Heavily Modified Waters in Europe

Case Study Danube

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PART I

3 Introduction

3.1 Choice of Case Study

The case study Danube (between Greifenstein and Vienna, see Figure 1) was chosen because of a combination of different uses. Beside navigation, flood protection, and urbanisation, hydropower generation is the main use in this river section. The focus of the case study is concentrating on two hydropower stations which have the main impact on the Danube river system in terms of channelisation and impoundment..

For the choice of this case study braided rivers with floodplain areas had been of special interest.

Another aspect for the choice of this part of the river Danube for this heavily modified case study was the fact that a variety of rehabilitation measures have been done showing improvements of the ecological conditions within this river section.

Several investigations have been performed in this area before and after the establishment of rehabilitation measures and therefore a large amount of information, for example surveys on macroinvertebrates and fish are available.

3.2 General Remarks

The Austrian section of the Danube is 350 km long (total course: 2850 km). Over the last 125 years the geomorphological properties of the river have been changed dramatically through regulation and damming. The first large scale regulation measures were undertaken in the second half of the 19th century in order to improve navigation and protect riverside residents from flooding (Schiemer & Waidbacher, 1992). Because of its approximately 0.04% average slope and high discharge, the Austrian part of the Danube has a high potential for hydroelectric power generation. Since the early 1950s, 10 hydroelectric power plants have been constructed (see Figure 2). The last of them, the Freudenau plant in Vienna, was completed in 1997 and forms the western boundary of one of the only two free-flowing sections of the Danube in Austria which has recently been designated as a National Park. The Austrian-Slovakian border is the eastern boundary of the Park.

The case study focus on the impounded Austrian Danube section between Greifenstein and Vienna. This river section has a length of about 50 km and is characterised by two hydropower stations, bank reinforcement and hydrologically isolated large floodplain areas.

The case study Danube is part of the **hydropower subgroup** of the heavily modified case study project.

This draft is the preliminary report of the heavily modified case study Danube and covers the chapters 3 – 7.1 of the terms of reference.

4 Description of Case Study Area

4.1 Geology, Topography and Hydrology

The Danube in Vienna is a 9th order stream (Wimmer & Moog, 1994) with a catchment area of about 102 000 km^2 (Chovanec et al., in press). The flow regime is dominated by high flows between May and July with a second flow peak in the winter months ("winter-nival" flow regime according to the flow regime typology of Mader et al. (1996). In 1995, low, medium and high discharges were 890 m^3/s, 2232 m^3/s and 6412 m^3/s. Before it was subjected to large-scale channelisation the Danube was a braided river. Gravel and sand depositions in the Vienna Basin encouraged the dynamic formation of side-arms and backwater systems. Since the 13th century this highly dynamic river has shown a tendency to change its course towards the north-east and, thus, to turn away from Vienna.

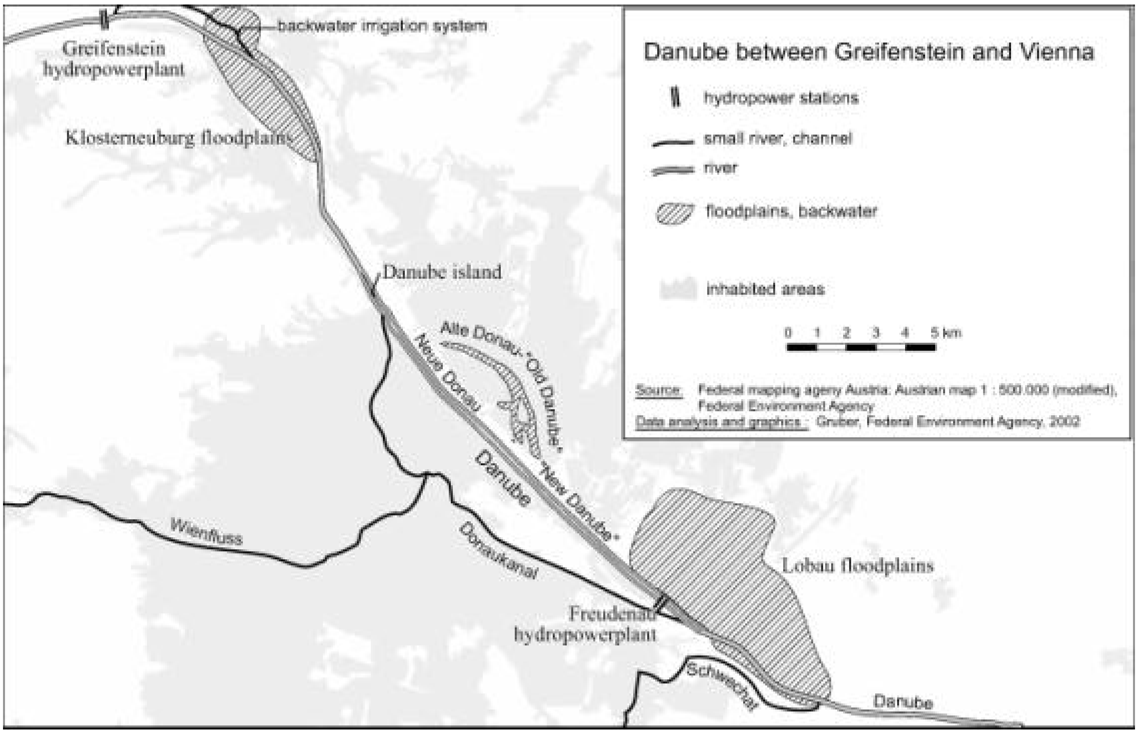

Figure 1 Study area (Danube between Greifenstein and Vienna) with its adjacent waterbodies.

4.2 Socio-Economic Geography and Human Activities in the Catchment

The population density in the catchment is about 148 persons per km². The river Danube runs through the city of Vienna with a population of about 2 million inhabitants.

The history of river regulation in the Vienna section of the Danube is closely related to urban development. The first regulation measures, aiming at increasing the navigability of the major Danube arms, date from the 17th century. In the second half of the 18th century embankments were constructed on a large scale. Catastrophic floods in 1830 and 1862 increased the call for improved control. Thus, between 1870 and 1875, a straightened channel of 13 km was constructed. The water of almost all the branches of the Danube were brought together in this new bed in order to improve the conditions for navigation in this area, to enhance flood control, to allow the construction of stable bridges, to relocate moorings closer to the centre of Vienna, and to establish industries, railway stations, military facilities etc. The cross-section of the channel was divided into two: the water bed with a width of about 300 m and the inundation plain with a width of about about 500 m

Increasing doubts about the effectiveness of this main channel and the embankments led to a plan to improve the flood protection of Vienna by constructing a bypass channel, the "New Danube" and a new embankment system (Figure 1) The excavation material was used to construct the "Danube Island", which separates the Danube from the New Danube. Work started in 1972 and was finished in the late 1980s. 200 m wide and about 21 km long (Danube stream km 1917-1937), the Danube Island has become a characteristic feature of the whole municipal area of Vienna. The construction of the New Danube has increased the flow profile of the river; at present, the Danube and New Danube have a flow capacity of 14000 m^3/s, 5200 of which can be led into the New Danube. The old flood protection system was only designed for 11700 m^3/s. Three weirs control the water level in the New Danube and steer its inflow in the case of flood events.

Although the Danube Island was planned and constructed as a technical structure, from the mid 1980s onwards design concepts began to adopt a more ecological approach. This is reflected in the decision to protect ecologically precious zones, such as a backwater fragment and to create and manage a network of aquatic habitats. Over the years the Danube Island has developed into a very popular recreational area. The central part of the island especially is intensively used by visitors due to its good accessibility and infrastructure (restaurants, bathing areas and other sport facilities, open air events). The northern and southern parts of the island are less developed and have remained in a semi-natural condition.

The construction of the Freudenau hydroelectric power plant has been the most recent impact on the Vienna section of the Danube. During its construction, the straight riverbanks of the Danube Island with their steep embankments were restructured to create shallow water areas, gravel banks, small side channels and temporary waters.

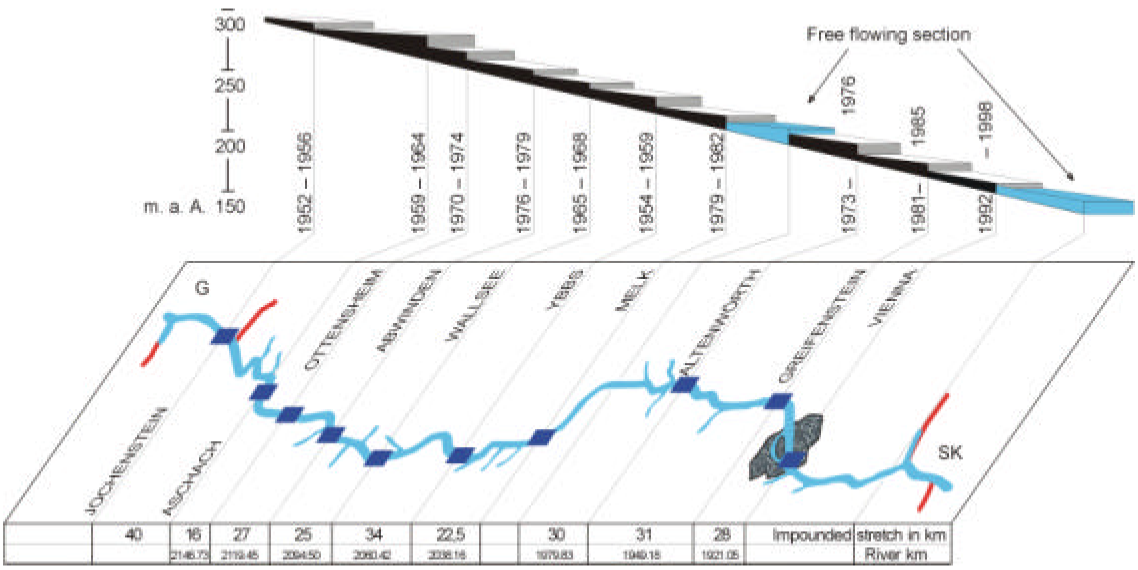

Figure 2 Overview of the Danube in Austria and the existing impoundments (from Fesl et al., 1999).

4.3 Identification of Water Bodies

The section of the river Danube between the 2 power stations Greifenstein and Freudenau has not been divided into different water bodies and is treated as one unit for this case study.

Classification of the water bodies was made according to system A and B, according Annex II of the WFD.

Table 1 Result of classification according to system A and B (See Water Framework Directive (WFD, Annex II, 1.2 "Ecoregions and Surface Water Body Types), European Commission, 2000).

Descriptors	**Classification**
Ecoregion	Alps, Central highlands
Altitude	200–500 lowland
Size typology	Large river
Geology	Flysch, sandstone

4.4 Discussion and Conclusions

The study area has not been divided into sub-water bodies. The hypothesis to classify the whole catchment as one water body is used, because in this case study the whole catchment is manly influenced by hydropower generation plants. The 50 km stretch of the river Danube was also treated as one water body for the ecological assessment.

PART II

5 Physical Alterations

5.1 Pressures and Uses

The main human impacts on the Danube river system in the case study area are caused by hydropower plants and flood protection and to some extend by navigation and urbanisation.

For the assessment of physical alterations the case study focused on hydropower as the most important use.

List of pressures and uses for the river Danube between Greifenstein and Vienna in order of importance

- Hydropower generation
- Flood protection
- Navigation
- Urbanisation

5.2 Physical Alterations

The following physical alterations can be identified as the dominant impacts in this river system:

- Change in river profile
- Disruption of the river continuum
- Interruption of bed load transport and disruption of the sand and silt transport
- Channelisation / longitudinal straightening
- Bank reinforcement
- Disruption of lateral connectivity due to dikes and river bed degradation
- Detached ox-bow lakes / wetlands
- Change in the flow regime
- Reduced flow in the river bed

5.3 Changes in the Hydromorphological Characteristics of the Water Bodies and Assessment of Resulting Impacts

The main effects of the hydromorphological changes can be summarized as follows:

- Reduced fluvial dynamics
- Reduced longitudinal and lateral connectivity
- Large deviation from a type-specific reference condition

5.4 Discussion and Conclusions

The major influences on the morphology of the river Danube are a chain of hydropower plants, alterations due to flood protection and to a less extent navigation and urbanisation. For this case study report mainly data for the assessment of hydropower use had been evaluated.

6 Ecological Status

6.1 Biological Quality Elements

Macroinvertebrates

Methods

The assessment of the macrozoobenthic coenosis of the Danube between Greifenstein and Vienna (hydropowerplant Freudenau) is based on studies of Bretschko & Schönbauer (1996), Moog (1996) and Schmidt-Kloiber et al. (1999). As these studies only describe the situation in the reach before damming, results of a comparable stretch of the Danube are used from studies at the next upstream impoundment, Altenwörth (Humpesch, 1996).

Results

The saprobic index of the reach between Greifenstein and Vienna (Freudenau) shows a value of II, which corresponds almost to the saprobic reference condition (Moog 1995) for this river type.

In unimpounded sections of the Danube, the composition of the macrozoobenthic coenosis (species level and higher taxa level) is very heterogeneous in a temporal and spatial scale (Humpesch, 1996; Fesl et al. 1999).

As a consequence of the impoundment Freudenau, following alterations can be expected for the Danube between Greifenstein and Vienna:

- The gradient in water velocity (from the uppermost part of the impoundment to the dam) leads to increased sedimentation towards the dam. The load of suspended particles decreases from the beginning of the backwater zone to the dam.
- Due to increase in sedimentation towards the dam, a significant decrease in the particle size (from dominating gravel to silt) of the riverbed is the result.
- Due to the reduced current velocity, increased water depth and accumulations of silty and muddy sediments, the impounded section of the river conforms to a habitat which supports a large biomass of a few benthic macroinvertebrate species.
- High organic and oxygen content of the silt create an excellent substratum for certain benthic macroinvertebrates, which occur in very high densities (up to 2 million individuals per m²). Studies at the impoundment Altenwörth show, that nearly all organisms (98%) in the impoundment section are Oligochaeta (Humpesch, 1996).
- Hence, on the upstream side of the dam the natural benthocoenosis of the hyporhithron/epipotamon has been replaced by a much more specialised biocoenosis that is typical for impounded areas.

Comparing the alterations cited above with the classification of the ecological status in the Water Frame Directive (European Commission 2000) the impoundment will have following consequences:

- A significant change in the composition and abundance of the invertebrate coenosis
- The loss of major taxonomic groups of the type-specific community
- The ratio of disturbance-sensitive taxa to insensitive taxa, and the level of low diversity, are substantially lower than the type-specific level and significantly lower than for good status

Summarizing all these facts, the ecological status for the reach between Greifenstein and Vienna (Freudenau) can be classified as moderate (3).

Dragonflies as bioindicators

Methods

The evaluation of the ecological integrity of river/floodplain systems is based on a comparison between the reference condition and the status quo of a given area. The degree of deviation from the former indicates the extent of human impacts. In accordance with different approaches for assessing the ecological integrity and the Water Framework Directive the following criteria are necessary for a dragonfly-oriented assessment procedure:

- Community structure
  - Number of species with self-sustaining populations (autochthonous species)
  - Odonate Habitat Index (OHI)
- Taxonomic composition
  - Abundances of autochthonous species
  - Number of sensitive autochthonous species

Sampling design, data collection in the field, determination of autochthony

Field collections should be performed in optimal weather conditions for dragonflies. In order to cover all phenological groups (from early spring species to late summer/autumn species) and to record the representative spectrum of Odonata species a minimum of 5 field sampling dates per year is recommended. Abundance estimates are ranked within a five class system: 1: single; 2: rare; 3: frequent; 4: abundant; 5: extremely abundant. When estimating abundances, species-specific habitat requirements and behaviour patterns including the sizes of territories have to be considered. Abundance class ranking is based on the field excursion with the largest number of individuals recorded.

Since the assessment approach emphasises breeding species with self-sustaining populations, the determination of autochthony is essential. Exuviae are the most important indicators of resident populations. For collecting exuviae the riparian vegetation, emerging parts of water plants, dead wood and abiotic riparian structures such as steep banks and gravel substrate should be surveyed thoroughly at each field sampling date.

The following criteria may also be used for checking the autochthony of species:

Records of

- newly hatched imagines
  They may be readily recognised by their shiny wings. Typically, this feature lasts only until the maiden flight initiates dispersal and should be a fairly accurate indicator of autochthony at a given site
  and / or
- larvae and / or
- reproduction behaviour (copula, tandem, egg deposition) or territorial behaviour
  Although waterbodies may act occasionally as “sinks” rather than “sources” for particular species, in most cases the observation of mating activities and oviposition indicates the successful larval development until emergence.

  and / or
- imagines in abundance class 3, 4 or 5 and / or
- imagines over a period > 1 month and / or
- the same species at several water bodies situated in the area.

The Odonate Habitat Index (OHI)

The method of calculation is based on existing macrozoobenthic analyses - i. e. the assessment of biological water quality expressed by a metric introduced by Pantle & Buck (1955) and modified by Zelinka & Marvan (1961) as well as the calculation of longitudinal stream zonation patterns and functional feeding groups - and has been specifically adapted to suit the requirements associated with dragonfly surveys. Only species with self-sustaining populations (autochthonous, breeding species) may be included in the calculation.

The parameters necessary for the calculation are

- species inventory
- species-specific habitat value
- indication weight
- abundance.

Valency point system

In order to describe the habitat preferences numerically, a 10-point system was used. According to specific habitat preferences, 10 valency points were distributed among five habitat types. For example, a species exclusively inhabitating temporary pools is given 10 valency points in the relevant category; for eurytopic species occurring in a wide range of stagnant waters of a floodplain system, the 10 points available will be more or less evenly distributed between different categories. This valency point distribution procedure has been developed on the basis of the authors’ recordings in the investigation area as well as at other sites, on autecological data and on expert consulting. Indication weights ranging from 1 for eurytopic species to 5 for stenotopic species (calculation according to Sladecek, 1964) have been allocated to each species in order to identify sensitive species (indication weight ≥ 3).

Habitat types

The assessment is based on the abundance of a set of dragonfly species appearing in river/floodplain systems within specific habitat types. These habitat types (H1 – H5) follow a gradient of lateral connectivity with the main river channel, ranging from H1 (Eu-/Parapotamon) to isolated floodplain waters (H5; Palaeopotamon; see also Amoros & Roux, 1988).

H1: Eupotamal permanent water bodies; the main river channel and its littoral areas and associated inshore structures; permanently connected side channels with high hydrological connectivity reflecting water level fluctuations of the main channel; no sedimentation processes; +/- lotic backwater sections downstream artificial openings of weirs; no macrophyte communities in the open water, open banks or *Phalaridetum* stands in the littoral area, riparian trees and shrubs; sand and gravel substrates are dominating.

H2: Littoral areas of parapotamal (e.g. dead arms retaining a connection to the main channel) or plesiopotamal (e.g. former braided segments that became disconnected from the main channel) standing and permanent backwaters; littoral areas of large gravel pits in the floodplain area; (significantly) reduced hydrological connectivity and dynamics; open banks; only few macrophytes (e.g. *Phalaridetum*); riparian trees and shrubs; high proportion of sand and gravel substrates.

H3: Open water areas of plesio- and palaeopotamal permanent standing waters and gravel pits, typically with floating macrophytes; significantly reduced hydrological connectivity and dynamics; high degree of sedimentation; dominating macrophyte associations: *Myriophyllo-Nupharetum*.

H4: Littoral areas of plesio- and palaeopotamal permanent standing waters and gravel pits with reed belts; significantly reduced hydrological connectivity and dynamics; sedimentation high; dominating macrophyte associations: *Phragmitetum, Typhetum, Sagittario-Sparganietum*; sludgy sediments dominate.

H5: Temporary pools; hydrological connectivity and dynamics significantly reduced; sedimentation high; at least one dried-up period per year (mostly summer-autumn); dominating macrophyte associations*: Phragmitetum, Typhetum, Sagittario-Sparganietum, Magnocaricetum*; terrestrial vegetation.

As this classification refers to potential dragonfly habitats and not to whole water bodies, several types may occur at one water body: e.g. littoral and open water areas of a disconnected backwater may be classified as H2, H3, and H4.

Individual species-specific habitat values (HV) are calculated by the following equation:

$$HV = \frac{(1\times H1 + 2\times H2 + 3\times H3 + 4\times H4 + 5\times H5)}{10}$$

with HV-values ranging from 1 to 5 (rheotopic species: HV = 1; species preferring temporary waters: HV = 5).

Table 2 summarises as example dragonfly species, the habitat valencies, habitat values, and indication weights of two different species.

Table 2 The habitat valencies, habitat values (HV) and indication weights (IW) of two different species; H1-5: habitat types as defined above.

	H1	H2	H3	H4	H5	HV	IW
Zygoptera							
Calopterygidae							
Calopteryx splendens (HARRIS, 1782)	9	1				1.1	5
Anisoptera							
Libellulidae							
Sympetrum vulgatum (LINNAEUS, 1758)		2	1	5	2	3.7	1

Method of calculation

The index is based on the summation of the habitat values, abundances and indication weights of all species present at the sampling site and is calculated using the following equation:

$$OHI = \frac{\sum HV \times A \times IW}{\sum A \times IW}$$

where

HV is the habitat value,

A is the estimated abundance (classes 1 - 5) and

IW is the species-specific indication weight.

This results in a number between 1 and 5, indicating habitat preferences of the dragonfly community breeding at the investigation site.

Selection of sampling sites

Before actual field work starts field excursions have to be carried out in order to select representative sampling sites reflecting the proportion of different habitat types present in the study area. A quantification of the habitat types can be made e. g. by measuring shoreline lengths per habitat type by using official maps (a scale of 1:50 000 is recommended). Sampling sites representing different habitat types may be situated at the same water body (e. g. both H2 and H3 often occur at large backwaters). To maintain a high degree of comparability, the sampling sites should be of the same size. With larger water bodies it is recommended to select stretches of 100 m shoreline length; smaller ones should be investigated in total.

The most likely distribution of the OHIs in a reference river/floodplain system is based on the estimation of habitat types and reference communities. Generally, in ecologically intact systems OHIs range between 1 and 5 and cover all habitat types due to an intact continuum along the gradient of lateral connectivity.

By comparing the status quo of a river/floodplain system with reference conditions, deviations caused by disturbances become visible and have to be classified in five classes. Most importantly, the definition of reference criteria – such as abiotic habitat criteria and potentially occurring species - must take into account the specific characteristics of each river type. This is why criteria for this dragonfly-based approach are given on a general level only, leaving room for adaptations in specific case studies (Table 3, Chovanec & Waringer, 2001).

Table 3 Classification scheme for the dragonfly-based assessment of river/floodplain systems (according Annex V of the Water Framework Directive).

Criteria	Ecological status				
	I / high	II / good	III / moderate	IV / poor	V/ bad
General description	Dragonfly community (nearly) totally corresponds to the type-specific reference condition; ecological integrity (nearly) undisturbed	Dragonfly community slightly deviates from the type-specific reference condition; ecological integrity slightly disturbed	Dragonfly community significantly deviates from the type-specific reference condition; ecological integrity significantly disturbed	Only remnants of the type-specific dragonfly community; ecological integrity heavily disturbed	Few if any species are present that correspond to the type-specific reference community; ecological integrity completely disrupted
Autochthonous species	Species of all or nearly all families of the reference community occur; total number of species is high	Species of all or nearly all families occur; number of species is slightly reduced	Few or some families are missing; some or many expected species are missing	Few or some families are missing; many expected species are missing	Some families are missing; most of the expected species are missing
OHI	OHI range high (> 1.5); all habitat types +/- equally represented or H1 dominating; mean OHI ≤2.5	OHI range high (> 1.5); 4 or 5 habitat types are present, at least H1 has to be found, but is not dominating; mean OHI ≤3.5	OHIs indicate that 1 or more habitat types are missing, range of OHIs < 1.5	OHIs indicate that more than 1 habitat types are missing, range of OHIs < 1.5	OHIs indicate that more than 1 habitat types are missing, range of OHIs < 1.5
Sensitive autochthonous species	Species number high, proportion of sensitive species	Number of sensitive species high or slightly	Number of sensitive species slightly or significantly reduced	Only few sensitive species	No sensitive species

	corresponds to that in the reference community or is slightly reduced	reduced

The investigation areas

Study area 1: Klosterneuburg floodplains

The Klosterneuburg floodplains (area 650 ha) are situated about 10 km upstream of Vienna on the right bank of the Danube. Water level fluctuations are mostly restricted to groundwater exchange. Hydrological surface water connectivity is maintained by a backwater channel running through the whole area. Other inflow channels are activated at a Danube discharge > 4500 m3/s. The spectrum of water bodies is dominated by temporary and permanent pools and ponds as well as backwater lakes and gravel pits. The assessment of this area is based on a survey made by Chovanec (1999) and current investigations at 13 sampling sites.

Study area 2: Lobau floodplains

The mapped area (size 525 ha) is situated in the municipal area of Vienna on the left bank of the Danube and is part of the “Danube Alluvial National Park”. Regulation measures at the Danube between 1870 and 1875 led to the cutting off of former side arms of the Danube, which have been subject to a high degree of terrestrialisation. Thus, hydrologically connected backwater systems have been transformed to standing water bodies. In addition to these permanent waters the study area is characterised by numerous bomb craters dating back to Allied bomb raids of the nearby oil refinery during the Second World War. Most of these craters are temporarily filled with groundwater. Assessment is based on investigations of Chwala & Waringer (1996) carried out at 10 sites.

Study area 3: Man-made inshore structures at the Freudenau impoundment (Vienna)

In the municipal area of Vienna the structure of the Danube channel itself has been strongly affected by river regulation and damming. Apart from the embankments, a bypass channel (the ”New Danube”), separated from the main river by an artificial island (”Danube Island”), is the key element of flood control. During the construction of the hydroelectric power plant, the previously straight shoreline of the 21 km long Danube island with its steep embankments was restructured by creating shallow water areas, gravel banks, small permanent backwaters and temporary waters. In 1998 a four-year monitoring project was launched in order to evaluate the efficiency of these newly created habitats by recording species characteristic of riparian areas and river/floodplain systems. In addition, the investigations are to elucidate whether these man-made structures, combined with existing wetland areas, serve as stepping stone biotopes and migration linkages on the Danube Island itself and whether they improve the corridor function of the Danube island between the disconnected floodplain areas in the north-west (Klosterneuburg) and south-east of Vienna ("Danube Alluvial National Park"). Dragonfly data (Chovanec et al., 2000; Chovanec & Raab, 2001; Raab, 2001) were collected at 13 sites.

Study area 4: Alte Donau ("Old Danube")

The Old Danube was one of the major arms of the braided Danube in the 19th century. Due to the river regulation and straightening carried out between 1870 and 1875 the arm was cut off from the channel and became a large stagnant backwater situated in the municipal area of Vienna (size 1.65 km2). The assessment was carried out by Chovanec (2002) on the basis of investigations at 9 sites.

Defining reference conditions

A target list of different species is given by Chovanec & Waringer (2001). A comparison of the current status with historical maps shows a clear reduction of aquatic areas and a shift of dominating habitat types from former parapotamal systems to plesio- and palaeopotamal backwaters.

From this it can be inferred that rheophilic species of the families Calopterygidae, Gomphidae and – probably – Cordulegasteridae played an important role in the dragonfly community. In addition, it can be extrapolated that due to hydrological dynamics habitat patches poor in vegetation and characterised by sand and gravel substrate also favoured the occurrence of species preferring habitat type H2. It can be assumed that all habitat types were represented, but stagnant water bodies subject to high sedimentation probably covered smaller areas. OHIs are likely to have ranged from 1 to 5 indicating that all habitat types were present. The mean OHI calculated on the basis of all species listed in Table 2 is 2.95, assuming abundances of 3. Due to the dominance of dynamic parapotamal water areas the mean OHI is considered to be < 2.5 (Table 4; Chovanec & Waringer, 2001).

Results and discussion

The assessment of the ecological status of the different sites as well as the characterisation of the reference situation is summarised in Table 4.

Table 4 Classification of the investigation sites and of the reference situation.

Criteria	Klosterneuburg	Lobau	Alte Donau	Danube Island	Reference
Autochthonous species (n)	32	29	17	39	59
Families (n)	8	6	6	7	9
OHI – mean	3.02	3.36	2.81	3.07	<2.5
OHI – range	1.31 - 3.49	3.19 - 3.80	2.49 - 3.05	1.10 - 3.96	1 - 5
Sensitive	15	13	5	20	37

autochthonous species (n)					
Ecological status	2	3	3	2	1

Fish fauna

Methods

Assessment method

In principle, the assessment method used follows the procedure proposed by Schmutz et al. (2000) using 7 biological criteria according to the normative classification of the ecological status as described by the WFD. Quantifications of population size is difficult in large river systems due to methodological limitations. However, in species-rich communities as the Danube the assessment based on criteria 1-5 are sufficient to guarantee sound classification of the ecological status.

Table 5 Criteria and verbal definition of 5 levels of ecological integrity (Schmutz et al., 2000)

Criteria	Ecological integrity levels				
	1 high	2 good	3 moderate	4 poor	5 bad
(1) Type-specific species	none or nearly none missing	some species missing	several species missing	many species missing	most species missing
(2) Self-sustaining species	none or some missing	several species missing	many species missing	most species missing	nearly all species missing
(3) Fish region	no shift	no shift	shift	shift	shift
(4) Number of guilds	no guild missing	no guild missing	single guilds missing	many guilds missing	most guilds missing
(5) Guild composition	no alteration	slight alteration	substantial alteration	complete alteration	complete alteration
(6) Biomass and density	no or nearly no changes	slight changes	substantial changes	heavy changes	extremely changed
(7) Population age structure	no or nearly no changes	slight changes	substantial changes	heavy changes	extremely changed

Biological sampling

The assessment of the Danube/Gießgang-system is based on two data sets. One data set has been compiled during a recent study of the Gießgang Greifenstein (Kummer et al., 1999). As there are no data available from the impoundment Greifenstein, results from a study at the next upstream impoundment, Altenwörth, are used (Waidbacher 1989). Although the Altenwörth impoundment is similar in its physical characteristics, it is influenced by the upstream located, last free flowing section of the Danube in this area. The classification of habitat requirements follows the guild system of Schiemer & Waidbacher (1992).

In the impoundment Altenwörth fish were sampled using electrofishing, long lines and seining over a period of 3 years covering summer, autumn and winter conditions.

In the Gießgang 584 representative samples were taken using electrofishing, gill nets, seining, long lines, and fyke traps resulting in a total catch of 35672 individuals. The following habitat types were distinguished: impoundments of the Gießgang (upper, middle and lower part) and oxbows (permanently connected, temporarily connected, disconnected).

Results

Reference conditions

The historic situation of the Danube according to the species composition is well documented (e.g. Jungwirth, 1984). The historic fauna comprised about 55 river-type-specific fish species, dominated by rheophilic species. The most common species were *Chondrostoma nasus* and *Barbus barbus,* characteristic species of the barbel region. Beside the rheophilic guild (29 rheophilic_A, 3 rheophilic_B species) eurytopic (n=16) and stagnophilic (n=7) contributed to the species-rich fauna. Two anadromous species (long distance migrants), *Acipenser stellatus* and *Huso huso* together with two other Acipenseridae (*Acipenser güldenstädti, Acipenser nudiventris*) are already extinct.

Present conditions

Table 6 summarises the results of the studies in the impoundment Altenwörth and in the Gießgang Greifenstein. In the impoundment 32 species (+ 2 exotic species) were found. The fauna is dominated by eurytopic species (n=14) such as *Rutilus rutilus, Leuciscus idus, Aspius aspius*. Rheophilic A (n=13), rheophilic B (n=2) and stagnophilic species (n=3) were found in low numbers. For only 16 species 0+ fish were recorded. Again, 0+ fish are mainly eurytopic (n=9), reproduction of stagnophilic species could not be proven.

The present fish fauna in the Gießgang comprises 43 type specific and 5 exotic species, 7 type-specific species have very low densities. The fish coenoses are dominated by eurytopic species throughout the system (57 – 75 %). The guild composition in the sequence of impoundments is characterised by 6-18 % rheophilic A, 4-7 % rheophilic B and about 15 % stagnophilic species. In permanently connected oxbows 14 to 17 species are found and stagnophilic species account for 30 % of the fauna. In temporarily connected oxbows the fauna decreases to 6 to 8 species and is dominated by eurytopic species followed by stagnophilic species. Disconnected water bodies inhabit 3 to 10 species, dominated by stagnophilic species. For 28 species successful reproduction was proved by evidence of 0+ fish (fish from the first year). Out of that 4 species showed very low 0+ proportions.

Combining the data of the impoundment and the Gießgang results in a total number of 44 species. The fauna is composed of 20 rheophil A, 3 rheophil B, 15 eurytopic and 6 stagnophilic species. Based on species with 0+ records the species composition is reduced to 13 rheophil A, 1 rheophil B, 12 eurytopic and 6 stagnophilic species totalling in 32 species. Both long distance migrants are extinct, only 7 medium distance migrants are found, others (37 species) are short distance migrants.

Fish ecological status

The fish ecological status of the impounded Danube at Greifenstein (including the Gießgang system) is characterised by a still comparable high species diversity. In spite of the damming and regulation about 80 % of the historic species remained. Therefore from the perspective of "number of type-specific species" (criterion 1) the Danube still remains in a "good status" (2).

Considering "self sustaining species" only - species with minimum population size and sufficient reproduction - the diversity drops to 58 % of the historic fauna resulting in a classification of this criterion as moderate status" (3).

According to the criterion "fish region" the shift from the former dominance of Chondrostoma nasus and Barbus barbus to *Rutilus rutilus, Abramis brama, Abramis boerkna, Leuciscus idus, Aspius aspius* results in a evident "potamalisation" toward metapotamal. Hence, this criterion is also classified as moderate (3).

Rheophilic species show the most dramatic change due to impoundment. About 60 % of the former rheophilic A species and all of the three rheophilic B species are heavily affected and do not reproduce sufficiently. Even about 40 % of the stagnophilic species are lacking adequate reproductive success. The least impact is documented with eurytopic species; about 75 % show effective reproduction. In addition long distance migrants are extinct, and medium distance migrants are reduced by about 40 %. Due to the loss of ecological guilds typical for the Danube criterion "number of guilds" is classified as "fair status" (respectively "moderate") (3). The strong shift from the former dominance of rheophilic to eurytopic species results in a classification of the criterion "guild composition" as "poor status" (4).

Based on the data used for this analysis the impounded Danube at Greifenstein is classified as "fair status" (respectively "moderate") (Index 3.0) as a consequence of the hydromorphological habitat alterations.

Table 6 Combined species list of the Altenwörth impoundment (Waidbacher, 1989) and Gießgang Greifeinstein (Kummer et al., 1999) (S…..single individuals)

Family	Taxa	historic	impoundment			Gießgang			total		
			adult	0+	total	adult	0+	total	adult	0+	total
Acipenseridae	Acipenser güldenstädti	x									
	Acipenser nudiventris	x									
	Acipenser ruthenus	x									
	Acipenser stellatus	x									
	Huso huso	x									
Salmonidae	Hucho hucho	x									
	Salmo trutta	x	x		x				x		x
Thymallidae	Thymallus thymallus	x									
Esocidae	Esox lucius	x	x	x	x	x	x	x	x	x	x
Umbridae	Umbra krameri	x									
Cyprinidae	Abramis ballerus	x	x		x	x	S	x	x	x	x
	Abramis bjoerkna	x	x	x	x	x	x	x	x	x	x
	Abramis brama	x	x	x	x	x	x	x	x	x	x
	Abramis sapa	x	x	x	x	x		x	x	x	x
	Alburnoides bipunctatus	x					S	x		x	x
	Alburnus alburnus	x	x	x	x	x	x	x	x	x	x
	Aspius aspius	x	x	x	x	x	x	x	x	x	x
	Barbus barbus	x	x		x	x	x	x	x	x	x
	Barbus peloponnesius	x									
	Carassius carassius	x	x		x	x	x	x	x	x	x
	Chondrostoma nasus	x	x		x	x	x	x	x	x	x
	Cyprinus carpio	x	x		x	x		x	x		x
	Gobio albipinnatus	x				x	x	x	x	x	x
	Gobio gobio	x	x	x	x	x	x	x	x	x	x
	Gobio kessleri	x									
	Gobio uranoscopus	x				S		x	x		x
	Leucaspius delineatus	x				S	S	x	x	x	x
	Leuciscus cephalus	x	x		x	x	x	x	x	x	x
	Leuciscus idus	x	x	x	x	x	x	x	x	x	x
	Leuciscus leuciscus	x	x		x	x	x	x	x	x	x
	Leuciscus souffia agassizi	x				S		x	x		x
	Pelecus cultratus	x	x		x	x		x	x		x
	Phoxinus phoxinus	x									
	Rhodeus sericeus amarus	x				x	x	x	x	x	x
	Rutilus frisii meidingeri	x	x		x				x		x
	Rutilus pigus virgo	x	x		x	x		x	x		x
	Rutilus rutilus	x	x	x	x	x	x	x	x	x	x
	Scardinius erythrophthalmus	x	x		x	x	x	x	x	x	x
	Tinca tinca	x	x		x	x	x	x	x	x	x
	Vimba vimba	x	x	x	x	S		x	x	x	x
Balitoridae	Barbatula barbatula	x				S		x	x		x
Cobitidae	Cobitis taenia	x				x	x	x	x	x	x
	Misgurnus fossilis	x				x	S	x	x	x	x
Siluridae	Silurus glanis	x	x		x	x	x	x	x	x	x
Gadidae	Lota lota	x	x		x	x	x	x	x	x	x
Percidae	Gymnocephalus baloni	x				x		x	x		x
	Gymnocephalus cernuus	x	x	x	x	x		x	x	x	x
	Gymnocephalus schraetser	x	x	x	x	x		x	x	x	x
	Perca fluviatilis	x	x	x	x	x	x	x	x	x	x
	Sander lucioperca	x	x	x	x	x	x	x	x	x	x
	Sander volgensis	x				S		x	x		x

Family	Taxa	historic	impoundment adult	impoundment 0+	impoundment total	Gießgang adult	Gießgang 0+	Gießgang total	total adult	total 0+	total total
	Zingel streber	x				x		x	x		x
	Zingel zingel	x	x		x	x		x	x		x
Cottidae	Cottus gobio	x	x	x	x	x		x	x	x	x
Gobiidae	Proterorhinus marmoratus	x	x	x	x	x	x	x	x	x	x
		55	32	16	32	41	27	42	43	32	44

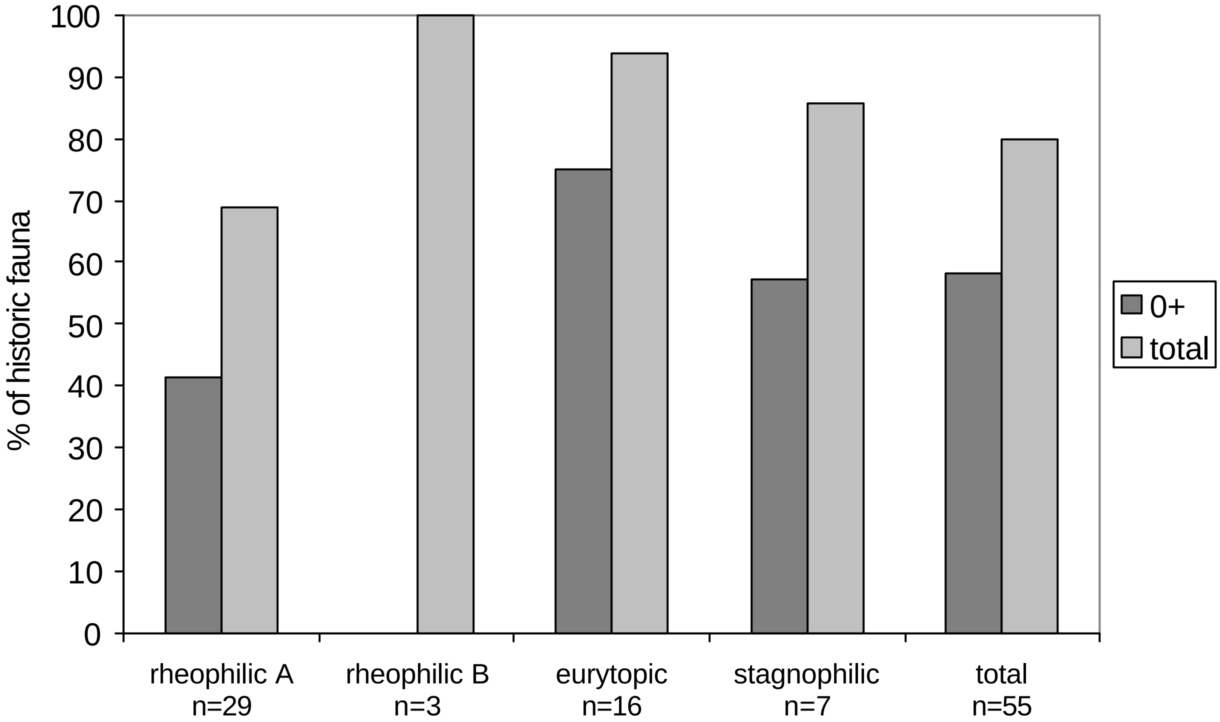

Figure 3 Present habitat guild composition of 0+ fishes and in total as percentage of number of historic species (combined data from Altenwörth impoundment (Waidbacher, 1989) and Gießgang Greifenstein (Kummer et al., 1999))

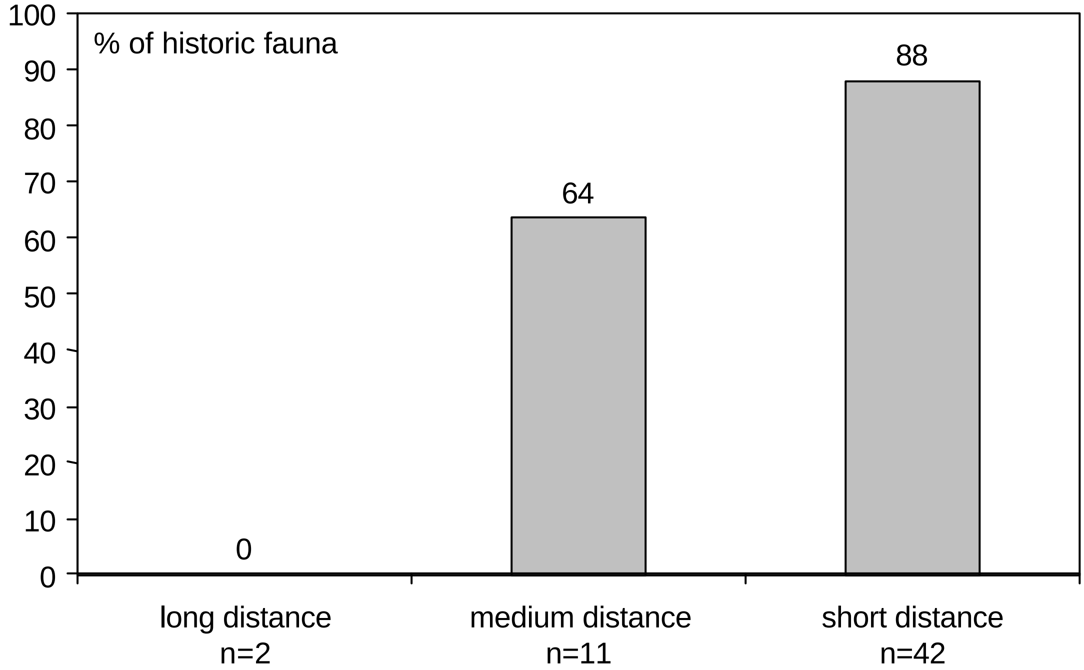

Figure 4 Present migratory guild composition as percentage of number of historic species (combined data from Altenwörth impoundment (Waidbacher, 1989) and Gießgang Greifenstein (Kummer et al., 1999))

6.2 Physico-Chemical Elements

A detailed information on the physico-chemical characterisation of the Danube is provided by the national water quality monitoring system (WWK/UBA 2000).

6.3 Definition of Current Ecological Status

The definition of the ecological status for the Danube between Greifenstein and Vienna was made by using the worst case from the classification with macroinvertebrates, dragonflies and fishes.

Defining reference conditions and assessment of the ecological status

Modern biological assessment procedures are oriented towards comparisons between the natural or near-natural characteristics of a type-specific community and the actual situation. The most obvious approach towards defining reference conditions is using data of reference sites along the same river. If there are no adequate reference sites at the river system investigated (e.g. due to large-scale regulation), it is possible to select reference sites in other river/floodplain systems situated in the same ecoregion.

River/floodplain systems belong to the most endangered aquatic systems and in many regions there are no relevant near-pristine areas left. In this case a reference community has to be defined by considering the following aspects:

- Historical abiotic data: old maps and reports as well as old paintings may provide useful information on undisturbed river/floodplain conditions, particularly with regard to the reconstruction of main habitat types and their hydrological dynamics. This information has to be related to habitat requirements and zoogeographical distribution patterns of species expected in the area.

- Historical faunistic data: data on dragonflies may be derived from literature or from collections in museums.

In order to define the “natural“ or “near-natural” conditions of a particular river stretch, the situation either known to have existed or assumed to have existed prior to first large-scale channel regulations and industrialisation (approximately middle of the19th century) is taken into account.

Table 7 Summary of the classifications for the Danube-reach between Greifenstein and Vienna

	Macroinvertebrates (+ saprobic quality index)	Odonata	Fishes	**Ecological status of the stretch**
Ecological Assessment	3	3	3	**3 - moderate**

6.4 Discussion and Conclusions

The assessment of the ecological status quo is discussed in terms of two indicator groups, macroinvertebrates and fish, which are considered to be the most relevant groups for the assessment of hydropower generation impacts.

The assessment for each indicator group was performed by using a type-specific approach.

Dragonflies are used in this case study as reliable indicators mainly for the assessment of the ecological status of the Danube river system in respect to the lateral connectivity.

The ecological status of the Danube is characterized by a moderate ecological condition.

7 Identification and Designation of Water Bodies as Heavily Modified

The case study area of the river Danube, impacted mainly by hydropower use, shows a variety of physical alterations and changes in the hydromorphological characteristics of the river.

The ecological status for this water body is classified as moderate (3).

This section of the river could be provisionally identified as heavily modified due to the physical alterations, hydromorphological changes and the moderate ecological status.

[Refer to HMW paper 7 ver 2].

7.1 Necessary Hydromorphological Changes to Achieve Good Ecological Status

Based on the assessment of the ecological status of impounded Danube river sections the following biotic deficits can be identified:

- lack of reproduction, in particular rheophilic species
- decrease of migratory species, in particular, long- and medium-distance migrants
- shift in species composition from rheophilic and stagnophilic to eurytopic species

Based on the impacts documented and deficits shown the following hydromorphological improvements would be (theoretically) necessary for achieving good ecological status:

- re-establishment of free flowing, dynamic river sections by
    - removal of dams, or
    - lowering the water level in the impoundment resulting in a free flowing section in half of the impoundment, or
    - dividing the Danube in two arms with 50 % flow allocation, one branch still used as impoundment and the other reconstructed according natural conditions
- re-establishment of dynamic floodplains along the newly created free lowing section
- re-establishment of longitudinal and lateral connectivity
    - hydrological connectivity between free flowing sections and flood plains
    - construction of fish pass facilities for upstream and downstream passage

These changes would have the following effects on the specified "Uses":

Due to urbanisation of the former braided Danube in Vienna the re-creation of dynamic floodplains is not possible any more. Suggested measures would be theoretically feasible for the Greifenstein impoundment but would cause

- significant reduction of hydropower generation (50 % loss),
- transfer from forest and agricultural land to flood plains of lower economic value
- increased maintenance work for navigation channel

In conclusion, a considerable amount of money is necessary for implementing defined measures and it is questionable if current users are able to contribute to the restoration or are even able to cope with necessary restrictions or cessation of use.

7.2 Assessment of Other Environmental Options

As hydroelectric power is an comparable environmental friendly, renewable energy source no other environmental options are considered.

7.3 Designation of Heavily Modified Water Bodies

As defined measures necessary to achieve good ecological status are disproportionately costly the impounded section of the Danube (power plant Greifenstein) is designated as heavily modified water body.

8 Definition of Maximum Ecological Potential (6 pages)

Due to the lack of a water bodies comparable with the impounded Danube (see chapter 8.3), in principle, the maximum ecological potential (MEP) is orientated on the original functioning of natural river/floodplain system. Measures defined strive to achieve original elements at least in some parts of the former system. The definition of maximum ecological potential is based on state-of-the-art concepts and technologies keeping in mind that regular adaptations may be required depending on current developments. According to state-of-the-art knowledge main focus is given to the reestablishment of hydrological dynamics and connectivity of river/floodplain system (Jungwirth 1998, Jungwirth et al. 2000, Schmutz & Jungwirth 1999).

8.1 Determining Maximum Ecological Potential

8.2 Measures for Achieve MEP

In the following chapter measures are described that would theoretically have to be undertaken in order to achieve maximum ecological potential. The appropriate level of mitigation has been defined by expert judgement based on experiences of a variety of restoration activities in Austrian lowland rivers and at the Danube (Kummer et al., 1999, Waidbacher 1999, Jungwirth et al. 2002,):

- 1/3 lowering of water level in the impoundment in order to create a free flowing section in the upper most part of the impoundment
- restructuring newly created free flowing section
- creating dynamic floodplains along the re-established free flowing section including flow allocation
- reconstructing the mouth of the Gießgang into the Danube
- re-establishment of longitudinal and lateral connectivity
    - hydrological connectivity between free flowing sections and flood plains (water bodies).
    - construction of fish pass facilities for upstream and downstream passage: new fish passes at Greifenstein and Donaukanal, improvement of Freudenau fish pass.
    - re-connecting tributaries and re-establishing migratory continuum within the tributaries (Traisen, Kamp, Mühlkamp, Krems)
    - providing free fish passage through the Gießgang and
- structuring the river bottom and banks along the impoundment compatible with navigation

8.3 Comparison with Comparable Water Body

In principle the impounded Danube represents an artificial water body not comparable with any other natural water type. It has lost most of its main fluvial characteristics but has only partly received elements of a stagnant water body. For example low flow velocities prevail in the impoundments for most of the time, however are replaced by high velocities during floods. Hence, the impounded Danube can be perceived as a water body switching between semi-lotic and early successional lentic conditions several times a year. As a consequence neither a typical riverine nor lacustrine fauna can develop. Therefore species with unspecific habitat requirements prevail.

8.4 Discussion and Conclusions

[Discuss lessons learned, any problems encountered and how they were overcome.]

9 Definition of Good Ecological Potential (6 pages)

9.1 Determination of Good Ecological Potential

The determination of good ecological potential to be achieved in the medium and long term is orientated by the MEP however is influenced by the practicability of the mitigation measures. The technical and economical feasibility of mitigation measures defined below is approved by a number of implemented or intended restoration programmes. Hence, the mitigation programme is based on state-of-the-art technologies.

9.2 Identification of Measures for Protecting and Enhancing the Ecological Quality

[In this chapter, please describe the options for measures designed to protect and if necessary enhance the ecological quality of the water body. WFD Article 11 requires the establishment of a programme of measures, distinguishing between basic and supplementary measures.]

9.2.1 Basic Measures

In the following chapter principle measures are described that would have to be undertaken in order to achieve good ecological potential. The appropriate level of mitigation has been defined on expert judgement based on experiences of a variety of restoration activities:

Greifenstein:

- creating dynamic floodplains along the upper most, free flowing section of the impoundment (Figure 5)
- reconstructing the mouth of the Gießgang into the Danube (Figure 6)
- re-establishment of longitudinal and lateral connectivity
    - hydrological connectivity between free flowing sections and flood plains including permanent flow allocation and large-scale inundation during flood
    - construction of fish pass facilities for upstream and downstream passage: new fish pass at Greifenstein.
    - re-connecting tributaries (Traisen, Kamp, Mühlkamp, Krems)
    - providing free fish passage through the Gießgang and
- structuring the river bottom and banks along the impoundment compatible with navigation

Freudenau:

Good ecological potential has widely been achieved due to

- creation of dynamic gravel bars and sand habitats in the upper most part of the impoundment
- connections to riparian floodplains and lateral water bodies
- structuring of the impoundment with riparian side arms and bays
- establishment of a fish bypass channel at the weir

For more details concerning implemented mitigation measures at the Freudenau dam see Waidbacher (1999).

Further mitigation measures should focus on structuring the river bottom in the impoundment and improved downstream fish passage at the dam.

9.3 Discussion and Conclusions

Using aquatic indicators such as fish and macroinvertebrates enabled to define heavily modified water bodies in the Danube case study. However, as identified ecological deficits and thereof derived restoration measures relate to floodplain vegetation to a considerable extend, floristic indicators such as floodplain forest should be included in future assessment methodologies.

[Discuss lessons learned, any problems encountered and how they were overcome.]

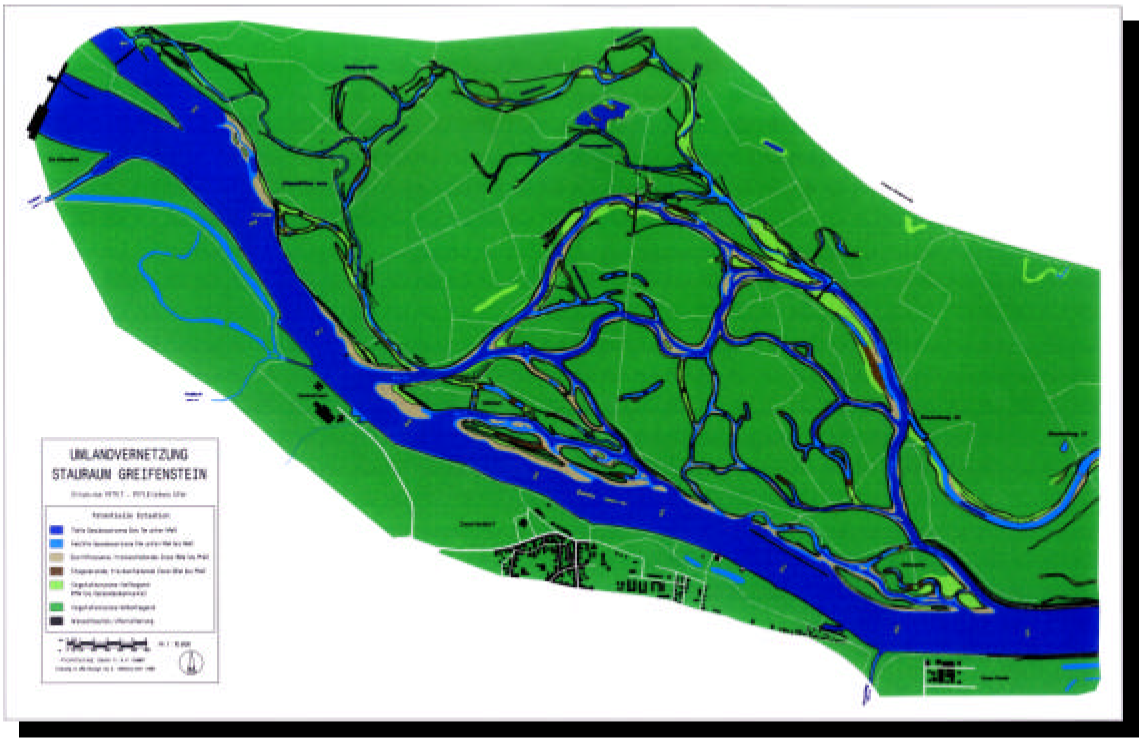

Figure 5 Example for creating dynamic floodplains along the upper most, free flowing section of the Greifenstein impoundment (Zauner & Kummer, 1999).

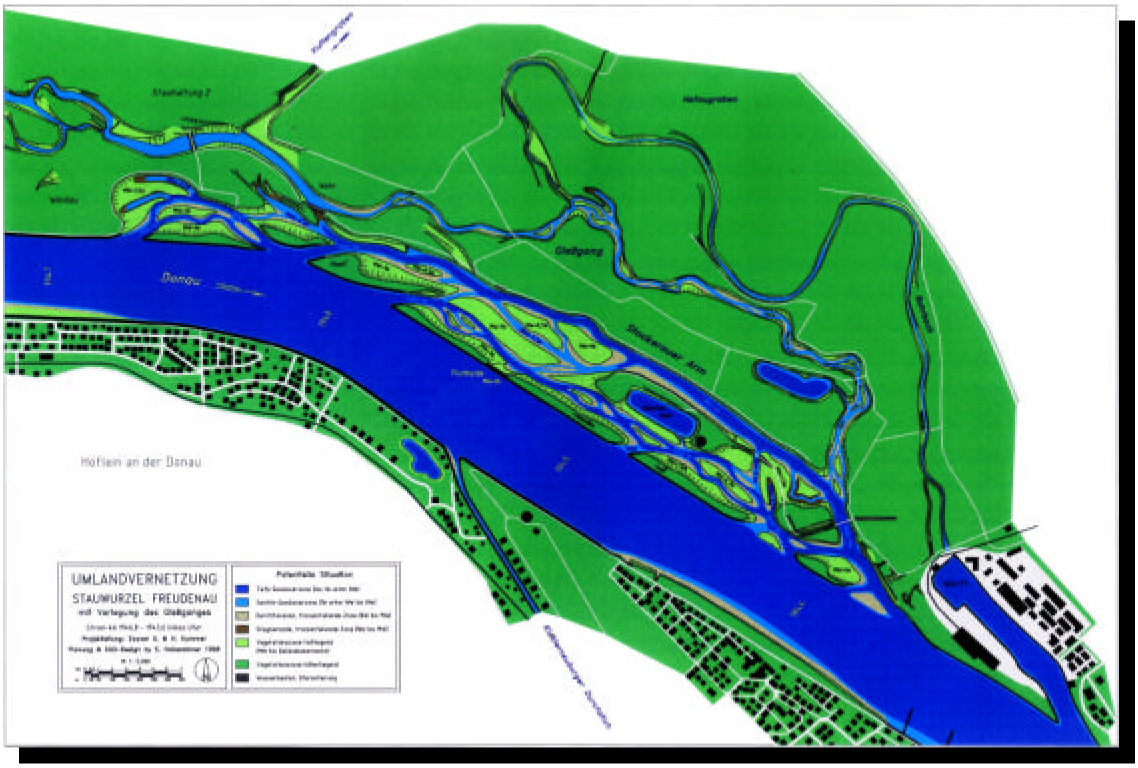

Figure 6 **Example for reconstructing the mouth of the Gießgang into the Danube (Zauner & Kummer, 1999).**

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12 List of Annexes

For further information on the methods of the fish assessment see *"schmutzetal2000.pdf*".