailwaters) maintain **functionally natural transition areas between land and main channel**, particularly in shallow water zones. (Exception: annual storage reservoirs in alpine regions with large fluctuations in water levels. Mitigation work in these areas should seek where possible to optimise scenic attributes and preserve landscapes that are of interest to tourists).
- *Large annual storage reservoirs and river impoundments:*
  Habitats requiring special conservation (including those which are not inventoried) must be preserved, along with landscape features that rely directly or indirectly on the river type and size.
- *Large annual storage reservoirs and river impoundments:*
  Reservoir management should take into account the **breeding, resting and wintering biotopes for migratory birds**.

Biocoenoses

- *Large annual storage reservoirs, river impoundments and sand traps:*
  If flushing procedures are being carried out in rivers inhabited by **rare and endangered species**, these species must not disappear irretrievably.
- *Large annual storage reservoirs, river impoundments and sand traps:*
  The flushing process scheduling and procedures should make allowance for the **reproductive ecology** of the most important fish species living in the river system, in order to make sure that enough juvenile fish survive to maintain the population. Power plants must therefore avoid flushing reservoirs during critical reproductive periods.
- **Side channels or tributaries allowing fish to retreat** must be accessible during the flushing procedures.

11.2 Basic requirements for assessing ecologically based reservoir management

The following prescriptive formulations indicate that the specified basic requirements are binding for every green hydroelectric power plant, regardless of the original ecological conditions involved. In ecologically justified exceptional cases, however, a deviation in accordance with the guidelines in Chapter 8 is possible.

Basic requirements: hydrological attributes		*Applicable to:*
(RM1)	**Management program for reservoir flushing** A management program for flushing procedures should entail checking initially whether draining the storage basin as planned is actually necessary or if there is another technical alternative that makes better ecological sense. If flushing the reservoir is unavoidable, this should take place during a natural high water period that is already underway in affected stretches. Flushing must be carried out in a way that prevents lasting damage to flora and fauna. This should be accomplished by methods such as gradually adjusting water flows during the initial and concluding phases of the flush wave.	*Seasonal or annual storage reservoirs and river impoundments*
(RM2)	**Management program for discharge fluctuations** If hydropower operating causes regular and unnatural discharge fluctuations, these should be structured in a way that prevents any long-term degradation of bank structures and riverine organisms. This applies particularly to power plants or chains of power plants running hydropeaking. They should above all conform to the requirements for ecologically based hydropeaking (see Ch. 10.2).	*River impoundments*
(RM3)	**Flushing procedures of sand traps** Sand traps should be flushed continually where this is possible or in periods when discharge levels are naturally high. Flushing procedures should dampen the pace of initial and terminal flows (see also solid material budget and morphology). While the sand trap is being flushed, maximum discharge rates should be quantitatively and temporally adjusted to prevent large sand deposits below the sand trap.	*Sand traps*

Basic requirements: connectivity of river systems		*Applicable to:*
(RM4)	**Formation of inlet zones in large annual storage reservoirs** Inlet zones in large annual storage reservoirs should be designed to allow fish passage despite changes in the reservoir's water level. Where possible, this should be done by designing natural-like inlets. This requirement only applies to inflowing streams that have been categorised as fish waters as defined in Ch. 8.	*Seasonal or annual storage reservoirs; only fish waters*
(RM5)	**Raising and lowering reservoir water levels** Fluctuations in reservoir water levels should not endanger or cause long-term damage to ecologically important riparian zones (particularly in shallow water areas) or impair the networks linking them to the reservoir. If deterioration cannot be avoided, those responsible for it should undertake special mitigation measures to optimise the ecological potential of these riparian zones.	*River impoundments*

(RM6)	**Ecologically based reservoir design and connectivity with tributaries** Power plants should maintain a functional network connecting reservoirs to tributaries and make sure that their banks or embankment structures reflect conditions to safeguard their connectivity with the regional hinterland. This should focus particularly on the shallow water zones. Flood control permitting, the layout of frontline dams should be designed for low and mean flow levels and should allow contiguous riparian zones or flood plains to be flooded in high water periods. This requirement does not apply to annual storage reservoirs in alpine regions, which feature large fluctuations in water levels. At the very least, however, optimisation work should be carried out in these areas, if technically feasible, to enhance scenic attributes and preserve landscapes that are of interest to tourists.	*River impoundments, seasonal and annual storage reservoirs (Exception: alpine annual storage reservoirs with large fluctuations in water levels)*
Basic requirements: solid material budget and morphology		*Applicable to:*
(RM7)	**No silting caused by flushing** All flushing procedures (incl. equalisation basins and sand traps) must be carried out in a way that does not lead to unnatural silting of the tailwater bed (this might require a correspondingly long follow-up flushing phase). Where possible, sediments should be transported downstream on a continual basis, particularly from the sand traps.	*Seasonal or annual storage reservoirs, river impoundments and sand traps*
(RM8)	**Ensuring bedload transport** The power plant should control reservoirs to make certain that it can meet the requirements for bedload management. In practical terms, this means that reservoirs should be designed in a way that allows solid material to be transported downstream on an ongoing basis. This may possibly involve local dredging to create specific conditions in the reservoir ensuring that bedload transport can take place in the area. In contrast, the plant should avoid carrying out wholesale gravel removal in the reservoir. If gravel removal occurs but is not being caused by the power plants, it should look into using eco-investments to fund measures to minimise the process. Power plants should implement special, ecologically enhanced arrangements to deal with specific cases of contaminated sediment.	*River impoundments*
Basic requirements: landscape and biotopes		*Applicable to:*
(RM9)	**Aggradation around the stagnation point in reservoirs** Sediment should be allowed to fill in areas within the reservoirs to serve as ecological compensation zone. Where possible, these should be turned into viable habitats (e.g. as breeding, resting and wintering biotopes for migratory birds). Eco-investments could be used to fund additional measures to augment such areas with artificial island structures (e.g. through gravel accumulations).	*River impoundments*
(RM10)	Special regulations for conserving **inventoried flood plains** Special regulations conforming to the requirements set out in Ch. 8 should apply to any inventoried flood plains lying within the bounds of a facility.	*Seasonal or annual storage reservoirs and river impoundments*

Basic requirements: biocoenoses		*Applicable to:*
(RM11)	**Threshold values for suspended material loads, temperature and oxygen concentration** Power plants should ensure that flushing procedures do not allow suspended material loads, temperatures and oxygen concentrations to reach critical levels capable of causing lasting damage to riverine organisms.	*Seasonal or annual storage reservoirs and river impoundments*
(RM12)	**Scheduling of flushing with respect to times of reproduction** Flushing procedures should be timed in order to sustain and avoid endangering the reproduction of naturally occurring fish species in affected river reaches.	*Seasonal or annual storage reservoirs and river impoundments*
(RM13)	**Retreat routes during reservoir draining** Power plants should take steps to safeguard migration routes allowing fish to retreat into tributaries when reservoirs are being drained, in order to minimise the risk of fish dying.	*Seasonal or annual storage reservoirs and river impoundments*

12 BEDLOAD MANAGEMENT

Significant ecological aspects of bedload management

Although bedload is considered to be one of the most important factors in river ecology, only a small minority of river systems in Central Europe nowadays have bedload regimes that are unaffected by anthropogenic influences. Nevertheless, a naturally diverse range of habitats is just as crucial in ecological terms as the naturally occurring high water flows in which bedload transport and channel rearrangement can take place. Disturbance like this play a vital role in preserving a wide variety of natural structures and species diversity. If bedload transport takes place upstream of a river impoundment, the material that gets carried into the reservoir is deposited in successive size-sorted accretions. The depositions become increasingly finer when approaching the weir. These effects can cause substantial alterations to the original channel structure, which besides homogenising the substrata can also produce siltation of the riverbed. Furthermore, decomposing sludge may form and oxygen depletion may occur. Under these circumstances, smaller river impoundments can quickly fill up with sediment.

Since smaller discharges have a reduced transport capacity, sediment deposits may accumulate in diverted river reaches downstream of weirs or dams. Within the diverted reaches, this sediments can only be shifted in periods of significantly higher flows. Resulting homogenisation of substrate as well as siltation can accentuate the degradation of river ecology affected by a minimum flow regime. On the other hand, abundant biocoenoses can also develop within a diverted river section provided that its physical habitats are diversely structured. Conversely, if there is a general bedload deficit (e.g. because sediment has already ceased being transported from areas above the reservoir or because reservoirs have been cleared through gravel removal) this can lead to erosion of the downstream river bed. Apart from the generation of an armour layer, this usually results in lower groundwater levels, which can thus cause long-term damage to contiguous flood plains. A bedload deficit can also cause considerable deterioration riparian structures that are responsible for connectivity between water and land areas and for the functionality of the ecologically important land-water ecotones.

12.1 Objectives for ecologically based bedload management

Main objectives

The aim of ecologically based bedload management is to establish regulations to ensure that the budget of solid materials is geared towards the natural characteristics of the river involved. Flood control permitting, this should enable bedload transport and channel rearrangements to occur in a way that develops morphological structures matching the river type concerned. Individually adapted bedload management strategies should apply to all main channels affected and to the most important tributaries. On the basis of the ongoing bedload situation i.e. taking the information available on bedload sources, retention and transport, and on sections experiencing erosion and deposit formation, the aim is to ascertain whether there is a specific problem with the bedload. If this is the case, ecologically optimised measures should be developed, which take into account flood control and, where possible, the overall sediment transport situation in the catchment area. In much the same way that individual facilities can take steps to promote fish migration, single power plants can act as connecting links to augment potential bedload transport and thus establish a basis for developing an integrated solution in the future. Here too, however, it would also be advisable and sensible to undertake a combined set of measures for an entire chain of power plants.

Ecological aims of individual environmental fields

Hydrological character

- *Only for run-of-the-river power plants:*
  Instream flow regulations (e.g. minimum flow) in diverted river reaches shall be adequate to enable **sediment transport** during regular flood events if sediment transport occurs naturally.
- *Only for run-of-the-river power plants:*
  Instream flow regulations (e.g. minimum flow) in diverted river reaches shall be sufficient to enable **channel rearrangement** (bank erosion and deposition) and **relocation of channel patterns** during large flood events if this would occur naturally.
- *Only for storage power plants:*
  The above requirements also apply in principle to large storage power plants, if bedload can be transported through the **reservoir**.

Solid material budget and morphology

- The influx of bedload into the tailwaters of reservoirs, dams and intakes (incl. material brought in from lateral channels) should be dimensioned in order to **prevent any erosion of the riverbed** that would dry out normally flooded sections or cut off side streams from the main channel. Naturally occurring lateral erosion should be allowed to go ahead in areas where flood control does not directly prohibit it.

- *Only for run-of-the-river power plants:*
  Power plants should maintain the solid material budget in the diverted river section (for diversion type power plants) or in tailwaters (for river power plants) at a level that enables **river beds to develop a typical morphology** and allows bedload to be transported through the reservoir.
- *Only for storage power plants:*
  Power plants should maintain the solid material budget in the diverted river reaches at a level that enables **river beds to develop a typical morphology**. Targeted lateral erosion or an influx of bedload from tributaries should be used as compensatory measures in the event of a **bedload deficit** in the main channel.
- The inlets of lateral streams into reservoirs should be able to form functionally **semi-natural debouchment inlet zones**.

Landscape and biotopes

- Power plants should permit a adequate **influx of bedload** into the tailwaters of reservoirs and impoundments to preserve and/or develop a typical **riverine landscape.**
- *Only for run-of-the-river power plants:*
  The **tailwater gradient** should be adequately steep to allow bedload transport to take place. Dredging should only be carried out in areas where it is required by flood control.

Biocoenoses

- Bedload management should ensure that **typical riverine habitats** are allowed to form.

12.2 Basic requirements for assessing ecologically based bedload management

The following prescriptive formulations indicate that the specified basic requirements are binding for every green hydroelectric power plant, regardless of the original ecological conditions involved. In ecologically justified exceptional cases, however, a deviation in accordance with the guidelines in Chapter 8 is possible.

Basic requirements: hydrological attributes		*Applicable to:*
(BM1)	**Bedload transport during flood periods** Power plants should control the discharge into bedload-carrying rivers so as to allow bedload transport downstream of dams and reservoirs during flood periods (see also basic requirement PD4). This requirement also applies to storage power plants, if bedload can be transported through the reservoir. In specific cases it must be ensured that this requirement does not conflict with flood control (see Appendix A2: BWG flood control case study)	*Run-of-the-river power plants* *Storage power plants (conditional)*
Basic requirements: solid material budget and morphology		*Applicable to:*
(BM2)	**Preventing bed erosion through adequate influx of bedload** The influx of bedload into the tailwaters of reservoirs, dams and intakes (including material brought in from lateral tributaries), should be dimensioned in order to prevent any erosion of river beds that would cause naturally flooded areas to dry out or lateral tributaries to be cut off from the main channel. Naturally occurring lateral erosion should be permitted in areas where flood control does not prohibit it.	*Storage and run-of-the-river power plants*
(BM3)	**Solid material budget for run-of-the-river power plants** Power plants should maintain the solid material budget in diverted river reaches (for diverted type power plants) or in tailwaters (for river power plants) at quantity and quality levels that allow the river system to develop a typical morphology. Bedload should be transported through the reservoir. In the case of reservoirs, this means ensuring that ongoing bedload transport takes place following an initial filling-in phase (lasting 1 - 2 years in small reservoirs and up to 10 years in large ones). Ongoing bedload transport is taken to mean an equilibrium level that evens itself out over a one-to-two-year period.	*Run-of-the-river power plants*
(BM4)	**Solid material budget in diverted river reaches caused by storage power plants** Power plants should maintain the solid material budget in diverted river reaches at a level that allows rivers to develop a typical morphology. Targeted lateral erosion or an influx of bedload from lateral tributaries should be used to compensate for a possible **bedload deficit** in the main channel.	*Storage power plants*
(BM5)	**Formation of natural lateral stream inlets** Lateral stream inlets should be able to form functionally **semi-natural inlet zones**.	*Storage and run-of-the-river power plants*

Basic requirements: landscape and biotopes		*Applicable to:*
(BM6)	**Tailwater gradient for bedload transport** The tailwater gradient should be adequately steep to ensure that bedload can be transported. Tailwater dredging should only be permitted if required by environmentally sustainable flood control. Federal flood protection guidelines on water and geology should be implemented for this purpose. According to these guidelines, flood control is only to be used as a preventative measure to protect people and significant amenities with a minimum degree of intervention in running waters (for wording see Appendix, Section V).	*Run-of-the-river power plants*
Basic requirements: biocoenoses		*Applicable to:*
(BM7)	**Formation of typical riverine habitats** Bedload management should ensure that typical riverine habitats are allowed to form.	*Storage and run-of-the-river power plants*
Cross-reference to reservoir management (flushing procedures)	**Damage to biodiversity** Flushing procedures and bedload withdrawals or accretions should not cause any long-term damage in qualitative or quantitative terms to fish populations and benthic fauna.	

13 POWER PLANT DESIGN

Significant ecological aspects of power plant design

The ecological impact of a hydroelectric power plant varies greatly depending on the way its technical installations are designed. This mainly applies to weirs and dams, head and tailwater channels, water intakes, turbine intakes, gates and screens. It also applies to technical or electronic systems that direct operations from the power plant control centre. In ecological terms, plant installations can have a direct or indirect impact. Examples of direct effects include substantial alterations to the natural landscape, emission of toxic lubricants, damage to organisms in turbines or mechanical disturbance of sediment transport. There are various ways in which plant design indirectly influences river ecology; it can affect bedload budget, bank and riverbed structure, water quality, the connectivity of river systems and thus eventually the status of riverine biocoenoses. Therefore, from an ecological point of view "green" requirements for plant design should focus on constructing installations or devising techniques that allow the original river connectivity to be restored. The integration of plant installations into the countryside is equally significant, and can play an important role primarily for large facilities. Another structural aspect of hydroelectric power plants concerns secondary uses of installations for recreational pursuits and flood control. These factors should also be considered when drawing up the ecological requirements.

13.1 Objectives for ecologically based power plant design

Main objectives

The aim of an ecologically based power plant concept is to enhance the way installations are built and operated in order to provide as much support as possible to the previous four management fields. In addition to this, power plant buildings should not irreversibly destroy or cause lasting damage to habitats requiring special conservation. Power plant buildings and operations should be designed in order to preserve the overall connectivity of river systems and thus make sure that all channels directly influenced by the power plant remain passable. The power plant should take particular efforts to ensure that it uses current state-of-the-art methods to prevent hydropower utilisation from lastingly impairing the ability of fish to migrate unimpeded through the affected river system. This applies both to the upstream and downstream fish passages.

Ecological aims of individual environmental fields

Hydrological character

- **The control and/or design of water intakes** should be designed to allow natural moderation of discharge flows below the impoundment. These should enable the power plant to regulate the timing of discharge flows to reflect natural fluctuations and not stop high water flows completely, even medium-sized ones, if this proves not to conflict with flood control.

Connectivity of river systems

- Power plants should use appropriate and effective state-of-the-art methods to ensure **that hydraulic structures** (such as weirs, dams, intakes etc.) **remain passable.**
- Bank reinforcements and constructions should be designed to prevent deterioration of the connection between **riparian zone and the main river channel**, assuming this does not conflict with flood control.
- Installations and power plant buildings should be designed so as not to cut off the **connection to tributaries**.

Solid material budget and morphology

- Barrage weirs should be designed and operated in a way that enables **bedload to be transported regularly** into tailwaters (assuming that bedload transport would take place naturally and after considering the overall bedload situation).

Landscape and biotopes

- Power plant buildings and installations should be designed and constructed so as to avoid irreversibly destroying the diversity of **habitats requiring special conservation**. This also applies to the non-inventoried locations, such as hedge sites or bird breeding grounds.
- No new buildings should be erected in **inventoried zones**. Existing structures and installations should be integrated as effectively as possible into the existing natural landscape.

Biocoenoses

- Power plants should be designed so as to allow **fish to migrate unimpeded**, including all naturally and potentially occurring fish species. This applies both to the upstream and downstream fish passages. The procedure should evolve continually to absorb the ongoing advances in current practice in order to enhance the effectiveness of future measures, particularly when it comes to downstream migration.
- The power plant should avoid any construction work which would be damaging the **stocks** and **diversity** of native fauna, using state-of-the-art techniques to specially protect them from the impact of installations and machines (e.g. turbines, tailwater channel).

13.2 Basic requirements for assessing ecologically based power plant design

The following prescriptive formulations indicate that the specified basic requirements are binding for every green hydroelectric power plant, regardless of the original ecological conditions involved. In ecologically justified exceptional cases, however, a deviation in accordance with the guidelines in Chapter 8 is possible.

Basic requirements: hydrological attributes		*Applicable to:*
(PD1)	**No abrupt release of high water flows** Power plant control systems should be designed to ensure that the high water flows are not abruptly released.	*Run-of-the-river power plants*
(PD2)	**Basic discharge in diverted river reaches of diversion type power plants** Hydroelectric power plants should take constructive measures to ensure that the basic discharge flows are always released into the minimum flow reach. This is particularly important under special operating conditions, such as plant inspections or breakdowns, in which case the power plant is taken off line. Essentially, installations should be structured technically so that the basic requirements for minimum flow management (particularly MF1 - MF3) can be met.	*Storage and run-of-the-river power plants (diversion type power plants)*
Basic requirement: connectivity of river systems		*Applicable to:*
(PD3)	**Ensuring unimpeded fish migration** Power plant design should create the necessary conditions to allow all formerly, and thus all potentially occurring fish species to migrate unimpeded, and make sure that such measures are in fact effective for migrating fish currently present in the river system (incl. small fish species). Whenever possible, this should be accomplished by activating old backwaters or creating bypass channels. If the power plant implements technical solutions, it must make sure that the upstream and downstream migrations are actually viable and keep a documented record. With the exception of large annual storage reservoirs and high-altitude alpine impoundments, all barriers in fish waters should be passable and conform to state-of-the-art technical standards. The power plant should implement current advances in practical methodologies and scientific knowledge, particularly when it comes to downstream fish migration.	*Storage and run-of-the-river power plants; only for fish waters*
Basic requirement: solid material budget and morphology		*Applicable to:*
(PD4)	**Bedload-adapted weir design** Weirs should be designed to cope with the bedload movement and make sure that it gets transported away in order to maintain an equilibrium bedload level in upper and tailwaters.	*Storage and run-of-the-river power plants*

Cross-reference	**Collaboration with bedload management** Expert coordination over a range of specialists should make sure that the requirements for power plant design are implemented in a way that provides sensible back-up to ecological measures being taken in all the other management fields. Care should be taken to assure this even if different specialist departments are responsible for handling the management fields involved.	*Storage and run-of-the-river power plants*
Basic requirements: landscape and biotopes		*Applicable to:*
(PD5)	**Power plant buildings in habitats requiring conservation** If there are power plant buildings and installations located in habitats requiring special conservation, they should be integrated ecologically so they do not cause irreversible destruction of these habitats. No new buildings should be constructed in the inventoried habitats. Existing buildings should be blended as effectively as possible into the natural landscape.	*Storage and run-of-the-river power plants*
(PD6)	**Additional habitats in artificial bypass channels** Artificial bypass channels should be designed to serve as additional and functional substitute habitats (for both aquatic and semi-aquatic and also terrestrial organisms). These measures should make special allowance for the habitat of rheophile organisms (➢ Glossary) as these disappear in extensive areas when river impoundments are built.	*Run-of-the-river power plants*
Basic requirement: biocoenoses		*Applicable to:*
(PD7)	**Conservation of species living in and around rivers** Organisms living in and around rivers should be protected from installation structures and machines (e.g. turbines, water impoundments, headwater and tailwater channels) in accordance with the current state-of-the-art technologies.	*Storage and run-of-the-river power plants*

Part IV:

Annotated Bibliography

14 Annotated bibliography

What is meant by the annotated bibliography?

As mentioned in Ch. 8, the annotated bibliography is designed to support the work of expert auditors. It contains information about each of the five management fields, divided up systematically into the following categories:

- General background literature and basic information to provide answers, if necessary, to any fundamental questions that crop up within a management field.
- Bibliographical references on current state-of-the-art techniques and methodologies, to make sure that all certification procedures for green electricity conform to comparable standards even within individual studies.
- Works on selected reference objects, project reports and practical case studies, in order to provide a comparative basis for evaluating the green-electricity certification procedure for a specific facility (only in the German version).
- In-depth scientific reference works to enable additional scientific questions to be resolved if necessary (only in the German version).

Quality assurance for green electricity basic requirements

In order to ensure that all certification procedures for green electricity adhere to comparable standards, specific basic requirements are always assessed using current state-of-the-art techniques. If individual certification procedures use different methods that are not quoted here, it must be ensured that these are consistent with a similar quality level. Decisions on methodological ambiguities and on introducing new techniques are taken only after coordinating the input of expert auditors (see Ch. 8). In principle, the basic requirements can be assessed using all scientifically recognised methods that conform to an equivalent set of standards.

Scope of the bibliography

The bibliography listed here is deliberately designed to contain only a selection of relevant studies in order to establish a coherent benchmark for the quality level within the management fields. It makes no claim to be an exhaustive catalogue. The EAWAG’s procedure should also safeguard its future credibility and maintain quality assurance by continually integrating any new and scientifically based measurement techniques that may be developed.

Literature and methodologies for studies in the field of

Minimum flow regulations

14.1 Literature and methodologies for studies in the field of minimum flow regulations

Background literature and basic information

Subject	COMMENTARY	QUOTE
Swiss guidelines for determining appropriate minimum flow rates	Overview presenting and summarising most important aspects of minimum flows as provided under the revised Swiss Surface Water Conservation Act. It deals with matters such as relevant legal background issues to procedural formats concerning the approval of water withdrawal, and sets out the most essential points regarding minimum flow contained in Art. 31 ff. It uses examples to describe various types of power plants in a range of different catchment areas. Specific minimum flows are implemented with due consideration for the interests of local stakeholders.	BUWAL (2000): Angemessene Restwassermengen - Wie können sie bestimmt werden? Bundesamt für Umwelt, Wald und Landschaft, *(Entwurf vom Mai 2000)*: P. 1-140.
Minimum flows	Basic requirements and legal (EU) framework conditions that must be adhered to when establishing minimum flow regulations in the light of the latest technical know-how (and especially modelling techniques). Arranged in a very compact format with contact addresses. The ''Graz Declaration'' (positional paper) can be found on pages 7 - 9; a framework concept for producing a guide to mandatory water discharge is discussed on pages 165 - 192.	EURONATUR (2000): Problemkreis Pflichtwasserabgabe „Ökologisch begründete Mindestabflüsse in Ausleitungsstrecken von Wasserkraf-werken“; natur+wissenschaft. Schriftenreihe der Stiftung Europäisches Naturerbe (Euronatur): Nr. 1/2000, ISSN 1439-6793.
Ecological integrity	European framework guidelines for water that call for all surface water bodies to be maintained in a ''good ecological condition''.	Directive of the European Parliament and of the Council 2000/60/EC establishing a framework for community action in the field of water policy. http://www.panda.org/europe/freshwater/pdf/wfd.pdf
Impact of water withdrawal and conventional techniques	Summary of technical approaches that have been commonly employed in the last 10 years in Germany, Austria and Switzerland. Although technological advances have to some extent superseded them, they are still partly in use. Provides a sound overview of the distinction between currently available techniques and traditional methods.	DVWK (1996): Gesichtspunkte zum Abfluss in Ausleitungsstrecken von Wasser-kraftanlagen, Schrift Nr. 114, Bonn.
Ecologically responsible hydropower utilisation	Combines the technical aspects of hydropower utilisation from both an engineering and natural science perspectives, including minimum flow issues. Good, objective and factual introduction to interdisciplinary thinking and consensus in the field of hydropower and stream ecology.	Hütte, M. (2000): Ökologie und Wasserbau – Ökologische Grundlagen von Gewässerverbauung und Wasserkraftnutzung. Parey Verlag, Berlin.
Hydropower utilisation and its environmental impact	Chapters 19 and 20 contain a roughly 50-page long overview covering ''hydropower and the environment'' and ''minimum flows and surface water structure''. In-depth discussion of these issues and dealing particularly with minimum flow determination.	Giesecke, J. & E. Mosonyi (1998): Wasserkraftanlagen – Planung, Bau und Betrieb, Springer Verlag.

Current state-of-the-art techniques (minimum flows)

Subject	Commentary	Quote
Currently available methods to determinate ecologically based minimum flows	Conference proceedings of the 1999 Conference on Problems Relating to Mandatory Water Discharges held in Graz (Austria). Features short contributions from nearly all the work groups from Germany, Austria and Switzerland who studied the problems associated with minimum flow regulations on a scientific basis. Represents the latest state-of-the-art in current practice and techniques for evaluating minimum flow measurement procedures, which are determined individually and tailored to specific habitats. It contains short descriptions of different measurement and modelling techniques, along with an in-depth guide to relevant literature. There is a table providing a good overview of available methods including contact addresses.	EURONATUR (2000): Problemkreis Pflichtwasserabgabe „Ökologisch begründete Mindestabflüsse in Ausleitungsstrecken von Wasserkraf-werken"; natur+wissenschaft. Schriftenreihe der Stiftung Europäisches Naturerbe (Euronatur): Nr. 1/2000, ISSN 1439-6793.
CASIMIR: module-based simulation model for instream flow regulations	Module-based model for estimating the ecological and commercial impact of minimum flows. Can predict the individually adjusted habitat conditions of fish, macro-zoobenthos, algae and macrophytes. Takes into account morphology, substrata, understorey vegetation and the dynamics of discharge (hydrograph curves). Has been used repeatedly and successfully to establish minimum flows in various river types and different kinds of power plant (run-of-the-river and storage power plants with a capacity of between 120 kW and 390 MW) in Germany, Switzerland and Norway. Measurements at different discharges are not compulsory but are advisable. (Contains in-depth description of the procedure for modelling fish[H] and benthic habitats[HH] using the CASIMIR simulation model).	Jorde, K. (2000): Das Simulationsmodell CASIMIR als Hilfsmittel zur Festlegung ökologisch begründeter Mindestwasserregelungen. In EURONATUR (vollständig. Zitat siehe oben): S. 69-74. [H] Jorde, K., M. Schneider & F. Zoellner (2000): Ökologisch begründete Mindestwasserregelungen, Wasserbewirtschaftung an Bundeswasserstrassen – Probleme, Methoden, Lösungen, Bundesanstalt für Gewässerkunde, Berlin, S. 203- 224. [HH] Jorde, K. & C. Bratrich (1998): Influence of River Bed Morphology and Flow Regulations in Diverted Streams on Bottom Shear Stress Pattern and Hydraulic Habitat. In: Bretschko G. & Helesic J. (Eds.), Advances in River Bottom Ecology IV, Backhuys Publishers, P. 47-63.
AQUASIM: temperature conditions, chem. water quality	One-dimensional water quality model for studying temperature conditions and dissolved particles in rivers and lakes. It provides temperature change prognoses for a range of discharge scenarios and can compare temperature conditions before the power plant was built with the present situation. Endowment trials and tracer measurements are necessary in order to calibrate and validate the model. Run-off hydrograph curves and readings of water temperatures and meteorological conditions are necessary to provide input values. This model was successfully used as part of EAWAG's green electricity project in an alpine case study.	Homepage: www.aquasim.eawag.ch Reichert, P. (1994): "AQUASIM - A tool for simulation and data analysis of aquatic systems", Wat. Sci. Tech. 30(2), 21-30. Reichert, P. (1998): AQUASIM 2.0 - User Manual, Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH-8600 Dübendorf, Switzerland. Reichert, P. (1998): AQUASIM 2.0 - Tutorial, Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH-8600 Dübendorf, Switzerland.
MADER: method for establishing minimum flows	Simplified model for estimating the abiotic effects of minimum flows: deals with morphology by taking measurements of depth, width, wetted areas, current velocity near riverbed; measurements at different discharges are necessary, although direct interfaces with biological systems are omitted. Several projects were implemented in Austrian rivers. A short description and further references can be found at the indicated pages in the bibliography.	Mader, H. (2000): Dotierwasserfestlegung auf Basis hydraulischer und flussmorpho-logischer Kenngrössen. EURONATUR (2000) S. 63-68.

Current state-of-the-art techniques (minimum flows, continued)

Subject	COMMENTARY	QUOTE
HARPHA: method for establishing minimum flows	Model for assessing fish habitats at different flows: the assessment involves measuring flow velocity at mid-depth and near the riverbed, depth and width statistics, water levels readings and link those with a wide variety of preference functions. Measurements at different discharges are necessary. Various commercial software programs (such as GIS) are used to conduct the analysis. The indicated document features various case studies in Austria where the procedure has been implemented, and these can also be found in EURONATUR (2000).	Parasiewicz, P. & S. Schmutz (1999): A hybrid-model-assessment of physical habitat coditions combining various modelling tools. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA (Contact EAWAG).
River System Simulator: a toolbox for assessing physical and hydraulic parameters	Along with simulation models for hydropower utilisation, the River System Simulator toolbox for use with rivers also features modules dealing with ice formation, a temperature model, a one-dimensional water quality model and a modified PHABSIM approach for fish habitat modelling. It is regularly and successfully used in Norway for evaluating minimum flows.	Harby, A. et al. (1999): Methods and Applications of Fish Habitat Modelling in Norway. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA (Contact EAWAG or visit homempage: www.sintef.no/units/civil/water).
MEFI: method for determining minimum flows	Model for assessing a minimum flow situation based on benthic habitats, flow velocities near the riverbed and measurements of sunlight penetration at different flows. The procedure has been used to study certain discharge routes in Bavaria.	Strobl, T. & S. Nothhaft (2000): Ermittlung ökologisch begründeter Mindestabflüsse mit dem MEFI-Modell. EURONATUR (2000): S. 75-79.
FST hemisphere-habitat model	Model for establishing minimum flows, which simulates the quality of benthic habitats using computed FST-hemisphere distributions (based on thalweg and substrate size). The procedure has hitherto been seldom tested in practice.	DVWK (1999): Schrift 123, Ermittlung einer ökologisch begründeten Mindestwasserführung mittels Halbkugelmethode und Habitat-Prognose Modell, Bonn.
EVAH/PHABSIM	PHABSIM is probably the oldest simulation model for fish habitats and is based on preferences relating to water depth, current velocity and substrata conditions. A large number of studies in North America since the early 80s have been carried out using this model. EVAH is a user-friendlier version of the classical PHABSIM simulation model for assessing the minimum flow situation on the basis of fish habitats running on Windows.	Ginot, V. (1995): EVAH, Un logiciel d'évaluation d'habitat sous Windows.- Bull. Fr. Pêche Pisci. 337/338/339, P. 303-308. Jorde, K. & Schneider, M. (1998): Einsatz des Simulationsmodells PHABSIM zur Festlegung von Mindestwasserregelungen, Wasser + Boden 50, Heft 4, S. 45-49.
Minimum flow measurement for mountain streams	This method measures both the optical and acoustic characteristics of rivers and, especially, builds a model of their flow patterns. It lacks a quantitative reference to biological systems. The procedure was used for the Brusio AG power plant's EIA.	Schälchli U. (1991): Morphologie und Strömungsverhältnisse in Gebirgsbächen: Ein Verfahren zu Festlegung von Restwasserabflüssen. Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH, 113, Zürich, 112 pp.

Literature and methodologies for studies in the field of

Hydropeaking

14.2 Literature and methodologies for studies in the field of hydropeaking

Background literature and basic information

Subject	Commentary	Quote
Review of hydropeaking up to 1985	Summarises the knowledge acquired from work undertaken in America concerning: (i) Impacts of hydropeaking (e.g. hydraulic effects, drying out, drift, temperature, etc.) (ii) Basic principles to be adopted for hydropeaking evaluation (iii) Possible measures for moderating flow variations.	Cushman, R. M. (1985): Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities: North Am. J. Fish. Man. 5, P. 330-339.
Review of hydropeaking from 1985 onwards	Uses work done in Europe and America to illustrate examples of the impact of hydropeaking on fish (e.g. drying out, current, depth, habitats, temperature, etc.).	Schöb, P. (1998): Untersuchung des Fischbestandes in der vom Schwellbetrieb des Kraftwerks Kubel beeinflussten Sitter: EAWAG-Praktikumsarbeit, 19 S. + Anhang. Interner Bericht, auf (Contact EAWAG). Limnex & EAWAG (2000): Auswirkungen des Schwallbetriebes des Kraftwerks Kubel auf die Wassertiere der Sitter: Auftragsbericht, 57 S. + Anhang. Archiviert bei Limnex AG, Zürich.
Brief overview	Lists major ecological effects on river ecosystems caused by hydropeaking and outlines potential measures for moderating peak flows.	Moog, O. (1993): Quantification of daily peak hydropower effects on aquatic fauna and management to minimize environmental impacts: Regulated Rivers: Res. & Man. (8) P. 5-14.
Influence of hydropeaking on different aspects of river ecology	SINTEF (the Norwegian National Surface Water Research Institute) does work in the field of hydropeaking operations on various levels relating to river ecology. Its homepage features projects such as laboratory and field studies on fish ecology (behaviour, energy needs, population structure, etc.), on vegetation, habitat structure and on modelling the effects of hydropeaking.	Environmental Effects of Hydropeaking (2000): A research program on environmental effects of rapid and frequent changes in water flow and water level in regulated rivers: http://www.sintef.no/units/civil/water/effekt/hydpeak.htm Harby A., K. Alfredsen, J. V. Arnekleiv, J. H. H. Halleraker, S. Johansen, S. J. Saltveit (1999): Impacts from hydropeaking on Norwegian riverine ecosystems. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA (Contact: SINTEF oder EAWAG).
Minimum flow management	Along with specific criteria relating to hydropeaking, additional basic materials are available to help assess minimum flow management (low flow period).	See bibliography for the minimum flow management field.

Current state-of-the-art techniques (hydropeaking)

Subject	COMMENTARY	QUOTE
Complete case study	Probably the most comprehensive alpine case study, which deals with a river heavily influenced by hydropeaking (in comparison with a non influenced reference site). The ecological situation is described before and after measures for moderate flow variations have been implemented. It is a long-term study (over 10 years in total) which goes into great detail for applied projects in the fields of habitats, morphometry/hydraulics, phytobenthic fauna, water temperature, macro-zoobenthos (without drift) and fish ecology.	Jungwirth, M., O. Moog, S. Schmutz, U. Grasser, P. Parasiewicz, G.A. Parthl (1998): Limnologische Gesamtbeurteilung des Kraftwerks Alberschwende: Auftragsstudie der BOKU Wien, 540 S. Archiviert bei der Universität für Bodenkultur, Abteilung Hydrobiologie, Fischereiwirtschaft & Aquakultur, Wien.
Modelling fish habitats	Modification and application of INSTREAM FLOW INCREMENTAL METHODOLOGY (IFIM) on river reaches influenced by hydropeaking in France. Modelling of weighted available areas (WUA) for trout.	Valentin, S., F. Lauters, C. Sabaton, P. Breil, Y. Souchon (1996): Modelling temporal variations of physical habitat for brown trout (*Salmo trutta*) in hydropeaking conditions. Regulated Rivers Res. & Man. 12, P. 317 - 330.
Modelling fish habitats	Modelling with a three-dimensional model SSIIM. Has been used for simulating physical conditions under a hydropeaking regime for various discharges in Norway.	Alfredsen K., J. V. Arnekleiv, J. H. H. Halleraker, A. Harby, S. Johansen, S. J. Saltveit, P. Borsanyi (1999): Physical habitat modelling in a Norwegian hydropeaking river. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA .
Bottom shear stress and macro-zoobenthos	Hemisphere method used to establish hydraulic preferences (according to bottom shear stress) for a large number of macro-invertebrate taxa for determining minimum flows. Used hitherto only in isolated cases for peaking discharge routes (see complete case study above).	Schmedtje, U. (1995): Ökologische Grundlagen für die Beurteilung von Ausleitungsstrecken. Schriftenreihe Bayerisches Landesamt für Wasserwirtschaft 25, 156 pp.
Invertebrate and algae drift	Current interim report on extensive experiments, which are still ongoing, studying the dependency of various drift parameters (density, rate, load, proportion) on the type and scale of hydropeaking operation.	Marrer, H. (2000): Gewässerökologisch verträgliche Ausgestaltung des Schwellregimes. Auftragsbericht, 45 S. + Beilage. Archiviert bei Büro für Gewässer- und Fischereifragen AG, Solothurn.

Literature and
methodologies for studies
in the field of

Reservoir management

14.3 Literature and methodologies for studies in the field of reservoir management

Background literature and basic information

Subject	Commentary	Quote
River impoundments		
Management	Brief outline of the possible ecological impacts of reservoirs: e.g. on the solid material budget, aquatic fauna, water quality and ground water. The effects on flood plains located in tailwaters or in the impounded area are also mentioned. Apart from this, the publication also describes supplementary measures to protect the environment, e.g. through weir regulation and dike removal.	BUWAL (1997): UVP von Wasserkraftanlagen. BUWAL, Bern, Nr. 8, S. 36-41.
Flushing	Guidance notes on what information concerning reservoir sediments and discharge conditions is required when assessing the ecological impact of reservoir flushing (focal point: turbidity and water chemistry in tailwaters).	ÖWAV (2000): Feststoffmanagement in Kraftwerksketten. Österreichischer Wasser- und Abfallwirtschaftsverband, Wien, Heft 137, S. 43-44.
Flushing procedures	Ecological effects of reservoir flushing on tailwaters and on the reservoir itself.	ÖWAV (2000): Feststoffmanagement in Kraftwerksketten. Österreichischer Wasser- und Abfallwirtschaftsverband, Wien, Heft 137, S. 61-65.
Reservoir and tailwater design	This document contains measures for designing both reservoirs and tailwaters in order to create and conserve habitats.	Binder, W. (1986): Beispiele zur Stauraumgestaltung aus Bayern. In Landschaftswasserbau: Naturnahe Gestaltung von Stauhaltungen, Hrsg. Institut für Wassergüte und Landschaftswasserbau Technische Uni Wien, Band 7, S. 307-339
Large or alpine reservoirs		
Management and flushing procedures	Brief outline of the possible ecological impacts in the reservoir itself and in the tailwaters (due to damming and flushing) e.g. on the solid material budget, water quality, flood plains and aquatic fauna. This document also contains potential environmental protection measures.	BUWAL (1997): UVP von Wasserkraftanlagen. BUWAL, Bern, Nr. 8, S. 43-48.
Flushing procedures	Hydrological, morphological and chemical changes during and after flushing, and their damaging effects on tailwater biocoenoses.	Gerster, S. & P. Rey, (1994): Ökologische Folgen von Stauraumspülungen. BUWAL, Bern, Schriftenreihe Umweltschutz Nr. 219, S. 20-26.
Sand traps		
Flushing procedures	Summary of the impacts of flushing sand traps on sediment transport, temperature and water chemistry, as well as general requirements for discharge conditions while sand traps are being flushed.	Forstenlechner, E., M.Hütte, U. Bundi, E. Eichenberger, A. Peter, & J. Zobrist (1997): Ökologische Aspekte der Wasserkraftnutzung im alpinen Raum. Vdf, Hochschul.-Verl. an der ETH, Zürich, S. 44–46 und S. 91–92. BUWAL (1997): UVP von Wasserkraftanlagen. BUWAL, Bern, Nr. 8, S. 111-134.

Current state-of-the-art techniques (reservoir management)

Subject	Commentary	Quote
River impoundments *Management*	Compilation of various measures using EIA case studies. Provides guidance notes on ecologically responsible reservoir management (e.g. through weir regulation) and advice on dealing with the reduction or loss of landscape features.	BUWAL (1997): UVP von Wasserkraftanlagen. BUWAL, Bern, Nr. 8, S. 111-134.
Reservoir and reservoir foreshore design	Case studies on how to create new biotopes in shallow water zones around banks and partially filled-in foreshore areas by inducing sedimentation.	Riegler, J. (1996): Sedimentmanagement an der österreichischen Donau. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen. Teil 2, Hrsg. Vischer, S. 131-144. Steiner, H.A. (1996): Ökologische Aspekte und Sukzessionsentwicklung spülgerecht gestalteter Stauraumvorländer an den Flusskraftwerken der Drau. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen. Teil 2, Hrsg. Vischer, S. 177-191.
Reservoir flushing	Paper addressing problems associated with threshold values, preservation-of-evidence questions, and damage assessments in connection with reservoir flushing.	Seifert (2000): Tagungsband der Fachvortrag bei 15. SVK-Fischereitagung. 19-20/02/2000.
Large or alpine reservoirs *Reservoir sedimentation*	This document contains both basic information and a specific case study (the Mauvoisin reservoir, Switzerland) for guidance on preventing or reducing problems caused by sedimentation in the reservoir area and in turbine intakes.	Schleiss, A., B. Feuz, M. Aemmer, & B. Zünd (1996): Verlandungsprobleme im Stausee Mauvoisin. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 37-58.
Conception and implementation of flushing procedures	This document recommends conceptual and methodological approaches to carrying out flushing procedures. It therefore contains advice on which parameters to adopt, on preventative measures prior to flushing, and suggests study parameters and technical procedures during or after flushing.	Gerster, S. & Rey, P. (1994): Ökologische Folgen von Stauraumspülungen. BUWAL, Bern, Schriftenreihe Umweltschutz Nr. 219, S. 40-44.
Curtailed flushing in streams carrying high bedloads	This document contains general proposals for curtailed flushing and a flushing program for a specific case (for the Angerbach stream in Austria). Points specifically mentioned are the correct timing of when to open and close the sluice gates and the beginning and the end of the turbine operation, in order to make sure that bedload is transported away in a natural manner with the surge wave.	Mader, H. (1993): Ausgewählte Probleme zur Dotierwasserabgabe. Wiener Mitteilungen – Wasser Abwasser Gewässer, Band 113, S. 99-116.
Ecological impacts of flushing on macro-invertebrate fauna	This document cites general recommendations for curtailed flushing through the bottom outlet and specially adapted measures for the Luzzone reservoir (Switzerland), which aim to minimise the ecological impact on macro-invertebrate fauna. It also contains information on the procedural methods for sampling and evaluating the macro-invertebrate population.	Ammann, M. & M. Kast (1996): 10 Jahre ökologische Spülungsbegleitung am Luzzone-Stausee (Bleniotal/TI). In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 198-203.

Current state-of-the-art techniques (reservoir management, continued)

Subject	COMMENTARY	QUOTE
Sand traps *Impact of sand removal on suspended solids and invertebrates*	Sediment deposits, incoming and outgoing drift and invertebrate colonisation are presented and discussed as exemplified by a sample sand trap (Klammbach water intake, Austria).	Hütte, M. (1994): Die Bedeutung einer Wasserfassung für die Ökologie eines alpinen Baches. Diss., S. 35-44.
Impact of flushing on invertebrates	The effects of flushing events on invertebrate fauna are presented and discussed as exemplified by two sample flushing procedures of a sand trap (Klammbach water impoundment, Austria).	Hütte, M. (1994). Die Bedeutung einer Wasserfassung für die Ökologie eines alpinen Baches. Diss., S. 55-95.
Advantage of continually flushed sand trap	A planned intake (in Saltina, Switzerland) is designed with a permanently flushed sand trap in order to prevent any ecological deterioration in the tailwater morphology and fauna.	Zurwerra, A. (1993): Wasserfassung und Entsander Grund. PRONAT AG, Winkelgasse 4, Brig. Im Auftrag: EBG AG PF 204, Brig, S. 14-31 (Contact: EAWAG).

Literature and
methodologies for studies
in the field of

Bedload management

14.4 Literature and methodologies for studies in the field of bedload management

Background literature and basic information

Subject	COMMENTARY	QUOTE
River morphology	Definition of riverbed forms (riffles, dunes, step-pools, etc.)	ASCE Task Force on Bed Forms in Alluvial Channels (1966): Nomenclature for Bed Forms in Alluvial Channel. *ASCE, J. of the Hydr. Division*, 92(HY3), P. 51-64.
River morphology	Standard work for defining channel forms (straight channel, meandering, forking).	Leopold L.B. & M.G. Wolman (1957): River Channel Patterns: Braided, Meandering and Straight. *Geological Survey Professional*, Paper 282-B.
River morphology, geo-morphology	Standard German-language work on the formation of channel forms.	Mangelsdorf J. & K. Scheuermann (1980): Flussmorphologie – Ein Leitfaden für Naturwissenschafter und Ingenieure. *Oldenbourg Verlag*, München Wien, 262 pp.
River morphology, geo-morphology	Detailed discussion of the geo-morphology of streams with a qualitative description of the river types in Central Europe.	Kern K. (1994): Grundlagen naturnaher Gewässergestaltung. Geomophologische Entwicklung von Fliessgewässern. *Springer-Verlag*, Berlin Heidelberg New York, 256 pp.
River morphology	Describes the interrelationship between hydrology, bedload transport and morphology in an alpine braided river system (case study: Melezza, canton of Tessin/Switzerland).	Roth M. und B. Zarn (1998): Eintiefung am Wildfluss Melezza – Voraussagen 1983, Messungen und Berechnungen 1997. *Wasserbau-Symposium: Planung und Realisierung im Wasserbau*, Garmisch-Partenkirchen, 15.-17. Oktober, *Bericht der Versuchsanstalt Obernach und Lehrstuhl für Wasserbau und Wasserwirtschaft der TU München*, 84,S. 187-199.
Bedload transport	Describes the long-lasting and large-scale impact of the river corrections on riverbed alteration and bedload transport (surface water bodies, all in Switzerland: the Thur, Emme, alpine Rhine)	Schilling M., R. Hunziker & L. Hunzinger (1996): Die Auswirkungen von Korrektionsmassnahmen auf den Geschiebehaushalt. *Interpraevent*, Garmisch-Partenkirchen, Band 4, S. 209-220.
River morphology, flood controls	Contribution to the discussion on morphological dynamics and revitalisation measures in flood control projects (expanded flood protection concept in alpine river construction).	Schöberl F. (1991): Morphologische Dynamik – Gewässerregulierung: Spannungsfeld alpiner Flussbau. *Österr. Wasserwirtschaft*, 43(F7/8), S. 171-178.
River morphology, renaturalisation	Systematic compilation of the impacts of hydroelectric power plants on mountain streams, ways to assess them and potential mitigation measures.	Schälchli U. (1995): Wasserkraftnutzung an Gebirgsbächen. Morphologie als Grundlage zur Beurteilung und Verminderung der morphologischen Auswirkungen von Wasserkraftnutzungen auf Gebirgsbäche. Regio Basiliensis, Basler Zeitschrift für Geographie, Nr. 36/2, S. 141-152.
River morphology	Describes the restoration potential of a braided river landscape whose hydrological regime has been changed by hydropower utilisation (surface water: the Rhone in Switzerland).	Bezzola G.R. (1989): Rhone und Pfynwald - Renaturierung einer Flusslandschaft. *Bull. Murithienne*, 107, S. 11.
Suspended-materials	Provides an overview of the fine materials' deposition and erosion processes in the river impoundments and discusses the effects of this on seepage.	Schälchli U. (1992): Kolmations- und Spülprozesse in Flussstauhaltungen. Berichte der Versuchsanstalt Obernach und des Lehrstuhls für Wasserbau und Wasserwirtschaft der Technischen Universität München. Band 73/1992, ISSN 0939-0308.

Current state-of-the-art techniques (bedload management)

Subject	COMMENTARY	QUOTE
Bedload rates in mountain torrents	Compilation of various procedures for assessing bedload rates in the catchments of mountain streams.	Zimmermann M. & C. Lehmann (1999): Geschiebefracht in Wildbächen: Grundlagen und Schätzverfahren. *wasser energie luft*, 91(7/8), S. 189-194.
Bedload rates in the Southern Alps	Method for estimating bedload rates during large flood events. (This method was developed in the Southern Alps).	D'Agostino V., M. Cerato & R. Coali (1996): Il trasporto solido di eventi estremi nei torrenti del Trentino orientale. *Interpraevent*, Garmisch-Partenkirchen, 1, P. 377-386.
Bedload rates	Method for estimating bedload rates during large-scale high water flows. (Developed in Austria's limestone Alps)	Kronfellner-Kraus G. (1984): Extreme Feststofffrachten und Grabenbildungen von Wildbächen. *Interpraevent*, Band 2, S. 109-118.
Bedload rates	Estimation of mean and maximum erosion rates in a mountain stream catchment. Developed in connection with flood control projects. (Riale di Prugiasco, Valle di Blenio, canton of Tessin/Switzerland).	Kant. Forstinspektion Tessin (1988): Riale di Prugiasco. Veränderungen entlang des Baches und Abtragskubaturen von 1946 bis 1985. *Eidg. Anstalt für das forstliche Versuchswesen*, Birmensdorf, 30. Juni 1999.
Bedload analysis	Standard method for calculating the particle size distribution in gravel-carrying rivers as the basis for analysing bedload transport.	Fehr R. (1987): Einfache Bestimmung der Korngrössenverteilung von Geschiebematerial mit Hilfe der Linien-zahlanalyse. *Schweiz. Ingenieur u. Architekt*(38), S. 1104-1109.
Bedload transport	Standard method for calculating bedload transport capacity. Applicable to gravel-bed rivers with a gradient of under 2 %.	Meyer-Peter E. und Müller R. (1949): Eine Formel zur Berechnung des Geschiebetriebs. *Schweiz. Bauzeitung*, 67(3).
Bedload transport	Standard method for calculating bedload transport capacity. Applicable to gravel-bed rivers with a gradient of over 0.5 %.	Smart G.M. und Jäggi M.N.R. (1983): Sedimenttransport in steilen Gerinnen. *Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 64, Zürich.
Bedload transport	Program for calculating bedload transport and riverbed alterations in river systems (one-dimensional).	Schilling M. & R. Hunziker (1996): Programm MORMO (MORphologisches MOdell). *Mathematische Modelle offener Gerinne, ÖWAV-Seminar*, Wien, 21. Nov., S. 91-104.
Bedload transport	Program for calculating bedload transport and riverbed alterations in barrage cascades (one-dimensional).	Roth M. & G.R. Bezzola (1999): Geschiebetransport in Wildbächen mit Sperrentreppen. *"wasser, energie, luft - eau, énergie, air"*, 91(11/12), S.1.
Surface layer stability	Compilation of different techniques for assessing top-layer streambed coarsening and stability.	Schöberl F. (1996): Grundlagen der Deckschichtbildung. Schriftenreihe des Österreichischen Wasser- und Abfallwirtschaftverbandes, Heft 105, S. 23-41.
Flow resistance	Compares a range of analytical approaches for determining the effect of vegetation on a channel's discharge capacity on the basis of the 1987 flood events.	Jäggi M. und P. Kuster (1991): Einfluss der Vegetation im Gerinne bei extremen Abflussmengen. Ursachenanalyse der Hochwasser 1987, Ergebnisse der Untersuchungen. Mitteilung des Bundesamtes für Wasserwirtschaft, Nr. 4.
Suspended-solids transport and silting	Basic information and methodologies for calculating the decrease in bed permeability and seepage.	Schälchli U. (1995): Basic equations for siltation of riverbeds. Journal of Hydraulic Engineering, Vol. 121, No. 3, pp. 274-287.

Literature and
methodologies for studies
in the field of

Power plant design

14.5 Literature and methodologies for studies in the field of power plant design

Background literature and basic information

Subject	Commentary	Quote
Hydroelectric power plants in general	One of the most comprehensive, more recent works on the construction and operation of hydroelectric power plants, which additionally features an extensive bibliography covering all relevant topic areas, e.g. water impoundments, channels, turbines, weirs and dams, environmental impact of hydropower utilisation etc.	Giesecke und Mosonyi (1998): Wasserkraftanlagen, 2. Auflage, Springer Verlag, Berlin.
Renewable energy sources in general with a section on hydropower	Gives a general idea of how all renewable energy sources work, including hydropower, and describes the most important mathematical principles. Features methods of analysing eco-balances, cost-efficiency, and environmental aspects.	Kaltschmitt & Wiese (1997): Erneuerbare Energien – Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 2. Auflage, Springer Verlag, Berlin.
Ecological sustainability	Features concise summaries of statements concerning ecological sustainability and how this can be assessed. Closely linked to water installations such as, for example, hydroelectric power plants.	ÖNORM M6232 (1995): Richtlinien für die ökologische Untersuchung und Bewertung von Fliessgewässern, Österreichisches Normungsinstitut, Wien.

State of the art techniques (power plant design)

Subject	COMMENTARY	QUOTE
Intakes	Design of intakes so that macro-invertebrates do not drift entirely into the intake but also partially remain on the river bed.	BUWAL (1997): Gestaltungsgrundsätze zur Gewässerökologischen Optimierung von Wasserfassungen, Umwelt-Materialien Nr. 74.
Intakes	Technical aspects of water withdrawal, particularly from bedload-carrying rivers and streams.	Scheuerlein, H. (1984): Die Wasserentnahme aus geschiebeführenden Flüssen, Ernst & Sohn, Berlin.
Small hydroelectric facilities	Practical instructions for the construction of small hydropower facilities < 1 MW.	Wasserwirtschaftsverband Baden-Württemberg (1994): Leitfaden für den Bau von Kleinwasserkraftwerken, 2. Auflage, Kosmos, Stuttgart.
Upstream fish migration	A guide to hydraulic computations and design of fish ladders.	DVWK (1996): Fischaufstiegsanlagen – Bemessung, Gestaltung, Funktionskontrolle, Heft 232, Bonn.
Upstream fish migration	Examples of ways to build small power plants cost-effectively.	Publikationen DIANE Kleinwasserkraftwerke: Fische und Kleinwasserkraftwerke, Bezug EDMZ, Nr. 805635 d+f .
Downstream fish migration	Bibliographical overview on the topic of downstream fish passages.	DVWK (1997): Fischabstieg – Literaturdokumentation, DVWK-Materialien 4/1997, Bonn, 229 pp.
Upstream and downstream fish migration	Comprehensive book on fish migration (upstream and downstream), numerous articles on the current state-of-the-art techniques and background information.	Jungwirth M., S. Schmutz & S. Weiss (1998): Fish migration and Fish Bypasses. Fishing News Books, Oxford.
Natural bypass channels	Article deals with the conceptual design of functional bypass channels (planning strategies and implementation). It is based on extensive experiences conducted in Austria.	Parasiewicz P., J. Eberstaller, S. Weiss & S. Schmutz (1998): Conceptual Guidelines for Nature-like Bypass Channels. In *Fisch migration and Fish Bypasses* (ed. M. Jungwirth, S. Schmutz, and S. Weiss), P. 348-362. Fishing News Books.
Design of rivers and their banks	A wide range of potential approaches to designing and constructing power plants in an ecologically responsible way.	Patt, H. , Jürging, P. & W. Kraus (1998): Naturnaher Wasserbau – Entwicklung und Gestaltung von Fliessgewässern, Springer, Berlin.
River impoundments, reservoirs	Guidance notes on designing reservoirs and their banks, though also covers many other questions relating to hydropower and ecology.	Hütte, M. (2000): Ökologie und Wasserbau – Ökologische Grundlagen von Gewässerverbauung und Wasserkraftnutzung, Parey, Berlin.

Appendix

A1
System overview

A1 SYSTEM OVERVIEW

A1.1 Contents and level of analysis

Appraisal sheets

The system overview is carried out as part of the preliminary study for certifying green hydroelectric power plants (see Ch. 3). If comparable data are not yet available for the system overview, the latter should be compiled with the help of four appraisal sheets. These surveys are structured so that Swiss power plants can carry them out for relatively little outlay, since they have been deliberately designed to conform closely to the inspection methods used by cantons or EIA procedures. Particular care was therefore taken to synchronise the survey with the step module concept (BUWAL 1998) in order to make fullest possible use of the data currently being compiled throughout Switzerland. However, other information gathering techniques are also acceptable for producing the system overview, provided that these correspond to equivalent standards; this especially allows countries outside Switzerland to apply the procedure. Assuming in a specific case that there is no corresponding data base, the system overview should consider the following environmental aspects:

1 Connectivity of river systems
2 Diversity (heterogeneity) of river reaches
3 Natural character of discharge
4 Local condition of fish populations

- The “connectivity of river systems” and the “diversity of river reaches” shall be examined by conducting a field inspection of the catchment, and working with any morphological data that already exist.

- Data for determining “discharge characteristics” will be obtained from existing literature and through information provided by the power plants (water diversion at each intake).

- A single analysis of selected sites is conducted as part of the system overview to assess the “condition of the local fish population”. These sites are chosen after consulting local experts and on the basis of existing environmental reports.

A.1.2 Overall evaluation of the system overview

The results of the system overview shall be summarised in a short expert report, which should primarily be used to help clarify the relevant fields of study (see Ch. 5.3). In particular, the report should resolve the following questions:

- Which parts of the catchment area contain intact river sections requiring conservation?
- Which river sections have developed a significant ecological deficit?
- Which of these sections are affected by additional uses (flood protection, water management in residential areas, agriculture)?
- Which sections are mainly affected by the power plant utilisation (appraisal sheet on discharge characteristics and temperature conditions)?
- In which river reaches would a structural change significantly enhance their ecological sustainability?
- Are there river sections in which specific aspects / individual parameters exhibit significant or extremely distinctive features in a way that requires further clarification?

A1.3 Parameters to adopt

Part 1 Integrity of river systems

The connectivity of river systems is determined by the parameters listed in table A-1. From the perspective of river ecology, the significance of the hydropower utilisation mainly revolves around the interrelationship between morphology and discharge. For this reason, the parameters described on this and the following appraisal sheet are primarily concerned with documenting the influence of construction-related obstructions. Ecologically optimised improvement measures should be carried out in places where it is possible to harness synergies between different areas of influence.

Table A-1: Assessing the integrity of river systems

Parameters for characterising connectivity of river systems (large font) and the ecological significance of parameters (small font)
Land use and riparian vegetation ▪ Landscape's natural connecting links ▪ Input and output of nutrients, organic material (e.g. litter, woody debris) ▪ Bank structure ▪ Shading
Average width of riparian zone ▪ Dynamic changes in riparian zones form the basis for natural diversity ▪ Buffer zones ▪ Temporary riverine habitats
Construction work on embankment base (extent/material) ▪ Zones of erosion and deposit formation ▪ Fish habitat ▪ Amphibian habitat ▪ Connectivity to lateral habitats and to flood plains
Construction work on riverbed (extent/material) ▪ Habitat for benthic organisms ▪ Water exchange: ground and surface water ▪ Connection to hyporheic zone and ground water
Aqueducts ▪ The lateral and vertical exchange of material flows and organisms is cut off, causing massive destruction in the natural functioning of the ecosystem.
Weirs, groins, natural barriers and culverts ▪ Interruption of the river continuum above all for migrating organisms

Part 2 Diversity and heterogeneity of river reaches

The structural diversity of river reaches shall be assessed using the parameters in table A-2.

Table A-2: Assessing the diversity and heterogeneity of river reaches

Parameters for characterising river reach heterogeneity (large font) and the ecological significance of parameters (small font)
Width variability of the water level ▪ Key variable for the connectivity to the regional hinterland ▪ Key variable for structural diversity ▪ Key variable for current diversity
Depth variability ▪ Key variable for heterogeneity of riverine habitats (pools, riffles, backwaters, pocket waters etc.) ▪ Key variable for dynamics of riverbeds ▪ Key variable for availability of fish habitats ▪ In combination with width variability: indicator for habitat quality
Woody debris ▪ Partial habitat of its own ▪ Hydraulic and morphological diversification ▪ Fish habitat ▪ Food supply
Algae / Periphyton ▪ Key variable for water quality ▪ Key variable for high water and bedload dynamics

Part 3 Discharge attributes (coarse characterisation)

Discharge characteristics shall be assessed using the parameters given in table A-3. Very simple and rough criteria have been chosen deliberately in order to utilise the overview study for performing a swift initial characterisation of the system's discharge situation. The parameters are thus intended as a single appraisal to highlight ecologically relevant sections for which more detailed studies must be carried out if necessary.

Table A-3: Appraisal sheet for assessing discharge attributes

Parameters for characterising discharge attributes (large font) and the ecological significance of parameters (small font)
Minimum flow requirements at the intakes ▪ Minimum flow rates and dynamics have considerable impact on aquatic habitats in diverted river reaches.
Characteristics of the minimum flow reaches ▪ The impact of water diversion is additionally influenced by structural conditions, which means that the ecological effects can be highly variable.
Seepage reaches ▪ Natural seepage routes can result in a complete dry-out, particularly within the diverted river reaches.
Characterisation of the hydropeaking ▪ Key variable for massive deterioration in colonisation of aquatic and semi-aquatic habitats.

Part 4 Current condition of fish populations (coarse characterisation)

The system overview is designed merely to give a general idea of the existing stock of fish species, and provide a qualitative characterisation of the population structures. It therefore calls only for random sampling studies, designed to record the parameters described in table A-4 during a one-day fishing campaign. Study areas are chosen on the basis of information obtained from the local fisheries or from environmental reports or inventories. The compiled data serve as biological background information to assist with the abiotic evaluation of river ecosystem. However, the random sampling method does not allow four-class assessment of the fish ecology as formulated in the aforementioned appraisal sheets.

Table A-4: Appraisal sheet for recording fish ecology in streams

Parameters for characterising fish populations (large font) and the ecological significance of parameters (small font)
Species inventory ▪ Key variable for natural diversity of the fish population.
Exotic species ▪ Indication of artificially altered biocoenoses.
Species on red list ▪ Designation of river reaches requiring special conservation.

A2
The BWG's cast study for flood protection

A2 THE BWG'S CAST STUDY FOR FLOOD PROTECTION (IN GERMAN)

Grundsätze für den Hochwasserschutz

Gefahrensituation klären. Um Schutzbedürfnisse beurteilen zu können, sind umfassende Kenntnisse nötig über die hydrologischen Verhältnisse, die wasserbaulichen Voraussetzungen und die massgebenden Gefahrenarten des betreffenden Gewässers. Durch die Dokumentation von Hochwassern in Ereignisdokumentationen, Ereigniskatastern und Gefahrenhinweiskarten können die vorhandenen Konflikte und Gefahren erkannt werden. Die Gefahrensituation ist periodisch zu überprüfen. Die vorhandenen Gefahren sind bei der Richt- und Nutzungsplanung zu berücksichtigen.

Ökologische Defizite ermitteln und beheben. Ein nachhaltiger Hochwasserschutz sorgt für eine gedeihende Ufervegetation und lässt genügend Raum zur Ausbildung einer natürlichen Strukturvielfalt in den aquatischen, amphibischen und terrestrischen Lebensräumen. Er schafft damit vernetzte Lebensräume.

Schutzziele differenzieren. Hochwasserschutzkonzepte bauen auf einer Differenzierung der Schutzziele auf: Hohe Sachwerte sind besser zu schützen als niedrige. Nach diesem Prinzip benötigen Kulturland und Einzelgebäude meist weniger Schutz als Siedlungen, Industrieanlagen oder Infrastruktureinrichtungen, während bei extensiven Nutzflächen in der Regel kein besonderer Hochwasserschutz nötig ist. Allerdings kann die Abklärung des möglichen Schadens im Einzelfall eine andere Gewichtung ergeben, weshalb alle Massnahmen bewertet werden müssen und auf ihre Verhältnismässigkeit zu prüfen sind.

Rückhalten wo möglich; durchleiten wo nötig. Wo immer möglich soll der Hochwasserabfluss in Rückhalteräumen verzögert werden, um Abflussspitzen zu dämpfen. Deshalb sind natürliche Rückhalteräume nicht nur zu erhalten, sondern wo immer möglich wiederherzustellen. Hochwasser sollen nur dort durchgeleitet werden, wo dies unumgänglich ist, wie etwa in eingeengten Siedlungsräumen. Dort sollen Abflusskorridore geschaffen oder freigehalten werden, damit auch extremen Ereignissen genügend Raum zur Verfügung steht.

Eingriffe minimieren. Ausreichende Abflussquerschnitte sind eine Grundvoraussetzung, damit der Hochwasserschutz sichergestellt, der Geschiebehaushalt im Gleichgewicht gehalten und die Entwässerung gewährleistet werden kann. Der Hochwasserschutz soll dennoch mit minimalen Eingriffen in den Naturraum sichergestellt werden.

Schwachstellen überprüfen. Den naturgegebenen Unsicherheiten ist besser Rechnung zu tragen. Die konstruktive Sicherheit der Schutzbauten ist entsprechend zu optimieren. Die Schutzbauten sind zudem auf ihre Funktionsfähigkeit und konstruktive Sicherheit gegenüber Überlastungen bei extremen Ereignissen zu prüfen. Durch die periodische Überprüfung der Tauglichkeit bereits getroffener Schutzmassnahmen können mögliche Schwachstellen rechtzeitig erkannt und beseitigt werden.

Unterhalt gewährleisten. Der sachgerechte Unterhalt der Gewässer ist eine Daueraufgabe. Er stellt sicher, dass sowohl die Substanz der vorhandenen Schutzbauten als auch die jeweiligen Abflusskapazitäten erhalten bleiben.

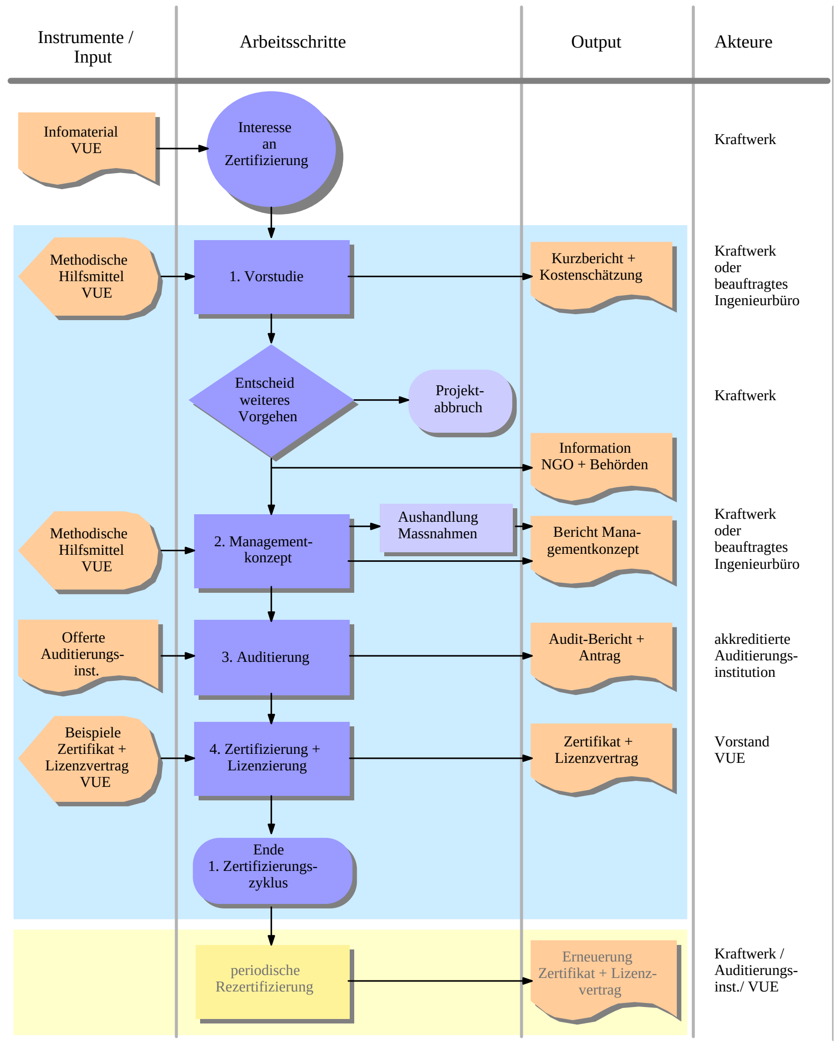
Raumbedarf sichern. Ein Bach soll mehr als eine Abflussrinne, ein Fluss mehr als ein Kanal sein. Bodennutzungen haben deshalb einen ausreichenden Abstand zu den Fliessgewässern einzuhalten. Die Kantone sind verpflichtet, den Raumbedarf der Fliessgewässer festzulegen, in der Richt- und Nutzungsplanung zu verankern und bei allen übrigen raumwirksamen Tätigkeiten zu berücksichtigen.

Bedürfnisse respektieren. Zu berücksichtigen sind auch die Bedürfnisse derjenigen, die an Bächen und Flüssen Erholung suchen und dort ihre Freizeit verbringen. Andererseits soll die nachhaltige Nutzung der Wasserressourcen, insbesondere der Wasserkraft, weiterhin möglich sein.

(Source: Bundesamt für Wasser und Geologie, BWG, 2001)

A3
VUE's procedure for certification of *naturemade star* hydroelectric plants

A3 VUE's PROCEDURE FOR CERTIFICATION OF NATUREMADE STAR HYDROELECTRIC POWER PLANTS (IN GERMAN)



Details, vgl. Richtlinien des VUE; Kontakt über www.naturmade.org
(Source: Richtlinien des VUE, Stand 2000)

A4
Example of a cost estimate for green power certification

A4 EXAMPLE OF A COST ESTIMATE FOR GREEN POWER CERTIFICATION (IN GERMAN)

Beispiel zur Berechnung der Vollkosten – "naturemade star", Ebene Produktion

Angenommen wird ein hypothetisches neukonzessioniertes Kraftwerk mit einer mittleren Energieerzeugung von 10 GWh/J.

Mittlere Energieerzeugung pro Jahr (GWh) 10

Die Amortisation der Kosten erfolgt über 10 Jahre, bei einem jährlichen Zinssatz von 5%.

	Best Case		Worst Case	
Verfahrenskosten (einmalig)	Fr.		Fr.	
Vorstudie (Schätzung)	5,000		5,000	
Managementkonzept: Abklärung Basisanforderungen (Schätz	10,000		10,000	
Managementkonzept: Detailstudie Ökostrominvestitionen (Scl	5,000		5,000	
Auditkosten (inkl. Fachaudit, Schätzung)	10,000		10,000	
Total	30,000		30,000	
Kosten für Massnahmen (einmalig)	Fr.		Fr.	
Massnahmen zur Erfüllung der Basisanforderungen (Schätzung	0		50,000	
Kosten für die Zertifizierung/Rezertifizierung (alle 5 J.)	Fr.		Fr.	
Zertifizierungs-/Rezertifizierungsgebühr VUE (500 Fr./alle 5 J.)	1,000		1,000	
Auditkosten der Rezertifizierung (alle 5 J., Schätzung)	5,000		5,000	
Total	6,000		6,000	
Resultierende Kosten pro Jahr	Fr./J.	Rp./kWh	Fr./J.	Rp./kWh
Verfahrenskosten (amortisiert über 10 Jahre)	4,887	0.0489	4,887	0.0489
Kosten für Massnahmen (amortisiert über 10 Jahre)	0	0.0000	8,144	0.0814
Kosten für Zertifizierung/Rezertifzierung (amortisiert über 10 Jah	783	0.0078	977	0.0098
Kosten Jährliche Lizenzvertragsprüfung (ca. 1'000 Fr./J.)	1,000	0.0100	1,000	0.0100
Jährliche VUE-Lizenzgebühr fix (200 Fr./J.)	200	0.0020	200	0.0020
Jährliche VUE-Lizenzgebühr variabel (35 Fr./GWh und J.)	350	0.0035	350	0.0035
Ökostrominvestitionen (Satz 0.1 Rp./produzierte kWh)	10,000	0.1000	10,000	0.1000
Ökostrominvestitionen (Satz 1 Rp./verkaufte kWh)	100,000	1.0000	100,000	1.0000
Total (mit Ökostrominvestitionen, Satz 0.1 Rp./produzierte kWh	17,220	0.17	25,558	0.26
Total (mit Ökostrominvestitionen, Satz 1 Rp./verkaufte kWh)	107,220	1.07	115,558	1.16

Die Kosten zur Erfüllung des sog. "VUE-Fördermodells" sind in der vorliegenden Vollkostenberechnung nicht berücksichtigt,
da sich diese Anforderung an Verteiler und nicht an Produzenten richtet.
Ebenfalls nicht berücksichtigt sind die Kosten zur Einführung eines Umweltmanagementsystems (UMS) gemäss ISO 14'001 oder EMAS
da diese Kosten nicht direkt auf die Produktionsanlagen umgelegt werden können.
(Gilt nur ab einer installierten el. Leistung von 10 MW; innerhalb von 5 Jahren ab dem Zeitpunkt der Zertifizierung).

Anmerkung: Das vorgestellte Beispiel gibt einen Überblick über die Kostenarten, die im Rahmen einer Ökostrom-Zertifizierung anfallen. Die spezifischen Kosten können im Einzelfall je nach Grösse, Typ und ökologischem Einfluss der Wasserkraftanlage, bzw. je nach Charakter des Einzugsgebiets von dem hier vorgestellten Beispiel abweichen.

(Source: Richtlinien des VUE, Stand 2000).

A5
Glossary

A5 GLOSSARY

Audit /Auditor — Independent inspection to check whether an electricity product or generation facility meets all requirements of the eco-label's issuing office. In general, the *audit* is carried out by an independent assessor (*auditor*). If the plant passes the audit, the independent examiner makes an application to the issuing office for the certification of the corresponding product or facility.

Action plan — Compilation of all ecological improvement measures that must be implemented within the scope of green electricity certification.

Basic requirements for green electricity — Ecological requirements met by every hydroelectric power plant that is accredited with the *naturemade* ***star*** eco-label. The *basic requirements* are general environmental criteria that apply to facilities regardless of the original ecological conditions of the plant. This ensures that all *naturemade* ***star*** facilities conform to similar basic ecological standards. A plant can only be certified if it conforms to the eco-investments principles (see below).

Bedload — Solid material that is transported in a stream by rolling, sliding or skipping along or very close to the bed.

BFG — Swiss Federal law on fishing passed 21 July 1991.

Control audit — An accredited *audit agency* conducts an annual inspection in accordance with the basic principles of the eco-label to check whether the information submitted by the power plant matches the stipulated requirements. In particular, the procedure involves performing a reconciliation of the amount of electricity sold, produced and certified by the power plant.

Daily and weekly storage reservoirs — Storage basins with a drainage time of up to 6 hours (daily storage reservoir) or from 6 - 25 hours (weekly storage reservoir).

EAWAG — The Swiss Federal Institute for Environmental Science and Technology - EAWAG is a research institution of the Swiss Federal Institutes of Technology (ETH).

Eco-investments — Fixed payment per kilowatt-hour of green electricity sold, invested in carrying out ecological mitigation measures geared toward local conditions. VUE has fixed this payment at 1 Rp./kWh for hydroelectric facilities accredited with the *naturemade* ***star*** label, making it a mandatory element of every green electricity certification.

Enhancement flow — Increased streamflow from reservoir releases that improves streamflow conditions for aquatic, terrestrial, recreational, and other resources.

Environmental management matrix — Basis of the EAWAG certification procedure for green electricity: a matrix with 25 elements produced by five environmental fields and five management fields. Each element provides ecological performance targets, basic requirements for green electricity and methodological guidance notes.

Environmental management system — Code of practice for structuring corporate environmental protection, usually based on the ISO 140001 system (international dissemination) or on the European community's EMAS system.

Eco-morphology — Assessment tool for ecologically significant structures in and around river systems (e.g. channel forms, bank structures, riverbed characteristics, buildings, etc.). In Switzerland, all cantons are compiling complete-coverage records of river morphology, which can be used as an evaluation basis for green electricity certification.

Edaphic — Pertaining to the chemical and physical characteristics of the soil, without reference to climate; Soil characteristics, such as water content, pH, texture, and nutrient availability, that influence the type and quantity of vegetation in an area. Example: the typical structure of a floodplain forest depends less on climate since it is a more *edaphic* form of vegetation.

Generator Machine that converts mechanical energy into electrical energy. This harnesses electromagnetic induction caused by moving a conductor loop inside a magnetic field.

Habitat Specific type of place within an ecosystem occupied by an organism, population, or community that contains both living and nonliving components with specific biological, chemical, and physical characteristics including the basic life requirements of food, water, and cover or shelter.

Hydropeaking Operating mode that enables power plants to gear their electricity generation to match demand (generally during peak production periods). *Hydropeaking* can occur both at storage facilities and run-of-the-river power plants in a chain formation. *Hydropeaking at storage power plants* involves quickly putting turbines into operation, which causes a rapid surge in peak flows in the affected return flow reaches. Chains of *run-of-the-river power plants* are brought on line successively in order to match the size of the water surge waive, resulting in increased power output during a longer time interval.

Hyporheic zone Lattice-work of underground *habitats* through the alluvium of the channel and floodplain associated with streamflows that extend as deep as the interstitial water in the substrate. It is located both underneath and adjacent to the river bottom and is a significant ecological ecotone between surface water and groundwater. It plays an important part during high water flows, for example, or as a spawning habitat.

kWh Energy unit: kilowatt-hour (3600 kJ).

Lead auditor Auditor responsible for ensuring that the overall audit is carried out properly. The *lead auditor* can bring in an expert auditor to help evaluate technical issues.

Lentic An aquatic system with standing or slow flowing water (e.g. lake, pond, reservoir, swamp, marsh, and wetland).

Licensing The formulation and signing of a licensing agreement, which sets out the rights and obligations between the eco-label's issuing office and the owners of the labelled product. The licensing agreement generally includes the payment of a license fee.

Lotic river reaches Fast flowing river reaches with a steep gradient.

Management concept The documentation of individual arrangements ensuring that a green power plant operates and structures its facilities in an ecologically compatible way. The management concept refers to the five management fields: minimum flow regulation, hydropeaking, reservoir management, bedload management, and plant design.

MW Unit electrical power: megawatt (10^6 or 1 million watts)

Naturemade basic Swiss declaration for identifying electricity from renewable sources. Includes an investment model for supporting the new renewable energy sources and does not require hydropower utilisation to be accompanied by any in-depth local or regional environmental measures. All production facilities with a capacity of over 10 MW must phase in an additional ISO 14001 *environmental management system*. The label is issued by the *VUE*.

Naturemade ***star*** Swiss eco-label for identifying green electricity from regenerative sources. *VUE* issues the label and imposes very stringent requirements regarding ecological sustainability. Certifying hydropower involves setting exacting standards to control its impact on the local and regional environment. The EAWAG procedure presented herein serves as the basis for the certification procedure.

Net production Energy production that can be certified as green electricity, calculated by deducting the energy quantities necessary to maintain the plant in operation. Particularly important for pumped storage facilities.

NHG Swiss Federal law on regional nature conservation passed on July 1, 1966.

Ongoing solid transport *Ongoing solid transport* means the solid material brought into a river section in a certain time period (at the most 1 - 2 years) is also transported away from the river reach within the same interval (maximum 1 - 2 years). The relevance of this concept for bedload management is that solid material should not be allowed to accumulate over a long period (e.g. for more than 5 years). Instead of flushing large amounts of solid material in one shot, regular flushing should take place.

Pool Deep section of a river that shows only very small or non-measurable currents; back currents occur frequently.

Preliminary study The first procedural step of the EAWAG certification process for green hydroelectric power plants: it gives a quick overview of the ecological boundary conditions and the cost structure of certifying a plant for green electricity.

Re-certification According to VUE's basic principles, a power station can continue using the *naturemade* ***star*** eco-label further after its licensing agreement expires, i.e. after a 5-year time span. In order to do this, it is checked whether there have been deficiencies or infringements against the licensing agreement and whether relevant ecological mitigation measures have been implemented in a practicable way. There is also an evaluation of how effectively *eco-investments* have been used.

Relevance matrix Matrix showing which study fields will be examined for each individual power plant during the certification procedure for green electricity. It is based on the *eco-management matrix* and results from the *preliminary study*.

Rheophile organisms Literally, current-loving organisms, i.e. organisms preferring sections of strong current.

Riffles Shallow reaches with fast flowing water in which the water surface is clearly agitated with broken stationary waves; usually over a gravely substrate.

Rp 1/100 of the Swiss Franc.

RPG Swiss Federal law on area planning passed June 22, 1979.

Seasonal and annual storage reservoirs Reservoirs that need between 25 and 500 hours (seasonal storage reservoir) or more than 500 hours (annual storage reservoir) to drain the entire volume of water. Certification procedures for green electricity usually deal with alpine storage basins with very sizeable fluctuations in water level, but may also include, for example, large drinking water reservoirs that also generate electricity as a secondary use. In the latter case, even big annual storage reservoirs would not be expected to exhibit substantial fluctuations in water level. (Both types have to meet different criteria for storage capacity management as described in Ch. 11).

Silting Deposition of suspended solids in and on riverbeds. On the one hand, this reduces riverbed permeability and on the other hand restricts pore space while simultaneously firming up the bottom substrate. Silted-up riverbeds can therefore impair the formation of groundwater reserves, and cause deterioration in riverine habitats and the hyporheic zone.

Simple monitoring Establishing and documenting simple and ecologically relevant benchmarks that can be used for quality assurance as part of a certification program for green electricity. Refers to changes in the way plants are run, technical operating procedures and key ecological variables. *Simple monitoring* includes compiling long-term records of water levels in the areas being studied, temperature data in reference sections, normal operating conditions and special events affecting the power plant.

System overview Part of the preliminary study for green electricity certification. It is based partly on an *eco-morphological* record of the most important river reaches. The *system overview* is designed to document ecologically significant sites and the overall condition of river system within the boundaries of the study area, so that certification costs can be estimated.

Tipping Operating method used by chains of run-of-the-river power plants to enable them to gear electricity generation to match demand (usually in peak production periods). *Tipping* involves all hydroelectric power plants in the chain putting their turbines into operation at the same time with the same throughflow, thus "tipping" the water level from a horizontal state to a downward incline in order to release the full capacity of the entire chain.

Transformer Electrical device used for converting a current from one voltage to other voltage values without any appreciable energy losses. The *transformer* consists of two coils, usually coupled inductively through an iron core, each with a different number of turns. It is used, for example, to transform the voltage of the current produced by the *generator* into the high voltage carried by the overland grid.

Transformer terminal Point at which electricity is collected from the transformer, equivalent to the point of delivery into the general grid. Larger power plants feed the total quantity of electricity generated by individual turbines into the grid through the transformer terminals. The certification of a green hydroelectric power plant is effective at the transformer terminals, which means that specific turbines or turbine groups within a power plant cannot be certified separately. *VUE* guidelines exempt small hydroelectric facilities and individual installations from this rule, provided that they are located in a hydrological area amenable to appropriate delimitation.

VUE Association for Environmentally Sound Electricity: an independent association that has launched the "*naturemade **star***" eco-label and whose board is composed in equal numbers of representatives of producer associations, distribution facilities, environmental and consumer bodies (NGOs).

Water Conservation Act Swiss Federal law on water conservation (Water Conservation Act, German abbreviation GSchG) passed on January 24, 1991 (and revised October 21, 1997).

A6
Bibliography

A6 BIBLIOGRAPHY

A6.1 Literature used in the conceptual part

Bratrich C. (2000): Das EAWAG Verfahren zur Ökostrom-Zertifizierung. In *Umweltmanagement und Ökolabeling für die Wasserkraft*, Ökostrom Publikationen Band 4 (Hrsg. J. Markard & B. Truffer), S. 63-71. EAWAG, Kastanienbaum.

BUWAL (1998:) *Modul-Stufen-Konzept.* Mitteilungen zum Gewässerschutz, Bundesamt für Umwelt, Wald und Landschaft, S. 1-41.

Markard J. & B. Truffer (1999): Der lange Weg zu einem Euro-Label für Strom. *Energiewirtschaftliche Tagesfragen. Zeitschrift für Energiewirtschaft, Recht, Technik und Umwelt:* 49/11, S. 724-729.

Markard J.(1998): Green-Pricing – Welchen Beitrag können freiwillige Zahlungen von Stromkunden zur Förderung regenerativer Energien leisten? Öko-Institut-Verlag, Freiburg.

Ökostrom (2000): www.oekostrom.eawag.ch

Truffer B., B. Seiler, S. Vollenweider und R. Dettli (2001): Umweltzertifizierung Kleinwasserkraftwerke. Projektbericht BfE, EAWAG, ISKB.

Truffer B., C. Bratrich, J. Markard und B. Wehrli (2001): Ökostrom: The Social Construction of Green Electricity Standards in Switzerland. In: Julie Thompson Klein et al. (eds.) Transdisciplinarity: Joint Problem Solving among Sicence, Technology and Society. An Effective Way for Managing Complexity. Birkhäuser, Basel, pp. 153-158.

WCD (2000): Dams and Development: A new Framework for Decision-Making: The Report of the World Commission on Dams, P. 75-77.

Wüstenhagen R. (2000): Ökostrom - von der Nische zum Massenmarkt. Entwicklungsperspektiven und Marketingstrategien für eine zukunftsfähige Elektrizitätsbranche. VdF Verlag, Zürich.

A6.1 Literature used for the annotated bibliography

(Comprehensive bibliography according to the German original version of this report. Some of the citations are not cited in the English version)

Ackermann, G., J. Ortlepp, P. Pitsch, P. Rey, & K. Robin (1996): Entleerung des Ausgleichsbeckens Ova Spin 1995. CRATSCHLA, 4/2/1996, S. 37-44.

Ammann, M. & M. Kast (1996): 10 Jahre ökologische Spülungsbegleitung am Luzzone-Stausee (Bleniotal/TI). In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 195-202.

ASCE Task Force on Bed Forms in Alluvial Channels (1966): Nomenclature for Bed Forms in Alluvial Channel. *ASCE, J. of the Hydr. Division*, 92(HY3), P. 51-64.

ATEL – Aare-Tessin AG für Elektrizität (1995): Neubau Kraftwerk Ruppoldingen – Bericht zur Umweltverträglichkeit 2. Stufe – Hauptbericht. Olten, S.**8-**3 bis **8**-42 .

ATEL– Aare-Tessin AG für Elektrizität (1991): Neubau KW Ruppoldingen. Bericht zur Umweltverträglichkeit *Arbeitsgemeinschaft Rus AG – Hollinger AG*, Baden.

Baudepartement des Kantons Aargau, Abteilung Landschaft und Gewässer (2000): Auenschutzpark Rohr – Rupperswil, Vorprojekt Rupperswil, Dynamische Flussaue. *Schälchli, Abegg + Hunzinger*, Zürich, Technischer Bericht.

Baudepartement des Kantons Solothurn, Bau- Verkehrs- und Energiewirtschaftdepartement des Kantons Bern und Baudepartement des Kantons Aargau: (1996): Hydraulische, geschiebemechanische und flussmorphologische Machbarkeitsstudie zur Reaktivierung des Geschiebehaushaltes der Aare zwischen der Emme und dem Rhein. Technischer Bericht.

Bayerisches Landesamt für Wasserwirtschaft (1991): Stützkraftstufe Landau a.d. Isar – Entwicklung der Pfanzen- und Tierwelt in den ersten 5 Jahren. Schriftenreihe des Bayer. Landesamtes für Wasserwirtschaft, München, Heft 24, S. 12-17.

Bezzola, G.R. (1989): Rhone und Pfynwald - Renaturierung einer Flusslandschaft. *Bull. Murithienne*, 107, P. 11.

Binder, W. (1986): Beispiele zur Stauraumgestaltung aus Bayern. In Landschaftswasserbau: Naturnahe Gestaltung von Stauhaltungen, Hrsg. Institut für Wassergüte und Landschaftswasserbau Technische Uni Wien, Band 7, S. 314-339.

Bremen, R. & P. F. Bertola (1996): Praxisgerechte Lösungen zur Optimierung von Stauspülungen. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 115-118.

Bundesamt für Wasser und Geologie und Regierungs-präsidium Freiburg i. Br. (2000): Geschiebehaushalt Hochrhein. *Schälchli, Abegg + Hunzinger*, Zürich, Technischer Bericht.

BUWAL (1987): Wasserentnahme aus Fliessgewässern: Auswirkungen verminderter Abflussmengen auf die Pflanzenwelt. Schriftenreihe Umweltschutz Nr. 72, 103 S.

BUWAL (1997): Gestaltungsgrundsätze zur Gewässerökologischen Optimierung von Wasserfassungen, Umwelt-Materialien Nr. 74.

BUWAL (1997): UVP von Wasserkraftanlagen. In *Mitteilungen zur Umweltverträglichkeitsprüfung (UVP) Nr. 8;* Bundesamt für Umwelt, Wald und Landschaft.

Cushman, R. M. (1985): Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities: North Am. J. Fish. Man. 5, P. 330-339.

D'Agostino, V., M. Cerato & R. Coali (1996): Il trasporto solido di eventi estremi nei torrenti del Trentino orientale. *Interpraevent*, Garmisch-Partenkirchen, 1, P. 377-386.

DIANE (1997) Publikationen Kleinwasserkraftwerke: Fische und Kleinwasserkraftwerke, Bezug EDMZ, Nr. 805635 d+f .

Direktion der öffentlichen Bauten des Kantons Zürich und Amt für Gewässerschutz und Wasserbau (1997): Geschiebetransport Stauhaltung KW Eglisau. Hyraulische und Geschiebe-mechanische Machbarkeitsstudie betreffend den Geschiebetransport durch das Stauwehr Eglisau bei Hochwasserabfluss durch periodische Staupegelabsekungen. *Schälchli & Abegg*, Zürich, 16. Dezember 1997, Technischer Bericht.

Dürr, A (2000): Auswirkungen von Abflussvariationen auf das aquatische Habitatangebot in der Teststrecke Kraiburg/Inn, Diplomarbeit, Universität Stuttgart, 80 pp.

DVWK (1996): Fischaufstiegsanlagen – Bemessung, Gestaltung, Funktionskontrolle, Heft 232, Bonn.

DVWK (1997): Fischabstieg –Literaturdokumentation, DVWK-Materialien 4/1997, Bonn, 229 pp.

DVWK (1999): Ermittlung einer ökologisch begründeten Mindestwasserführung mittels Halbkugelmethode und Habitat-Prognose Modell, Schrift 123, Bonn.

EAWAG (2000): Endbericht zur Restwassersynthese im Rahmen des Ökostrom Projektes. EAWAG Bericht.

Eberstaller, J., M. Hinterhofer & P. Parasiewicz (1998): The Effectiveness of Two Nature-like Bypass Channels in an Upland Austrian River. In Fish migration and Fish Bypasses (ed. M. Jungwirth, S. Schmutz, and S. Weiss), P. 363-383. Fishing News Books.

ECOHYDRAULICS (1994): Proceedings of the 1st Conference on Ecohydraulics, SINTEF, Trondheim, Norway.

ECOHYDRAULICS (1996): Proceedings of the 2nd Conference on Ecohydraulics, ECOHYDRAULICS 2000, Quebec City, Canada.

ECOHYDRAULICS (1999): Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA.

Elektrizitätswerk der Stadt Zürich und Ingenieurbüro für bauliche Anlagen (1998): Erneuerung Limmatwerk Wettingen. Konzessionsprojekt und Umweltverträglichkeitsbericht. Archiviert bei *creato - Netzwerk für kreative Umweltplanung*, September 1998.

EURONATUR (2000): Problemkreis Pflichtwasserabgabe „Ökologisch begründete Mindestabflüsse in Ausleitungsstrecken von Wasserkraftwerken"; natur+wissenschaft. Schriftenreihe der Stiftung Europäisches Naturerbe (Euronatur): Nr. 1/2000, ISSN 1439-6793.

Fehr, R. (1987): Einfache Bestimmung der Korngrössenverteilung von Geschiebematerial mit Hilfe der Linienzahlanalyse. *Schweiz. Ingenieur u. Architekt*(38), S.1104-1109.

Forstenlechner, E., M. Hütte, U. Bundi, E. Eichenberger, A. Peter & J. Zobrist (1997): Ökologische Aspekte der Wasserkraftnutzung im alpinen Raum. Vdf, Hochschul.-Verl. an der ETH, Zürich.

Gerster, S. & P. Rey, (1994): Ökologische Folgen von Stauraumspülungen. BUWAL, Bern, Schriftenreihe Umweltschutz Nr. 219.

Giesecke, J. und E. Mosonyi (1998): Wasserkraftanlagen, 2. Auflage, Springer Verlag, Berlin.

Ginot, V. (1995): EVAH, Un logiciel d'évaluation d'habitat sous Windows.- Bull. Fr. Pêche Pisci. 337/338/339, P. 303-308.

Hälg, R. (1996): Spülung des Stausees Ova Spin. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 171-187.

Harby A., K. Alfredsen, J. V. Arnekleiv, J. H. H. Halleraker, S. Johansen, S. J. Saltveit (1999): Impacts from hydropeaking on Norwegian riverine ecosystems. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA.

Harby, A. (1999): Methods and Applications of Fish Habitat Modelling in Norway. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA.

Holinger AG (1995): Zusammenfassender Bericht über die Entwicklung der Makroinvertebratenfauna des Brenno in den Jahren 1985-1994. Auftraggeber: Officine Idrelettriche di Blenio SA. (Contact: EAWAG).

Hong, L.B. und Davies T.R.H. (1979): A study of stream braiding. *Bulletin Geological Society of America*, 90(Part II), 1839-1859.

Humpesch, U.H., M. Dokulil, J.M. Elliott, A. Herzig (1981): Ökologische Auswirkungen der thermischen Gewässerbeeinflussung. Erschienen in der Reihe Forschungsarbeiten Wasserwirtschaft Wasservorsorge. Herausgegeben vom Bundesministerium für Land- und Forstwirtschaft (Sektion IV), Wien, 257 S.

Hunzinger, L. (1998): Flussaufweitungen – Morphologie, Geschiebehaushalt und Grundsätze zur Bemessung. *Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 159, Zürich, 206 S.

Hütte, M. (1994): Die Bedeutung einer Wasserfassung für die Ökologie eines alpinen Baches. Dissertation.

Hütte, M. (2000): Ökologie und Wasserbau – Ökologische Grundlagen von Gewässerverbauung und Wasserkraftnutzung, Parey, Berlin.

Hydra (1995): Fischökologische Untersuchungen an der Melezza. Schlussbericht zuhanden Dipartimento del Territorio del Cantone TI, Ufficio Caccia e Pesca. (Contact: EAWAG).

Jäggi, M. und P. Kuster (1991): Einfluss der Vegetation im Gerinne bei extremen Abflussmengen. Ursachenanalyse der Hochwasser 1987, Ergebnisse der Untersuchungen. Mitteilung des Bundesamtes für Wasserwirtschaft, Nr. 4.

Jorde, K. (1997): Ökologisch begründete, dynamische Mindestwasserregelungen bei Ausleitungskraftwerken, Mitteilungen des Instituts für Wasserbau, Heft 90, Universität Stuttgart, 158 S.

Jorde, K. (2000): Das Simulationsmodel CASIMIR als Hilfsmittel zur Festlegung ökologisch begründeter Mindestwasserregelungen. In EURONATUR (vollständig. Zitat siehe oben): S. 69-74.

Jorde, K. & C. Bratrich (1998): Influence of River Bed Morphology and Flow Regulations in Diverted Streams on Bottom Shear Stress Pattern and Hydraulic Habitat. In: Bretschko G. & Helesic J. (Eds.), Advances in River Bottom Ecology IV, Backhuys Publishers, S. 47-63.

Jorde, K. & Schneider, M. (1998): Einsatz des Simulationsmodells PHABSIM zur Festlegung von Mindestwasserregelungen, Wasser + Boden 50, Heft 4, S.45- 49.

Jorde, K., M. Schneider & F. Zoellner (2000): Ökologisch begründete Mindestwasserregelungen, Wasserbewirtschaftung an Bundeswasserstrassen – Probleme, Methoden, Lösungen, Bundesanstalt für Gewässerkunde, Berlin ,S.203- 224.

Jungwirth, M. (1992): Fliessgewässer: limnologische und fischökologische Probleme. Landschaftswasserbau (13) S. 15 – 28.

Jungwirth, M., O. Moog, S. Schmutz, U. Grasser, P. Parasiewicz, G.A. Parthl (1998): Limnologische Gesamtbeurteilung des Kraftwerks Alberschwende: Auftragsstudie der BOKU Wien, 540 S. Archiviert bei der Universität für Bodenkultur, Abteilung Hydrobiologie, Fischereiwirtschaft & Aquakultur, Wien.

Jungwirth, M., S. Schmutz & S. Weiss (1998): Fish migration and Fish Bypasses. Fishing News Books, Oxford.

K. Alfredsen, J. V. Arnekleiv, J. H. H. Halleraker, A. Harby, S. Johansen, S. J. Saltveit, P. Borsanyi (1999): Physical habitat modelling in a Norwegian hydropeaking river. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA.

Kaltschmitt, M. & A. Wiese (1997): Erneuerbare Energien – Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 2. Auflage, Springer Verlag, Berlin.

Kant. Forstinspektion Tessin (1988): Riale di Prugiasco. Veränderungen entlang des Baches und Abtragskubaturen von 1946 bis 1985. *Eidg. Anstalt für das forstliche Versuchswesen*.

Kanton Graubünden (1998): Prüfung des Wehrreglementes des Kraftwerkes Reichenau. Studie über den Einfluss von Kraftwerkbetrieb und Kiesentnahmen auf den Geschiebehaushalt und die Sohlenveränderungen im Alpenrhein zwischen Reichenau und der Maschänser Rüfi. *Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 4119, Zürich, 3. Dezember 1998, Technischer Bericht.

Kern, K. (1994): Grundlagen naturnaher Gewässergestaltung. Geomophologische Entwicklung von Fliessgewässern. *Springer-Verlag*, Berlin Heidelberg New York, 256 S.

Kraftwerke Brusio AG (1992): UVP-Bericht Konzessionsprojekt 1991, Teilbericht Restwasserbemessung.

Kraftwerke Brusio AG (1996): Restwasserbericht „Weiterbetrieb der bestehenden Anlagen im oberen Puschlav nach Ablauf der Konzession Ende 1997.

Kronfellner-Kraus, G. (1984): Extreme Feststofffrachten und Grabenbildungen von Wildbächen. *Interpraevent*, Band 2, S. 109-118.

Leopold, L.B. & M.G. Wolman (1957): River Channel Patterns: Braided, Meandering and Straight. *Geological Survey Professional*, Paper 282-B.

Liebig, H., R. Cereghino, P. Lim, A. Belaud & S. Lek (1999): Impact of hydropeaking on the abundance of juvenile brown trout in a Pyrenean stream. Arch. F. Hydrobiol. 144 (4): 439-454.

Limnex & EAWAG (2000): Auswirkungen des Schwallbetriebes des Kraftwerks Kubel auf die Wassertiere der Sitter: Auftragsbericht, 57 S. + Anhang. Archiviert bei Limnex AG, Zürich.

Limnex & Schälchli & Abegg (1994): Untersuchung am Inn bei Celerina im Zusammenhang mit der Konzessionserneuerung des Elektrizitätswerkes St. Moritz. Hauptbericht und Anhang 3. Auftragsbericht, 36 + 17 S.

Mader, H. (1993): Ausgewählte Probleme zur Dotierwasserabgabe. Wiener Mitteilungen – Wasser Abwasser Gewässer, Band 113, S. 99-116.

Mader, H. (2000): Dotierwasserfestlegung auf Basis hydraulischer und flussmorphologischer Kenngrössen. EURONATUR (2000) S. 63-68.

Mader, H., G. Unfer & S. Schmutz (1998): The Effectiveness of Nature-like Bypass Channels in a Lowland River, the Marchfeldkanal. In Fish migration and Fish Bypasses (ed. M. Jungwirth, S. Schmutz, and S. Weiss), 384-402. Fishing News Books.

Mangelsdorf, J. & K. Scheuermann (1980): Flussmorphologie – Ein Leitfaden für Naturwissenschafter und Ingenieure. *Oldenbourg Verlag*, München Wien, 262 S.

Marrer, H. (1996): Erneuerung Kraftwerk Ritom. Kapitel 5.3 und Anhang 5.3-6 des Umweltverträglichkeitsberichtes (Hauptuntersuchung). Auftragsbericht, 77 + 34 S..

Marrer, H. (2000): Gewässerökologisch verträgliche Ausgestaltung des Schwellregimes. Auftragsbericht, 45 S. + Beilage. Archiviert bei Büro für Gewässer- und Fischereifragen AG, Solothurn.

Matthäi, C. D. (1996): Disturbance and invertebrate patch dynamics in a prealpine river: Diss.ETH Nr. 11765, 169 S.

Meyer-Peter, E. und Müller R. (1949): Eine Formel zur Berechnung des Geschiebetriebs. *Schweiz. Bauzeitung*, 67(3).

Moog, O. (1993): Quantification of daily peak hydropower effects on aquatic fauna and management to minimize environmental impacts: Regulated Rivers: Res. & Man. (8) 5-14.

Moog, O., M. Jungwirth, S. Muhar, B. Schoenbauer (1993): Berücksichtigung ökologischer Gesichtspunkte bei der Wasserkraftnutzung durch Ausleitungskraftwerke. Österreichische Wasserwirtschaft 45, 197 - 210.

Morrison, H.A., K. E. Smokorowski (2000): The applicability of various frameworks and models for assessing the effects of hydropeaking on the productivity of aquatic ecosystems: Canadian Technical Report of Fisheries and Aquatic-Sciences (in print).

Muhar, S., M. Schwarz, S. Schmutz & M. Jungwirth (2000): Identification of rivers with high and good habitat quality: Methodological approach and applications in Austria: Hydrobiologia: (422/423) 343-358.

ÖNORM M6232 (1995): Richtlinien für die ökologische Untersuchung und Bewertung von Fliessgewässern, Österreichisches Normungsinstitut, Wien.

ÖWAV (1998): Entleerung, Spülung und Räumung von Speichern und Becken. Österreichischer Wasser- und Abfallwirtschaftsverband, Wien, Heft 117.

ÖWAV (2000): Feststoffmanagement in Kraftwerksketten. Österreichischer Wasser- und Abfallwirtschaftsverband, Wien, Heft 137.

Parasiewicz, P. & S. Schmutz (1999): A hybrid-model-assessment of physical habitat conditions combining various modelling tools. Proceedings 3rd Conference on Ecohydraulics, Salt Lake City, June 1999, CD-Rom, Utah State University, USA.

Parasiewicz, P., J. Eberstaller, S. Weiss & S. Schmutz (1998): Conceptual Guidelines for Nature-like Bypass Channels. In *Fish migration and Fish Bypasses* (ed. M. Jungwirth, S. Schmutz, and S. Weiss), 348-362. Fishing News Books.

Patt, H. , Jürging, P. & W. Kraus (1998): Naturnaher Wasserbau – Entwicklung und Gestaltung von Fliessgewässern, Springer, Berlin.

Petz-Glechner (2000): Fachvortrag bei 15. SVK-Fischereitagung. 19-20/02/2000.

Reichert, P. (1994): "AQUASIM - A tool for simulation and data analysis of aquatic systems", Wat. Sci. Tech. 30(2), 21-30.

Reichert P. (1998): AQUASIM 2.0 - User Manual, Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH-8600 Dübendorf, Switzerland.

Reichert, P. (1998): AQUASIM 2.0 – Tutorial, Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH-8600 Dübendorf, Switzerland.

Rey, P. & J. Ortlepp (1995): Spülung des Staubeckens Ova Spin – Begleitende Untersuchung und Abschätzung der ökologischen Folgen.

Riegler, J. (1996): Sedimentmanagement an der österreichschen Donau. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen. Teil 2, Hrsg. Vischer, S. 140-142.

Roth, M. & G.R. Bezzola (1999): Geschiebetransport in Wildbächen mit Sperrentreppen. *"wasser, energie, luft - eau, énergie, air"*, 91(11/12), S.1.

Roth, M. und B. Zarn (1998): Eintiefung am Wildfluss Melezza – Voraussagen 1983, Messungen und Berechnungen 1997. *Wasserbau-Symposium: Planung und Realisierung im Wasserbau*, Garmisch-Partenkirchen, 15.-17. Oktober, *Bericht der Versuchsanstalt Obernach und Lehrstuhl für Wasserbau und Wasserwirtschaft der TU München*, 84, S. 187-199.

Schälchli U. (1991): Morphologie und Strömungsverhältnisse in Gebirgsbächen: Ein Verfahren zu Festlegung von Restwasserabflüssen. Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH, 113, Zürich, 112 S.

Schälchli U. (1993): Die Kolmation von Fliessgewässersohlen: Prozesse und Berechnungsgrundlage. *Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 124, Zürich, 273 S.

Schälchli, U. (1992): Kolmations- und Spülprozesse in Flussstauhaltungen. Berichte der Versuchsanstalt Obernach und des Lehrstuhls für Wasserbau und Wasserwirtschaft der Technischen Universität München. Band 73/1992, ISSN 0939-0308.

Schälchli, U. (1995): Wasserkraftnutzung an Gebirgsbächen. Morphologie als Grundlage zur Beurteilung und Verminderung der morphologischen Auswirkungen von Wasserkraftnutzungen auf Gebirgsbäche. Regio Basiliensis, Basler Zeitschrift für Geographie, Nr. 36/2, 141-152.

Schälchli, U. (1995): Basic equations for siltation of riverbeds. Journal of Hydraulic Engineering, Vol. 121, No. 3, pp. 274-287.

Scheuerlein, H. (1984): Die Wasserentnahme aus geschiebeführenden Flüssen, Ernst & Sohn, Berlin.

Schilling M. & R. Hunziker (1996): Programm MORMO (MORphologisches MOdell). *Mathematische Modelle offener Gerinne, ÖWAV-Seminar*, Wien, 21. Nov., S. 91-104.

Schilling, M., R. Hunziker & L. Hunzinger (1996): Die Auswirkungen von Korrektionsmassnahmen auf den Geschiebehaushalt. *Interpraevent*, Garmisch-Partenkirchen, Band 4, 209-220.

Schleiss, A., B. Feuz, M. Aemmer, & B. Zünd (1996): Verlandungsprobleme im Stausee Mauvoisin. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1.

Schmedtje, U. (1995): Ökologische Grundlagen für die Beurteilung von Ausleitungsstrecken. Schriftenreihe Bayerisches Landesamt für Wasserwirtschaft 25, 156 S.

Schmutz, S. & P. Parasiewicz (1999): Biotische Habitatmodellierung, Gewässerbetreuungskonzept Traisen. HFA-BOKU & Donau Consult. Im Auftrag des BMLF, Wien.

Schöb, P. (1998): Untersuchung des Fischbestandes in der vom Schwellbetrieb des Kraftwerks Kubel beeinflussten Sitter: EAWAG-Praktikumsarbeit, 19 S. + Anhang. Interner Bericht.

Schöberl, F. (1991): Morphologische Dynamik – Gewässerregulierung: Spannungsfeld alpiner Flussbau. *Österr. Wasserwirtschaft*, 43(F7/8), S. 171-178.

Schöberl, F. (1996): Grundlagen der Deckschichtbildung. Schriftenreihe des Österreichischen Wasser- und Abfallwirtschaftverbandes, Heft 105, S.23-41.

Seifert (2000): Tagungsband der Fachvortrag bei 15. SVK-Fischereitagung. 19-20/02/2000.

Sigmaplan (1995): Ökologische Begleituntersuchungen zur Erneuerung des Kraftwerks Amsteg. Schlussbericht Sachbereich Geschiebe und Hydraulik, Technischer Bericht.

Smart, G.M. und Jäggi M.N.R. (1983): Sedimenttransport in steilen Gerinnen. *Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 64, Zürich.

Steiner, H.A. (1996): Ökologische Aspekte und Sukzessionsentwicklung spülgerecht gestalteter Stauraumvorländer an den Flusskraftwerken der Drau. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen. Teil 2, Hrsg. Vischer, S. 178-186.

Strobl, T. & S. Nothhaft (2000): Ermittlung ökologisch begründeter Mindestabflüsse mit dem MEFI-Modell. EURONATUR (2000): S. 75-79.

Umweltbundesamt (1994): Ramsar-Bericht 2 – Stauseen am Unteren Inn. Umweltbundesamt, Wien, 3-19/27-45/47-56.

Universität Stuttgart (2000): Umweltverträglichkeitsstudie zur Wasserkraftanlage Werdohl-Schlacht an der Lenne: Technischer Bericht TB 2000/5, Institut für Wasserbau, Universität Stuttgart, 80 S.

Valentin, S., F. Lauters, C. Sabaton, P. Breil, Y. Souchon (1996): Modelling temporal variations of physical habitat for brown trout (*Salmo trutta*) in hydropeaking conditions. Regulated Rivers Res. & Man. 12, 317-330.

Vehanen T., P. L. Bjerke, J. Heggenes, A. Huusko, and A. Mäki-Petäys (2000): Effect of fluctuating flow and temperature on cover type selection and behaviour by juvenile brown trout in artificial flumes. Journal of Fish Biology, Vol. 55 (4) 923-937.

Vigl, L. & E. Pürer (1996): Speicher Bolgenach – Feststoffbewirt-schaftungskonzept und erforderliche Massnahmen. In VAW: Verlandung von Stauseen und Stauhaltungen, Sediment-probleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 123-129.

Wagner, E.K., N. Karlsböck & H. Niedermühlbichler (1996): Spülung des Speichers Margaritze. In VAW: Verlandung von Stauseen und Stauhaltungen, Sedimentprobleme in Leitungen und Kanälen, Hrsg. Vischer, Teil 1, S. 123-136.

Wasserwirtschaftsverband Baden-Württemberg (1994): Leitfaden für den Bau von Kleinwasserkraftwerken, 2. Auflage, Kosmos, Stuttgart.

Young, W.J. und Davies T.R.H. (1991): Bedload transport processes in a braided gravel-bed river model. *Earth surface processes and landforms*, 16, p.12.

Zarn, B. (1997): Einfluss der Flussbettbreite auf die Wechselwirkung zwischen Abfluss, Morphologie und Geschiebetransportkapazität. *Mitteilung der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH*, 154, Zürich,
242 S.

Zimmermann, M. & C. Lehmann (1999): Geschiebefracht in Wildbächen: Grundlagen und Schätzverfahren. *Wasser energie luft*, 91(7/8), S. 189-194.

Zimmermann, M. (1989): Geschiebeaufkommen und Geschiebebewirtschaftung. Grundlagen zur Abschätzung des Geschiebehaushaltes im Emmental. *Geographica Bernensia, Geographisches Institut der Universität*, G34, Bern, 97 S.

Zurwerra, A. (1993): Wasserfassung und Entsander Grund. PRONAT AG, Winkelgasse 4, Brig. Im Auftrag: EBG AG PF 204, Brig, S. 14-18, S. 22-23 und S. 31.

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