Revised Terms of Reference [28/11/2000]

Heavily Modified Waters in Europe
Case Study on the River Lahn

- Draft -

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PART I

1 Preface (1 page)

Within the scope of the European project "Identification and Designation of Heavily Modified Water Bodies under the Water Framework Directive" 25 case studies in eleven member states are realised. The aim is the development of assessment criterias for the designation of heavily modified water bodies in contrast to natural surface waters.

As the normative definitions of „heavily modified waters“ in the Water Framework Directive are widely interpretable, and the quality requirements for „heavily modified waters“ are minor compared to natural surface waters, the project is dealing with the determination of uniform quality levels to be implemented in Europe. Thus, the approach includes the assessment of the ecological situation and the specification of quality targets ("high status" for natural waters respective "maximum ecological potential" for heavily modified waters). To identify measures; to improve the ecological situation and finally to achieve the given quality target the Germany group examines scenarios in the river basins Elbe, Lahn, Seefelder Aach and Dhünn.

2 Summary Table (2 pages)

	Item	Unit	Information
1.	Country	text	Germany
2.	Name of the case study (name of water body)	text	Lahn River
3.	Steering Committee member(s) responsible for the case study	text	Dr. Ulrich Irmer, Dr. Bettina Rechenberg German Federal Environmental Agency (UBA)
4.	Institution funding the case study	text	German Federal Environmental Agency (UBA)
5.	Institution carrying out the case study	text	Institute of Water Resources Research and Management, University Kassel
6.	Start of the work on the case study	Date	01.05.2000
7.	Description of pressures & impacts expected by	Date	30.10.2000
8.	Estimated date for final results	Date	30.04.2002
9.	Type of Water (river, lake, AWB, freshwater)	text	River
10.	Catchment area	km^2	5.309 (gauging station Limburg-Kalkofen)
11.	Length	km	242
12.	Mean discharge	m^3/s	47,1 (gauging station Limburg-Kalkofen)
13.	Population in catchment	number	ca. 1.150.000
14.	Population density	Inh./km^2	ca. 200
15.	Modifications: Physical Pressures / Agricultural influences	text	Hydropower Generation, Navigation, Flood Protection, Diffuse source pollution from agricultural land use, combined waste water effluents.
16.	Impacts?	text	Impact Group “Hydropower Generation”: Disruption in river continuum & sediment transport;artificial water level, water surface size and flow conditions above weirs. Modification of physical-chemical parameters such as temperature, oxygen and nutrients.
17.	Problems?	text	Tendency to eutrophication particulary with regard to the tailback regions. Alterations/Damages on aquatic communities (fish fauna, macroinvertebrates, etc.) due to disruption of river continuum, modified flow conditions and pollution.

18.	Environmental Pressures?	text	Navigation (national aterway), recreational uses particularly canoes.
19.	What actions/alterations are planned?	text	Connection of rural areas to sewers; stormwater treatment. Construction of fish pathways, establishment of buffer strips. Establishment of Best Management Practices in Agriculture including reduction of nutrient surplus.
20.	Additional Information	text	
21.	What information / data is available?	text	German River Habitat Survey, public measurements of physical-chemical parameters of the Federal States, inventories of aquatic and terrestrial fauna, flora and vegetation, particularly fish and benthic invertebrate fauna
22.	What type of sub-group would you find helpful?	text	
23.	Additional Comments	text	

3 Introduction (2 pages)

3.1 Choice of Case Study

Case study "Lahn River" has been chosen as one of four case studies in Germany treated in the framework of the European project on "heavily modified water bodies". These stream systems differ with respect to size (small, medium, large [Lahn River] and very large sized), geography/topology, main uses and main pressures.

Substantial data from earlier and actual studies on the Lahn River collected by official measurements of departments and ministries of the Federal States Rhineland Palatinate and Hesse, German Federal Institute of Limnology, Koblenz, Universities of Mainz, Gießen, Marburg and Kassel, private offices etc. are available, for example

- water quality: physical and chemical parameters, nutrient loads with regard to catchment areas, water quality modellings
- hydromorphology: assessment of 26 parameters in the framework of the German River Habitat Survey (Lahn River and tributaries)
- biology: various investigations on fish fauna, benthic invertebrate fauna and other aquatic organisms and also examinations on flora, vegetation and fauna of river banks and flood plains
- flood protection: flood protection concept for Lahn River system, measurements available and planed
- stocktaking of weirs (weir cadaster).

3.2 General Remarks

Main part of the river basin of the Lahn is situated in the Federal State Hesse, Central Germany. Lahn River is a typical low mountain range water. It has its source on Ederkopf in the southern Rothaargebirge in the Federal State North Rhine-Westphalia, flows eastwards at first and than in a southward and lastly westward direction through the Federal State of Hesse. After 244 km it meet into the Rhine River near Lahnstein in the Federal State Rhineland Palatinate.

The study area can be subdivided into four sub-basins:

a) upper upstream section from source in North Rhine Westphalia to hessian frontier (about 10 km)

b) upstream section in Hesse up to the river mouth of the tributary Ohm (about 39 km),

c) middle section between River Ohm inflow and city Gießen (about 48 km),

d) lower section from city Gießen to the river mouth into the Rhine (about 147).

The last section has been developed for navigation and has the status "National Waterway". It can be divided in the hessian section (91 km) and the Rhineland Palatinate part (56 km).

Lahn River system was chosen for a case study within the **sub-group “Hydropower generation”**. There are 57 hydropower plants overall the hessian Lahn River section (0,32 weirs per km). All are privately owned with authorisations to use a capacity between 150 l/s and 2000 l/s. The hydropower plants disturb the hydromorphology and interrupt the longitudinal connectivity of the river courses and the migration of aquatic fauna.

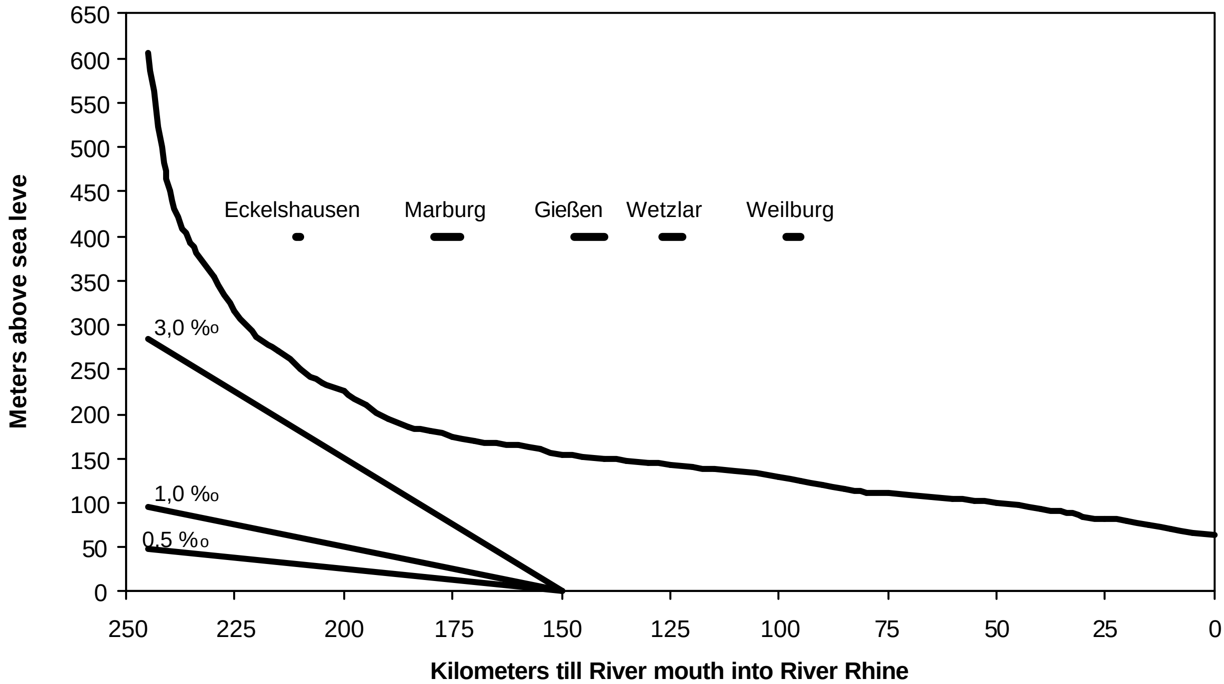
4 Description of Case Study Area (3 pages)

4.1 Geology, Topography and Hydrology

Lahn River system is situated in Central Germany. It is a subbasin of the River Rhine. The Lahn River catchment area amounts to 5927 km² and represents a large river system. The river length overall approximates 244 km with 178 km in the Federal State of Hesse.

Altitude: Source is at 605 and river mouth at 63 m above see level. Longitudinal profile is typical for low mountain gradient rivers. Incline of the upper Lahn is relatively high (up to 3 ‰), whereas underneath the city of Marburg incline shows a constantly low level between 0,5 and 1‰. Overall incline is 552 m with an average of 2,3‰.

Figure 4.1.1: Longitudinal profile of the Lahn River



Hydrological situation of the hessian Lahn River system can be described by measurements of the gauging station Limburg-Kalkofen in Rhineland-Palatinate (Table 4.1.1).

Table 4.1.1: Hydrological data of the Lahn River (data refer to outflow gauge Limburg-Kalkofen; Limnological yearbook, 1989)

Catchment area	A_{Eo}	5.309 km²
Lowest low water discharge	NNQ	3 m³/s
Mean annual discharge	MQ	47,1 m³/s

Mean low water discharge	MNQ	10,1 m³/s
Highest high water	HHQ (1909)	840 m³/s

Discharge regime of the Lahn River system is characterised by preponderant winterly flood and summerly low tide with often long periods.

Between Lahn River mouth into the Rhine River and city Gießen (about 140 km) Lahn River has been strongly modified. This section is used for navigation and has the status "National Waterway". Several high tailback stages caused by hydropower generation transform the river into a string of flow-reservoirs in this river section.

Numerous tributary streams with nearly 5.000 km lenght overall belong to the Lahn River System. Rivers Ohm and Dill are by far the largest tributary streams (Table 4.1.2). Concerning flow rate, Ohm River is comparable to upper Lahn River.

Table 4.1.2: Major tributary streams of the River Lahn

Name of stream	**Inflow Left / Right**	**River basin** km^2	**Length of stream** km	**Incline** ‰
Lahn		**5964,0**	**244,0**	**2,22**
Ohm	L	982,5	58,0	6,62
Dill	R	717,3	53,8	7,49
Elbbach	R	323,7	39,0	9,56
Emsbach	L	320,3	38,5	14,81
Aar	L	311,7	47,7	6,81
Weil	L	248,2	45,5	13,54
Wetschaft	L	196,2	28,0	5,93
Kleebach	L	163,5	26,6	9,29
Salzböde	R	138,1	26,5	10,04
Lumda	L	131,5	28,4	5,63
Wieseck	L	119,6	24,0	5,67
Perf	R	113,1	19,5	10,92
Solmsbach	L	111,9	24,3	11,32
Allna	R	92,0	18,8	9,57
Ulmbach	R	62,5	22,6	17,57
Dautphe	R	41,8	8,8	27,39
Banfe	R	39,1	15,7	16,37

Density of inhabitants is relatively low and amounts to approximately 200 inhabitants/km². Centres of population are the cities of Marburg, Gießen and Wetzlar (Hesse) and Limburg (Rhineland Palatinate).

Lahn River basin shows a clear partition into two different geological regions: folded paleozoic era of the Rheinisches Schiefergebirge (schist mountains) in the west and the triassic of the hessian mountain land in the east. Soil formation based on silicate bedrock predominantly, but also loess reached noteworthy rates. Furthermore basalt and to a minor degree lime bedrock are present.

The most productive aquifers are the sand stone complexes of the bunter sand stone, the triassic basalts and the gravels in the Lahn River valley. Lime bedrocks are of little importance due to their small extension.

4.2 Socio-Economic Geography and Human Activities in the Catchment

The Lahn River basin has been populated since early times of human settlement. Modern industrialisation determined linear clains of urban areas in the flood plains of the Rivers Lahn and Dill. The Lahn catchment area is sparcely populated. The total population in the river basin is about 1.150.000 people, with approximately 200 inhabitants per square kilometre. The largest cities are Gießen (Federal State Hesse) and Limburg (Rhineland Palatinate).

Agricultural land covers 43,5 % of the total area, therewith 61 % acre and 39 % grassland. Forestry covers about 41 %, settlements, industry, trade and traffic nearly 13 % of the Lahn catchment area. Waters and miscellaneous have a ratio of 2,4 %.

Important human activities are industry (see tables below) and agricultural land use. Mean density of undertakings in the Lahn catchment area is 16,6 per 100 km^2. Ohm catchment area merely achieved 6,5 undertakings per 100 km^2, whereas in Dill catchment area 27,1 concerns per 100 km^2 are registered. Another criterion of undertaking structures are the dominance of small and middle firms. Mean size is 16 employees per undertaking. In the case of large concerns (in Marburg, Stadtallendorf and Wetzlar), they often domineer the industrial waste water profile of the corresponding community and determine its character.

Table 4.2.1: Evaluation of the potential pressures on the Lahn River and the two largest tributaries Ohm and Dill by industrial waste water

Main receiving water	Outflow gauge	Mean low water discharge [m^3/s]	Industrial waste water [m^3/s]	equivalent to % mean low water discharge
Lahn	Leun	5.920	0,476	8,0
Lahn	Sarnau	0,567	0,061	10,7
Ohm	Hainmühle	2,140	0,076	3,6
Dill	Asslar	1,080	0,140	13,0

Table 4.2.2: Waste water volume [m^3/a] caused by industry

Sector of industry	Waste water volume [m^3/a]	Waste water volume [%]

Stones and earths	2.044.140	29,8
Mechanical engineering, metall	1.428.300	20,8
Foundry	771.750	11,3
Chemistry	938.736	13,7
Synthetics processing	57.100	0,8
Nourishment industry	1.187.445	17,3
Print offices	4.340	0,1
Glassware, ceramics	90.675	1,3
Wood, paper	46.480	0,7
Clothing	290.070	4,2

Most relevant sectors of industry with regard to waste water volume are chemistry and stones and earths (table 4.2.3).

Table 4.2.3: Lahn River sections strongest cumbered by industrial undertakings having distances between 1 and 5 kilometres from Lahn River

Lahn River Section	Industrial waste water volume [Tsd. m^3/a]	Main responsible trade
km 190	119	Chemistry
km 170	523	Chemistry
km 150	267	Stones and earths
km 140	712	Stones and earths

Another relevant use in the Lahn catchment area is agriculture. Intensity of agricultural land use is predominantly extensive, except for regiones in the Ohm catchment area. Nitrogen input from diffuse sources is relatively low in the Lahn River catchment area and amounts to approximately 8 kg nitrogen per hectare and year. Same for loads of dissolved phosphorus. Nitrogen output is relevant with emphasis on the Ohm River and the upper Lahn region.

Due to structure and intensity of cultivation and existing regulations, concentration of phytosanitary means is not very high in the water bodies of the Lahn River catchment area. Nevertheless, in definite periods residues of phytosanitary means reach concentrations above limited value of drinking water regulation. Corresponding to present state of knowledge they are predominantly due to direct inputs caused by improper handling. Pollution of ground water by phytosanitary means can not be registered in the Lahn River region.

Downstream city Gießen, Lahn River body had been strongly developed (canalisation, river bank fixation, tailback stages (weirs, sluices) and used for navigation (National Waterway). Traffic of goods had been stopped since 1981. Today navigation of passengers is still relevant, shipping traffic for recreational use is a continuous problem.

Whole Lahn River has been used for hydropower production. This causes problems concerning hydromorhology, water quality, water body morphology/habitat quality and in consequence biology. For flood protection reasons, flood plains of the Lahn River and its larger tributaries had been diked, particularly between town Cölbe (near Marburg) and Gießen. Therewith flood plains were uncoupled from the water body and water balance had been disturbed. Due to missing flooding and disturbed groundwater level, wetland but also species and communities which typically live in flood plains are endangered or already disappeard. Other relevant flood protection measurement in the Lahn catchment area are detection basins and dams (table 4.2.4).

Table 4.2.4: Flood detention basins (FDB) with nationwide relevance in the Lahn River basin

Name, Type	**Stream**	**Location (town)**	**Volume Mio m³**
FDB Wohra	Wohra	Wohra	1,61
FDB Kirchhain	Ohm	Kirchhain	14,90
Dam Krombachtalsperre	Rehbach	Rehe	4,20
Dam Driedorfer Talsperre	Rehbach	Driedorf	1,10
FDB Beilstein	Ulmbach	Beilstein	0,77
FDB Breidenstein/Perf	Perf	Breidenstein	2,52
Dam Aartalsperre	Aar	Bischoffen	3,18
		Sum	**28,28**

4.3 Identification of Water Bodies

Lahn River basin has been described according to WFD Annex II, 1.2. "Ecoregions and surface water body types", (table 4.3.1). Lahn River basin is part of the ecoregions no. 14 "central flat country" and no. 9 "central low mountain range" (WFD Annex XI) at "middle-altitude to lowland" and "large-sized". Geology is classified as siliceous predominantly and limy sectoral.

Table 4.3.1: Description of the Lahn River system

Descriptors	**Description**
Ecoregion	Central low mountain range (Annex XI)
Altitude	middle-altitude to lowland
Size	large
Geology	predominantly siliceous, sectoral limy

Lahn River overall can be subdivided into five water bodies (see chapter 3):

1. **Upper upstream section** which reached from source in the Federal State North Rhine-Westphalia to the hessian frontier (about 10 km)
2. **Upstream section** reached from hessian frontier to inflow of the tributary Wetschaft and Ohm respectively (about 39 km)
3. **Middlestream section** in Hesse from tributary Ohm to Gießen (origin of National Waterway) (about 48 km)
4. **Downstream section** in Hesse (National Waterway) (91 km)
5. **Downstream section** in Rhineland Palatinate till river mouth into the Rhine River (National Waterway) (about 56 km)

Lahn River catchment area amounts to 5.964 km^2 with 971 km^2 in the Federal State of Rhineland Palatinate, 331 km^2 in the Federal State of North-Rhine Westphalia and 4.662 km^2 in the Federal State of Hesse. The largest tributaries of the Lahn River, Ohm and Dill, have catchment areas of 717 km^2 and 983 km^2 respectively.

PART II

5 Physical Alterations (5 pages)

5.1 Pressures and Uses

Lahn River system is affected by different pressures and uses. As can be seen on table 5.1.1 various pressures and uses are predominant in the different sections of the Lahn River.

Table 5.1.1: Assessment and Classification of the resulting impacts on the water body „Lahn“

River Lahn				
Sections / Pressures	1 Upper Stream in Hesse[1] (til inflow of the tributary Wetschaft)	2 Middle Stream in Hesse[1] (inflow Wetschaft up to city Gießen)	3 Down Stream in Hesse[1] (National Waterway)	4 Down Stream in Rhineland-Palatinate[1] (National Waterway)
Navigation			■	■
Flood Protection		■		
Hydropower generation	■	■	■	■
Agriculture / Forestry				
Water supply				
Urbanisation			■	

[1] Federal State

■	significant
	not significant

Main detrimental effects are caused by hydropower generation, navigation and, flood protection (table 5.1.1). These pressures have shaped the todays appearance of the morphology of the water body in a significant way (see chapter 5.2). They have been identified as significant pressures on the water body of the Lahn River in the assessment process (see table 5.1.2) by means of the underlying criteria which were worked out by the LWAW working group “Significant Affects”.

Table 5.1.2: Criteria for the identification of significant pressures on surface-waters (LAWA 2001, modified and completed)

Pressures/Uses	significant	not significant
Navigation	1. > 10 % impounded river length at mean low water flow 2. navigation of passengers, goods-traffic, national waterway 3. not passable artificial barriers with a height > 30 cm 4. Proportion of river length with discharge acceleration with - Ratio profile depth to profile width 1:4, - Bank (single or both sides) 10 % total length with bank impairments and - Longitudinal profile 70 % stretched or straightened	1. at mean low water flow 2. recreational uses, motor boats, rowboats and canoes, 3. artificial barriers with a height 30 cm, passable artificial barriers with a height > 30 cm respectively 4. Proportion of river length with discharge acceleration with - Ratio profile depth to profile width < 1:4; - Bank (single or both sides) < 10 % total length with bank impaiments and - Longitudinal profile < 70 % stretched or straightened
Flood Protection	1. flood-protection structures (dams, dikes) located within a strip up to 100 m at the potential floodplain along the river and directly connected with the river or located within a strip of 40 % of the adjacent potential flooded riparian zones **and** - > 50 % dike construction works at the free-flowing river length	1. flood-protection structures (dams, dikes) located within a strip up to 100 m at the potential floodplain along the river, located at least outside of 40 % of the adjacent potential flooded riparian zones **and** - 50 % dike construction works at the free-flowing river length
Hydropower generation	1. > 10 % impounded river length at mean low water flow	1. at mean low water flow

	2. not passable artificial barriers with a height>30 cm 3. Proportion of river length with discharge acceleration with - Ratio profile depth to profile width 1:4, - Bank (single or both sides) 10 % total length with bank impairments and - Longitudinal profile 70 % stretched or straightened 4. Intermittend flow regulation with flow spills	2. artificial barriers with a height 30 cm, passable artificial barriers with a height > 30 cm respectively 3. Proportion of river length with discharge acceleration with - Ratio profile depth to profile width < 1:4; - Bank (single or both sides) < 10 % total length with bank impaiments and - Longitudinal profile < 70 % stretched or straightened 4. flow regulation without spills
Agriculture/Foresty	1. tillage and grassland > 50 % of the river length 2. special crops > % of the river length 3. not passable artificial barriers with a height > 30 cm 4. > 50% of the entire river length in the rural landscape is impaired in the adjacent land zone	1. tillage and grassland 50% of the river length 2. special crops % of the river length 3. artificial barriers with height 30 cm, passable artificial barriers with height > 30 cm 4. 50% of the entire river length in the rural landscape is agriculture-like impaired in the adjacent land zone

Table 5.1.2: Criteria for the identification of significant pressures on surface-waters (LAWA 2001, modified and completed) - (continuation)

Pressure	significant	not significant
Water supply	1. drafts > 10 % of mean low water flow 2. Fluctuated discharge = 10 % of mean water flow 3. No minimum discharge (according to respective land regulations) in rivers 4. without recharge > 0,1 mean low water flow per single installation and > 0,5 mean low water flow total 5. with recharge > 0,3 mean low water flow per single installation	1. drafts 10 % of mean low water flow 2. Fluctuation of the discharge < 10 % of mean water flow 3. minimum discharge (according to respective land regulations) in rivers 4. without recharge 0,1 mean low water flow per single installation and 0,5 mean low water flow total 5. with recharge 0,3 mean low water flow per single installation
Urbanisation	1. urban areas > % of the river length 2. > 50% of the entire river length are urban with bank fixation	1. urban areas % of the river length 2. fixation

Table 5.1.3: Specification of the main physical pressures (marked fields) and other uses in the case study "Lahn"

Pressures & Uses	Sections of the Lahn River* (from source to mouth into the Rhine River)			
	1	2	3	4
Navigation	uses in slight extent: recreational mainly	recreational uses mainly: Water sports like row-boats and canoes and motor boats	National Waterway, goods-traffic is official discontinued in 1981	National Waterway goods-traffic is officially discontinued in 1981, today the river is used for navigation of passengers and recreation: motor boats, rowboats and canoes (about 90.000 boats per year)
Flood Protection	nonexistent	60 % of the flowing waters length	nonexistent	nonexistent
Hydropower generation	not passable artificial transverse-structurers with a head more than 30 cm are existent	not passable artificial transverse-structurers with a head more than 30 cm are existent	not passable artificial transverse-structurers with a head more than 30 cm are existent	data not available
Agriculture/ Forestry	adjacent field and grassland surfaces: about 41 % of the flow distance	adjacent field and grassland surfaces: about 44,4 % of the flow distance	adjacent field and grassland surfaces: about 42,2 % of the flow distance	adjacent field and grassland surfaces: about 30 % of the flow distance
Water supply	For the river Lahn there are no significant water abstractions identified so far; for the tributaries water abstractions are realised.			
Urbanisation	Land-use pattern: settlements about 18 % of the flow distance	Land-use pattern: settlements about 44,5 % of the flow distance	Land-use pattern: settlements about 54 % of the flow distance	Land-use pattern: settlements about 43 % of the flow distance

* information are not related to the catchment area, they refer to the River and its adjacent surfaces

Hydropower generation has been identified as significant pressure for the whole Lahn River. The corresponding physical alterations affect the water body almost in the same manner. Tailback stages (weirs, sluices) have direct and indirect negative effect on hydromorphology (flow conditions, sedimentation, substrate diversity etc.), temperature-, nutrient- and oxygen balance and the aquatic communities (see chapter 5.2 and 5.3).

Number of transverse buildings (weirs) on the hessian Lahn River is 57 overall. This corresponds to average value of 0,32 weirs per kilometre. Number of weirs used for hydropower generation is 22 overall, whereby frequency in the upper Lahn River section is highly by far (table 5.1.4). Some weirs formerly build for hydropower generation were used otherwise today, for example for irrigation of agricultural land, river bed fixation or as fire protection pond, some have no more function today and for a few function is unclear. Weirs along the National Waterway are typically combined with sluices and were used for both hydropower generation and navigation.

Hydropower stations on the Lahn River are constructed as outflow route- or river power stations; storage power stations are nonexistent. Most of the weirs along the Lahn River are overflow weirs. Approximately one third of the outflow passes these weirs so that the impact of tailback and negative impacts connected with it will be put into perspective. Outflow channels which are connected with overflow weirs on the Lahn River show approximate typical stream conditions. Corresponding macroinvertebrate communities include a series of rheobiont species which are typically for upstream sections. These outflow channels act as a reservoir for species typically for running waters. In winter when flow increases, these species take for new colonaisation in the downstream region.

But outflow channels have also negative effects on hydromorphology and aquatic communities. Water level vacillates according to vacillating outflow due to rotating business times. These artificial conditions affecte aquatic communities too.

Table 5.1.4: Weirs and fish fauna of the hessian Lahn River

	Section 1 Upper Stream	Section 2 Middle	Section 3 Nat. Waterway
Length [km]	39	48	86
Slope and Weirs			
No. of weirs	29	11	15
Rate of weirs per kilometre [-]	0,75	0,23	0,19
No. of weirs with hydropower generation	5	6	11
Aggregated congestion height [m]	37	19	34
Slope: difference in altitude [m]	107	37	49
Rate of free dip on altitude [m]	70	18	15
Rate of free dip on altitude [%]	65	49	31
Possibility for fishes to pass the			

weirs [Ascent /Descent in %]			
1 (passable)	17 / 83	0 / 27	0 / 25
2 (conditionally passable)	27 / 7	0 / 18	56 / 37
3 (mostly passable)	28 / 7	18 / 55	19 / 25
4 (impassable)	28 / 3	82 / 0	25 / 13
Fish fauna			
No. of gathered fishes	21.236	24.614	15.950
No. of fish per kilometre	544,5	513	185,5
Fish weight per kilometre [kg/km]	30	52,8	22,1
No. of gathered fish species	20	20	24
No. of gathered fish species to be found under potential natural conditions	17	17	19
Species deficit according to potential natural conditions (reference)	17	17	19
No. of fertile/reproductive species	10	12	14

On the hessian Lahn River 9 weirs overall with a head more than 30 cm are not passable for aquatic organisms (head up to more than 2 m (section 2) and up to nearly 4 m (section 3). Ratio of weirs which were not passable is particularly high in the Lahn River section between mouth of River Ohm and city Gießen (section 3). (Corresponding data for Lahn River in Rhineland-Palatinate are not available?).

Navigation is a significant pressure on the water body of the lower Lahn River downstream Gießen. In this section (section 3 and 4) Lahn River has been constructed in several stages as National Waterway. This has caused profound modifications on the water body morphology for example longitudinal profile, fixation of river bed and banks, depth of river bed, river continuum (sluices) and discharge regime.

Traffic of goods has been noticeable decreased in 1971 (closure of the stone bridge in Rhineland Palatinate) and official stopped in 1981. Particularly Lahn River in Rhineland-Palatinate is used for transport of passengers and also for recreation. Today navigation of motor boats and sportboats without motor (rowboats, canoes) are registered to an increasing degree. Number of vehicles registered on the sluices between Limburg and Lahnstein uninterrupted decreased from 25.500 in the year 1970 to about 87.300 in 1992, whereby trend aspires to a constant value of about 90.000 (data registered by Water- and Navigation Department, Koblenz, between 1980 and 1992). Ratio of sportboats without motor amounts to approximately 30 %, whereby rate increases with increasing distance from Rhine River from 19 % near Lahnstein to 51 % near Limburg (registration 1989), ratio of motor boats amounts to ca. 50 % (increasing), ratio of passenger ships is relatively low (ca. 3 %). Passenger boats driving upstream from the

Lahn River mouth are not relevant concerning number of passengers. Want of landing stages vastly decreased and lead to fixation of the river banks and corresponding constructions.

Status "National Waterway" is valid up to now. Upkeep measures will be continued until further notice. German Federal Institute of Limnology, Koblenz,is responsible for the proper conduct and has worked out a concept which takes into account the ecological requirements.

Flood protection has been identified as significant pressure on the water body of the Lahn River by means of the LAWA criteria only between inflow of Ohm River and Gießen (section 2). Because of low incline and large width of flood plains in this section, frequency of flooding is large in natural and therefor flood protection measures are absolutely essential. Consequently 60 % of the river length outsite of settlements are accompanied by flood protection dams.

Furthermore, **other impacts**, particularly urbanisation (settlement, traffic, industry, gravel mining) and agricultural use have changed the pristine / original appearance of the Lahn catchment but have not been assessed as significant pressures according to the criteria given by the LAWA working group. Water supply on the other hand is not relevant.

5.2 Physical Alterations

The physical alterations caused by the above mentioned pressures clearly appeared in the (hydro-)morphological structur of the Lahn River. Its quality had been assessed according to the standardised procedure for stream habitat survey in Germany (Hessisches Ministerium für Umwelt, Landwirtschaft und Forsten 2000). Assessment of the relevant parameters on each of the four sections of the Lahn River and also the overall-evaluation (mean value) shows clear deficits concerning river morphology (table 5.2.1). The parameters "longitudinal devolution" and "longitudinal profile" and also overall-assessment show noticeable decrease from upstream section to river mouth into the Rhine River. Morphology of Lahn River in Rhineland Palatinate (not shown in table 5.2.1) is still stronger affected than in the lower Lahn River section in Hesse (section 3).

Table 5.2.1: Quality of the morphological structure of the hessian Lahn River – selected parameters

	Section 1 Upper Stream	Section 2 Middle	Section 3 Nat. Waterway
Length [km]	39	48	91
Stream Habitat Survey [Classes from 1 „nearly natural" up to 7 „completely modified"]			
River Continuum	5	6	7

Longitudinal Profile	3	5	7
Transverse Profile	6	6	6
River Bed	7	7	7
River Bank	5	4	4
Riparian Zone/ Flood Plain	6	6	6
Allover evaluation (Average)	5	6	6
Sup-Parameters			
Longitudinal curvature	5	5	5
Profile type	4	4	5
Profile depth	4	5	4
River bank fixation	3	3	3

Figure 5.1.1 illustrates the assessment of the parameters “longitudinal curvature” and “river bank fixation” along the longitudinal gradient from source to river mouth. Together with the parameter “depth of river bed” they had been identified beeing significant criteria in the assessment process of “discharge regulation” (LAWA).

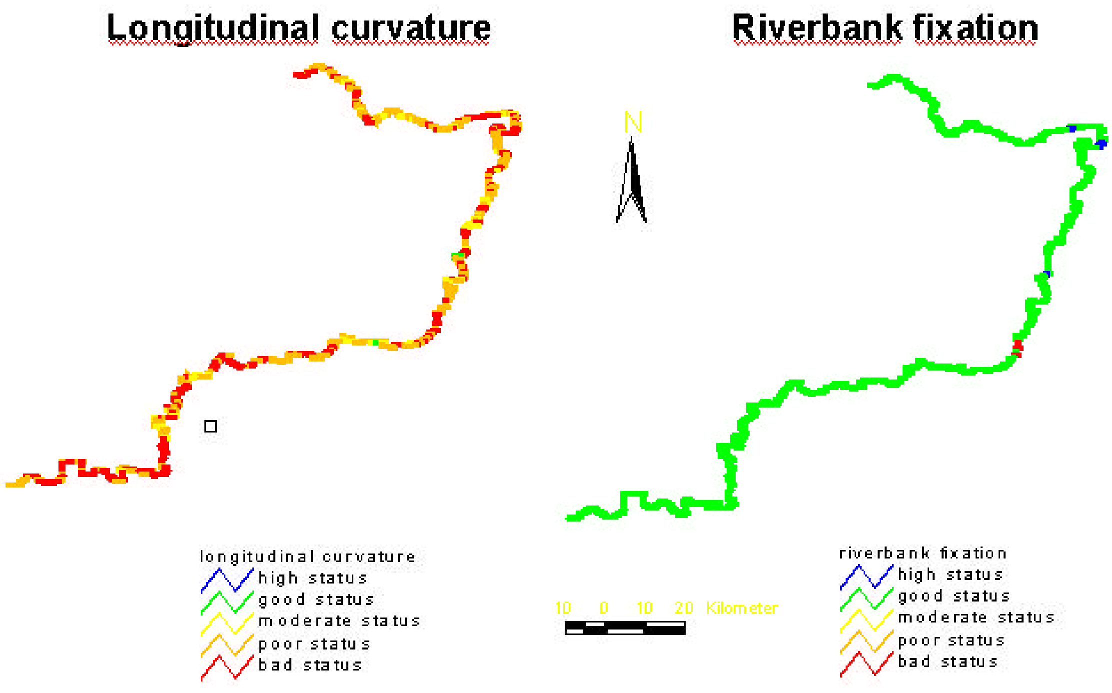


Figure 5.1.1: Specific hydromorphological parameters of the River Lahn

Comparision between the current situation and the desired status according to the develoment plan of the Federal State of Hesse is shown in figure 5.1.2.

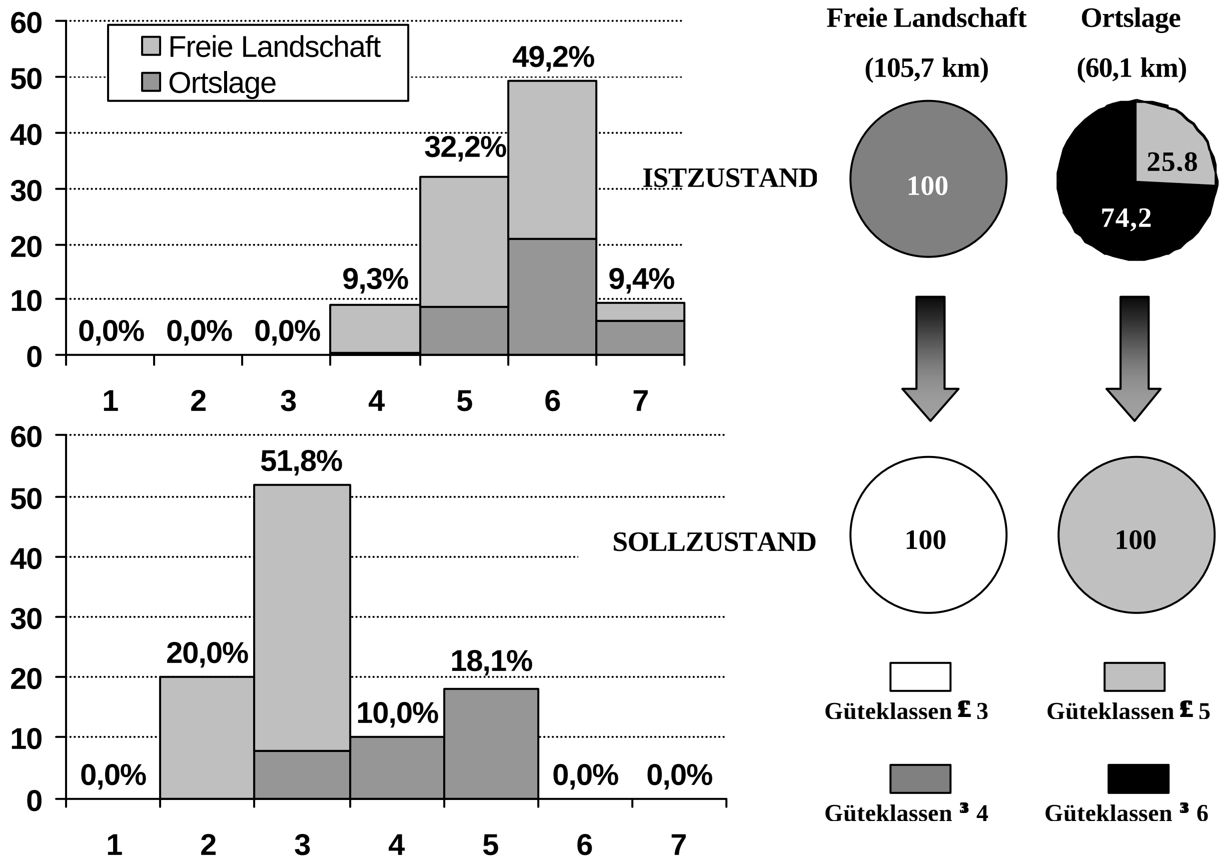


Figure 5.1.2: Frequency distribution of morphological quality classes of the River Lahn - current and strived situation (x-axis: morphological quality classes, 1: pristine, 7: completly modified; y-axis: percental share. Data current situation: Hessian Ministry for Environment, Agriculture and Forestry (2000); data desired situation: approxemately values according to the minimum request of the development plan of the Federal State Hesse (r.s.: rural sections, u.s.: urban sections).

Current morphological situation of Lahn River considerably differs from desired situation. stream sections close to nature and also moderate modified ones do not exist any longer.

Hydropower generation is a main pressure on the Lahn water body with direct and indirect negative effects on hydromorphology and linear continuity of the river system. Hydropower production is interconnected with encroachments which modify discharge regime (water level, flow conditions), morphological structure of the river bed, habitat properties, ballances of temperature, oxygen and nutrients and last but not least the ability of migration for aquatic organisms in a negative way.

Physical alterations caused by hydropower production are described below with emphasise on the hessian Lahn section as an example. Tailback on a weir causes low or even no free flow in the upper region. Such regions can be regarded as lakes and tend to eutrophication (see chapter 5.3). Type of construction and operating mode decrease and inhibit respectively up and/or down migration for aquatic organisms particularly fish fauna. Beyond it, plant facilities (turbines, rake systems) cause damages on fishes. Abrupt pressure drop in turbines can also cause damages on invertebrate fauna.

Another negative effect of weirs particularly fixedly ones is heightened sedimentation. In consequence interstitial occluded and lost its efficiency. Furthermore natural sediment transport is interrupted and diversity of structure of river bed and banks is limited.

Inflow channel of the weirs in general cause artificial conditions concerning geometry and discharge for both, upstream and downstream region. Particularly variability of riparian zoon is often limited and riparian zone is affected. Inflow channel is a dead-end street for flow oriented organisms by upward migration if there is no functioning.

Due to tailback, water level and surface inceases and therewith extent of unshadowed surface. This promotes eutrophication.

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

Hydromorphological changes which result from the direct physical alterations caused by hydropower generation are:

- changes in discharge/flow regime and in flow conditions: low water level downstream tailback construction, relatively (unnatural) high water level, large unshadowed water surface and reduced to nonexisting flow velocity upstream tailback construction connected with damages of temperature, oxygen and nutrients ballances
- modified hydromorphology has negative consequences for temerature and nutrient ballances and particularly oxygen level and supported eutrophication
- sedimentation of anorganic suspendd matter increases due to slight streaming ➔ number of filter feeders decreases
- disturbed ballance in erosion and sedimentation, interrupted sediment transport, hightened sedimentation underneath the tailback construction (weir), limited diversity of river bed sediment
- damage on interstitial and limitation of its efficiency (interchange, habitat)
- adverse effect on quality of habitat structure for aquatic and riparian fauna and flora
- artificial discharge in inflow channel and outflow channel.

But weirs and other tailback constructios can have also positive effects. They cause an increase of ground water table, wetness of flood plains and frequency of floodings. Therewith they improve the naturalness of riparian zone and floodplains which are usually affected nowadays including improvement of living conditions for flora, vegetation and fauna typically for functioning river systems.

5.4 Discussion and Conclusions

- According to the LAWA criteria merely water body and not catchment area has been treated in the case studies. (For example flood detention basins are no significant criteria for the assessment of the pressure “flood protection”). Consideration of the catchment area in addition will provide different results because some uses e.g. flood protection, agriculture, urbanisation will become relevant in a larger extent.
- Some weirs which were constructed for hydropower generation were used otherwise or supplementary today, for example for irrigation of agricultural land or as fire protection pond, or type of use is not clear. That means correlation of affect/pressure and causer – in this case: hydropower generation, agriculture, and/or urbanisation – and also determination of their ratios is difficult.
- Weirs can also have positive effects which will be cancelled with the loss of the weir.

6 Ecological Status (7 pages)

6.1 Biological Quality Elements

Range of biological measurements

For the assessment of the ecological status of the Lahn River substantial data are available which were collected on selected sampling sites in various examinations and research projects (table 6.1.1). The range of biological measurements contains communities from water body, riparian zone and flood plains: phytoplankton, macrophytes, phytobenthos, macroinvertebrates, fish fauna, snails, mussels and cancer and also fauna (selected species groups, e.g. beetles, dragonflies and birds), flora and vegetation of river banks and flood plains. This “biological elements” are adequate to reflect the pressures resulting from the physical modification upon the water body.

Table 6.1.1: Examinations and research projects at the Lahn River

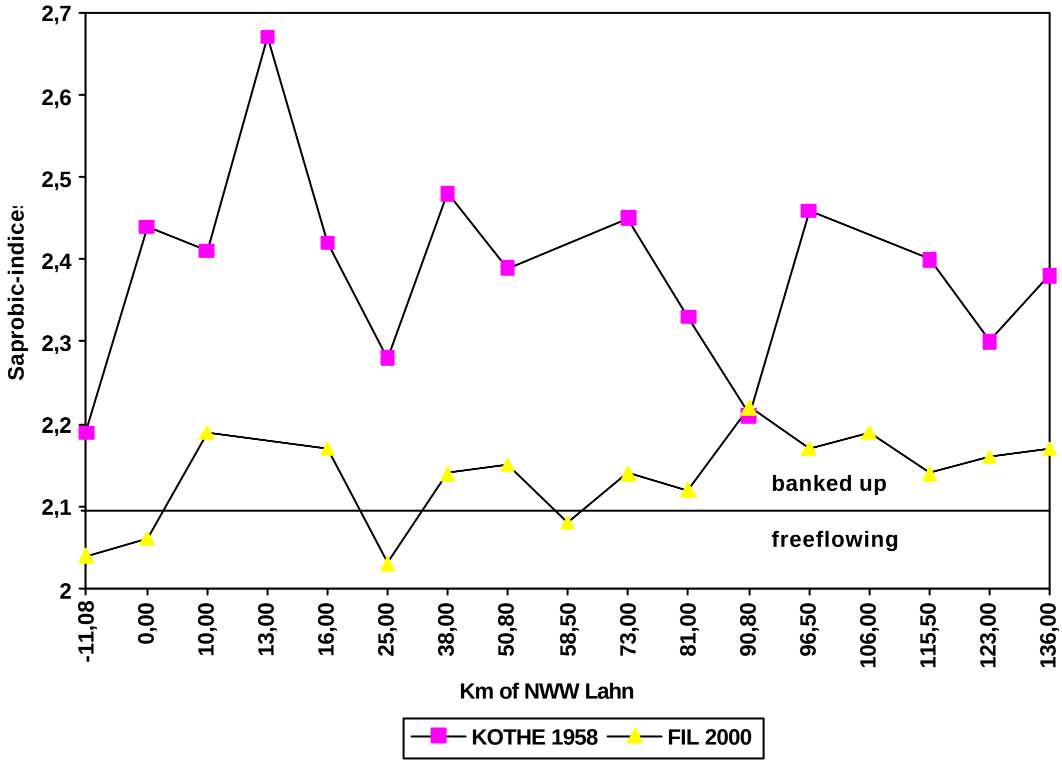
	Phytoplankton	Macrophytes	Phytobenthos	Macroinverte-brates	Fish fauna
Upper Lahn	Lahn-Project-Hesse (1991, 1994)	Lahn-Project-Hesse (1991, 1994)	Lahn-Project-Hesse (1991, 1994) Hyporheic-Zone-Project (2001)	Lahn-Project-Hesse (1991, 1994) HLfU-Hesse regular	Lahn-Project-Hesse (1991, 1994) Adam and Schwevers (1996)
Middle Lahn	Lahn-Project-Hesse (1991, 1994)	Lahn-Project-Hesse (1991, 1994)		Lahn-Project-Hesse (1991, 1994) HLfU-Hesse regular	Adam and Schwevers (1996)
Lower Lahn				Lahn-Project-Rhineland-Palatinate (1994) LAWA- of Rhineland-Palatinate regular	Lahn-Project-Rhineland-Palatinate (1994) Adam and Schwevers (1996)

For the upper Lahn River, particularly concerning the Federal State of North Rhine-Westphalia, no data of benthic macroinvertebrates are available. Furthermore macroinvertebrate data of original river bends and ox-bow lakes in the extended riparian zones of Hesse are missing. Concerning phytobenthos a longitudinal examination can give more information about water quality and trophic level in the deeper zones of the great backwaters in the middle and lower part of the Lahn River. Aquatic macrophytes which have been disappeared nearly completely for 40 years come back at present. Their return and in consequence the come back of a hole community should be documented.

Extent to which the impacts upon biology are a consequence of the physical alterations, other important pressures and how can they be separated?

In the 1950ties water-pollution in the Lahn River turned to its climax. Looking on Saprobic-indices based on the sampling-lists of Kothé (1958) only one pressure can be seen: pollution (figure 6.1.1).

Figure 6.1.1: Saprobic indices based on the sampling lists of Kothé (1958) compared with data of an examination of the Federal Institute of Limnology (2000)



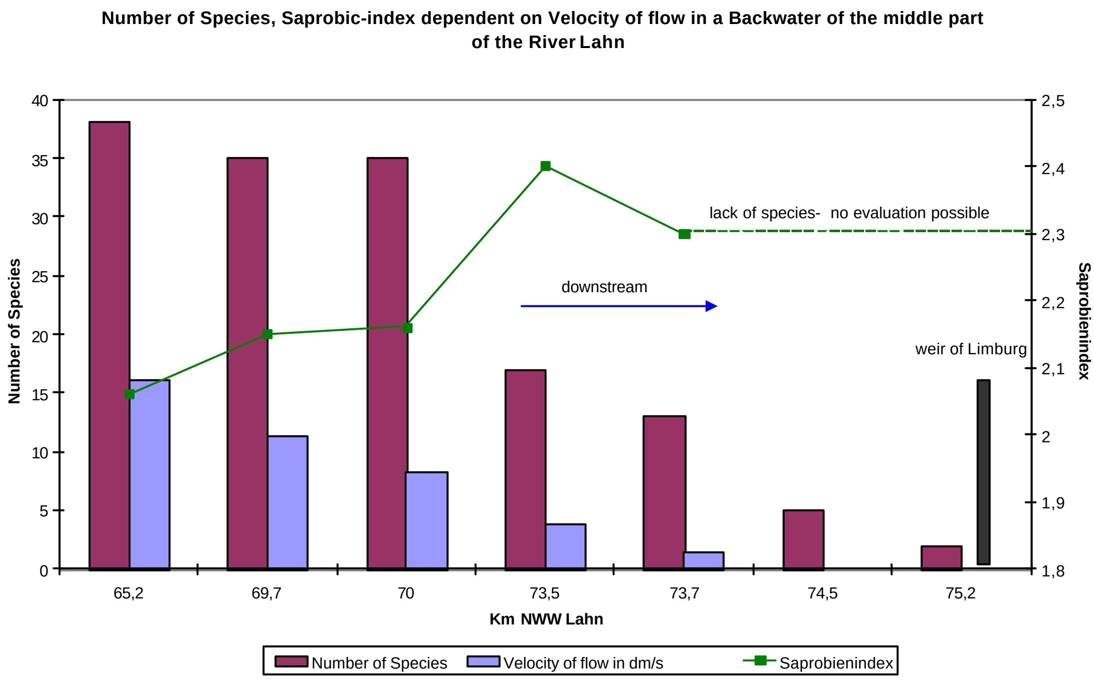
In 2000 the ecological situation has changed and alterations/damages of macroinvertebrate communities caused by hydropower generation can also be documented by saprobic index as shown above. Only the samples taken from extended freeflowing sections show saprobic indices better than 2.1. All the sampling sites in the backwaters above the weirs show worse indices.

The extent to which hydropower generation and the pressures connected with it cause damages on the aquatic fauna can be described by means of fish and macroinvertebrate fauna as an example. Number of fish species which have to migrate long distances compared with to those which were present when the river continuum would not have been interrupted is one criteria which illustrates the extent to which hydropower generation affected fish fauna (see chapter 6.3).

Damages of macroinvertebrate communities can be documented by various criteria such as number of macroinvertebrate species above and below the weirs along the Lahn River. Derogations on macroinvertebrate communities can also be documented by saprobic index and Potamon-Type-Index (PTI) (see below).

Comparision of number of macroinvertebrate species, Saprobic-index and the velocity of flow in the backwater of the weir of Limburg is shown in figure 6.1.2. Saprobic index above the weir is higher than upstream in the freeflowing sections.

Figure 6.1.2: Number of species is compared with the Saprobic-index and the velocity of flow in the backwater of the weir of Limburg.



These pressures can hardly be separated because of complex and dynamic correlations. This applies to most of the pressures affecting the Lahn River. Nevertheless specific species and criteria can be used as indicator for the identification of specific pressures. Examples for this are loss of shredder due to hydraulic pressure, increase of bioturbators due to high solids and loss of specific species such as *Rhyacophila fasciata* and *Silo pallipes* due to chemical load (Podraza 1999). Another example is the significant reduction of number of species and filter-feeders registered above the weirs along the National Water Way of the Lahn River compared with the situation above. Species reduction is not clearly attributed to hydropower generation and/or navigation. Even the existence of weirs and their backwaters may represent a pressure. The harshness depends on the hight of the dam, the extension of the backwater and the hydraulic stress which is attributed to the discharge. In the middle part of the Lahn River backwaters are not as voluminous than in the lower Lahn. Here in the little backwaters species were often registered who otherwise were found in bays and ox-bow lakes, such as *Viviparus contectus*, a scarce water snail.

6.2 Physico-Chemical Elements

The physical alterations caused by hydropower generation have an impact upon the physico-chemical elements. Examples of such impacts are artificial water levels, artificial flow conditions: sections with low flow velocity or without flow and in consequence disturbed balances of temperature, nutrients and oxygen. Water quality of the Lahn River has been improved according to improvement of the waste water treatment plants in the last years.

Furthermore other pressures, particularly pollution, are important. Above all, diffuse inputs from the agricultural land use cause partly significant affects. Waste water inflows from waste water treatment plants have become less important today because of upgraded purification efficiency – exept for combined waste water discharges, which are still problematic. They cause pollution, including high level of germs, and beyond it hydrolic stress on macroinvertebrate species. Figures 6.2.1 and 6.2.2 show data of solved ammonium nitrogen and total-phosphorus from Kothé 1958 compared with measurements of the HLfU (Hesse)1997.

Figure 6.2.1: Dissolved ammonium nitrogen in 1958 compared with 1997

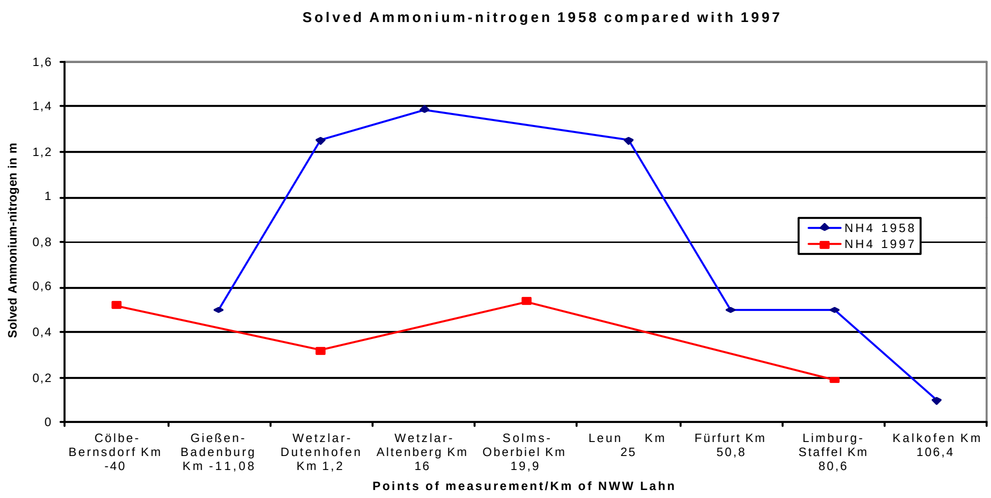
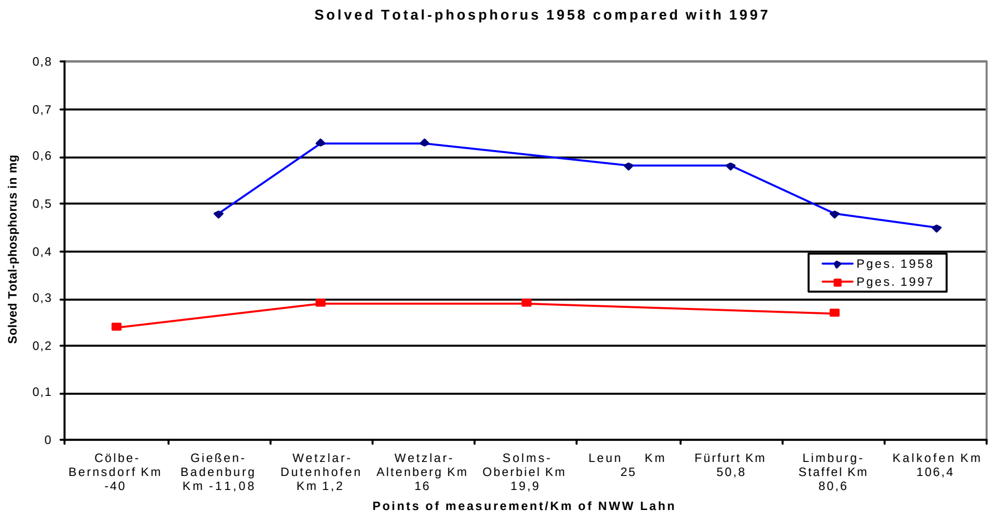
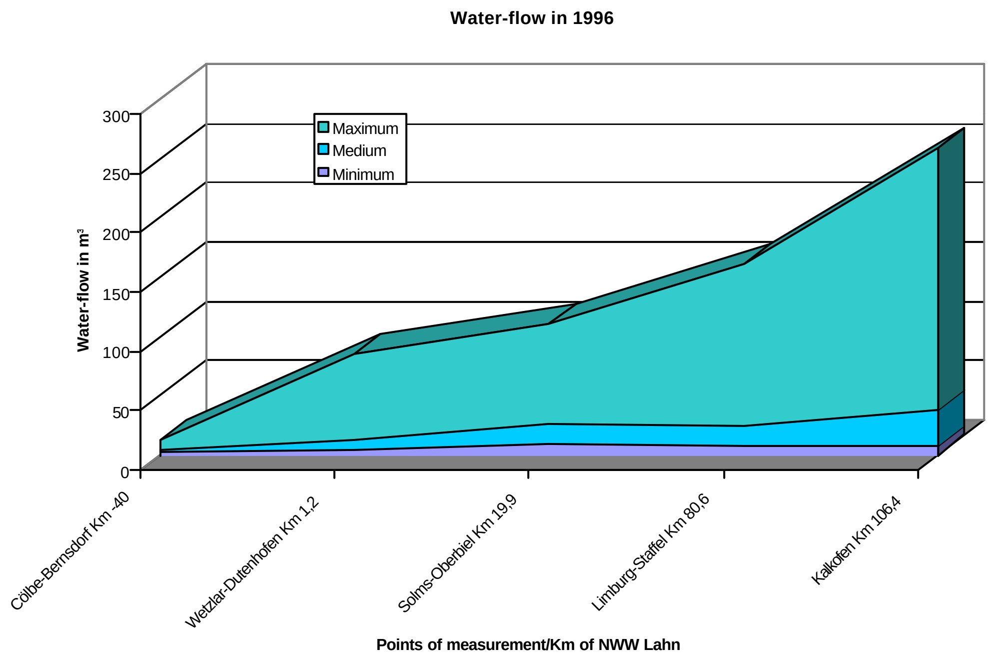


Figure 6.2.2: Dissolved total-phosphorus in 1958 compared with 1997



As shown above, the loads of ammonium and total-phosphorus, representative for chemical water quality, have decreased in the last years. But wide parts of the catchment area of the Lahn River are laying in summer-arid zones. Therefore there is a great difference in water-flow rates between summer and winter and, in consequence, a concentration-effect on physico-chemical water-parameters takes place in times of low water-flow rates. In the middle- and lowstream Lahn River the increase of nutrient loads, especially total-N and total P led each year to occurring alga blooms. (Concentration of total Chlorophyll in may 2001 up to 102µg/l, own measurements at Kalkofen).

Figure 6.2.3: Discharge of the Lahn River in 1996

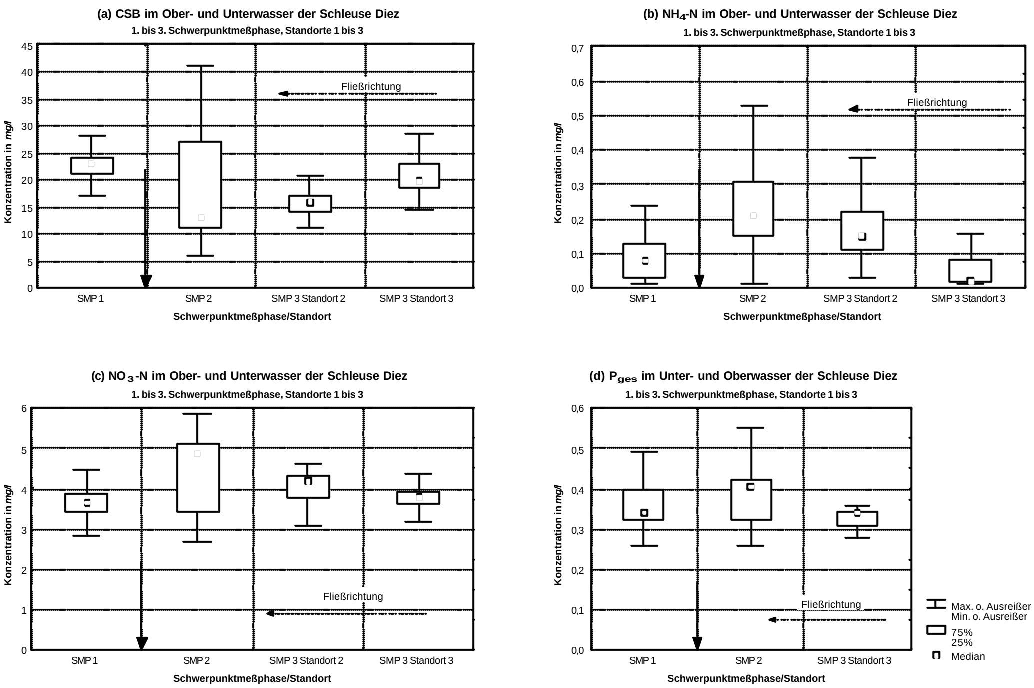


In hot summer months this concentration-effect is strengthened in the extended backwaters at the lower Lahn by increasing evaporation-rates and high temperatures in the unshadowed sheets of water.

The appearing alga-blooms can cause high pH-values a labil oxygen-status and a radical changement in the benthic community (change from a multifunctional benthic community with gracers, collectors, predators, shredders and hunters to a collector-gatherer and filter-feeder community). This leds to an higher trophic level Borchardt (1994). After alga-blooms a great amount of organic matter appears in the river, sinks to the river bed and In times, when living Alga also use oxygen (heterotrophie during the night) its decomposition goes conform to an oxygen-deficit.

The extended backwaters at the lower Lahn River also show an influence on chemical parameters. Concerning the Chemical Oxygen Demand (COD), which is often correlated to the rates of suspended matter, its shown, that the beginning sedimentation in the backwater leds to lower results (figure 6.2.4a). In spite of this the parameters ammonium-nitrogen, nitrate-nitrogen and total-phosphorus (figure 6.2.4b,c,d) show increasing loads towards the weir. This effect depends on waste water inflow and the failing catabolism in the standing and often stratified backwaters.

Figure 6.2.4: Influence of the weirs on chemical parameters in the impoundments at the lower Lahn River (Borchardt und Mang, 1999)



6.3 Definition of Current Ecological Status

Assessment of the current ecological status of the Lahn River within the scope of the case study based on two relevant indicator groups: fish fauna and macroinvertebrate communities.

Assessment of fish fauna

Evaluation of the fish fauna had been carried out/ implemented according to the ichthyofaunistical assessment procedure of the ARGE Elbe, Hamburg (ARGE Elbe 2000). Species formation and abundance were taken into account for case study Lahn. Data regarding aeging structure were not available. For single criteria and quality classes see ARGE Elbe (ARGE Elbe 2000).

Assessment of species formation resulted in an inhomogeneous result for both upper region of the Lahn River (section 1) and hessian national water way (section 3). Due to historic well known species, both sections were asigned to quality class 2 because of existence of vast majority of historic well known species. Regarding existence of leitfish and corollary fish species, the upper Lahn region has been classified to quality class 1 (grayling [leitfish], and corollary fish species existent), whereas down stream region (section 3) obtained quality class 3 (barbel [leitfish] existent, typical corollary fish species are partly missing). Considering species which have to migrate large distances (such as salmon and lake trout, both regions obtained a relatively bad rating, quality class 5, because these fishes are missing; existence of eel is due to stocking measures. Regarding species abundance (leitfish, corollary fish species, and relative ratio of leitfish and corollary fish species), upper region of the Lahn River (section 1) obtained quality class 1 (grayling: rezedent; chubs, minnow, gudgeon, dace, roach, smerling, sickleback and brook trout: eudominant to rezedent; relative ratio of leitfish and corollary fish species >> 50%), whereas hessian national water way (section 3) had been classified to quality class 3 (barbel: dominat; chubs, gudgeon, dace, roach: eudominant to rezedent and several corollary fish species (smerling, nase) subrezedent; relative ratio of leitfish and corollary fish species << 50%). Concerning age group of leitfish and corollary fish species data were insufficient for evaluation according to the ichthyofaunistical assessment procedure of ARGE Elbe - which requires differentiation of the three age groups of leitfish and corollary fish species – and hence classification into quality classes was not possible. However, in section1, leitfish and corollary fish species were reproductive; in section 3, leitfish was reproductive and corollary fish species were reproductive, except of nase which is due to stocking measures.

Regarding fish fauna, defintion of the current ecological status in the framework of the case study "Lahn" provides a good approximation to the definition of good ecological status as defined by the directive (see Annex V).

Assessment of macroinvertebrate communities

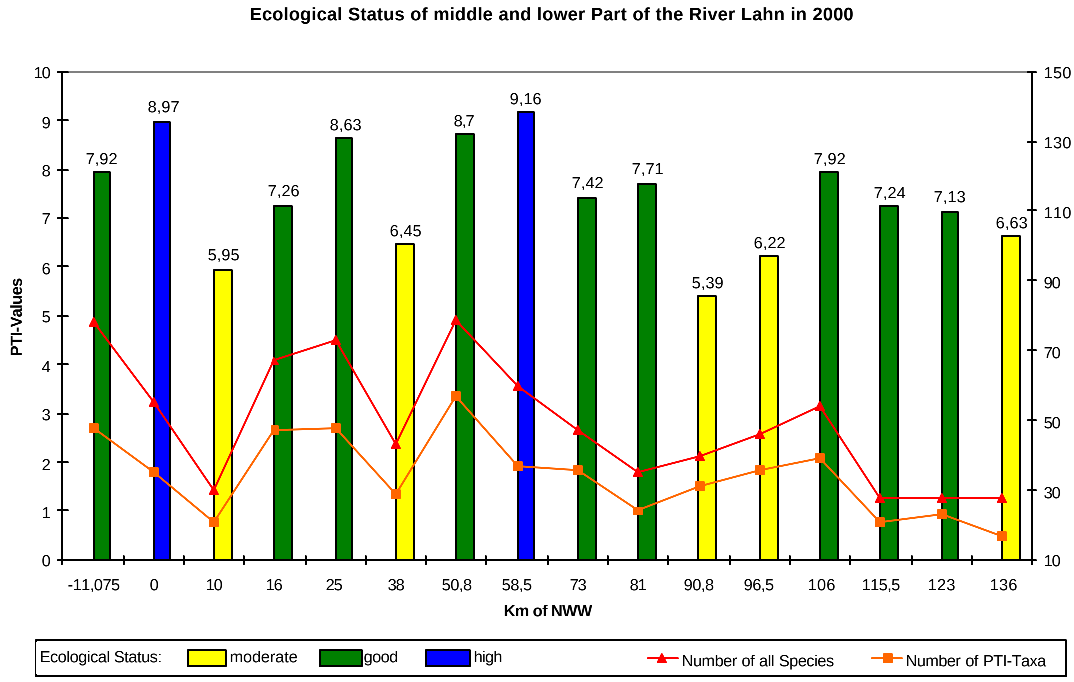
Macrozoobenthic communities had been evaluated by means of saprobic index and Potamon Type Index. Additionally Rheo-Index – a measure indicating the flow conditions by the ratio of specific species with an affinity to flow – was used.

The hessian part of the Lahn River is characterised by diversity of habitats. Little backwaters are alterating with free flowing sections. Canalisation in the 18th and 19th century left a lot of meanwile often tumbling down structures like groynes along the banks. Therefore river is rich of different biotops what is reflected in the high amount of macroinvertebrate species. Nevertheless there are deficites! Saprobic index and Rheo-Index are good instruments to characterise the differences in velocity of flow and pollution. But they are not able to give an impressure of the current ecological status.

Examinations on macrozoobenthos in the longitudinal gradient of the lower Lahn River in Rhineland-Palatinate show that the largest rates of the Lahn River can not be evaluated by saprobic assessment. Reasons for this are additional pressures such as tailbacks and navigation. Rheo-Index varies according to the sequence of tailbacks. This index characterises the Lahn River in Rhineland-Palatinate during the summer months nearly as a lake.

Regarding benthic macroinvertebrate fauna, definition of the current ecological status in the framework of the case study "Lahn" differs from the definition of good ecological status as defined by the directive (see Annex V) (see chapter. 6.4). To get better results in comparing the ecological deficits a new index, the Potamon Type Index (Schöll and Haybach, 2001) was used. It allows to analyse the different sampling-sites in the potamon region of the Lahn River downstream of Marburg. As can be seen in figure 6.3.1 the PTI-index leds to comparable results between the middle and lower parts of the river concerning the current ecological status.

Figure 6.3.1: Potamon Type Index and current ecological status.



6.4 Discussion and Conclusions

In the current definition based on saprobic index and PTI the relevant criteria such as community structure, abundance, ratio of damageable compared to robust species see Annex V, WFD) were not taken into account and evaluation was not model-oriented. According to the requirements of the WFD, for a first evaluation in the framework of the case studies we followed the assessment procedure based on saprobic index and corresponding quality classes (from 1 to 3) as suggested by Rechenberg (2000).

Additionally we used PTI for evaluating the ecological status concerning macroinvertebrate communities on the Lahn river except for the upper Lahn section. (PTI is limited to (large) potamal streams and therefor can not be used in all case studies and for all sections of a stream or river).

Weakness of saprobic index is that it is primary limited to evaluate pollution and that is not ideal for the assessment of the ecological status. It our case study it was used in default of adequate indices and assessment procedures respectively. Problem is (still) to define the ecological status of streams with benthic macroinvertebrate fauna adequately.

7 Identification and Designation of Water Bodies as Heavily Modified (6 pages)

7.1 Provisional identification of HMWB

The process of the provisional identification of HMWB for the case study “ described in three worksteps. They were passed through in accordance to the structure of the “Terms of Reference”.

Workstep 1: In workstep “hydromorphological impacts” the existing uses such as navigation, flood protection, hydropower generation, land use, water supply and urbanisation were examined. The effects of each use on the water body were specified. based on adequate criteria an evaluation took place with regard to determined loads (see table 5.1.1 up to table 5.1.3).

Workstep 2: The next workstep “ecological status” requires an evaluation of the biological status of the Lahn River. Concerning this, a first estimation was made in the context of the Lahn River by available data of macroinvertebrate communities and fish fauna. Evaluation of macroinvertebrate communities was realised by the Potamon Type Index (PTI) developed by the Federal Institute of Limnology, Koblenz. Assessment of fish fauna resulted from the ichthyofaunistical evaluation procedure of the ARGE Elbe, Hamburg. If application of these procedures doesn´t make sense (PTI) or is not possible due to insufficient data base, the ecological status has been evaluated by means of the saprobic index or selected parameters of the fishstock.

Workstep 3: designation process takes place according to a multi-level testing method, developed in the context of the international subgroup “navigation”. The methodology up to the provisional identification is represented in figure 7.1.1. Thus the development of a “provisional negative/positive list” follows in accordance to the worksteps 1 and 2 after stocktaking. This list contains specifications of the impacts of pressures on hydromorphology and biology on surface waters. Based on adequate criteria, the identification takes place from “significant” and “not significant” impacts. Table 7.1.1 shows a general Negative/Positive list as a function of the pressure “hydropower generation”. Significant impacts on the Lahn River become led provisional on the first negative list; not significant impacts are constituent of the first positive list. For further representations and evaluations the upper Lahn River section is regarded exemplary. Figure 7.1.1 shows the specified Negative/Positive list concerning this river section.

Based on the provisional negative list, the upper Lahn River is designated provisional as heavily modified (identification).

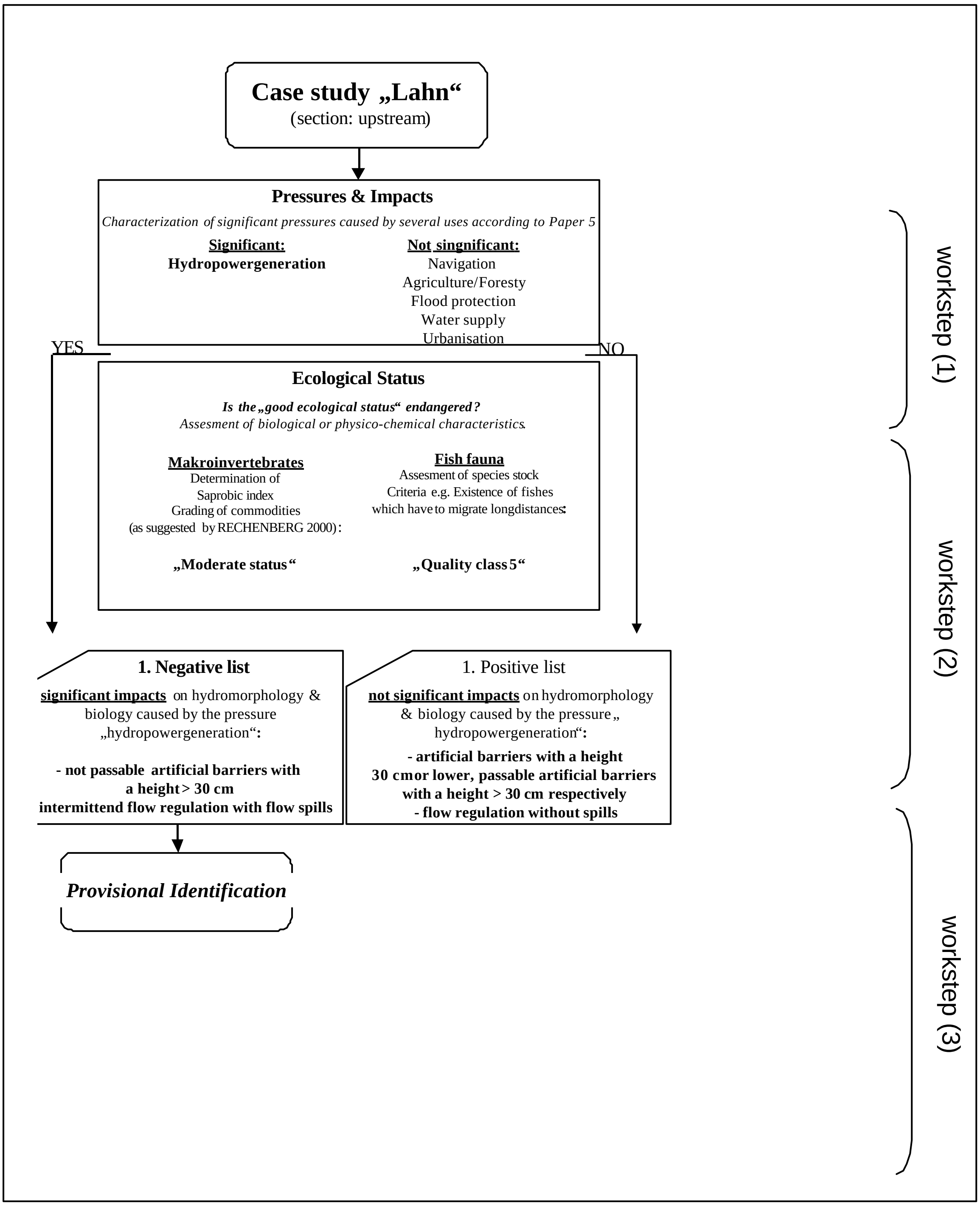


Figure 7.1.1: Process of the "Provisional Identification of Heavily Modified Water Bodies" concerning the subgroup "navigation"

Tab. 7.1.1: Effects on the quality of the morphological structure of the Lahn River caused by the pressure "hydropower generation" (LAWA 2001, modified and completed)

Negativ list *i.e.* ***significant*** *impacts on hydromorphology & biology caused by the pressure " Hydropower generation "* *> provisional designation of the water body as heavily modified*	**Positiv list** *i.e.* ***not significant*** *impacts on hydromorphology & biology* *caused by the pressure " Hydropower generation "* *> „good ecological status“ available*
➢ > 10 % impounded river length at mean low water flow	➢ at mean low water flow
➢ Proportion of river length with discharge acceleration with - Ratio profile depth to profile width 1:4 <u>or</u> - Bank (single or both sides) 10 % total length with bank impairments <u>or</u> - Longitudinal profile 70 % stretched or straightened	➢ Proportion of river length with discharge acceleration with - Ratio profile depth to profile width < 1:4 <u>or</u> - Bank (single or both sides) < 10 % total length with bank impaiments <u>or</u> - Longitudinal profile < 70 % stretched or straightened
➢ not passable artificial barriers with a height > 30 cm	➢ artificial barriers with a height 30 cm, passable artificial barriers with a height > 30 cm respectively
➢ cross-linking of the river with ox-bow-lakes nonexistent	➢ cross-linking of the river with ox-bow-lakes existent
➢ Intermittend flow regulation with flow spills	➢ flow regulation without spills

7.2 Necessary Hydro-morphological Changes to Achieve Good Ecological Status

For the final verification of a water body as heavily modified (designation), further test units are necessary (see figure 7.2.1). On the basis of the provisional 1. Negative list, measures are derived to reduce use-conditioned impacts. The environmental objective is to achieve a “good ecological status”. In the context of an economic analysis the measures are examined regarding their possible significant adverse effects on pressures. In case the measures impair existing pressures “better environmental options" are submitted of an economic view. The determined measures are checked for their technical feasibility and financial proportionateness. According to the results of this economic analysis arises the so-called "2. Negative/Positive list". The 2. Positive list contains the not significant impacts of the provisional 1. Positive list and in addition impacts, which were first classified as significant (cp. 1. Negative list) and now reduced or even removed toward “good ecological status” assistanced by economically checked measures. Specified impacts on the 2. Positive list do not lead to a designation of water bodies as heavily modified. It applies the environmental objective "good status".

All significant impacts caused by pressures, which cannot be modified or given up by economic proved measures remain on the 2. negative list. The determined impairments of the hydromorphological and biological characteristics of water bodies are accepted. Are there after the economic analysis still specifications on the 2. negative list, the water body or sections of the water body is to be designated as heavily modified. As environmental target the "good ecological potential" is to be aimed at.

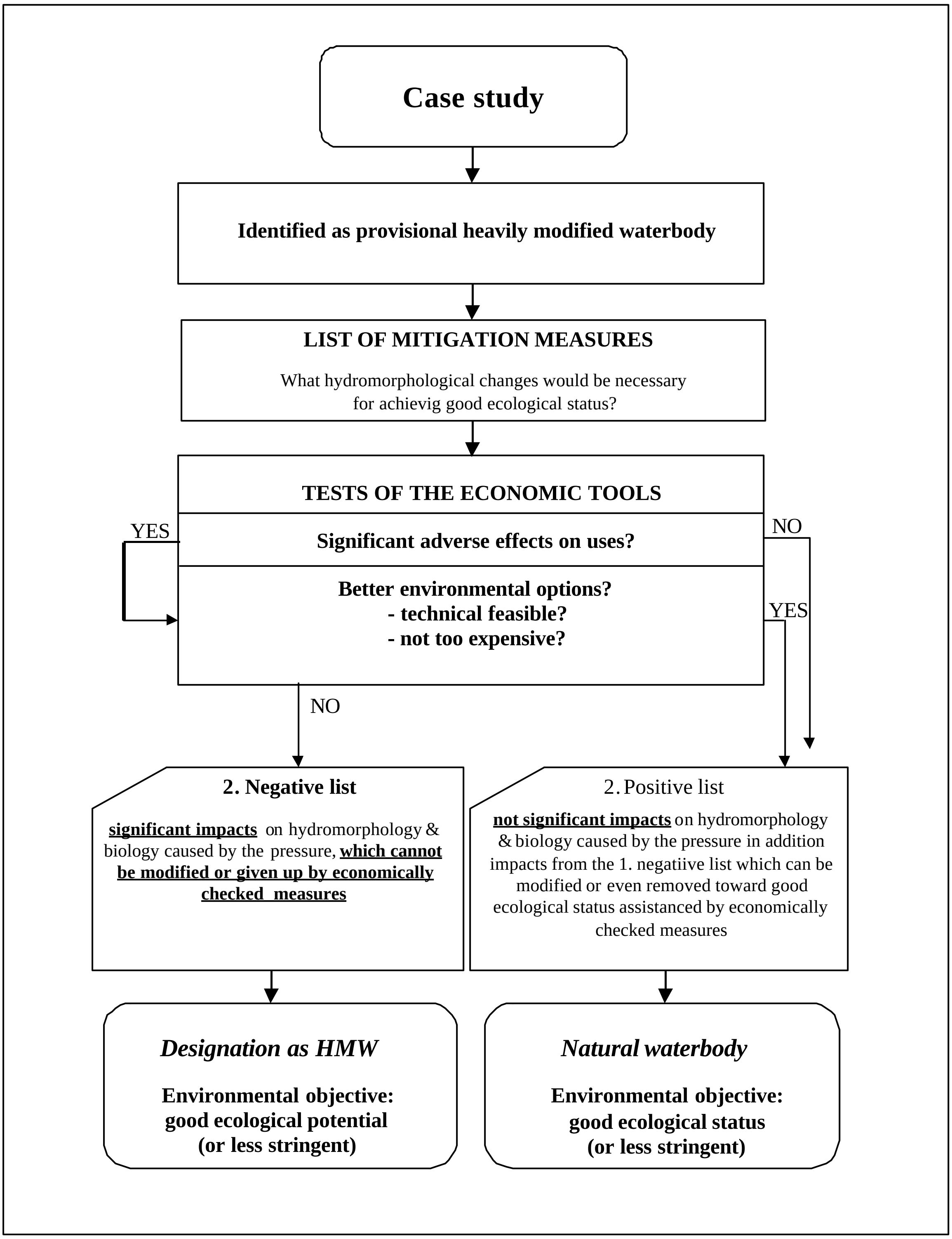


Figure 7.2.1: Further process of the "Identification of Heavily Modified Water Bodies" after designation as "Provisional Identification of Heavily Modified Water Bodies" concerning the subgroup "navigation"

For further representations and evaluations the upper Lahn River in Hesse (section 1) is regarded exemplary. This section reaches from the border to the Federal State North Rhine-Westphalia up to river mouth of the tributary Wetschaft (about 39 km). As main physical pressure on this section of the Lahn Basin hydropower generation is identified (see marked fields in table 5.1.2).

7.2.1 Required hydro-morphological changes and required measures to achieve the Good Ecological Status

Lahn River system is affected by various pressures and uses which have caused significant impacts on hydro-morphology (see chapter 5). The following description relates to the upstream section of the Lahn River (section 1, which reached from the hessian frontier to the river mouth of the tributary Wetschaft and Ohm respectively, about 39 km) as an example. In this river section the use ‚hydropower generation' has been considered to have led to significant impacts on hydro-morphology. The suggested mitigation measures therefore refer to hydropower as the dominant use.

As a general approach, two scenarios are assessed to achieve a good ecological status for the regarded section of the Lahn River: a modification of the pressure (a less extreme scenario, scenario B) as well as an abandonment of the weirs including the facilities and application factors associated with them in dependency of area-specific characteristics, i.e. depth erosion danger (as the most extreme case, scenario C) (tab. 7.2.1). Maintenance of hydropower (scenario A) will not be treated below because the good ecological status can´t be achieved with this quasi “status quo” scenario.

The mitigation measures which are considered in order to achieve a good ecological status refer primarily to the retrieval of the longitudinal river continuum by abandonment and modifications of the weirs respectively.

Tab. 7.2.1: Mitigation measures for the case study "Lahn"

(Section 1, hessian Lahn River up to river mouth of the tributary Wetschaft)

	Pressure: Hydropower generation		
	Scenario A	**Scenario B**	**Scenario C**
	Maintenance of hydro-power-generation	**Modification of hydropower-generation**	**Abandonment of the hydro-power-generation**
Action areas	i.e. unrestricted use of hydropower-generation further on	i.e. possible restriction of the use hydropower-generation is going to be accepted	i.e. omission of the use hydropower-generation incl. facilities and application factors associated with it
River continuum (Patency)	• Reduction of the barriers resulted from the capital equipment (i.e. by turbine rakes considering of the staff distance and incident-flow velocity)	• Abandonment of weirs out of action in dependency of area-specific characteristics (weir no. 45), • Building of a bypass channel (weir no.38), • Building of fish mitigation passes (weirs no. 28, 36, 37, 39, 42, 48, 51, 52, 56), • Observance of minimum rate of flow (particularly weirs no.36, 37, 52), • Lowering device of water level in impounded streches to max. 1m (all weirs), • Building of turbine rakes considering the staff distance and incident flow velocity (weirs no. 28, 36, 37, 39)	• Abandonment of weirs incl. facilities and application factors associated with them in dependency of area-specific characteristics (i.e. depth erosion danger)
Hydromorphology	• Decrease of building and maintenance measures	• Removement of bank and river bed fixation (operating ditch weir no.45) • Decrease of building and maintenance measures (all weirs)	• Removement of bank and river bed fixation/subnatural formation, rural development of the course and –removal (operating ditch), • Renaturation of bypass chanells
Catchment area	-	-	-

A distinction can be made between the weirs, which are still used by hydro-electric power plants and such weirs which are no longer used. The following measures are considered:

- removal of weirs which are no longer used
- restoration of the longitudinal river continuum by building fish migration passes at weirs without use of hydroelectric power
- restoration of the longitudinal river continuum by building fish migration passes at weirs with the use of hydroelectric power
- modification of the use (requirements to minimum rate of flow)
- abandonment of hydroelectric power (scenario C).

7.2.2 Impacts on water uses and significant adverse effects

Impacts on water uses arise in scenario B as a result of the costs for implementing fish migration passes as well as profitability losses by reduced generation and thus reduced income. Restoration measures at weirs which are not any longer in use for hydropower purposes, probably cause costs for local authorities / municipalities. However, no adverse effects for the use itself are involved. Therefore, in the first step (assessment of adverse effects on uses) only the weirs are regarded which still serve the purpose of hydropower generation.

At present at the Upper Lahn, there are still five small hydro-electric power plants with a maximum capacity of <100 kW in operation. Considering the effects of the suggested measures, (whether they lead to significant impacts or not) one has to differentiate between the local and national views. Regarding the percentage of power generation from small hydro-electric power plants in relation to the total electricity consumption in Germany, loss of the generation of the plants at the Lahn is not considered as significant (in 1994 only 0,33% of total consumption was provided from small hydroelectric plants).

Regarding the economics of business, meeting the ecological requirements will have impacts on the profitability of the plants. An assessment of the quantitative effects depends on maximum capacity, the amount of investment costs and the type of plant. An exact analysis of each affected plant cannot be done within the scope of this assessment. Therefore, we have to consider a range of variations. The following table summarise the results for a plant as an example concerning production costs.

Table 7.2.2: Effects of ecological requirements on production costs

Type of small hydro-electric plant				*Production costs [EUR/kWh]*		
Capacity	***Type of invest-ment***	***Investment costs [EUR/kW]***		***Without eco-logical re-quirements***	***With ecological requirements***	
					mean	*changes in [%]*
10 kW	new building	high	[17.895]	0,39	0,48	23%
		mean	[12.782]	0,28	0,37	32%
		low	[8.692]	0,19	0,28	48%
	re-building	high	[13.293]	0,29	0,38	31%
		mean	[9.715]	0,21	0,30	43%
		low	[6.647]	0,14	0,23	62%
	modernisation	high	[5.113]	0,11	0,20	81%
		mean	[3.579]	0,08	0,17	115%
		low	[2.556]	0,06	0,15	161%
60 kW	new building	high	[17.895]	0,39	0,42	7%
		mean	[12.782]	0,28	0,30	9%
		low	[8.692]	0,19	0,22	14%
	re-building	high	[13.293]	0,29	0,32	9%
		mean	[9.715]	0,21	0,24	12%
		low	[6.647]	0,14	0,17	18%
	modernisation	high	[5.113]	0,11	0,14	24%
		mean	[3.579]	0,08	0,10	34%
		low	[2.556]	0,06	0,08	48%
100 kW	new building	high	[17.895]	0,39	0,41	5%
		mean	[12.782]	0,28	0,30	6%
		low	[8.692]	0,19	0,21	10%
	re-building	high	[13.293]	0,29	0,31	6%
		mean	[9.715]	0,21	0,23	9%
		low	[6.647]	0,14	0,16	12%
	modernisation	high	[5.113]	0,11	0,13	16%
		mean	[3.579]	0,08	0,10	23%
		low	[2.556]	0,06	0,07	32%

Two conclusions can be drawn. On the one hand it can be stated that the plants can hardly break even power generation since the production costs are higher than the reimbursement (0,0767 €/kWh), even without ecological requirements. It is obvious that other (but not known) private interests are the main reason for investment and operation of the plants rather than profitable electricity generation. That means that the actual use seems not to be power generation. Effects on this (unknown) use, however, can hardly be assessed.

The starting point for economic assessment is the effect of (mean) ecological requirements on production costs. The percentage effects concerning ecological requirements compared to the previous production costs are shown (with - without conditions).

In a next step, the focus was put only on costs which will increase due to lower power generation (according to minimum water requirements). Capital costs for fish passes were not taken into consideration. The results show that in seven of nine cases, the cost increases are below 10%. If the effects on production costs are considered as a measure for assessment of significance the following has to be regarded. For the calculations above some simplifications are made: As basic assumptions, only new building, reactivation or modernisation of a plant with accordingly high capital costs are regarded. But, in the case of the Lahn very old plants are involved. Therefore, only operation costs have to be considered (and no amortisation). However, if only operating costs and no capital costs are included, current production costs are lower and ecological measures will not cause a loss on this scale.

Based on these considerations the effects on use are only partly regarded as significant.

The abandonment of the hydro-power (scenario C) is supposed as a significant impact. There is no need for any further assessment (clear cut).

7.2.3 Impacts on the wider environment

Adverse effects on the wider environment are not expected due to the mitigation measures.

7.3 Assessment of Other Environmental Options

7.3.1 Identification and definition of the beneficial objectives served by the modified characteristics of the water body

The beneficial objective served by the hydro-morphological changes of the water is the power generation. A closer look in the case of the river Lahn shows that the existing hydro-power plants possibly fulfil other functions. Although within the designation process these reasons cannot be taken into consideration.

7.3.2 Alternatives to the existing "water use"

Alternatives to achieve the same beneficial objective are the modification or abandonment of hydro-power generation and replacing this function with other energy sources. Only a replacement with existing power supply is considered. Hence, the existing use is compared with the modification as the proposed alternative and discussed concerning the technical feasibility, the environmental effects and the costs. The technical feasibility of the restoration measures is given.

Costs

Different types of costs can be differentiated: on the one hand the investment costs for measures at the weirs that are currently not used for hydro-power purposes. On the other hand, the costs concerning existing use: investment costs as well as costs for foregone economic benefits due to ecological requirements.

The following table summarises total costs.

Table 7.3.2: Costs of alternatives [in €]

measure	*Weir*	*cost*
restoration costs for non-used weirs		

removal of weirs	45	10.000
building of a bypass channel	38	95.000
construction of fish passes [1-2m]	56, 42	70.000
construction of fish passes [2-3m]	51, 48	130.000
removal of bank reinforcements [100m]	45	8.500
investment costs without hydroelectric plant		**313.500**
restoration costs for hydroelectric plants		
fish pass [10 kW]	37, 39	78.210
fish pass [60 kW]	28, 52	217.876
fish pass [100 kW]	36	116.800
investment costs for hydroelectric plants		**412.886**
income losses due to requirements [10 kW]	37, 39	5.738
income losses due to requirements [60 kW]	28, 52	10.044
income losses due to requirements [100 kW]	36	5.739
forgone benefit total		**21.521**
present value of foregone benefit (3%, 50J)		*553.731*
total costs (50 years)		**1.280.117**
costs per km delivered		38.327
annual costs		**49.4756**

Environmental effects

Next to costs, the environmental effects of the alternative ‚modification have to be taken into account. The advantages of hydropower plants as a renewable energy source refer to electricity generation without carbon-dioxide emissions. A methodological approach for the valuation of these environmental benefits bases on the estimation of avoidance costs. In relation to the total emissions in Germany 0,1% CO_2-emissions can be avoided due to hydro-power in general. For the small hydro-power plants only, the percentage is accordingly lower. On the other hand, negative environmental effects on the ecosystem and morphological conditions of the water course have been caused by hydro-power plants.

Disproportionate costs

Costs and the question of whether they are disproportionate or not have to be measured by comparing the ecological benefit which could be achieved with the restoration of the Upper Lahn. As a general approach, these benefits should be valued in monetary terms to carry out a cost-benefit analysis and by comparison of overall costs and benefit on a national level to arrive at the net social benefit.

Despite the difficulties involved in valuing positive and negative effects, the production costs of plants which cannot reach break-even point indicate that power generation with small hydro-power plants is a rather expensive way to avoid CO_2-emissions. Furthermore, they cause environmental damage. It is concluded that the negative impacts (measured in the value of a restored water course) compensate the positive effects (measured in avoidance costs) and therefore the costs are not disproportionate.

7.4 Designation of Heavily Modified Water Bodies

Based on the considerations and given information above the Upper Lahn should not be designated as heavily modified. On an overall economic view the proposed ecological measures do not have significant adverse effects on uses in general, the costs are not disproportiante including the negative adverse effects on environment. Concerning the economics of the business significance of impacts can only be assessed on a case-by-basis.

7.5 Discussion and Conclusions

Regarding the use ‚hydro-power generation' and particularly the case of small hydro-electric power plants the primary question refers to the level of view, i.e. considering local or national alternatives. For the decision both views should be taken into account.

Ecological measures probably affect the current uses. The reason is, that even if no ecological requirements are met the plants are not profitable in electricity generation – as shown. A profitable use of the plants therefore cannot be assumed a the main objective. Focussing on the national view and the beneficial objective ‚energy production' it can be concluded that the benefits of a modification are higher than the overall effects regarding the avoidance of CO_2-emissions.

Despite these general considerations with regard to the designation process the possibilities for restoration measures in the case of hydro-power plants are limited by the existing statutory background and decisions could be only be done on a case-by-case basis anyway.

Again it is pointed out that the use ‚hydro-power generation' has been treated as an example. That means, that the implementation of the mitigation measures above (Tab. 7.2.1) will not be sufficient to achieve the good ecological status at the Lahn River section regarded here.

The decision whether a water body is to designate as heavily modified or not, crucial depends on the underlying significance criteria (cp. Positive/Negative list, tab. 7.1.1). These criteria have to be greatly deliberated and carefully defined.

PART III

10 Conclusions, Options and Recommendations (5 pages)

10.1 Conclusions

10.1.1 Identification of water bodies, scaling

The very different characteristics within a river regarding morphological structures and pressures requires a subdivision into homogeneous sections (water bodies). This subdivision should be orientated primarily on the relevant pressures named in paper 5. A subdivision into several water streches with constant size as well as a subdivision according to administrative unities is unpracticable and not usefull. Also water bodies must not be too small, because the designation process is unpracticable and consequences such as operative monitoring of heavily modified waters require disproportionate effort.

Particularly large waters show different patterns of pressures along their longitudinal gradient (see case studies Lahn and Elbe). In many cases the headwaters represent widely undisturbed conditions while the downstream sections are more or less modified due to multiple anthropogenic uses. A subdivision according to the significant pressures will retrieve the upper, middle and downstream section in many cases as a result of the designation process. Where appropriate these sections may be differentiated in more detail. Small waters with relatively homogeneous pressures such as Seefelder Aach do not require a subdivision and can be treated as one water body.

A subdivision according to the relevant pressures will lead to meso-scaled units and water bodies. The german case studies indicate that water sections withmore than 40 kilometers in length and catchment areas up to ca. 1000 square kilometers are adequate.

10.1.2 Reference conditions

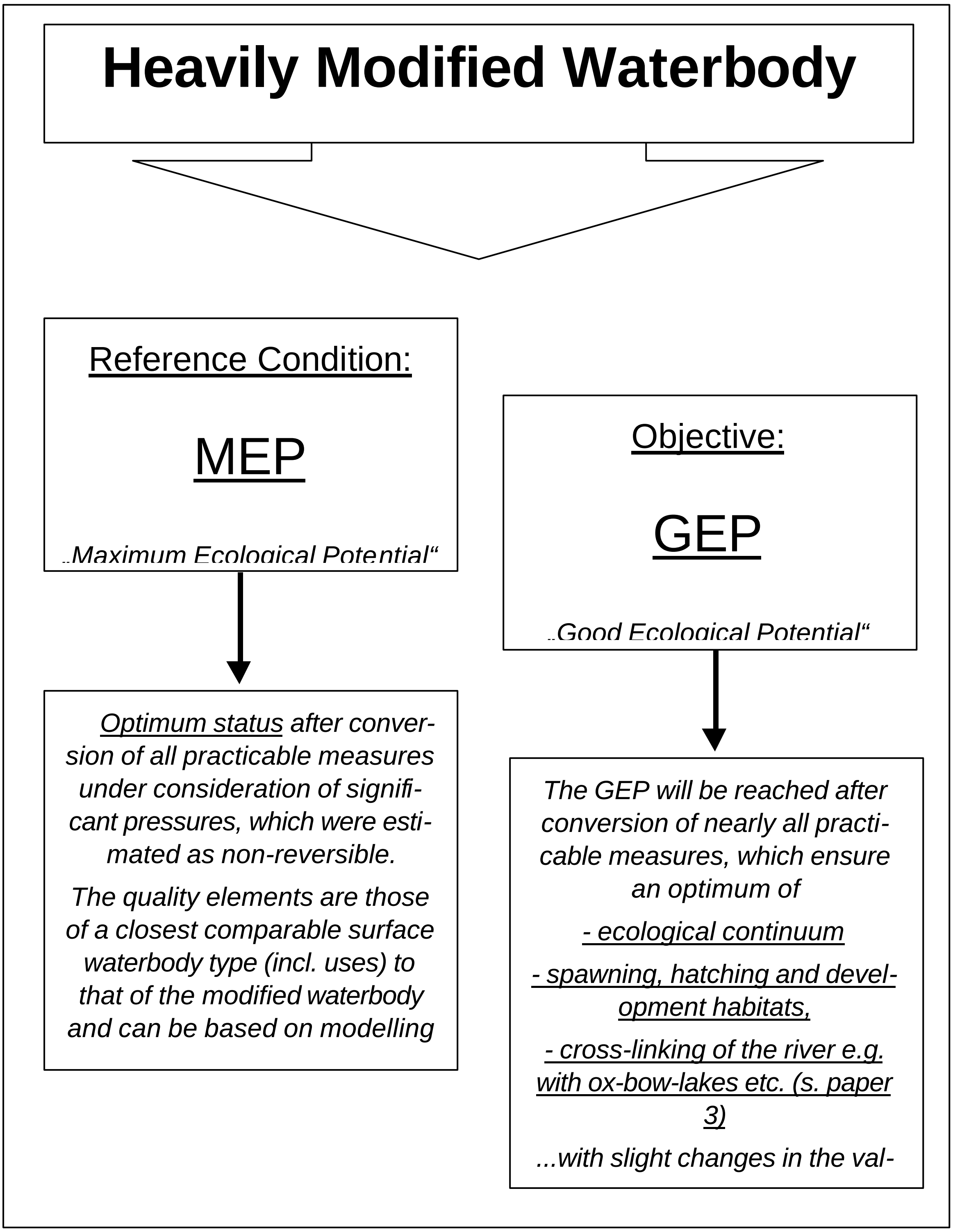
The definition of reference conditions on which status classification of HMWB is based is a difficult task and has not been solved in straightforeward approach. In our case studies we solely used natural waters as references which was proofed to be sufficient. There was no need to change the water type or even the water category. Even the upper Lahn River which is modified due to numerous impoundments (weirs, sluices) has been clearly identified as a running water.

The use of another HMWB as reference is not usefull according to our experiences.

10.1.3 Definition of MEP and GEP

For water bodies identified as being heavily modified, the reference conditions on which status classification is based, is called MEP.

Table 10.1.3: Maximum and Good Ecological Potential for Heavily Modified Waterbodies



HMWB have to meet certain minimum standards such as (see paper 3):

- River continuum

- Hydromorphological criteria (navigation, impoundments; see upper Lahn section and Elbe River)

10.1.4 Significant pressures / significance criteria

The designation of water bodies as being heavily modified substantially depends on the derivation of criteria for significant pressures and impacts, especially those which define physical alterations and damaged hydromorphology.

For the evaluation of the determined loads suitable criteria have to be applied. Currently significance criteria are compiled in the context of the LAWA-committee "Surface waters and coastal waters" following the WFD annex II. They were examined in modified and completed form in the case studies. Within this framework not the entire river catchment but the respective water body was regarded. That leads to the fact that despite of the development towards a national waterway, the use “navigation” may not be identified as being a significant pressure without specified properties (see case study “Elbe”). For this river weirs were not built over extended stretches of the water body and the longitudinal profile was evaluated as being "very good", while the fourth criterion according to table 5.1.2 is eliminated. Thus in this section the use "navigation" is not evaluated as being significant.

Within a total catchment area- analysis including tributaries numerous weirs with a height more than 30 cm have to be considered, which are established - among others - for navigation purposes. According to table 5.1.2 the use "navigation" would be classified as significant in these cases.

Another eventuality is a river not developed towards a national waterway, but is managed with the same boundary conditions. According to LAWA (2001) three criteria are examined in connection with each other. If two criteria are eliminated because of being in “good status” and one criterion is fulfilled, the river would not be designated as being “Provisionally Heavily Modified”.

These aspects clearly show the relevance of meaningful scales in a catchment area.

10.1.5 Quality elements

Quality elements for heavily modified water bodies are the same as for natural waters.

The four case studies clearly showed shown that despite of given significant pressures the analysis of the biological status does not inevitably lead to the designation as being a HMWB. Therefore the final designation of water bodies as being heavily modified should not be based on the river morphology alone. The biological status is the decisive factor for the designation of water bodies as heavily modified.

10.1.6 Designation as HMWB oder minor objectives

The question, how to handle waters/water bodies with disturbed river continuum and loss of migratory fish species, is still open. Numerous rivers e.g. the upper Lahn and

Dhünn may have a “good status” according to the majority of biological quality elements, but populations of long distance anadromous fish species, e.g. salmons, sea trouts and lampreys are missing due to barriers in downstream stretches. These water bodies must not designated as being heavily modified (see Terms of References), but “minor objectives” obtain.

10.1.7 Relation of HMWB and natural waters

In our study „Clarification of the EU WFD to heavily modified surface water bodies“ we have examined four rivers (Elbe, Lahn, Seefelder Aach and Dhünn) which differ in size, ecoregion and pressures and in so far can be seen as being representative for a wide range of conditions. None of the rivers and river sections has been designated as being heavily modified although they show significant hydromorphological alterations. This emphasises the fact that even significant physical alterations do not inevitably lead to the designation of a water/water body as being heavily modified. IN this respect the negative/positive lists of specified pressures were proved to be useful for decision processes.

10.2 Options and Recommendations

1. Identification of water bodies should be based on significant pressures supported by positive/negative lists with specified characteristics (see paper 5).

2. Regarded scale: meso scaling is sufficient and adequate.

3. Reference conditions for HMWB should be derived from natural waters. If necessary the category or type of water body may be changed.

4. HMWB have to meet certain minimum standards such as river continuum and a set of hydromorphological properties (see paper 3).

5. For the definition of MEP only natural waters should be used as references. MEP should be derived from natural references.

6. The analysis and the final designation of water bodies as being heavily modified substantially depends on significance parameters for categories of pressures. These have to be applied carefully and specific for each category.

7. The biological status (not river morphology) is the decisive factor for the designation of water bodies as being heavily modified. Chemical status is an important, but independent feature and boundary condition without consequences for the designa-

tion result.

8. For waters/water bodies with disturbed river continuum, missing anadromous fish species, but being biologically in “good status” for other quality elements minor objectives obtain.

9. Significant physical alterations do not inevitably lead to the designation of a water/water body as being heavily modified. Therefore, they may be designated as being “provisionally heavily modified” and ecological status may be evaluated using relevant indicators either based on existing data or operational monitoring.

10. For Germany (and potentially other countries with comparable population densities and infrastructure) numbers of waters/water bodies which have to be straightforwardly designated as being “heavily modified” may be rather the exception than the rule.

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12 List of Annexes