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D6.6.1 BOKU

Textual description of the river Kamp case study focusing on basic ecological and socio-economic features for an integrative and sustainable development of the riverine landscape

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Revision [0]

Abstract

This deliverable presents the detailed textual description of the river Kamp case study. It generally follows the structure of the deliverable D6.1 “Framework for conceptual QR description of case studies”. The two presented models capture important problems related to the sustainable development of the riverine landscape Kamp but with validity for most European river landscapes.

The first model focuses on the process of development and implementation of measures and points out the importance of information and participation for reaching a high integration of stakeholder interests and a low resistance of the local population against measures. A high sustainability of measures is achieved, when the acceptance of the measures is high. The approach is mainly based on experiences within the Kamp project.

The second model focuses on the restoration of a river stretch impacted by channelization and water abstraction with regard to the EU water framework directive. This approach tries to capture the problem in a more general way, reducing the complexity of multiple impacts by assumptions. An important aspect of restoring water abstraction is the application of management strategies like investing money to increase the efficacy of power plants to minimize economic loss and maximize the amount of water in the river. This aspect is not explicitly described within this deliverable but will be implemented during the modeling process. Generally the upcoming modeling process is supposed to significantly contribute to the further development of the presented models and scenarios.

Document history

Version	Status	Date	Author
1	Draft, initial version.	01.11.06	Andreas Zitek
2	Final version	30.11.06	Andreas Zitek

Content

1 INTRODUCTION

1.1 General objectives of the Austrian case study

The main focus of the case study from Austria lies on the sustainable development and management of riverine landscapes and is based on a project at the river Kamp. A second, more general focus is the restoration of the ecological integrity of the river for fish impacted by water abstraction and channelization with regard to the EU-Water-Framework-Directive (WFD). The qualitative reasoning case study from Austria therefore has the following objectives:

- To develop a better understanding and representation of entities and processes involved into the very complex task of sustainable development and management of riverine landscapes in European countries.
- To develop a QR-approach representing river restoration with regard to fish and the EU-WFD.

1.2 Background information to the River Kamp project

Catastrophic floods and inundations in August 2002, a nearly 2000-annual event, set new conditions for life and economy in the in the Kamp-valley (Fig. 1) facing flood control management, landscape architecture and land use planning with essential and future challenges.

Figure 1: The Kamp valley during the high flood event in 2002.

At the same time the question of an EU-Water Framework Directive-consistent treatment of the topics flood control/natural retention/prevention is arising. Consequently, the high water event finally represents a chance to develop the riverine landscape together with the local population as well as with the concerned scientific disciplines considering social, economic and ecological claims with regard to the EU-WFD. On this basis an overall integrated concept towards the sustainable development of the River Kamp landscape is being developed at the University of Natural Resources and Applied Life Sciences, Vienna. Besides the consideration of the spatial scale (from catchment level up to planning onto municipalities) the interdisciplinary work of the different disciplines biology/nature conservation, landscape planning, water resources management, regional planning, agriculture and forestry and hydropower production is of central relevance for the project. Moreover, planning is conducted in participation with authorities, stakeholders and the local population. The integration of the population into the planning activities exceeds pure information policy with the possibility for the local population to actively participate in developing the future scenarios for their valley.

The following working tasks are treated within the project (see also Fig. 2):

(1) A comprehensive investigation and representation of the current situation of the Kamp valley within 20 work-packages as well as of the different claims of stakeholders (uses, expectations, etc.).

(2) Adjustment and integration of planned and ongoing activities (flood control measures, flood forecasting and action plans for emergencies).

(3) Elaboration of sectoral mission statement concepts for the development of the valley from the viewpoint of the different disciplines as well as the municipalities/population (Fig. 3). Content and characteristics of a sectoral mission statement:

- Visionary & operative mission statement ("limits of reality")
- Values and deficits
- Development of actions ("Increase and protect values and decrease deficits")
- In total mission statements were developed by 14 work packages (Tab. 1)

(4) Collective elaboration of scenarios and actions for the future development of the riverine landscape of the Kamp valley (WP05 to WP20) which integrate the sectoral concepts/targets/requests considering general basic parameters (conditions/general regulations, like the aims of the WFD, Habitats directive, Birds directive, Natura2000...) (Fig. 2).

- In total 320 actions out of 14 sectoral mission statements were defined and have been grouped according to superordinated issues and spatial relevance (hydropower production, agriculture, tourism…).
- Visualization of reciprocal actions of the single actions to identify potential conflicts or positive interactions based on a matrix (Tab. 2 and Tab. 3).
- Identification of potential solutions

(5) Development of a super ordinate management plan on the basis of the scenarios developed in (4) (Fig. 3).

(6) Detailed planning at a pilot municipality.

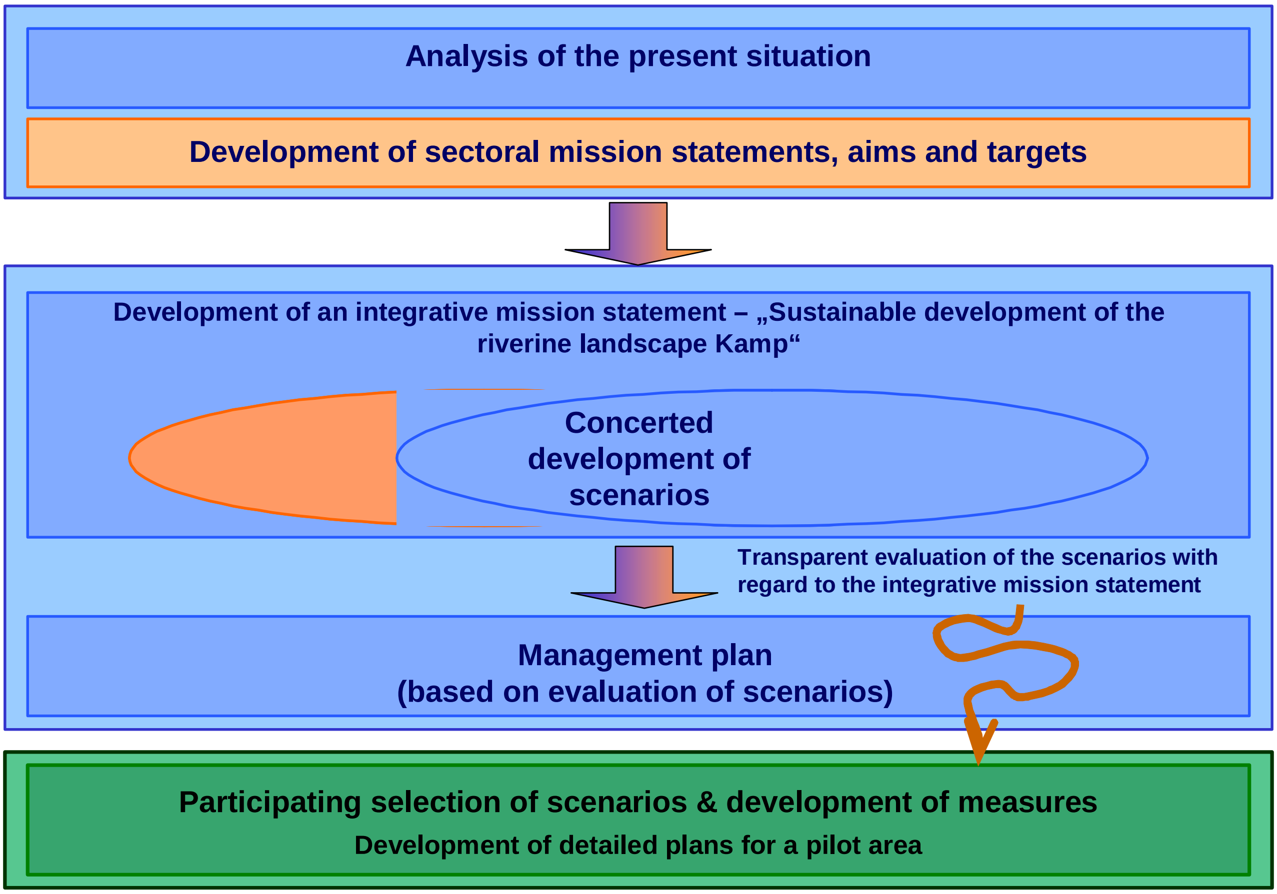

Figure 2: Project structure.

Table 1: Work packages that analyzed the current situation and developed mission statements; superordinated issues used to group mission statements from different working packages.

Current situation	Mission statement	Working package	Sectoral mission statements		Superordinate issues
Yes	Yes	WP05	Surface water runoff management	(1)	Hydropower management/hydrology
Yes	Yes	WP06	Influence of vegetation - woody debris	(2)	Energy production
Yes	No	WP07	Traffic infrastructure	(3)	Sediment managent
Yes	No	WP08	Building & construction secureness	(4)	Fishery management
Yes	Yes	WP09	Hydraulic engeneering & Energy production	(5)	River characteristics
Yes	Yes	WP10	River morphology and sediment transport	(6)	Groundwater and Siedlungswasserbau
Yes	Yes	WP11	Groundwater	(7)	Flood protection
Yes	Yes	WP12	Hydraulic engeneering for settlement	(8)	Hydrology
Yes	No	WP13	Catastrophe management	(9)	Infrasturcture
Yes	No	WP14	Ascertainment of loss	(10)	River connectivity
Yes	Yes	WP15.1	Fish fauna	(11)	Agriculture & forestry
Yes	Yes	WP15.2	Macrozoobenthos	(12)	Lateral water bodies
Yes	Yes	WP15.3	Floodplain vegetation & river structures	(13)	Public relations
Yes	Yes	WP15.4	Nature protection fundamentals	(14)	Land use planning
Yes	Yes	WP16	Land use planning	(15)	Woody debris
Yes	Yes	WP17	Agriculture, forestry	(16)	Tourism/recreation
Yes	Yes	WP18	Tourism	(17)	Shoreline
Yes	No	WP19.1	River basin management	(18)	Vegetation
Yes	Yes	WP20	Participation	(19)	Dynamic river landscape features
				(20)	Water quality

Table 2: Interactions between the actions developed by the different working packages: positive feedback loops (green) and conflicting targets (orange).

	AP5	AP6	AP9e	AP9w	AP10	AP11	AP12	AP15.1	AP15.2	AP15.3	AP15.4	AP16	AP17	AP18	AP20
AP5	AP5														
AP6		AP6													
AP9e			AP9e												
AP9w				AP9w											
AP10					AP10										
AP11						AP11									
AP12							AP12								
AP15.1								AP15.1							
AP15.2									AP15.2						
AP15.3										AP15.3					
AP15.4											AP15.4				
AP16												AP16			
AP17													AP17		
AP18														AP18	
AP20															AP20

Table 3: Interactions between the actions developed by the different working packages: number of positive feedback loops (green) and number of conflicting situations between working packages.

	AP5	AP6	AP9e	AP9w	AP10	AP11	AP12	AP15.1	AP15.2	AP15.3	AP15.4	AP16	AP17	AP18	AP20
AP5		9	8	15	18	0	9	9	7	18	25	40	3	0	36
AP6	9		12	33	16	2	0	0	10	45	69	0	3	0	28
AP9e	8	12		0	5	0	0	17	4	6	2	0	0	0	17
AP9w	15	33	0		33	9	14	0	19	25	62	9	0	0	22
AP10	18	16	5	33		1	0	7	37	68	74	3	1	0	32
AP11	0	2	0	9	1		7	0	11	4	3	0	0	0	0
AP12	9	0	0	14	0	7		0	3	0	6	0	0	0	5
AP15.1	9	0	17	0	7	0	0		9	23	30	0	0	0	25
AP15.2	7	10	4	19	37	11	3	9		30	44	18	3	0	21
AP15.3	18	45	6	25	68	4	0	23	30		106	34	6	0	47
AP15.4	25	69	2	62	74	3	6	30	44	106		6	33	0	61
AP16	40	0	0	9	3	0	0	0	18	34	6		5	0	5
AP17	3	3	0	0	1	0	0	0	3	6	33	5		2	1
AP18	0	0	0	0	0	0	0	0	0	0	0	0	2		0
AP20	36	28	17	22	32	0	5	25	21	47	61	5	1	0	2
Anzahl der "grünen" Matrizenfelder (positive Verstärkung)	*197*	*227*	*71*	*241*	*295*	*37*	*44*	*120*	*216*	*412*	*521*	*120*	*57*	*2*	*302*
Gesamtfelder je AP	*3036*	*4554*	*1771*	*2783*	*3542*	*2024*	*3036*	*4807*	*3289*	*4554*	*11638*	*2530*	*1771*	*5060*	*9614*
%-Anteil der grünen Matrizenfelder an den Gesamtfeldern des jeweiligen AP's	*6,5*	*5,0*	*4,0*	*8,7*	*8,3*	*1,8*	*1,4*	*2,5*	*6,6*	*9,0*	*4,5*	*4,7*	*3,2*	*0,0*	*3,1*

	AP5	AP6	AP9e	AP9w	AP10	AP11	AP12	AP15.1	AP15.2	AP15.3	AP15.4	AP16	AP17	AP18	AP20
AP5		0	5	3	0	0	0	0	1	5	4	0	1	0	8
AP6	0		0	10	0	0	0	0	4	14	33	0	1	0	6
AP9e	5	0		0	4	0	0	27	9	22	16	0	0	0	12
AP9w	3	10	0		11	0	0	0	3	14	20	0	0	0	2
AP10	0	0	4	11		0	0	0	0	0	2	0	0	0	16
AP11	0	0	0	0	0		0	0	0	0	0	0	0	0	0
AP12	0	0	0	0	0	0		0	0	0	0	0	0	0	0
AP15.1	0	0	27	0	0	0	0		0	0	1	0	0	0	13
AP15.2	1	4	9	3	0	0	0	0		0	0	0	0	0	3
AP15.3	5	14	22	14	0	0	0	0	0		7	0	3	0	22
AP15.4	4	33	16	20	2	0	0	1	0	7		0	19	2	20
AP16	0	0	0	0	0	0	0	0	0	0	0		0	0	2
AP17	1	1	0	0	0	0	0	0	0	3	19	0		0	0
AP18	0	0	0	0	0	0	0	0	0	0	2	0	0		0
AP20	8	6	12	2	16	0	0	13	3	22	20	2	0	0	12
Anzahl der Konfliktfelder	*27*	*68*	*95*	*63*	*33*	*0*	*0*	*41*	*20*	*87*	*124*	*2*	*24*	*2*	*116*
Gesamtfelder/AP	*3036*	*4554*	*1771*	*2783*	*3542*	*2024*	*3036*	*4807*	*3289*	*4554*	*11638*	*2530*	*1771*	*5060*	*9614*
%-Anteil an den Gesamtfeldern/AP	*0,9*	*1,5*	*5,4*	*2,3*	*0,9*	*0,0*	*0,0*	*0,9*	*0,6*	*1,9*	*1,1*	*0,1*	*1,4*	*0,0*	*1,2*

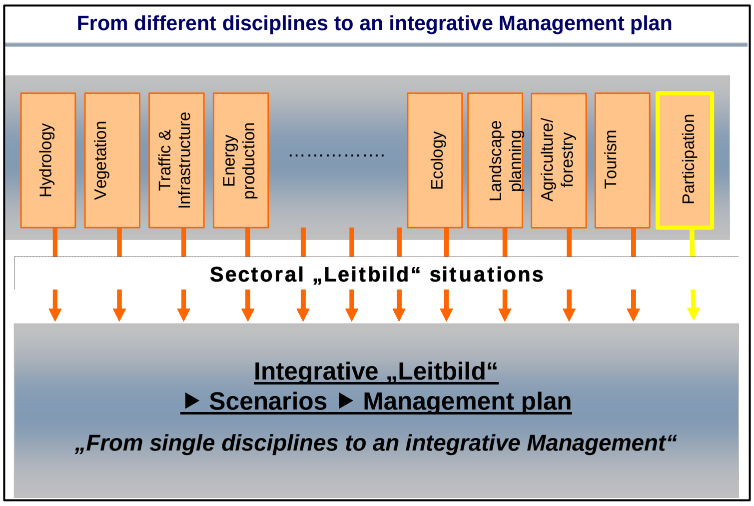

Figure 3: From single disciplines to an integrative management plan.

1.3 The Kamp Valley

1.3.1 Site description

The River Kamp lies in the North-Eastern part of Austria (Fig. 4). It has a length of 160 km and a catchment area of 1753 km² (Muhar, 1998); the mean slope of the river in the project area is between 1‰ and 3.4‰. The natural discharge regime is a pluvio-nivale A regime (Mader et al., 1996). Mean annual discharge at the downstream end of the project area, at the water gauge at Stiefern near its confluence with the river Danube is about 8 m³ (HDÖ, 1999). Other possible discharge situations are presented in Tab. 4.

Table 4: Different discharge situations at the Kamp valley.

Event	Annuality	Maximum discharge
Unit	(years)	(m³/s)
Flood 2002	> 1000	640
Flood 1996	10-20	155
< Flood 1996	< 10	115
> Flood 1996	50	240
>> Flood 1996	100	280

The river course varies between (anthropogenic and natural) straightened and meandering. The dominating geological formation is characterized by siliceous material (granite and gneiss). Nowadays the discharge regime and the temperature regime of the river are heavily modified by large impoundments in the upstream part of the project area used for energy production.

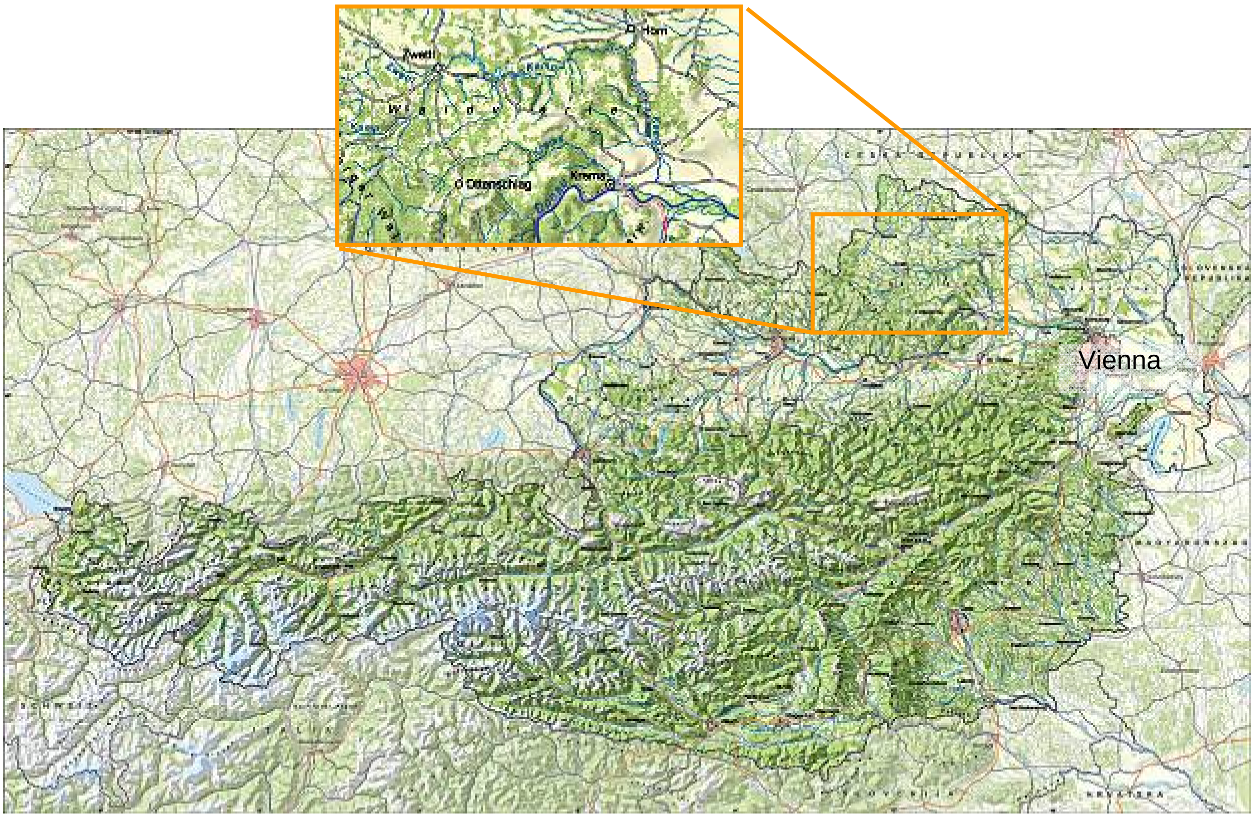

Figure 4: Situation of the River Kamp in Austria.

1.3.2 Human occupation of the basin

1.3.2.1 History of settlement and population density

The Kamp valley region with an area of about 5600km² represents about 30% of the area of Lower Austria. Population density with about 55 inh/km² is relatively low with regard to the population density in Lower Austria (81 inh/km²). In total 310 875 people are living on 5614 km². 3421 km² are permanent residential area (61%) and 37% are covered by forest. In the central management area on 350 km² about 23 000 people are living within 13 municipalities (Zwettl, Rastenfeld, Pölla, Krumau am Kamp, St

Leonhard am Hornerwald, Altenburg, Rosenburg-Mold, Gars am Kamp, Schönberg am Kamp, Langenlois, Hadersdorf-Kammern, see Fig. 5). Mean population density within these municipalities is low (36 inh/km²).

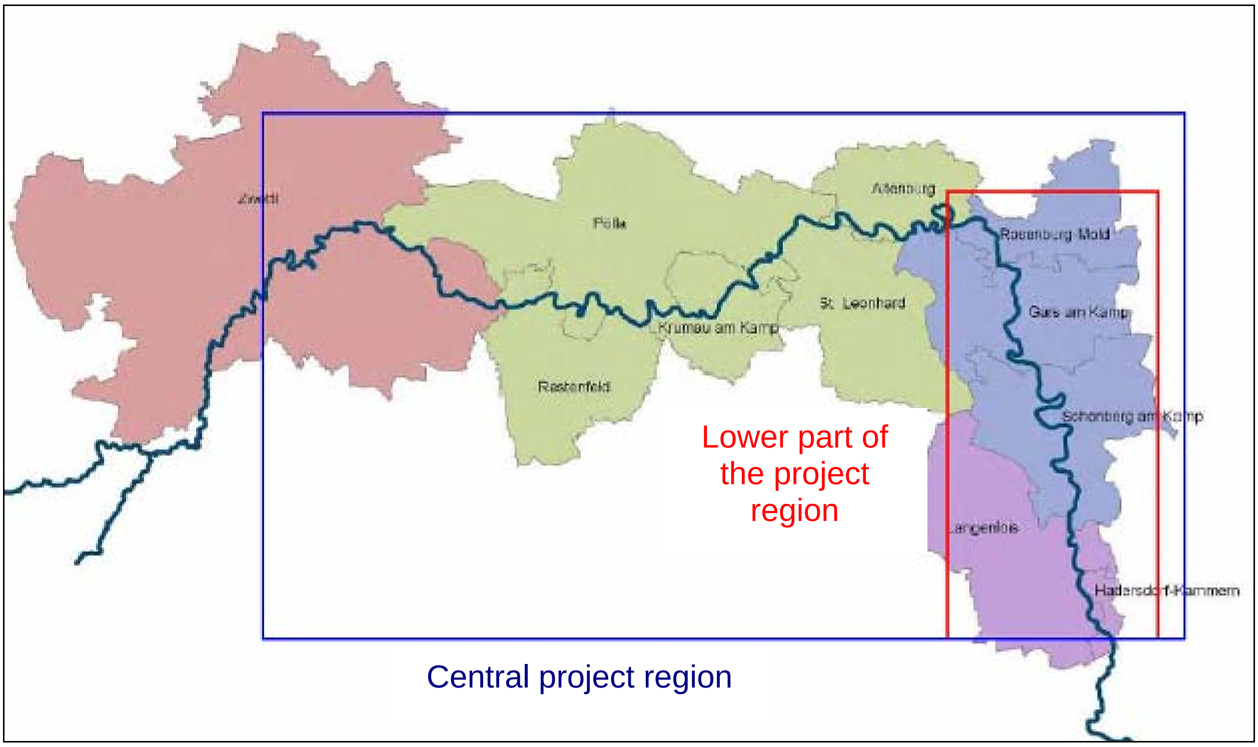

Figure 5: Municipalities within the central project region.

Settlement of the upper and lower project region has been documented since the younger stone age. More intensive settlement within the Kamp valley started in the 8th century; due to its wider valley floors the upper and lower regions were preferred to the middle region, where steep mountains are dominating and only castles were built. The most downstream section was used for settlement and agriculture since the mid-age. Cultural centers at this time were Zwettl, Gars and Altenburg. There has been a long tradition in waterpower use for mills and saw mills within the whole valley.

1.3.2.2 River engineering and energy production

The first river engineering measures exceeding local bank protection were carried out around 1900. In the middle valley section unlike the lower reaches of the river the river only local river engineering measures are existing. The analysis of the historical evolution of the run-of-river power stations showed that most sites have existed for several centuries and that only the initial use of the mills had changed. On account of this evolution and by the establishment of the artificial lakes (Ottenstein, Dobra and Thurnberg) used for hydropower production the character of the river has been substantially changed. The three reservoir power stations existing at upper section of the project area were built in the sixties and are responsible for an constant discharge regime (about 4 m³/s) without small and medium flood events and for the change of the natural temperature regime of the river due to hypolimnetic releases of water.

About 16 running power stations lie in the central to lower investigation area (Fig. 6). The drop heights range between 13,0 and 1,1 m. the middle drop height is 2,9 m, the mean turbine discharge lies at 4,9 m³/s (2,4 to 10,0 m³/s). These weirs create continuum interruptions for migrating fish as only a few of them are equipped with fish migration facilities. Some of the power plants situated at the valley abstract water from the river for hydropower production and cause significant problems to fish by the creation of residual flow stretches. A third of the turbines is between 26 and 50 years old. The capacity for energy production of the individual power plants is between 25 to 850 kilowatt. The total efficacy of the individual plants is between 0,61 and in the ideal case 0,85. Important problems related to the energy use within the Kamp valley are the damages by the high flood in 2002, the state and the age of the small hydropower stations, the mode of operation and the state of the weirs.

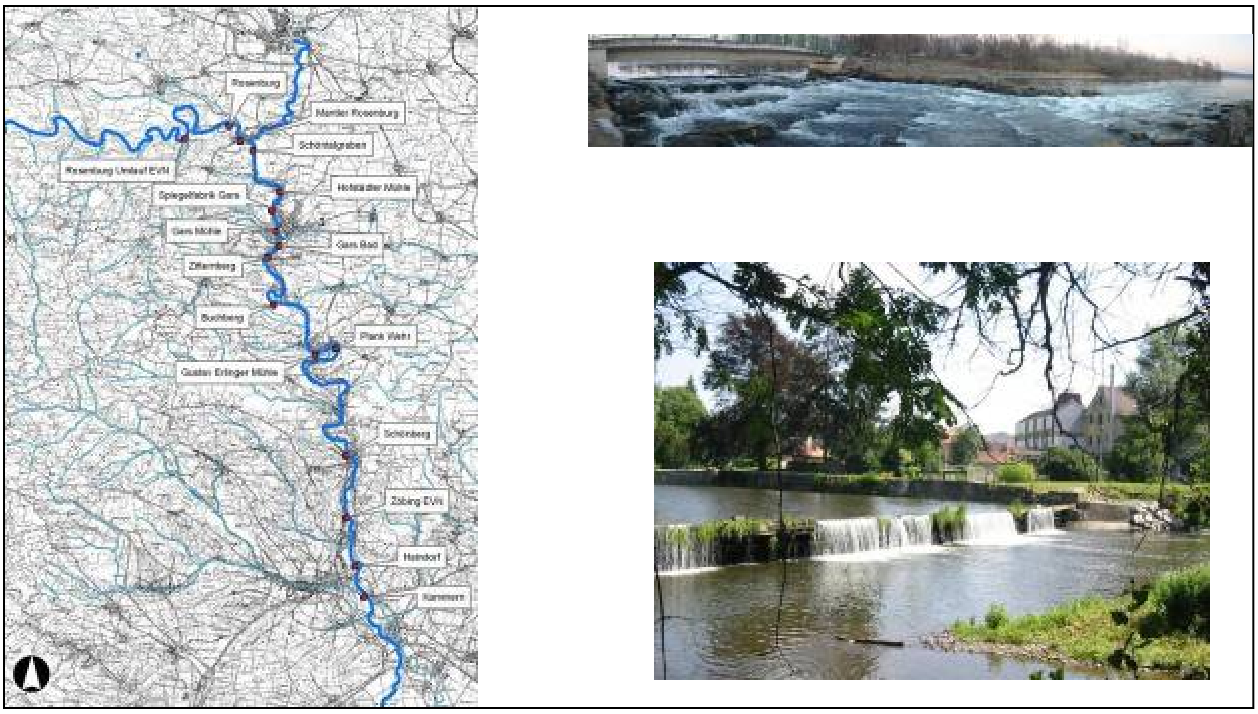

Figure 6: Location of weirs used for energy production in the lower part of the Kamp river.

1.3.2.3 Flood protection

Along the course of the river Kamp after the catastrophic floods in 2002 damage to buildings at a amount of 198 Mio € have been documented. Due to relatively low precipitation at this area conflicts between settlement and the riverine landscape have been circumstantial in the past. By now, about 0.9% of building land is situated within the HQ100 area in the upper project area (Zwettl-Altenburg); between Rosenburg-Mold and Hadersdorf-Kammern about 6.4% of the building land is situated within the HQ100 area; this is to be traced back to the wider valley situation in this area. Superior aim of the integrative flood protection management is safety for buildings up to a 100-year flood. Integrative measures should also favor natural flora and fauna and should be accepted by the local population. The acceptance of measures by the local population is an important task here. With regard to the safety of buildings and Infrastructure active (dams) and passive (retention areas) flood management actions will be set.

1.3.2.4 Biotic community

In total in the catchment area of the river Kamp Natura2000 protected areas for 45 animal (15 fish species) and plant species of Appendix II, and 18 habitat types of appendix I of EU-Habitat directive as well as 26 bird species listed in appendix I of the Bird directive are existing. The biotic fish community is characterized by four different community compositions (from 2 in the upper regions to 50 species at the river mouth to the Danube) divided into leading species, accompanying and rare species based on (Haunschmid et al., 2006) (Fig. 7).

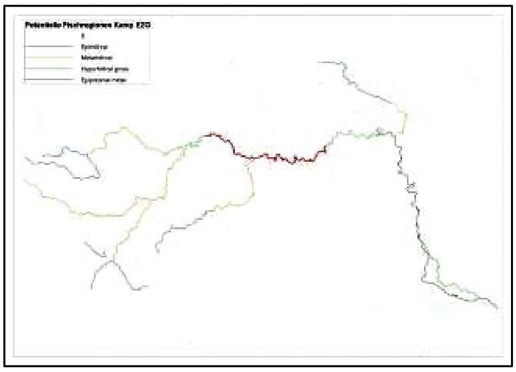

Figure 7: Potential zonation of the river Kamp catchment with regard to fish communities (Haunschmid et al., 2006).

Fish ecological integrity (shown in a five level scheme based on Haunschmid et al, 2006 in Fig. 8) is impacted by various human pressures. Only small sections of the river Kamp are in a good ecological status with regard to the EU-WFD.

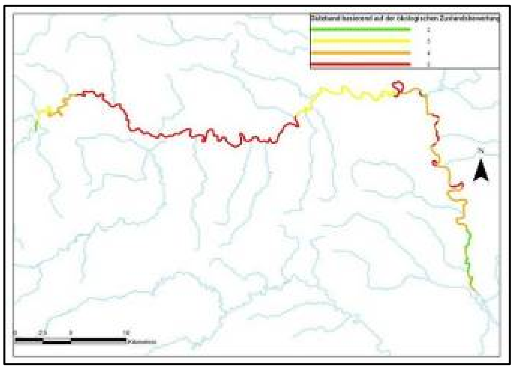

Figure 8: Ecological status (5-level scheme) of the river Kamp with regard to fish and the EU-WFD.

The main pressures on the fish fauna within the Kamp valley are (1) water abstraction and altered hydrology, (2) altered temperature regime, (3) interruption of the longitudinal connectivity, (4) loss of lateral connectivity, (5) channelisation and (6) lack of natural river widening. The large impounded river sections upstream are classified as heavily modified with regard o the WFD.

Possible actions for restoring the ecological integrity (except for the heavily modified areas of the large impoundments) include:

- Restoration of the longitudinal connectivity.
- Restoration of the natural hydrology.
- Restoration of the temperature regime.
- Restoration of the lateral connectivity.
- Minimizing residual flow situations.
- Fisheries management based on ecological issues.
- Restoration of channelised river sections.

Analysis of the possible restoration measures within a efficiency matrix showed, that only the combination of all types of measures will help to reach the „good ecological status“ of the water bodies at the river Kamp in the project area.

1.3.3 Participation and information policy

One of the most important management tasks within the River Kamp project was the participation of the local population for as a sustainable development of the valley landscape. Through participation of citizens less popular measures for reduction of conflicts and costs that are necessary could be implemented. Local people have been involved within workshops where regional visions and targets with regard to society, traffic, education, culture, landscape, agriculture, forestry, fisheries and hunting, economy/jobs, energy production and tourism have been developed. To address the public as broad as possible information on all relevant topics was provided by personal telephone calls, press sending via the municipality newspaper and/or regional newspapers, posters, information events as well as via the project Web site. Participation of citizens is considered as a main component of the sustainable development of the river Kamp landscape.

1.3.4 River restoration with regard to the EU-Water-Framework-Directive

In 2000 the European union launched a new water legislation, the EU-Water Framework Directive (EU-WFD, http://www.euwfd.com). This legislation represents the overriding framework for sustainable river management of surface water resources. Within this framework is the development of a programme of measures which are targeted to rehabilitate the impact of current and historical activities which have degraded the ecology of waters across Europe. The main focus of the WFD is the management of river basins, the natural geographic and hydrologic unit. One of the key objectives of the WFD is to achieve the “good ecological status” of running waters by 2015. Fish are one out of four organism groups (fish, macrozoobenthos, algae, macrophytes) that can be used as an indicator to describe the ecological status of running waters. (Tab. 5). National legislation also forms an important frame for activities with regard to the development and management of riverine landscapes, why national instruments are needed to optimize restoration measures; particularly as the WFD demands for economic analyses to evaluate the most efficient combination of measures.

Table 5: Definitions used to define high, good and moderate status of fish fauna according to the WFD.

High status	Good status	Moderate status
Species composition and abundance correspond totally or nearly totally to undisturbed conditions. All the type-specific disturbance-sensitive species are present. The age structures of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any particular species.	There are slight changes in species composition and abundance from the type-specific communities attributable to anthropogenic impacts on physico-chemical and hydromorphological quality elements. The age structures of the fish communities show signs of disturbance attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements, and, in a few instances, are indicative of a failure in the reproduction or development of a particular species, to the extent that some age classes may be missing.	The composition and abundance of fish species differ moderately from the type-specific communities attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements. The age structure of the fish communities shows major signs of anthropogenic disturbance, to the extent that a moderate proportion of the type specific species are absent or of very low abundance.

The basic step for the implementation of the WFD was the assessment of the current state of Austrian rivers based on the "Common Implementation Strategy Guidance Documents" of the EU. Based on various different methods, the DPSIR-method (Fig. 9) was used to assess pressures, their relevance and their effect on the ecological integrity of rivers (BMLFUW, 2005). In principle the modelling approach will follow this approach. A fish-based typology of rivers, a national assessment method for assessing the ecological status of rivers by fish (Haunschmid et al., 2006) and the European Fish Index "EFI" (Pont et al., 2006) form the basis for assessment and development of measures for restoring Austrian rivers with regard to the EU-WFD.

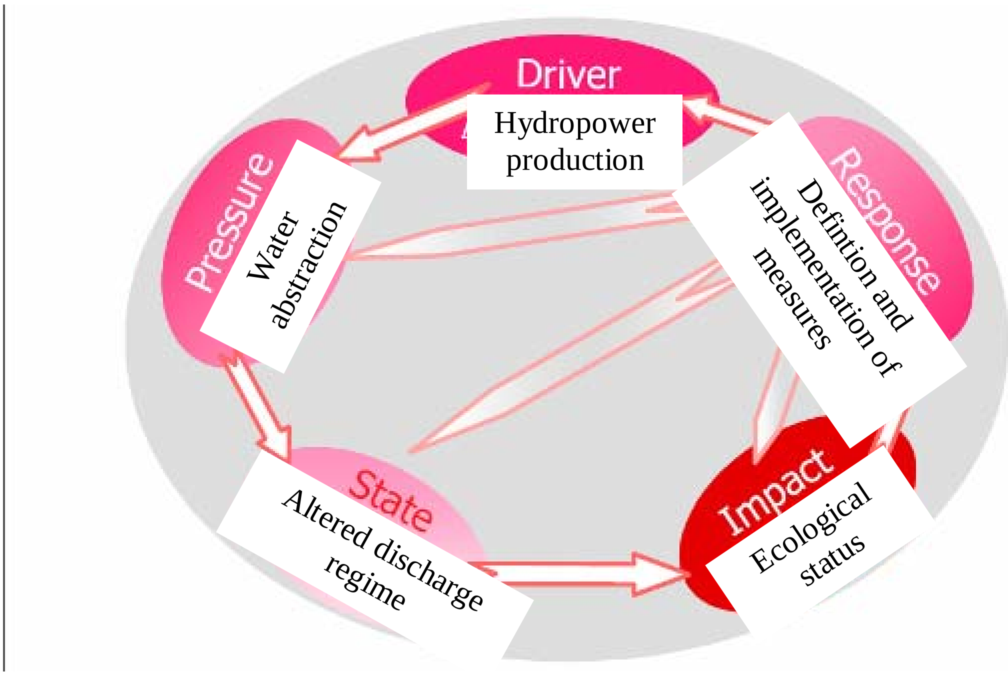

Figure 9: Principle of the DPSIR method: driver=relevant activity, pressure=type of pressure, state=actual ecological integrity, impact=effect on ecological status, response=measure (BMLFUW, 2005)

1.3.4.1 Restoration approach

River restoration has proceeded from actions ameliorating impacts at the reach scale to serious plans to re-regulate or unregulate entire catchments of large rivers, expressly to enhance natural attributes that have been measurably degraded (Stanford & Ward, 2001).

The term restoration, which in the most formal sense is returning an ecosystem to its original pre-disturbance state (Bradshaw, 1996; Middleton, 1999; Roni et al., 2005), has commonly been used to refer to all types of habitat manipulations including enhancement, improvement, mitigation, habitat creation, and other actions (Fig. 10). These activities are more accurately termed rehabilitation, as most do not truly restore a system and in many areas were the land use is predominantly agricultural, residential, urban or industrial, true restoration is not feasible in the foreseeable future (Stanford et al., 1996). As the WFD demands for the restoration of riverine systems towards the original pre-disturbance state, focusing on all main components of the ecological integrity of riverine systems, the term habitat restoration is further used.

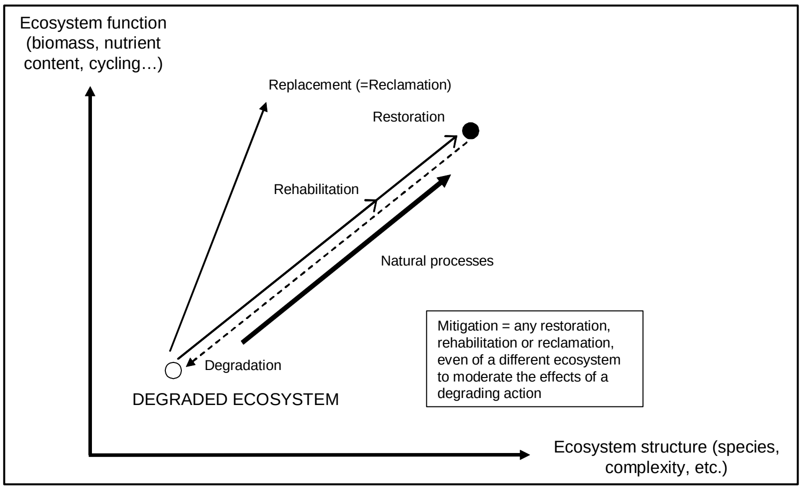

Figure 10: Several different options in remediation work (from Bradshaw, 1996).

Knowing that it takes time for fish to recover habitats (Niemi et al., 1990; Detenbeck et al., 1992; Raborn & Schramm, 2003), which besides natural variability will influence the interpretation of the efficiency of measures, treating restoration as reversed impact (Fig. 10) is being considered as a pragmatic way to reduce the hydromorphological pressures at Austrian rivers.

Main pressures on Austrian rivers are generally mainly of hydro-morphological character as water quality problems have been solved during the last two decades. The following pressures are thought to be most relevant for Austrian rivers (Zitek, 2006):

- alteration of the natural flow regime (hydropeaking, water diversion)
- impoundment
- reservoir flushing (is considered as a critical short term impact altering water
- quality and natural morphological character)
- land use (is considered to be an important indicator being indirectly related to
- many kinds of impacts)
- alteration of the natural morphological character (channelisation)
- alteration of water quality (pollution)
- loss of lateral, longitudinal and vertical connectivity
- shipping
- river bed degradation
- fish eaters, stocking, fishing pressure and alien fish species are additionally considered as potential factors that can influence the fish fauna at a given site.
- multiple/cumulative impacts.

2 Orientation and initial specification

2.1 Main model goals

Based on River Kamp case study two main model goals were identified to represent basic processes for a sustainable development of riverine landscapes:

- To develop a better understanding and representation of entities and processes involved into the very complex task of sustainable development and management of riverine landscapes in industrialized countries.
- To develop a QR-approach representing river restoration with regard to fish and the EU-WFD.

Therefore the first model focuses on the process of development and implementation of measures and points out the importance of information and participation for reaching a high integration of stakeholder interests and a low resistance of the local population against measures. A high sustainability of measures is achieved, when the acceptance of the measures is high. The approach is mainly based on experiences within the Kamp project.

The second model focuses on the restoration of a river stretch impacted by channelization and water abstraction with regard to the EU water framework directive. This approach tries to capture the problem in a more general way, reducing the complexity of multiple impacts by assumptions. An important aspect of restoring water abstraction is the application of management strategies like investing money to increase the efficacy of power plants to minimize economic loss and maximize the amount of water in the river. This aspect is not explicitly described in this deliverable but will be implemented during the upcoming modeling process.

2.2 River Kamp Sustainability concept map

To describe the most important concepts being involved into the sustainable development of the riverine landscape Kamp, a concept map has bee developed (Fig. 11). This concept map includes the basic concepts of sustainable development like human society (with its sub-concepts of legislation, infrastructure, culture), institutions, nature and economy.

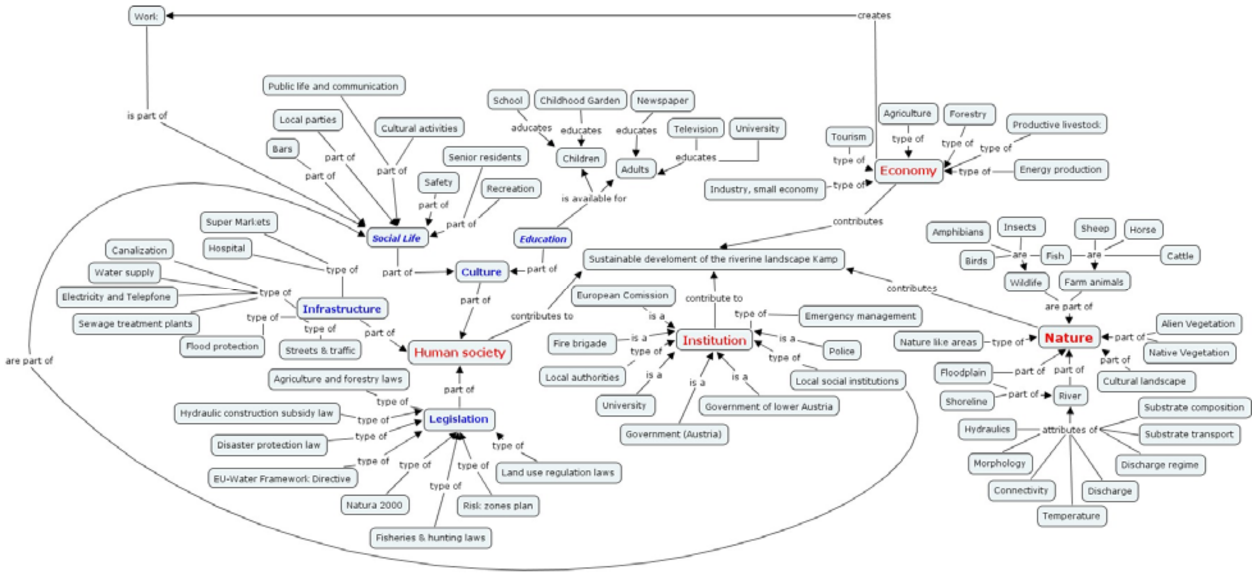

Figure 11: Concept map representing the basic concepts involved into the sustainable development of the riverine landscape Kamp.

2.3 Building up the River Kamp system structure

To set the system boundaries for the modeling approach that represents the interactions between energy production, flood protection and the river the system structure including the main interactions of the entities involved is developed (Fig. 12). Entities involved are human, infrastructure, hydropower production, economy, flood protection, vegetation, land, river, animal, river features, legislation and institution.

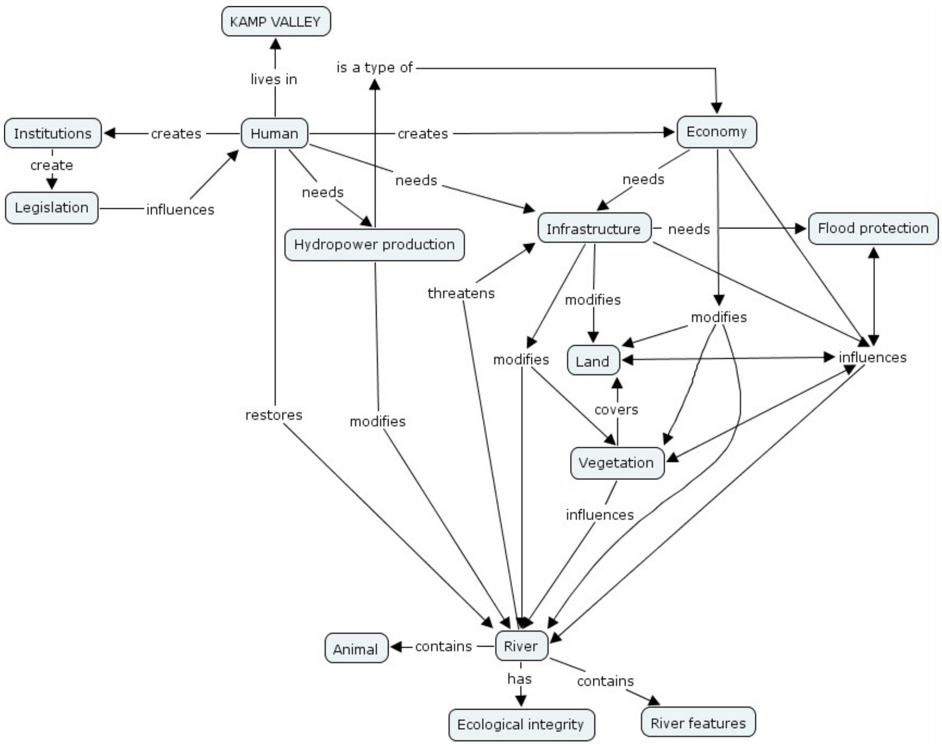

Figure 12: System structure of the Kamp valley without restoration activity.

3 System selection and structural model

Two sub-systems were selected for the modeling process:

- the development and implementation of measures with regard to information and participation processes with the acceptance of a measures as indicator for sustainability
- the restoration of river sites impacted by water abstraction and channelization with regard to the EU-WFD.

3.1 Model A - *“Acceptance of a measure”*

3.1.1 Entities overview for the “Acceptance of a measure model” (Model A)

The most relevant entities for the model A are “Environment” (Local environment, social environment), Human (Stakeholder, Local population, Politician, Planner), “Management action” (Information, Participation, Development of measures, Implementation of measures), “Economic unit” (Money) and “Indicator” (Acceptance of a measure).

3.1.2 Configurations overview

An initial list of entities and their configurations is presented below. If new entities are to be included, new configurations may be required.

- Human *lives in* Environment
- Planner *sets* Management action
- Economic unit *influences* Management action
- Information *informs* local population and stakeholders
- Participation *integrates* stakeholders
- Management action *influences* indicator

3.1.3 Agents

An catastrophic event sets the pre-requisition for the development of measures and is treated as an agent.

3.1.4 Assumptions

The WFD defines the role that ecological targets have within planning activities; environmental sustainability due to measures should be reached following the approach of minimizing economic loss. It is assumed that the participation process creates multipliers, that have a high influence on the acceptance of a measure within the local social environment. But additionally official information is still important to increase the integration of the local environment to reach a high acceptance of the measures.

3.2 *Model B - “River restoration focusing on channelization and water abstraction”*

The most relevant entities for the model B are “Water body” (River, Residual flow stretch), “River feature” (Water, Habitat, Substrate, Shoreline vegetation), “Driver” (Hydropower production, Flood protection), “Technology” (Hydropower plant), “Human pressure” (Water abstraction, Channelization), “Indicator” (Fish, Ecological integrity), “Management action” (Restoration), “Economic unit” (Money).

3.2.1 Configurations overview

An initial list of entities and their configurations is presented below. If new entities are to be included, new configurations may be required.

- Water body *contains* river features
- Human pressure *modifies* river features
- River features *influence* indicators

- Management action *modifies* human pressure
- Management action *influences* economic unit

3.2.2 Agents

The WFD directive is acting as an agent that influences the whole modeling approach (5-level scheme, economic commensurability of measures, indicators…)

3.2.3 Assumptions

It is assumed, that flood protection of a riverine landscape is often achieved by river channelization together with the construction of levees. But only channelization is treated as an direct impact on habitat heterogeneity within the models neglecting the importance of lateral connectivity for fish that is lost due to levees. It is further assumed that the WFD status reflects the degree of the impact. Temperature changes due to the impoundment upstream are not integrated into models yet. Also the effect of the interruption of longitudinal connectivity is not integrated.

4 Global behaviour

In this section the global behavior of models A and B is described. Two causal models are presented in order to address the two modeling issues.

4.1 Defining processes

Exploring the concept of processes yielded four types of processes, according to the principal entities involved: water; biological; energy; human actions. They are presented below in tables identifying the process, the entities involved, the proposed main quantities (rates (r) and state variables (sv)), their effects and the conditions for the processes to be started, stopped and/or modified.

4.1.1 Water Processes

Name	Entities	Quantities (rate/sv)	Effect	Start/stop & modification conditions
Natural water flow	- water body - river features (temperature, substrate, lateral connectivity, discharge regime, amount of water) - indicator (fish) - human pressure (water abstraction)	- natural flow (r) - Water volume (sv)	Due to variable rainfall, snow melt, climate, geology various human pressures (water abstraction) rivers transport different water volumes resulting in different quantities of water at certain times of the year caused by a regime (natural or modified, constant or variable). (Natural) variable regimes with floods are necessary to keep the habitat quality for fish (mainly the quality of spawning places) by cleaning substrate and preventing it from clogging. In residual flow stretches substrate clogging is an effect. Another effect caused by a reduction of water is the change of temperature regime (warming of the water due to water abstraction and/or removal of shoreline vegetation). A variable discharge regime also provides lateral connectivity to the floodplain which is also a basic requirement for successful reproduction and recruitment of some fish species.	In normal conditions, this process is variable, and only stopping or constant if there isn't enough water in the river (e.g. due to abstraction).

4.1.2 Energy processes

Name	Entities	Quantities (rate/sv)	Effect	Start/stop & modification conditions
Energy flow	- water body (residual flow stretch) - river features (water temperature) - solar energy - vegetation (shoreline vegetation)	- energy flow (r) - temperature increase (sv) - shoreline vegetation (sv) - shaded area (sv)	Energy flow may increase or decrease amount of energy in physical bodies and change its temperature. It might be changed due to removal of shoreline vegetation which decreases the amount of shaded areas and abstraction of water which decreases the rate of water discharge and increases the temperature due to reduced water transport.	Energy flow always happens. Temperature difference triggers the process, and temperature equality stops it. Human pressures influence this process; reducing pressures (increase water transport and amount, development of shoreline vegetation) will reduce/stop the alteration.

4.1.3 Biological Processes

Name	Entities	Quantities (rate/sv)	Effect	Start/Stop conditions
Reproduction	- fish - river features (substrate)	- reproduction (r) - Amount of reproduction (sv)	Reproduction is a continuous phenomenon responsible for the preservation of sustainable populations. Adults produce eggs (after migrating to spawning places), larvae hatch out of eggs, are distributed to downstream areas, overwinter as juveniles in suitable habitats; after several years many species return to the place of their birth to reproduce again (homing).	It starts usually with adult individuals at certain environmental conditions, is being reduced at higher ages and lower densities of adult fish. Human pressures can stop this process by destroying the access to suitable habitats. Reproduction in residual flow stretches is mainly reduced due to sediment clogging and the lack of water; channelization also reduces the amount of necessary for a successful reproduction.

4.1.4 Human actions

Name	Entities	Quantities (rate/sv)	Effect	Start/stop & modification conditions
Energy production	- human; - river features (amount of water, natural flow, discharge regime) - economic unit	- energy production (r) - water abstraction (r) - water abstracted (sv) - water in the river (sv) - economic loss (sv) - economic benefit (sv)	Since centuries humans use rivers for energy production – first they used the energy directly for running machines; then hydropower use changed to the production of electricity. Water is abstracted and used to run generators for energy production. Water abstraction lead to the reduction of food organisms, changed water depths and flow velocities, reduction of habitats and reduction of species diversity, density and individual fish condition.	Starts with the demand for electricity and ends, when all electricity is produced by other sources or by the end of human settlement on earth. Humans started the process of hydropower production. Currently the construction of small hydropower plants (below 10MW productivity) is also forced by law given incentives) because water energy is a sustainable energy source. Legislation like the WFD try to the reduce the impact in river sections where it is possible; in other river sections (heavily modified water bodies) the good ecological potential must be reached without influencing the

				existing use. Legislation, energy saving behavior, technology and the use of other energy sources (air, sun) might reduce the pressure on rivers by hydropower production.
Water abstraction	- water - minimum flow stretch - river features - management action	- water abstraction (r) - amount of water in the river (sv) - amount of water abstracted (sv) - discharge dynamics (sv) - substrate clogging (sv) - temperature increase (sv)	Water is abstracted for energy use, and cause significant effects on fish (reduction of size and species diversity) depending also on the morphology of the river section. Depending on the length of the minimum flow stretch below a weir, temperature might be changed (increased) with distance from weir; also shoreline vegetation plays a role. The natural discharge regime is significantly changed (sometimes total water abstraction at minimum flow and mean flow situations), changing the substrate composition causing sediment clogging (which impacts the reproduction of fish). Minimum flow stretches also might act as migration barriers for fish.	Legislation might stop or reduce the impact of this pressure; also service of hydropower stations might reduce the impact because the efficiency of stations is sometimes very low. Service could be very a effective management action compensating for the amount of water that has to be given back to the river.
Restoration	- river features - human pressures - indicator	- restoration (r) - ecological integrity (sv) - different habitat features (sv) - biomass (sv) - density (sv) - species diversity (sv) - reproduction (r,sv)	Restoration for the WFD to reach the good ecological status for the WFD is a complex task. It can be understood as stepwise reduction of multiple pressures causing cumulative impacts.	Started with single actions in Austria since 1984, and is no formalized by the EU WFD. Will stop, when all water bodies at risk are in a good status.
Information	- local population - management action - indicator (acceptance)	- information (r) - acceptance of a measure (sv) - integration of local environment (sv)	Acceptance of a measure can be influenced by information increasing the number of informed people and the degree of information.	Should start with the planning processes and usually end with the end of the project. If neglected at the beginning, resistance against measures creates pressure on politicians, which force the planners to start the participation process (adapted management).
Participation	- management action - indicator (acceptance)	- participation (r) - acceptance (sv) - integration of stakeholder interest (sv)	Participation is seen as one of the most important management actions within the sustainable development of riverine landscapes	Usually starts with the beginning of the project and ends with implementation of measures. If neglected at the beginning, resistance against measures creates pressure on politicians, which force the planners to start the participation process (adapted management).

4.2 External influences

The most important external influences that might change the system in some way are changes in the global environment (climate change), global technical developments changing e.g. the technological options for energy production (and use) reducing the pressure of hydropower production at rivers, laws like the EU-WFD, causing extensive restoration activities, catastrophic events, that increase the interest of the local population for developing and implementing measures. Some processes will be considered as being the result of agent actions, because they are not directly related to the main elements of the Kamp valley system.

4.3 Causal Models

Human occupation of the Kamp valley has substantially altered the riverine landscape and the river features reducing the ecological integrity of the river. A catastrophic event has set a new basis for the development of the riverine landscape. This process requires a high integration of stakeholder interests and a high integration of the local (social) environment. Hydropower production and channelization for flood protection cause the most important pressures to the riverine system. Sustainable restoration activities integrating all stakeholder interests are an important task, especially with regard to the EU-WFD.

To illustrate these typical situations in the Kamp valley, two causal models are presented: the first explores the acceptance of a measure as an indicator of social sustainability; the second is about restoring the combined effects of water abstraction and river channelization on fish with regard to the EU-WFD.

4.3.1 Acceptance of a measure

Figure 13 shows the causal model for the acceptance of a measure. The success and sustainability of a measure largely depends on a high agreement of the local population (integration of the local environment) and other stakeholders to the proposed measures. Information, participation, integration of stakeholder interests and of the local environment (typical habits of the local population, landscape history …) mainly influence the acceptance of measures. Catastrophic events, increasing the motivation of the local population influencing the political interest for the development and implementation of measures is treated as an important external influence (agent).

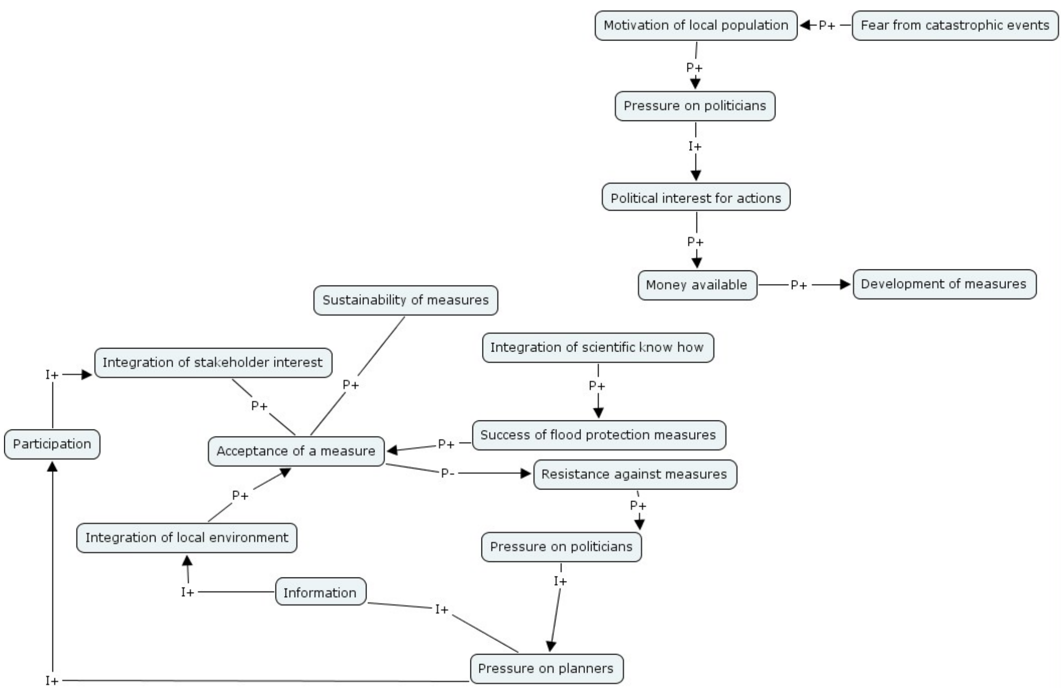

Figure 13: Causal model "acceptance of a measure" with "catastrophic event" as agent.

According to the causal model shown in the Figure 12, some of the relations read as follows:

- Fear from catastrophic events increases the motivation of local population for actions (P+) which increases the pressure on politicians (P+) which positively influences the political interest for actions (I+); this propagates positively the money available (P+) and the development of measures (P+) as a pre-condition for the following steps.

- The integration of scientific know how positively influences the success of the measures (P+).
- Participation and Information processes increase the integration of stakeholder interests and the integration of the local environment (I+).
- Both affect the acceptance of the measure (P+).
- If the acceptance of the measure is low, resistance against measures is high (P-).
- If resistance against measures is high, pressure on politicians is high (P+) which increases the pressure on planners (P+) which activates the information and participation process (P+).

4.3.2 River restoration with regard to water abstraction and channelization

Water abstraction and river channelization are known as two of the main pressures to Austrian rivers. Both pressures cause impacts on the riverine fish fauna interacting in a certain way. Figure 14 shows the causal model for different possibilities of river restoration activities to restore the ecological integrity of impacted rivers with regard to the WFD. According to the two pressure types, two restoration activities might reduce the pressures which positively influences the related river features and the indicators.

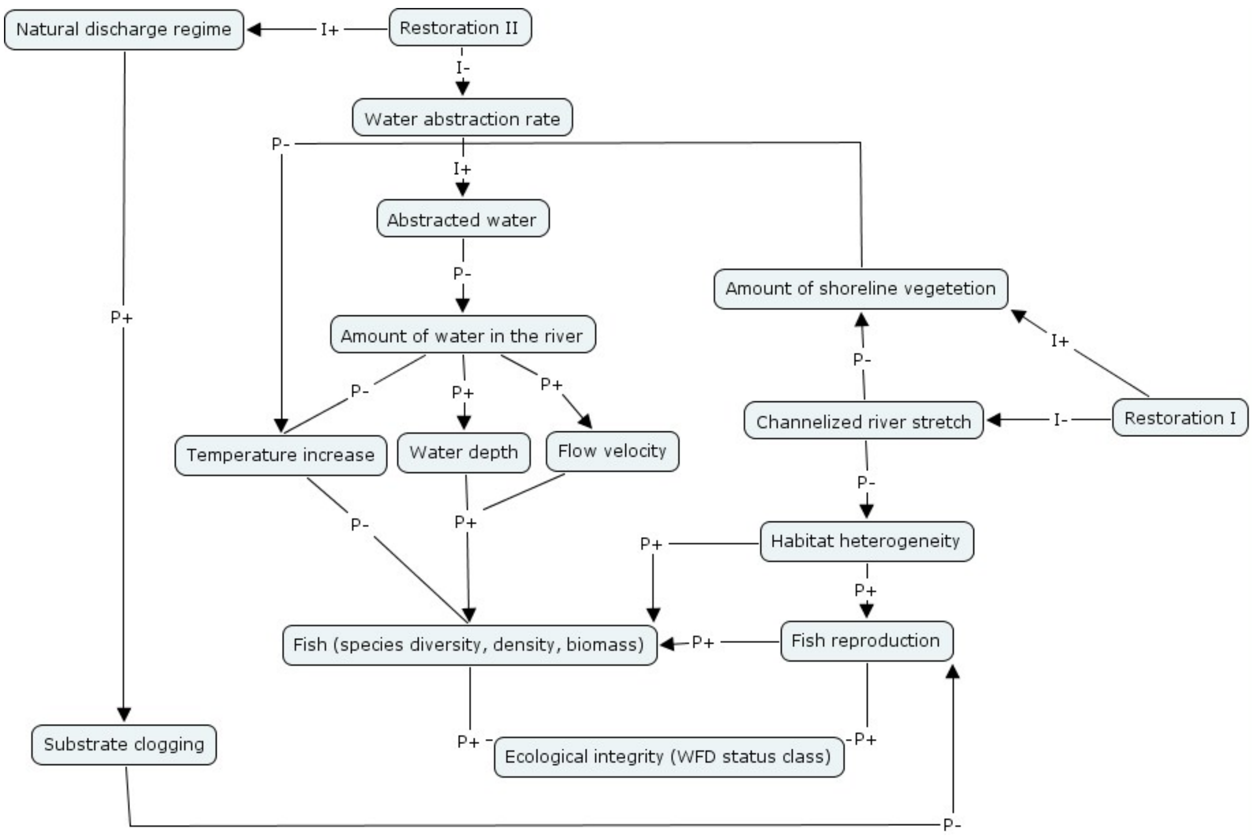

Figure 14: Causal model "river restoration with regard to the WFD".

In the causal model shown in the Figure 14, some relations can be described as follows:

- The Water abstraction rate positively influences the amount of abstracted water (I+).
- The higher the amount of abstracted water, the lower is the amount of water in the river (P-) lowering the depth and flow velocity (P+), but the higher is the temperature increase (P-); these factors are known to be relevant factors influencing fish biomass, density and species diversity (P+), representing indicators for the ecological integrity (P+).
- River channelization reduces habitat heterogeneity (P-); a high habitat heterogeneity is responsible for high fish reproduction, biomass, density and species diversity (P+), all indicators for the ecological integrity of a river (P+). Channelization is often accompanied with a reduction of shoreline vegetation (P-) which increases the temperature increase of a river section (P-).

Restoration opportunities (I and II) can be seen as single or combined processes, that continuously reduce the amount of the single pressure types for restoring the natural fish community of a river section impacted by the described pressure types.

5 Detailed system structure and behaviour

5.1 Acceptance of a measure (Model A)

5.1.1 Structural details

The following ingredients are specified within this section:

- Entity types
- Configurations

5.1.1.1 Entities overview

Environment
    Local environment
        Social environment
Management action
    Information
    Participation
    Development of measures
    Implementation of measures
Human
    Stakeholder
    Local population
    Politician
    Planner
Economic unit
    Money
Indicator
    Acceptance of a measure

5.1.1.2 Configurations overview

Lives in, sets, influences, is a

5.1.2 Agents

Catastrophic event (see section 3.1.3).

5.1.3 Assumptions

See section 3.1.4 for details.

5.1.4 Quantities and quantity spaces

5.1.4.1 State variables

Indicator
    Acceptance of a measure
    Sustainability of a measure
Local environment
    Integration of local (social) environment
Management action
    Success of flood protection measures
    Integration of scientific know how
    Development of measures

Sustainable implementation of measures

Human

Fear from catastrophic events
Motivation of local population
Integration of stakeholder interests
Interest for actions
Resistance against measures

Economic unit

Money available

5.1.4.2 Rate variables

Management action

Participation
Official information

Human

Pressure on politicians
Pressure on planners

Table 6: Quantities and quantity spaces in the river Kamp "Acceptance of a measure" model (Model A)

Type	**Quantity**	**Quantity space**
State	Fear from catastrophic events	*low, medium, high*
	Motivation of local population	*low, medium, high*
	Political interest for actions	*low, medium, high*
	Money available	*low, medium, high*
	Integration of scientific know how	*low, medium, high*
	Integration of stakeholder interests	*low, medium, high*
	Integration of local (social) environment	*low, medium, high*
	Acceptance of a measure	*zero, low, medium, high*
	Resistance against measures	*zero, low, medium, high*
	Success of flow protection measures	*low, medium, high*
	Sustainability of measures	*low, medium, high*
	Development of measures	*zero, plus*
	Sustainable implementation of measures	*zero, plus*
Rate	Participation	*low, medium, high*
	Official information	*low, medium, high*
	Pressure on politicians	*zero, plus*
	Pressure on planners	*zero, plus*

5.1.5 Scenarios and behaviours

Table 7: States in the "low information and low participation, high resistance against measures" scenario.

State	Values and (in)equality	Description
1	Agent catastrophic event active, fear from catastrophic events is high and motivation of local population is high, pressure on politicians is plus, interest of politicians for action is low but increasing.	After a catastrophic event, the local population and different stakeholders claim for political actions to develop flood protection measures for the valley.
2	Political interest is high, money available is high and development of measures is set to plus.	Political interest makes money available for actions which onsets the process of development and implementation of measures.
3	Integration of scientific know how is high, therefore the proposed success of flood protection measures and ecological integration are high; but information and participation are both low setting the acceptance of a measure to low and the resistance against measures at high. Sustainable implementation of measures is zero. Sustainability of the planned measures is low.	Various disciplines are integrated into the development and implementation of measures, why a high flood protection and a high degree of ecological integration can be reached; but information and participation are neglected leading to high resistance of local population and stakeholders against measures. The local population and various stakeholders create pressure on politicians. If no further action is set, the measures will not be implemented (process stops) or an not sustainable implementation of measures against local resistance will be done based on laws.

Table 8: States in the "high information and high participation, implementation of measures successful" scenario.

State	Values and (in)equality	Description
1	Agent catastrophic event active, fear from catastrophic events is high and motivation of local population is high, pressure on politicians is plus, interest of politicians for action is low but increasing.	After a catastrophic event, the local population and different stakeholders claim for political actions to develop flood protection measures for the valley.
2	Political interest is high, money available is high and development of measures is set to plus.	Political interest makes money available for actions which onsets the process of development and implementation of measures.
3	Integration of scientific know how is high, therefore the proposed success of flood protection measures and ecological integration are high; information and participation are both high setting the acceptance of a measure to high and the resistance against measures at zero. Sustainability of measures is high, activating the sustainable implementation process.	Various disciplines are integrated into the development and implementation of measures, why a high flood protection and a high degree of ecological integration can be reached; information and participation lead to a high degree of stakeholder integration and integration of the local environment. Therefore the resistance against measures is zero and the implementation of measures is successful with a high degree of sustainability.

Table 9: States in the "low information and low participation, adaptive management" scenario.

State	Values and (in)equality	Description
1	Agent catastrophic event active, fear from catastrophic events is high and motivation of local population is high, pressure on politicians is plus, interest of politicians for action is low but increasing.	After a catastrophic event, the local population and different stakeholders claim for political actions to develop flood protection measures for the valley.
2	Political interest is high, money available is high and development of measures is set to plus.	Political interest makes money available for actions which onsets the process of development and implementation of measures.
3	Integration of scientific know how is high, therefore the proposed success of flood protection measures and ecological integration are high; but information and participation are both low setting the acceptance of a measure to low and the resistance against measures at high; this activates the pressure on politicians which again activates the pressure on planners.	Various disciplines are integrated into the development and implementation of measures, why a high flood protection and a high degree of ecological integration can be reached; but information and participation are neglected leading to high resistance of local population and stakeholders against measures. The local population and various stakeholders create pressure on politicians. Politicians create pressure on planners to force an integration process
4	Pressure on planners is plus, activating the participation and information process. This reduces the resistance against measures and increases the acceptance of measures setting the sustainability of the measures to high and the sustainable implementation process to plus.	Planners are forced by politicians to start an information and participation process, that will reduce the resistance against measures and increase the acceptance of measures and the sustainability of the project. A sustainable implementation process can be started.

5.1.6 Description of basic model fragments

QR models generally comprise a hierarchical library of model fragments, utilizing the quantities previously defined. In this section the basic model fragments for the River Kamp case study are defined. The model fragments are classified as static fragment, process fragment and agent fragment.

5.1.6.1 Static model fragments

The purpose of static model fragments is to define structural relations between entities as well as to indicate propagation of changes from one quantity to another by using proportionalities.

Name: Sustainability of measures

- Conditions:
  - Entities: Indicator, Human
  - Configurations: influences
- Consequence
  - Quantities: Acceptance of a measure, Resistance against a measure, Sustainability of measures

  - Causal dependencies: Acceptance of a measure propagates negatively to resistance to a measure (P-) and positively to sustainability of a measure (P+).

Name: Acceptance of a measure

- Conditions:
  - Entities: Indicator, Human, Local environment
  - Configurations: influences
- Consequence
  - Quantities: Acceptance of a measure, Integration of stakeholder interest, Integration of local environment
  - Causal dependencies: Integration of stakeholder interests and Integration of local environment propagate positively to acceptance of a measure (P+)

5.1.6.2 Process model fragments

Process model fragments describe how values of quantities cause changes to occur in other quantities via direct influences (I+ and I-).

Name: Information process

- Conditions:
  - Entities: Planner, local population, stakeholders, management action, indicator
  - Configuration: sets, informs, influences
- Consequence
  - Quantities: Information, Integration of local environment, Acceptance of a measure
  - Causal dependencies: Information process has a positive influence (i+) on Integration of local environment.

Name: Participation process

- Conditions:
  - Entities: Planner, local population, stakeholders, management action, indicator
  - Configuration: sets, participates, influences
- Consequence
  - Quantities: Participation, Integration of stakeholder interests, Acceptance of a measure
  - Causal dependencies: Participation process has a positive influence (I+) on Integration of stakeholder interests.

Name: Pressure on politicians/resistance

- Conditions:
  - Entities: Local population, stakeholders, politician, planner, management action
  - Configuration: influences, sets
- Consequence
  - Quantities: Pressure on politiciens, pressure on planners
  - Causal dependencies: Pressure on politicians has a positive influence (I+) on pressure on planners which has an positive influence on participation (I+) and information (I+).

5.1.6.3 Agent model fragments

Agent model fragments are a special kind of process model fragment (containing direct influences I+, I-), that model how external influences cause changes in a system. They generally relate to processes that humans can potentially exert some control over, as opposed to natural processes, that humans generally can`t or don`t directly control.

Name: Pressure on politicians/political interest

- Conditions:
  - Entities: Local population, politician
  - Configuration: influences
- Consequence
  - Quantities: Pressure on politicians, Political interest
  - Causal dependencies: Pressure on politicians has a positive influence (I+) on political interest for actions.

5.2 River restoration focusing on channelization and water abstraction (Model B)

5.2.1 Structural details

The following ingredients are specified within this section:

- Entity types
- Configurations

5.2.1.1 Entities overview

Water body

River
Channelized river stretch

River feature

Water
Habitat
Substrate
Shoreline vegetation

Driver

Hydropower production
Flood protection

Technology

Hydropower plant

Human pressure

Water abstraction
Channelization

Indicator

Fish
Ecological integrity

Management action

Restoration

Economic unit

Money

5.2.1.2 Configurations overview

Contains, modifies, influences, is a.

5.2.2 Agents

Refer to section 3.2.2.

5.2.3 Assumptions

Refer to section 3.2.3.

5.2.4 Quantities and quantity spaces

5.2.4.1 State variables

Driver

Value of hydropower production

Importance of flood protection

Human pressure

Degree of channelization

Technology

Efficacy of hydropower plant

River feature (= State)

Amount of water in the river

Impact on discharge regime

Impact on water depth

Impact on flow velocity

Temperature increase

Habitat heterogeneity

Amount of shoreline vegetation

Substrate clogging

Indicators (= Impact)

WFD status

Species diversity

Size of fish

Loss of sensitive species

Biomass

Reproduction

Economic unit

Economic commensurability

Economic loss

5.2.4.2 Rate variables

Management action (= Response)

Restoration of channelization

Restoration of natural discharge regime

Increase of efficacy of power plant

Human pressure

Rate of water abstraction

Water

Rate of natural flow from upstream

Rate of water flow downstream

Table 10: Quantities and quantity spaces in the river Kamp "channelization and water abstraction" model

Type	Quantity	Quantity space
State	Value of hydropower production	*zero, very low, low, medium, high*
	Importance of flood protection	*zero, very low, low, medium, high*
	Degree of channelization	*zero, very low, low, medium, high*
	Efficacy of hydropower plant	*zero, very low, low, medium, high*
	Amount of water in the river	*zero, very low, low, medium, high, natural*
	Impact on natural discharge regime	*natural, slight impact, medium impact, high impact, very high impact*
	Impact on water depth	*natural, slight impact, medium impact, high impact, very high impact*
	Impact on flow velocity	*natural, slight impact, medium impact, high impact, very high impact*
	Temperature increase	*zero, very low, low, medium, high*
	Habitat heterogeneity	*natural, high, medium, low, very low*
	Amount of shoreline vegetation	*natural, high, medium, low, very low*
	Substrate clogging	*zero,very low, low, medium, high*
	WFD status	*high, good, moderate, poor, bad*
	Species diversity	*natural, high, medium, low, very low*
	Size of fish	*natural, high, medium, low, very low*
	Loss of sensitive species	*zero, very low, low, medium, high*

	Biomass	*very low, low, medium, high, natural*
	Reproduction	*natural, high, medium, low, very low*
	Economic commensurability	*zero, very low, low, medium, high*
	Economic loss	*zero, very low, low, medium, high*
Rate	Restoration of channelization	*zero, plus*
	Restoration of natural discharge regime	*zero, plus*
	Restoration of shoreline vegetation	*zero, plus*
	Rate of water abstraction	*zero, very low, low, medium, high*
	Increase of efficacy of power plant	*zero, very low, low, medium, high*
	Rate of inflow from upstream	*zero, very low, low, medium, high*
	Rate of outflow downstream	*zero, very low, low, medium, high*

5.2.5 Examples for scenarios and behaviours

In this section the basic scenarios for river restoration with regard to channelization, shoreline vegetation and water abstraction are described. In the upcoming modeling process, with regard to restoration and management efforts the economic loss and economic commensurability will be added. The scenarios described in Tabs. 11-13 basically capture and represent the effect of restoration measures with regard to the WFD status of a river.

Table 11: States in the "restoration of channelization and shoreline vegetation with ongoing water abstraction and disturbance of natural discharge regime" model.

State	Values and (in)equality	Description
1	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is high. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Substrate clogging is high. Reproduction is very low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad. Restoration of channelization is plus, restoration of water abstraction and natural discharge regime is zero.	After heavy channelization and removal of shoreline vegetation the river is heavily impacted and the WFD status is bad.
2	Degree of channelization is medium, therefore habitat heterogeneity is low, the amount of shoreline vegetation is low. Temperature increase is medium. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Substrate clogging is high. Reproduction is very low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad.	Decreasing the impact of channelization and removal of shoreline vegetation restores partially the heterogeneity of habitats and the temperature regime; but the lack of a natural flow regime leads to clogging of sediment having a negative influence on fish reproduction.
3	Degree of channelization is low, therefore habitat heterogeneity is medium, the amount of shoreline vegetation is medium. Temperature increase is low. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Substrate clogging is high. Reproduction is low. Species diversity is low, size of fish and biomass are low, loss of sensitive species is high. WFD status is poor.	
4	Degree of channelization is very low, therefore habitat heterogeneity is high, the amount of shoreline vegetation is high. Temperature increase is very low. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Substrate clogging is medium. Reproduction is medium. Species diversity is low, size of fish and biomass are medium, loss of sensitive species is high. WFD status is poor.	
5	Degree of channelization is zero, therefore habitat heterogeneity is high, the amount of shoreline vegetation is natural. Temperature increase is zero. Amount of water in the river is low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Substrate clogging is medium. Reproduction is medium. Species diversity is medium, size of fish and biomass are medium, loss of sensitive species is medium. WFD status is moderate.	Eliminating the impact of channelization and removal of shoreline vegetation restores partially restores in to a high extension the heterogeneity of habitats and the temperature regime; but the lack of a natural flow regime leads to clogging of sediment having a negative influence on fish reproduction. Due to the lack of water, water depths and flow velocities are still impacted. The WFD status of the river the can be reached by reducing the degree of channelization to zero is therefore "moderate".

Table 12: States in the "restoration of water abstraction and disturbance of natural discharge regime but with channelization as remaining press-disturbance" model.

State	Values and (in)equality	Description
1	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is high. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Reproduction is very low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad. Restoration of channelization is zero, restoration of water abstraction and natural discharge regime is plus.	After heavy channelization and removal of shoreline vegetation the river is heavily impacted and the WFD status is bad.
2	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is high. Amount of water in the river is low, rate of water abstraction is medium. Annuality of discharge regime, water depth and flow velocity are medium impacted. Reproduction is low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad.	
3	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is high. Amount of water in the river is medium, rate of water abstraction is low. Annuality of discharge regime is medium impacted, water depth and flow velocity are medium impacted. Reproduction is low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad.	
4	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is medium. Amount of water in the river is high, rate of water abstraction is very low. Annuality of discharge regime is slightly impacted, water depth and flow velocity are medium impacted. Reproduction is low. Species diversity, size of fish and biomass are low, loss of sensitive species is high. WFD status is poor.	
5	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is medium. Amount of water in the river is natural, rate of water abstraction is zero. Annuality of discharge regime is natural, water depth and flow velocity are medium impacted. Reproduction is low. Species diversity, size of fish and biomass are low, loss of sensitive species is high. WFD status is poor.	Restoring the discharge regime without restoring the effects of channelization (still acting as "press disturbance") does not restore the ecological integrity of the river. Therefore the WFD status is poor.

Table 13: States in the "restoration of water abstraction, restoration of the natural discharge regime and restoration of channelization" model.

State	Values and (in)equality	Description
1	Degree of channelization is high, therefore habitat heterogeneity is very low, the amount of shoreline vegetation is very low. Temperature increase is high. Amount of water in the river is very low, rate of water abstraction is high. Annuality of discharge regime, water depth and flow velocity are highly impacted. Reproduction is very low. Species diversity, size of fish and biomass are very low, loss of sensitive species is high. WFD status is bad. Restoration of channelization is plus, restoration of water abstraction and natural discharge regime is plus.	After heavy channelization and removal of shoreline vegetation the river is heavily impacted and the WFD status is bad.
2	Degree of channelization is medium, therefore habitat heterogeneity is low, the amount of shoreline vegetation is low. Temperature increase is medium. Amount of water in the river is low, rate of water abstraction is medium. Annuality of discharge regime, water depth and flow velocity are medium impacted. Reproduction is low. Species diversity, size of fish and biomass are low, loss of sensitive species is medium. WFD status is poor.	
3	Degree of channelization is low, therefore habitat heterogeneity is medium, the amount of shoreline vegetation is medium. Temperature increase is low. Amount of water in the river is medium, rate of water abstraction is low. Annuality of discharge regime, water depth and flow velocity are slightly impacted. Reproduction is medium. Species diversity, size of fish and biomass are medium, loss of sensitive species is low. WFD status is moderate.	
4	Degree of channelization is very low, therefore habitat	

	heterogeneity is high, the amount of shoreline vegetation is high. Temperature increase is very low. Amount of water in the river is high, rate of water abstraction is very low. Annuality of discharge regime, water depth and flow velocity are slightly impacted. Reproduction is high. Species diversity, size of fish and biomass are high, loss of sensitive species is very low. WFD status is good.	
5	Degree of channelization is zero, therefore habitat heterogeneity is natural, the amount of shoreline vegetation is natural. Temperature increase is zero. Amount of water in the river is natural, rate of water abstraction is zero. Annuality of discharge regime, water depth and flow velocity are natural. Reproduction is natural. Species diversity, size of fish and biomass are natural, loss of sensitive species is zero. WFD status is high.	Restoring both, the natural discharge regime, and the effects of channelization leads to the natural state of the river. This is represented by the WFD status class "high".

5.2.6 Description of basic model fragments

5.2.6.1 Static model fragments

The purpose of static model fragments is to define structural relations between entities as well as to indicate propagation of changes from one quantity to another by using proportionalities.

Name: Channelization

- Conditions:
  - Entities: Human pressure, River feature, Water body
  - Configuration: influences, contains
- Consequence
  - Quantities: Degree of channelization, Habitat heterogeneity,
  - Causal dependencies: The degree of channelization negatively propagates to the habitat heterogeneity (P-)

Name: Habitat heterogeneity and fish

- Conditions:
  - Entities: Water body, Indicator, River feature
  - Configurations: influences, contains
- Consequence
  - Quantities: Habitat heterogeneity, Species diversity, Size of fish, Loss of sensitive species, Biomass, Reproduction
  - Causal dependencies: Habitat heterogeneity positively propagates to species diversity, size of fish, biomass and reproduction (P+) and negatively to the loss of sensitive species (P-).

Name: Amount of water in the river

- Conditions:
  - Entities: Water body, River feature
  - Configurations: contains, influences
- Consequence
  - Quantities: Amount of water, Impact on water depth, Temperature increase, Impact on flow velocity
  - Causal dependencies: The amount of water in the river negatively propagates to the impact on water depth, flow velocity and temperature increase (P-).

Name: River feature and fish

- Conditions:
  - Entities: Water body, River feature, Indicator
  - Configurations: contains, influences
- Consequence
  - Quantities: Amount of water, Impact on water depth, Temperature increase, Impact on flow velocity, Species diversity, Size of fish, Loss of sensitive species, Biomass.
  - Causal dependencies: Impact on water depth and flow velocity negatively propagate to species diversity, size of fish, and biomass (P-) and positively to loss of sensitive species (P+).

Name: WFD status

- Conditions:
  - Entities: Indicator
  - Configurations: is calculated from

- Consequence
    - Quantities: Species diversity, Size of fish, Loss of sensitive species, Biomass, Reproduction, WFD status.
    - Causal dependencies: Species diversity, size of fish, reproduction and biomass positively propagate to ecological integrity (P+) and loss of sensitive species propagates negatively to the WFD status class (P-).

Name: Natural discharge regime

- Conditions:
    - Entities: River feature
    - Configurations: influences
- Consequence
    - Quantities: Impact of natural discharge regime, Substrate clogging
    - Causal dependencies: Impact of natural discharge regime positively propagates to substrate clogging (P+).

Name: Substrate clogging

- Conditions:
    - Entities: River feature, Indicator
    - Configurations: influences
- Consequence
    - Quantities: Substrate clogging
    - Causal dependencies: Substrate clogging negatively propagates to reproduction (P-).

Name: Shoreline vegetation

- Conditions:
    - Entities: River feature
    - Configurations: influences
- Consequence
    - Quantities: Amount of shoreline vegetation, Temperature increase
    - Causal dependencies: The amount of shoreline vegetation negatively propagates to temperature increase (P-).

5.2.6.2 Process model fragments

Process model fragments describe how values of quantities cause changes to occur in other quantities via direct influences (I+ and I-).

Name: Water abstraction

- Conditions:
    - Entities: Water body, River feature, Human pressure
    - Configuration: contains, influences
- Consequence
    - Quantities: Water abstraction rate, Water abstracted, Water in the river,
    - Causal dependencies: The water abstraction rate positively influences the amount of abstracted water (I+) which negatively influences the amount of water in the river (I-).

Name: Restoration I

- Conditions:
    - Entities: Management action, Human pressure, River feature
    - Configuration: influences
- Consequence
    - Quantities: Degree of channelization, Restoration rate, Amount of shoreline vegetation
    - Causal dependencies: Restoration I negatively influences the degree of channelization (I-) and positively influences the amount of shoreline vegetation (I+).

Name: Restoration II

- Conditions:
    - Entities: Management action, Human pressure, River feature
    - Configuration: influences
- Consequence
    - Quantities: Rate of water abstraction, River feature
    - Causal dependencies: Restoration II negatively influences the rate of water abstraction the impact on the natural discharge regime (I-).

5.2.6.3 Agent model fragments

No agent model fragments are currently used within model B.

6 Conclusions

This document sets the textual description of the river Kamp case study, using QR vocabulary. The detailed description of the system behaviour forms the basis for the next step in the modeling effort – the implementation of the models.

The presented models A and B capture important problems related to a sustainable development of riverine landscape Kamp, but they also have validity for most European countries. The first model focuses on the process of development and implementation of measures and points out the importance of information and participation to reach a high integration of stakeholder interests and a low resistance of the local population and stakeholders against measures. A high sustainability of measures is achieved, when the acceptance of the measures is high.

The second model focuses on the restoration of a river stretch impacted by channelization and water abstraction with regard to the EU water framework directive. This approach tries to capture the problem in a more general way, reducing the complexity of the impacts with some assumptions. An important aspect of restoring water abstraction is the application of management strategies like investing money to increase the efficacy of power plants to minimize economic loss and maximise the amount of water in the river. This aspect is not explicitly described within this deliverable but will be implemented in the models. But without reducing the effects of other pressures like channelization the goal of the WFD to reach the good ecological status of the river can not be reached. As the assessment of the ecological integrity of rivers with regard to the WFD, a five level scheme was used for most of the relevant quantity spaces. The challenge of modelling will be, to calculate the value correspondences and tables of allowable values in the given situations. A possible approach to reduce the complexity of the model could be the reduction of quantity spaces to less than five classes.

During the upcoming modelling process the two presented models and scenarios will be further developed and specified. At the end both models will represent basic aspects of a sustainable development of riverine landscapes with validity throughout Europe.

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