PREFACE

With the present research conception, the German Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF) intends to support a sustainable development of the river Elbe catchment area, a region with economical and ecological loads and chances. The conception deals with a new approach to scientific research in the realm of the ecology and the management of rivers, flood plains and catchment areas. Over a period of the next five years the ministry will spend about 30 million DM for organised interdisciplinary efforts meeting the main objectives, *Leitbild* procedures and main problems which are elaborated in the conceptual framework.

This conception is the result of intensive discussions among experts of the scientific community, authorities and decision-makers from the different states along the river Elbe, and representatives of important federal authorities, as well as in close contact with the *Internationale Kommission zum Schutz der Elbe* (IKSE). To gain wide agreement on the main objectives, tasks and issues in the preliminary stages of a longterm research programme is one and perhaps the most important basis for a successful problem-solving process.

One of the most important challenges is to maintain the relatively pristine dynamics of the waterway Elbe under the influence and necessary interventions of an accellerating economical development. The main issue of concern is to balance the requirements of merely intact ecological functions and the needs of economical and social welfare.

Based on results, particularly from the previous BMBF research programme „Ecological concepts for the restauration of small streams“, the new task and the challenge for the future is to combine ecological, social and economical affairs in a compatible, sustainable way. These objectives are tightly connected with the development of new tools for assessing and forecasting the ecological response of rivers to different measures of hydraulic engineering and changes in land use.

There are further issues of concern: What are the causes and the effects of the river bed erosion in parts of the river course? Is it possible to forecast unfavourable processes early in time, e.g. loss of habitats and species in the course of sinking groundwater tables? And if so, what could be done to stop the process? Another point of concern are the flood catastrophes of the last years, leading to the idea of regaining larger, even the ancient flooding areas. Do we get a better flood protection, by removing dams and dykes? Can we combine flood protection and the ecological demand for reafforesting foodplain forests? Furthermore, there is a great need for new concepts for eco-compatible agricultural land use in the flood plains and the catchment area, new ways to deal with gravel mining, as well as new means and instruments to restore ecologicaly deprived areas.

As a result and experience of the previous research activites sponsored by the BMBF, the management of the catchment areas of rivers and their tributaries is the be-all and end-all of a sustainable economy and a balanced ecology with a high biodiversity. Consequently, the

presented conception is to a considerable extent focused on the main questions of agricultural uses of the landscape, the flood plains as well as the catchment area of the river Elbe. The mainly recommended research strategies for several relative topics are: Searching for and assessing changes in land use which are already in progress; evaluating and monitoring the ecological and economical benefits, development of practicable alternatives for the income of the farmers, e.g. payments for ecological services done by farmers.

Most of the questions posed in the concept and most of the defined objectives are distinctly aiming towards a broad transfer of ecological knowledge in economical decisions.

The research conception in the Elbe catchment area is subdivided into four sections: It begins with a brief outline of the main problems, objectives and tasks (frame concept), which is differentiated by the three sub-concepts „Ecology of Flowing Waters“, „Ecology of Flood Plains“ and „Land Use in the Catchment Area“.

The presentation of this concept does not conclude the compilation of issues of concern, but shall stimulate the definition of further needs of research. In the course of the next years the issues of concern will be updated and expanded with particular regard to socio-economic items.

Frame Concept

1 FRAME CONCEPT

1.1 INTRODUCTION AND OBJECTIVES

With its funding priority *Ökologische Konzeptionen für Fluß- und Seenlandschaften,* the ***B**undes**m**inisterium für **B**ildung,Wissenschaft, **F**orschung und Techologie* (BMBF) is pursuing the comprehensive objective of creating decision support for practical implementation. This complex objective makes it necessary to

- improve the level of knowledge of the functioning of ecosystems,
- demonstrate strategies for the remediation and structuring of ecosystems which have to be environmentally, economically and socially compatible, and based on this
- draw up management concepts for sustainable, i.e. permanent environmentally acceptable, development.

Within the framework of these objectives it was decided to fund application-oriented research projects by way of example in the Elbe river basin. This programme provides emphatic support for the "Convention on the **I**nternational **C**ommission for the **P**rotection of the River **E**lbe (ICPE)" of October 1990, with the aim of achieving an ecosystem in the catchment area of the Elbe which is as natural as possible with a corresponding biodiversity. Research in the main channel of the river, the flood plains and the whole catchment area of the Elbe is particularly important and urgent for the following reasons:

- In spite of the different types of exploitation and interventions in the river ecosystem, in comparison to other large rivers numerous sections of the Elbe remained largely pristine in structure, dynamics and biological make-up. Therefore the Elbe provides information on the pristine or near-natural interrelations in a large river basin.
- The water quality has improved considerably due to the activities of the federal states and the federal government, in particular by the ICPE, the ***Ar**beits**ge**meinschaft zur Reinhaltung der **Elbe*** (ARGE ELBE) and the BMBF (leading project "Elbe 2000"). The above-mentioned activities must be complemented by ecological research. In particular, it is desired to increase the knowledge about interactions between abiotic habitat structures and biocoenoses. The changes in the former German Democratic Republic (new federal states) open up the opportunity of working on transferable solutions to eliminate or avoid harmful effects, in cooperation with the federal states bordering the Elbe and based on the present state-of-the-art. This research linking federal and state activities shall provide decision support for selecting measures intended to solve conflicts on use, taking into consideration socioeconomic boundary conditions and ecosystematic relationships.
- Only few holistic approaches have been made towards ecologically based development concepts for large river basins considering the river together with its flood plains and catchment area as a functional unit. Findings from other large European rivers, such as Rhine, Danube or Oder, can be transferred only to a limited extent due to the special features. Considering the maintenance and development measures being planned or already implemented, priority must be given to eliminating these deficits in knowledge.

1.2 SITUATION, PROBLEMS AND KNOWLEDGE DEFICITS

1.2.1 Ecological situation in the Elbe catchment area

1.2.1.1 Flowing waters

With a length of about 1,100 km and a catchment area of approx. 148,000 km^2, the Elbe is one of the largest river systems in Central Europe and is used as an inland waterway. On German territory, the course of the Elbe is regulated in particular by river engineering structures (groynes, head and ground sills, headworks and bank covering, filled-in potholes) as well as by a barrage at Geesthacht (upstream of Hamburg). The river has been straightened only to a comparatively small extent. Currently, extensive reconstruction work is carried out on dilapidated river engineering structures, e.g. groynes.

In the Czech Republic, the Elbe is regulated and canalized by numerous barrages and river engineering structures. In the German and Czech tributaries of the Elbe, some of which are used as inland waterways, e.g. Vlatava, Saale, Havel, Elde, there are numerous reservoirs, weirs and barrages (some with hydroelectric power plants). These artificial structures interfere with biological permeability along the course of the river, its water quality, bed load, budget of suspended matter and ground water, and water level dynamics.

The natural runoff dynamics of the Elbe are particularly characterized by the location of the head waters and by the tributaries in the low mountain region (rain-snow type). Floods mainly occur in winter and spring. In dry years, distinct low-water periods prevail in summer and autumn. Due to the geological and hydraulic conditions, the transported solids display considerable discontinuities in longitudinal and cross-section within short distances. Average grain diameters range from 50 mm in the upper reaches to about 0.3 mm in the Geesthacht backwater area. From km 380 (counted downstream from the Czech border), the grain sizes mainly comprise medium sand ("sand stream"). As these grain sizes are easily transported by the water, sedimentation processes as well as the formation of banks and ripple marks shape a diversified river bed with high-relief forelands, in part as dune areas. Ice scour action can cause considerable morphological changes along the river banks, particularly by erosion (spalling) or by the formation of deposits. These shifting sediments can satisfy the various demands made by different species on their habitat, e.g. they may as spawning or growing grounds for many species of fish.

Today large sections of the Elbe suffer from serious erosion, in places the river has deepened up to 2 m in 50 years. The interaction of the various causes is little known. Due to the depth erosion, the water level of the river drops in places and affects the ground water level in the valley flood plains and the estuaries of the tributaries. This phenomenon impairs the living conditions of the flora and fauna. Information on the impacts of measures to stabilize the Elbe bed and thus the water level, e.g. by the artificial input of bed load, is not yet sufficient.

A large part of the natural inundation areas is cut off from the Elbe flood regime by dykes in order to use these areas for settlement or agriculture. The erected dykes, barrages and struc-

tures for regulating the river interfere seriously with the natural runoff dynamics, i.e. particularly with respect to water level conditions, affecting the interactions of river and flood plains as well as the flow-dependent transport of solids in the Elbe. Ecological flood control by repositioning the dykes is currently discussed.

Until recently the Elbe was one of the most heavily polluted rivers in Europe due to the discharge of inadequately treated sewage waters. The restructuring of the East German industry and the installation or extension of numerous sewage water treatment plants have perceptibly reduced the local inputs of pollutants into the Elbe system. Along with the improved water quality and under favourable ecomorphological conditions, river and river bed have been recolonized by typical species and biocoenosis in many places. In order to promote this emerging improvement, all hydraulic engineering measures must be assessed with respect to changes in abiotic structures and the biocoenosis depending on the latter. Information relating to this topic can be found in the *"Ecological Study on the Protection and Design of Water Structures and River Bank Regions of the Elbe"* by the ICPE, 1994 (in German).

Conflicting goals result from the complex pattern of competences, liabilities and different scopes of the authorities. As a federal inland waterway, the Elbe is subject to the jurisdiction of the ***B**undes**m**inisterium für **V**erkehr* (BMV), which is responsible for the safety and ease of navigation, including hydraulic engineering measures and maintenance. Most of the remaining tasks concerning planning provisions, nature conservation and water management are under the authority of the adjacent federal states. Matters of paramount importance concerning ecology and nature conservation are subject to federal jurisdiction (***B**undes**m**inisterium für **U**mwelt, Naturschutz und Reaktorsicherheit* - BMU).

1.2.1.2 Flood plains

Flood plains are the natural inundation area of a river basin. Their development is decisively characterized by the flooding dynamics (frequency, extent, duration). In spite of the large number of engineering interventions, numerous typical river valley biotopes have been retained along the Elbe, e.g. the largest continuous flood plain forests in Central Europe. They form a unique habitat for a typical and extraordinarily diverse flora and fauna. The Elbe flood plains are of international significance as a resting and transition area for many migrating bird species.

On stretches of the main river and along numerous tributaries of the Elbe, the pristine functions of the flood plains (filter, sink, water budget and retention, habitat for specific plants and animals) are impaired due to the wide variety of demands made on its use:

- dyke constructions reduce the natural inundation area from an original width of on average 10 km to just 1 km today, in the district of Magdeburg only 16 % of the original inundation area are still present,
- hydraulic engineering measures result in a deepening of the river bed and a consequent drop in the ground water level (in extreme cases desiccating the flood plains), as well as

in reducing the natural water balance dynamics by levelling, or by separating, the water level dynamics of river and flood plains,
- large-scale gravel mining is planned to take place in the Elbe flood plains, which will heavily interfere with the flood plain dynamics, e.g. by disturbing the ground water conditions and by destroying natural habitats,
- pollution of the Elbe foreland soils and the ground water by local or diffuse inputs into the flood plainsand flowing waters,
- changes in the water budget and mass balance by inappropriate intensive agriculture in the flood plains, particularly by arable farming (surface erosion and the associated direct inputs of various matters into surface waters) and
- other types of use, such as residential settlement, recreation or supply of drinking water.

By experience with the river Rhine we know about the high expenditures, necessary for re-naturation, e.g. as part of the Integrated Rhine Programme, or the costs of balancing flood damages, i.e. the impairment of the pristine functions of the flood plains causes impacts on nature with considerable financial consequences.

Conceptual designs are required for an ecologically justified and socioeconomically acceptable development, maintaining or restoring the natural functions of the flood plains. The conditions for such an approval are currently very favourable in the Elbe region, as there are the possibilities of

- influencing hydraulic engineering measures and maintenance work which are still at the planning stage,
- introducing an ecological flood control by repositioning, or breaching, dykes in order to regain flood retention in the catchment area, which is presently discussed,
- controlling land availability by programmes, guidelines and ordinances from the EU, federal government and federal states, e.g. set-aside or extensive management programmes, nature reserve designs, contract nature conservation as well as
- utilizing the great potentials for ecological development of the Elbe flood plains.

1.2.1.3 Catchment area

Large regions of the Elbe catchment area are still characterized by agricultural structures as practised in the former German Democratic Republic, which in some parts impaired the natural dynamics of the landscape considerably. Damage was caused by enlargement of the farm areas with an associated reduction of landscape structures, increased surface erosion due to crop rotation unfavourable for the site, inappropriate livestock farming, as well as interventions in the water budget of the landscape with grave consequences for low-moor sites (complex melioration). The present situation is characterized by more extensive land use, which has been achieved by abandoning maximum-yield agriculture and by a comprehensive set-aside programme after the reunification of the two German states.

Now that the number of emitting point sources has been reduced, attention is shifted to the diffuse input of matter. In 1989, the diffuse input of nitrogen from the Elbe catchment area

amounted to approx. 130,000 t/a. About 2/3 of this amount entered via the ground water. The diffuse input of phosphorous from the Elbe catchment area totalled about 10,000 t/a, with soil erosion representing the most important input path. The proportion of diffuse inputs accounted for by agriculture was more than 80 % for nitrogen and more than 85 % for phosphorus. Data on changes in the diffuse input are presently available only for certain areas.

According to rough estimates, approx. 12 % of the annual total pollution of the North Sea with nitrogen and phosphorus originates from the Elbe area. The international commitment made by Germany to implement a 50 % reduction in nutrient inputs (2nd International Conference on the Protection of the North Sea, London, 24/25 November 1987; art. 16-2) can only be achieved by an immediate reduction of diffuse immission. As yet, there is a nationwide lack of economically acceptable management concepts. Biosphere sanctuaries are particularly suitable as model regions for evolving concepts on environmentally compatible and forward-looking economic development in rural areas.

Flooding of the meanwhile abandoned excavations from open-cast brown coal mining in the basins of Black Elster, Mulde, Saale and Spree/Havel has seriously impaired the water budget and mass balance even in the adjacent areas. The flow rate of the Elbe will be perceptibly influenced for several decades, above all during low-water periods, due to reduced contributions of drainage waters as well as to retained surface and ground waters.

The runoff is also influenced via the land´s water budget, i.e. by the type and intensity of land use in the catchment area. Thus the creation or maintenance of natural retention structures can counterbalance flood situations. In view of the experiences with the hydraulic regulations from the Rhine, we should avoid mistakes in the future structuring and development of the Elbe region. However, we do not know about the effectiveness of existing retention structures and those to be created.

1.2.2 Socioeconomic situation in the Elbe region

Large rivers, such as the Elbe, together with their flood plains and catchment areas, fulfil a wide range of socioeconomic functions, such as a habitat for human beings (settlement, work, recreation), for various resources and uses (drinking water, agriculture, industry, tourism) or as a carrier for the traffic and transport network (road, rail, waterway).

Considerable economic restructuring has taken place in large regions of the Elbe catchment area with the aim of reducing economic disparities between the old and new federal states. Due to the change in economic structure especially in the new federal states, numerous production sectors and plants have been cut down, shut down or reorganized. This influences the boundary conditions for future transport, regional and residential development.

In July 1992 the first federal plan for transport and communications for the whole of Germany was adopted, including the *Verkehrsprojekte Deutsche Einheit*. These projects are thought to improve the general situation and the traffic conditions for trade and industry. In addition to road and rail, a waterway project is envisaged to extend the west-to-east water-

way Hannover-Berlin by a planned Elbe crossing at Magdeburg, independent of the water level (“Project 17“).

Furthermore, hydraulic engineering and extension measures are planned on the federal waterways of the Elbe from the frontier with the Czech Republic downstream to Geesthacht as well as on the Saale and Havel. Measures on the Elbe primarily shall serve to regulate the low-water and middle-water level in order to ensure the safety and ease of navigation and to improve the competitiveness of inland shipping. The bottlenecks restricting the unloading depth at Torgau and Magdeburg are envisaged to be removed. It is desired to obtain a navigation channel with a continuous depth of ≥ 1.6 m and a width of ≥ 50 m on at least 345 days in a normal year from Geesthacht upstream to Schmilka. The planned engineering measures are intended to achieve a more constant gradient and to increase the depth of the waterway especially under low water conditions. This will increase bed erosion and impair biocoenosis, and measures to stabilize the bed of the Elbe will become necessary.

Within the catchment area of the Elbe on the territory of the former German Democratic Republic (corresponding to 54 % of the entire Elbe catchment area or 73 % of the area of the new federal states) restructuring of agriculture has been largely completed. As the individual farms are large in comparison with those in the old federal states, they provide favourable conditions for extensive management and for a site-oriented reduction in the area under cultivation. The aim of restructuring agriculture in the new federal states is to stabilize the rural areas and to develop a diversified structure for an environmentally compatible form of agriculture which is competitive on an international level.

The plans for nature conservation in the Elbe region, e.g. nature reserve designs, include the expansion of the "Middle Elbe" biosphere sanctuary and foundation of the "Elbe Valley Flood Plain" biosphere sanctuaries. They challenge an ecological change in economic activities and land use towards more ecology. The resulting economic risks can only be offset on condition that the natural potential of the region is not impaired ("intact landscape"), i.e. by means of appropriate concepts making use of the specific development potential in the conservation areas, e.g tourism, ecological farming.

1.2.3 Knowledge deficits from the perspective of the Federal States in the Elbe catchment area

The competent authorities of the federal states in the Elbe catchment area have identified an urgent need for research on the design and the parametrization of regionally specific, ecological *Leitbilder*, as well as on the development and improvement of realistic procedures for assessing the present status or measures already implemented.

An inventory is to be made on literature and data that are already available. National data bases and geographic information systems (GIS) are regarded as indispensable instruments for the acquisition, analysis and assessment of data on the catchment area. Findings or concepts for measures compiled in other river basins must be examined with respect to their transferability to the Elbe and its catchment area. The various research programmes of the federal government and the federal states, as well as the ICPE, should be considered as far

as possible in the applied ecological research of the BMBF. In order to ensure the implemention of the findings, the federal government´s research activities must be closely coordinated with the present programmes and current plans of the federal states.

From the perspective of several federal states, the currently most urgent problem of the Elbe is the river bed instability, above all the progressive depth erosion and its possible impacts on the flood plain and adjacent catchment area. There fore the significance of the tributaries in providing bed load must be elucidated. Interventions in river systems, e.g. reconstruction of groynes, bank protection, transverse structures (for hydroelectric applications), are not sufficiently optimized with respect to subsequent effects and ecological criteria.

A crucial point is the lack of holistic, implementable water conservation concepts. The reason for this is inadequate knowledge about the interactions between the declining water levels in the river, the ground water levels, as well as the vegetation and fauna in the forelands (flood plains). There is a lack of practical concepts for environmentally compatible land management, such as for

- extensive land use along with flood plain renaturation,
- treatment of polluted inundation areas,
- reestablishment of flood plain forests,
- incorporation of back waters,
- dykes to be abandoned,
- gravel mining and
- recreational facilities.

Great significance is attached to ecological flood control and reclamation of retention areas. At appropriate sites, the hydraulic, hydrological and ecological impacts of repositioning or breaching dykes along with reestablishing flood plain forests should be investigated. Before retention areas are established, subsequent impacts on residents downstream must be considered. Particularly for flood control, cooperation between the various federal states is an essential prerequisit.

Realizing sustainable farming in the flood plains and catchment area has to overcome economical obstacles and reluctant public acceptance. The know-how concerning site-oriented, ecologically and economically acceptable land use concepts is regarded as relatively advanced so that an implementation in model areas is planned for the near future. The ecological and socioeconomic consequences of extensive management over wide areas must still be assessed. In addition to information on business impacts, economic cost-benefit analyses of current use in comparison with alternative types of use are required (eco-audits).

1.3 STRATEGIES AND INSTRUMENTS FOR ECOLOGICAL DEVELOPMENT

In view of the required holistic approach, four closely interconnected, paramount research objectives emerge (cf. Section 1.3.1 to 1.3.4):

- **Elaboration of ecological *Leitbilder* as objectives for a permanently environmentally compatible, i.e. sustainable development**
- **Evaluation of the environmental capacity of pristine as well as of cultivated landscapes**
- **Provision of models for forecasting the consequences of interventions**
- **Proposal of measures to improve or stabilize ecological and socioeconomic conditions**

1.3.1 Elaboration of ecological *Leitbilder*

The *Leitbild*-oriented approach is made to ensure the implementation of scientific research in political and aministrative decisions. It is based on the experience from terminated BMBF model projects on the remediation of six small rivers. This way of action facilitates structuring and coordination as well as interrelation and evaluation of interdisciplinary research projects. Within the framework of the present research conception, ecological *Leitbilder* are required for the process of :

1. Establishing **ecological reference states**
2. Assessing **the *Ist-Zustand***
3. Defining **ecological *Leitbilder***
4. Implementing **development objectives,** which are ecologically and socioeconomically balanced
5. **Monitoring and assessing** the effects of implemented measures.

For these purposes science has the task

1. to establish regional and specific ***ecological reference states*** by means of parameters and indicators for assessment procedures. The basis for this is provided by the *near-natural state*, which can be deduced from near-natural reference areas, that have remained, or can be (re)constructed by historical analyses.

2. to analyse, document and evaluate the ***Ist-Zustand*** in defined natural regions and assess this by comparison with a reference state. The kind and the number of the physical, chemical and biological parameters to be examined, the spatial limits and the issues of priority have to meet the different boundary conditions of the region and its land use. The assessment of the *Ist-Zustand* displays *ecological deficits.* To counterbalance these deficits, measures have to be derived for the rehabilitation of the considered system.

3. to define ***ecological Leitbilder*** which are specific to the natural region. A *Leitbild* represents the *maximum approximation to the pristine states still achievable under present conditions*, i.e. taking into consideration irreversible development in the past. In order to

apply these *Leitbilder,* targets have to be established by comparison with reference states using suitable abiotic parameters and biotic indicators. These targets will serve as a long-term guideline for future plans and measures.

Authorities and administration have the task to

4. establish **development objectives *(Entwicklungsziele)*** specific to the region on the basis of the *Leitbilder* and to implement the needs for action. This process has to be harmonized on the sociopolitical level. *Entwicklungsziele* represent *approximations to the Leitbild. which remains the long-term planning objective.* They consider the ***ecological and socioeconomic*** boundary conditions and are *socially realizable in the short term*. They are subject to social changes as well as to the scientific state of the art.

The task of science and the authorities is to

5. analyse and assess the implemented measures with respect to their *ecological success* (via the parameters and indicators mentioned above) as well as their *socioeconomic efficiency* (***monitoring and assessing the recovery of the system, i.e. the succes of the measures)***. In this way science and authorities found the basis for the development of further measures and concepts.

1.3.2 Determination of the environmental capacity of cultivated and pristine landscapes

Ecosystems are resilient, i.e. they react elastically to disturbances and return to their original steady state as long as the impact does not exceed a certain limit. This limit indicates the point beyond which the systems suffer irreversible changes. The range up to this limit is termed the „environmental capacity of ecosystems“ and depends on their structure and dynamics.

The *Umweltgutachten 1994* comments on the concept of environmental capacity: *"In the opinion of the **S**achverständigen**r**at für **U**mweltfragen* (SRU), *it is necessary to incorporate civilization systems in the natural network supporting them and thus the sustainable orientation of the progressively developing economies towards the environmental capacity of ecological systems." [...] "In principle, the environmental capacity of the natural environment prescribes the limit which a sustainable development of civilization must not exceed".*

There are knowledge deficits concerning the land use compatible with the environmental capacity of the Elbe and its basin. The objectives of exploitability and naturalness can only be achieved, if the socioeconomic and ecological demands on the area, the river and the flood plains are balanced in such a way that the environmental capacity of the ecosystems is not overtaxed. The concept of environmental capacity includes the question of whether the environmental quality objectives defined in the *Entwicklungsziele* are sufficient to ensure in the long term those environmental quality objectives defined in the ecological *Leitbild*. With respect to the scientific issues to be supported by the BMBF; this means: investigations should use the quality objectives of the *Leitbild* to indicate the limits within which a given utilization is ecologically acceptable in order to maintain or develop the ecological condi-

tions still present. The concept of environmental capacity aims at a much stronger interconnection of scientific, sociological, legal and economic issues than it has previously been the case in order to fulfil the ecological objectives.

1.3.3 Forecast of the possible consequences of interventions

Many controversies concerning the Elbe result from different estimates of the consequences of economic developments on ecological interactions, e.g. between runoff and morphodynamics of the river, water and material balance of the flood plain and catchment area, as well as the biocoenosis.

An essential prerequisite for improving the predictive power concerning the ecological and economic impacts of planned measures is the expansion of scientific knowledge on the causal and functional effective interrelations in ecosystems. In order to solve possible conflicts concerning use, findings from "what would happen if ...?" scenarios should facilitate the necessary consensus in the decision-making process, which also includes small-scale survey models and detailed submodels.

1.3.4 Proposing measures

A major goal of the research conception is to draw up concrete plans of action to maintain and improve the ecological state of the waters, their flood plains and catchment areas. The proposed measures are to be optimized according to ecological and socioeconomic criteria and should correspond to the development goals for the specific natural region.

1.4 PRIORITY RESEARCH TASKS

The current priority research tasks are described in detail in the three separate subconcepts

- **"Ecology of Flowing Waters",**
- **"Ecology of the Flood Plains"** and
- **"Land Use in the Catchment Area".**

A summary follows in Sections 1.4.1 to 1.4.3 of this framework concept; a diagrammatic overview of the issues and their interfaces is given in the Appendix.

This research conception will be continously updated during the next few years depending on the results of further workshops as well as on new findings.

In the long term, a joint international effort with the Czech Republic is envisaged, which will have to be coordinated with the ICPE study groups.

1.4.1 Ecology of flowing waters

The subconcept "Ecology of Flowing Waters" comprises the issues "Ecomorphology", "Structure-bound turnover processes" and "Species and Biocoenosis". Against the background of planned interventions in the Elbe and its major tributaries, studies on "Ecomorphology" are particularly important. Priority is given to the main river and major tributaries

in the region between the Czech boundary and the weir at Geesthacht. The tidally influenced Elbe downstream of Geesthacht and the Elbe Estuary are comparatively well studied within the frame of the ***S**onder**f**orschungs**b**ereich* 327 (SFB 327) of the ***D**eutsche **F**orschungs**g**emeinschaft* (DFG).

1.4.1.1 Ecomorphology

- **Problem-oriented evaluation of available research findings**

– Available data as well as models or model approaches are to be documented and evaluated with respect to the (further) development of small- and large-scale models. Deficits in the data bases are to be identified, and strategies are to be presented for the necessary data acquisition. In particular, data on geometry, hydrology and morphology in different spatial and temporal resolutions are required

- **Development of ecological *Leitbilder***

– Abiotic parameters and biological indicators must be defined to develop *Leitbilder* for the river morphology of the Elbe. Available evaluation procedures must be developed in such a way that morphological structures and ecological functions can be assessed along with their natural and anthropogenic changes

- **Development of tools to analyse the morphodynamics and to forecast the consequences of interventions**

– Large- and small-scale topographic models for the Elbe or stretches of the Elbe, as well as for the confluence regions of important tributaries, including the forelands and dykes, are to be (further) developed with the aid of available or data sets still to be collected on the transverse and longitudinal profiles.

– On the basis of these topographic models, forecasting instruments are to be compiled (flow, ground water and morphological models) and to be tailored to the requirements of the future users. These models are to cover the following factors for different resolutions in time and space:

  - runoff dynamics,
  - transport of suspended and solid matter,
  - river bed stability (depth erosion),
  - ripple mark formation and
  - interactions between river water level and ground water level.

– Future changes of natural or anthropogenic origin are to be described concerning

  - abiotic factors, e.g. runoff dynamics, morphological structure, as well as
  - biological functions and processes in the river and flood plain, e.g. development of flora and fauna, and their interactions.

– This particularly applies to an assessment of the subsequent impact of existing or planned river engineering or water management interventions, such as

- groyne reconstruction,
- bed stabilization,
- dyke reconstruction/repositioning/breaching and
- shaping of banks.

Measures are to be proposed which satisfy both ecological and economic demands. It must be examined whether shifts towards more natural or near-natural structures can achieve a better flow stability than the classical engineering methods.

1.4.1.2 Structure-bound turnover processes

- The following priority research tasks are envisaged, but have not been determined in detail for this issue.:

– survey and evaluation of matter retention in the inundation areas,
– bioconversion between the flowing water, water/substrate interfaces and the interstitial system below the river bed as a function of river morphology and toxic potentials, e.g. with respect to the self-purifying capacity of flowing waters.

1.4.1.3 Species and biocoenosis

Previous approaches of bioindication for assessing the current state of flowing waters are only suitable to a limited extent. As a rule, they only consider one factor out of the biological demands of a species, e.g. available oxygen for the saprobic index. The presence of a given species is determined, however, by many habitat factors and their variability in time and space. For a holistic consideration of the ecological situation in flowing waters, more complex evaluation systems are required, including also river morpology. The tasks of research are:

- **Problem-oriented evaluation of available findings**

– leading to qualified estimates of the impacts of hydrology engineering measures on typical species and on developmental stages in the life cycle of selected, relevant indicators.

- **Development of ecological *Leitbilder***

– representing the interrelations between the complete life cycles of the currently occurring, and potentially expected, typical species of the Elbe and the pristine physical, chemical and, in particular, the morphological boundary conditions.

- **Biocoenotic studies**

– So far, a need for research on the fish fauna was identified. Fish are regarded as indicators for both large- and also small-scale conditions of flowing waters and their hinterland. Use can be made of comprehensive preliminary work, e.g. by the ARGE ELBE. The required biocoenotic studies will be specified in an update of this research conception.

- **Contributions to the knowledge on the ecological demands of the fish fauna**
  - significance of the river bed structures and the interstitial system for fish fry, larvae and juvenile fish in large rivers

- survey, characterization and evaluation of grounds for spawning and growth (type, extent, specific site, number of sites in the area, frequency of use)
- survey of the migrations for spawning and feeding between different subhabitats of the river, its tributaries and flood plains (longitudinal, lateral, vertical migrations). Elaboration of measures to protect the dispersal routes.
- qualitative and quantitative forecasts of population dynamics considering various scenarios of the future state of the Elbe
- proposal of measures for selected stretches of the river concurring with the *Leitbild*, e.g. concepts for the sustainable use of the fish fauna

1.4.2 Ecology of the flood plains

The flood plains are highly influenced by the dynamics of the runoff and the geomorphology. Hence the "Ecology of the Flood Plains" touches the issue “Ecomorphology“. Preferred areas of research are the flood plains along stretches of the Elbe and its tributaries showing serious depth erosion or being threatened by engineering projects or measures, which are about to be carried out by the federal states, e.g. repositioning of dykes, installing reservations, measures for renaturation or extensive management.

- **Problem-oriented evaluation of available findings**

– There is already a high number of scientific publications available on the functioning of flood plains, their species and biocoenoses. Hence a qualified survey of the actual status and state-of-the-art must precede the field research. Evaluation of the existing data should focus on the items:
  - establishment of a datafile on Elbe-specific keystone species following the pattern of natu- ral regions
  - parametrization of the demands that are put to the habitats by species, populations and biocoenoses
  - selection of qualified indicator species and biocoenoses
  - closing knowledge deficits on essential indicator species.

- **Interrelations between river and flood plains**

– Priority is given to the analysis of interactions between the river and flood plains; especially to:
  - natural or anthropogenic changes in runoff dynamics of the river and impacts on the water budget of the flood plains, particularly on the dynamics of the ground water table
  - significance and influence of runoff and ground water dynamics on the ecological status of former side channels of the Elbe, backwaters, flood channels, flood plain lakes and ponds
  - significance of the microrelief for flood plain biocoenosis, particularly with respect to changes in the ground water as well as in the dynamics of flow and morphology of the flood plains.

- **Development of ecological *Leitbilder***

– The development of *Leitbilder* requires the :
  - reconstruction of the development of the river and flood plains since the last ice age (pristine landscape) for selected periods of human history. Particular attention is to be paid to pristine open landscapes and successions in the region close to the river in order to es tablish reference states
  - determination of the environmental capacity of the present flood plains
  - description of the maximum approximation to the near-natural state achievable under pre sent conditions (environmental quality objectives for concrete and representative areas or stretches along the river).

- **Assessment and bioindication**

  – development, testing and standardization of practical evaluation procedures for the ecomorphological structures of the river bank and flood plains.

  – reduction of knowledge deficits in the ecology of the indicator species selected for the *Leitbilder*,

  – development and standardization of practical bioindication procedures as a tool for controlling and forecasting the subsequent impact of changes in the runoff and ground water dynamics, particularly as a result of exploitation and intervention in the river and flood plains, such as river engineering measures (depth erosion), gravel mining, flood retention and flood plain renaturation (abandoning dykes), farming in the inundation area.

- **Management concepts**

Management concepts concurring with the *Leitbilder* and oriented towards the ecological capacity of the ecosystems must be established and implemented. They must be realized as models for an economic development of the flood plain and assessed with respect to their ecological and socioeconomic effects.

– **Gravel mining**

  - Analysis and evaluation of the impact of gravel mining on the flood plains, ground water, available water resources and existing biotopes. Concepts for dealing with abandoned gravel pits must also be developed.

– **Flood retention and flood plain renaturation**

  - Research has to accompany pilot projects on the realization of ecological flood protection concepts with respect to

    - reconstruction of the natural retention areas by repositioning or breaching the dykes,
    - the hydrological, hydraulic and ecological impacts of removing the dykes.

- Concepts for dealing with reclaimed inundation areas, e.g. agricultural use or rehabilitation of flood plain forests.

– **Farming in the inundation area**

- Realization and evaluation of concepts for site-specific land use in the inundation area, i.e. considering the natural functions of the flood plain, particularly for the reduction of diffuse immission of matters into the waters and to remedy structural deficits, such as land fragmentation, drainage , river regulation, dyke construction

1.4.3 Land use in the catchment area

The issue "Land Use in the Catchment Area" calls for environmentally compatible concepts of use and their implementation. Governmental programmes for the realization of concepts require complementary research on the ecological and socioeconomic impacts. Particular attention should be paid to the impacts on the land´s water budget and mass balance, as well as to economic acceptance and to the creation of alternative ways of income for the concerned inhabitants. Priority is given to model projects in representative mesoscale areas tackling the following issues:

· **Problem-oriented evaluation of available findings**

– The detailed know-how available must be applied to develop sustainable land use concepts:

- Data must be evaluated in order to assess the present state of hydrology, matter, geomorphology and biocoenosis, as well as the current social and economic situation. Deficits in the data base and strategies for the necessary data acquisition must be identified.
- The suitability of relevant simulation models to forecast impacts of changes in use must be examined, e.g. on the water budget and mass balance, as well as the socioeconomic consequences.
- Completed, current or planned governmental programmes on land use, also in other regions, must be evaluated by way of comparison with respect to objectives, efficiency and performance control.

· **Classification of the catchment area to natural regions and socioeconomic criteria**

– As a precondition for the transfer of findings from model projects, the catchment area must be classified according to natural region and socioeconomic criteria using available approaches.

· **Development of ecological *Leitbilder***

– Parameters and indicators have to be defined in order to establish specific ecological models for the natural region for land use (quality objectives for representative areas) as a

basis for deriving *Entwicklungsziele*. The environmental capacity of the present cultivated landscape has to be determined.

· **Model projects to determine the ecological and socioeconomic impacts of changes in land use**

– On the basis of model projects, programmes, run or planned by the competent authorities, in representative landscapes of the federal states bordering the Elbe, should be evaluated in order to understand the ecological and socioeconomic impacts of changes in land use. Socioeconomically accepted land use concepts, which conform to the *Leitbild*, are to be developed further and to be optimized site-specifically with respect to an area-wide realization. The following issues of changes in land use are to be studied:

  - Changes in the water budget of the area, e.g. impacts of the reconstruction of natural retention structures on the area runoff and water retention with respect to the natural ground water recharge, material retention and flood protection, as well as changes in the area mass balance, e.g. diffuse material pollution of the ground water and surface waters in the Elbe catchment area.
  - Changes in the biodiversity typical of the natural region.
    Supra-regional impacts on the available water resources and water quality by structural changes in brown coal opencast mining.
  - Consequences of changed farming methods for the income situation of those affected. Development of concepts for alternative ways of income, e.g. as a compensation for "ecological services".
  - Holistic cost-benefit analysis of different forms of farming; business and economic impacts (eco-audit).
  - Application or (further) development of simulation models for forecasting and assessing the regional land use concepts with respect to their ecological and socioeconomic efficiency, as well as instruments for performance control of environmental policy measures.

1.5 IMPLEMENTATION AND FUNDING OF THE RESEARCH CONCEPTION

1.5.1 Funding conditions

Funding is preferentially given, if

- the projects are urgent with respect to planned interventions,
- the the expected findings are probable to be representative or transferable,
- extensive regions are available for research and implementation, e.g. biosphere reserves or national parks,
- water catchment areas, regional unities or characteristic stretches of water are considered,

- interdisciplinary collaborative research is being performed
  (*Support for a preliminary phase or for a limited period may be offered to permit the adaption of scope and organization to the needs of collaborative research projects*.)
- research findings can be put into practice (*minimum research expenditures shall allow to gain maximum ecological benefits*),
- innovative methods will be developed or applied,
- EU, federal and state institutions or activities are incorporated (cf. list in the Appendix) and
- a comprehensive data base is available as a starting point.

The data gathered within the frame of research projects must be processed in a conventional format, (e.g. GIS maps - ARC/INFO-compatible; data - ORACLE-compatible) to facilitate their utilization by other researchers. After completion of the projects at the latest, all information must be made available on data carriers to the BMBF and to the *Projektgruppe Elbe-Ökologie*.

1.5.2 Tasks and functions of the Projektgruppe Elbe-Ökologie

The *Projektgruppe Elbe-Ökologie* was set up by the BMBF as a task force to establish research priorities and incorporate them in a research conception which must be continuously updated. The work of the group is based on expert conferences or workshops on the various issues, as well as on extensive discussions with the ICPE and the competent authorities of the federal government and the concerned federal states. Furthermore, the Project Group provides organizational or expert support for coordination of collaborative and individual research projects. Contributions to interdisciplinary concepts are intended by processing the current research findings, e.g. the development of models, or the identification of obstacles to implementation through the administration.Close cooperation with national and foreign research teams and with the executive authorities is to be established.

1.5.3 Application procedure

As a first step *Projektskizzen* are to be submitted to the ***P**rojekt**t**räger **B**iologie, **E**nergie, **Ö**kologie* of the BMBF. The scope and the formal structure of the *project outlines* are described in this conception, they are binding (see information in the Appendix).

The *Projektträger* and the *Projektgruppe Elbe-Ökologie* will assess the *Projektskizzen* and submit them for review and evaluation to the *Scientific Council*. This is a group of experts appointed by the BMBF for this purpose. She selected applicants will receive application forms calling for detailed research applications (*Projektantrag*). The subject matter of the final project application is to be coordinated with the *Projektgruppe Elbe-Ökologie*. Again, the *Wissenschaftlicher Beirat* will evaluate the applications, whereas the BMBF will make the ultimate funding decision.

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Subconcept
„Ecology of flowing Waters“

2 SUBCONCEPT „ECOLOGY OF FLOWING WATERS“

2.1 ECOMORPHOLOGY

2.1.1 Introduction and objectives

"Ecomorphology" refers to the interrelation between structuring, i.e. habitat-shaping, factors of the aquatic, amphibious or terrestrial compartments of riverine systems and the colonization of the resulting structures by organisms. The morphological structures, their functions and the processes, which are confined to them, result from runoff dynamics together with the associated transport of solid matter. These dynamics are characterized by the natural conditions together with the anthropogenic use of the river basin and, for their part, determine the physical structure of the habitat. The ecomorphological research by the BMBF on the Elbe catchment area aims at

- recording the changes in morphological structures over space and time and their ecological functions,
- understanding, assessing and forecasting their interdependencies, and
- establishing developmental concepts to ensure a sustainable development of the river and its flood plains.

Stress is laid on the abiotic structures, their interconnection to the biotic functions and processes in the river and flood plains, as well as on their changes. Interactions between the abiotic and biotic factors can only be identified if interfaces between the individual research disciplines are well defined and interdisciplinary research projects are carried out collaboratively. The identification of links between river morphology and the various issues of "Ecology of the Flood Plain", "Structure-bound turnover processes" and "Fish Fauna" is considered to be particularly important.

2.1.2 Problems and knowledge deficits

The morphology of the river Elbe and its flood plains has been considerably impaired by anthropogenic interventions, such as settlement, land use, shipping, hydropower plants, flood protection and reservoirs, causing the major problems specific to the Elbe:

- destabilization of the bed,
- serious depth erosion in places,
- disturbed interaction between the river and its subsidiary channels (flood plains),
- changed or restricted flood plain development and
- change in transport conditions for economic, i.e. competitive, inland shipping.

2.1.2.1 Dynamics of runoff and morphology

The runoff dynamics of the Elbe are characterized by the location of the headwaters and the tributaries in low mountain ranges: floods mainly occur in winter and spring (rain-snow type). In dry years, distinct low-water periods occur in summer and autumn causing problems both for the safety and ease of navigation on the Elbe as a federal waterway, as well as for economic competitiveness of inland shipping.

The characteristic geological and morphological processes of the Elbe basin favour depth erosion. Erosion phenomena have reached serious dimensions on some stretches (2 m in 50 years in the Middle Elbe). In the upper reaches mean grain diameters are around 50 mm. In the backwater area of the Geesthacht weir, grain sizes have decreased to about 0.3 mm. However, along longitudinal transects the grain diameters do not drop continuously, considerable discontinuities have been observed within short stretches due to geological and hydraulic conditions. Grain sizes differ also along transverse transects through the river bed with diameters varying in part three- to tenfold. From km 380 downstream, the spectrum of grain sizes is that of medium sand ("sand river"). The great mobility of these sediments causes a multiform river bed, characterized by sedimentation processes, formation of sand banks and ripple marks, as well as by high-relief forelands with, in part, large dune fields, altogether forming a wide range of habitats.

Apart from limited stretches dominated by depth erosion, many sections of the Elbe have a quasi-stable bed at present. Hence all hydraulic engineering measures must be assessed with respect to changes in the local as well as in the large-scale bed stability. Bed stability interferes with all biotic aspects in the river and flood plains and represents an important interface.

Geomorphological studies on the Elbe date from the sixties and nineties. More extensive measurements and studies are required to verify and consolidate existing findings. Knowledge deficits concern the

- analysis and assessment of the variability in time and space concerning all processes of flow and solid transport,
- differentiated mass balancing of the transport of bed load and suspended matter,
- significance of the interstitial as an important habitat for the (re-)colonization of the river bed and
- development of alternative, ecologically compatible hydraulic engineering measures.

The extent of erosion is relatively well-known, especially for the stretches concerned, whereas synergisms promoting erosion in certain stretches are often just hypothetical (morphology, flow dynamics, engineering measures etc.).

2.1.2.2 Hydraulic engineering measures

In the Czech Republic and in Germany, the Elbe and its large tributaries are used as inland waterways. The course of the German Elbe is regulated by natural barriers, i.e. cropping out rock such as the Domfelsen at Magdeburg, along with river regulation structures such as groynes, sill beams, headworks and bank coverings. Except for the barrage at Geesthacht (km 586 on the Elbe, upstream of Hamburg), all Elbe barrages are on Czech territory where they retain a major fraction of bed load. In the Czech Republic, shipping with a draught of about 2 m is possible for approx. 210 km of the course throughout almost the entire year.

The ***B**undes**m**inisterium für **V**erkehr* (BMV) strives for the extension of the Elbe waterway to a depth of ≥ 1.6 m and a width of ≥ 50 m for at least 345 days in a normal year. In order to achieve this target without erecting barrages, extensive repairs are currently being made to delapidated river regulation structures. This redevelopment measure may intensify bed erosion and thus impair the biocoenosis typical of flowing water and flood plains. It must be clarified for the future, how these measures are to be designed and implemented sustainably from the morphological and ecological aspect, and not only according to economic criteria. Shortening of the river course and restricting its width are the main reasons for erosion. Due to the current height of the groynes and bank coverings ("outgrowing") as well as to the planned levelling of the Elbe bed by future engineering measures, greater flow volumes will pass with increased velocity through the river channel and thus cause depth erosion. Future engineering and redevelopment must be adapted to the prevailing water level conditions in order to stabilize the river bed. Measures, that are already implemented in or currently applied to other rivers in order to stabilize the water level and thus reduce erosion, e.g. weirs to reduce ground water runoff, or addition of bed load, must be examined with respect to their transferability to the Elbe. New findings should be incorporated in the drafting of maintenance and accompanying plans.

The tributaries of the Elbe are crossed by numerous weirs and barrages, some of which serve in producing hydroelectric power. Barrages as well as the river regulation structures on the Elbe, which are in part delapidated, interfere considerably with the runoff dynamics, solids budget and biological permeability along the river ecosystem. These structures cause depth erosion and alter recolonization potentials for organisms.

River-regulating engineering and repair work impairs the hyporheic interstitial of the river bed and river bank, which has a wide range of ecological functions, e.g. as a refugium biotope, a habitat for micro- and macroorganisms, spawning grounds for fish, or for self-purification of the stream ecosystem. There is a need for further knowledge concerning the relations between the habitat functions of morphological structures and their colonization by organisms as well as the impacts of river engineering measures.

Flow conditions in the valley aquifers of the Elbe are complicated. These aquifers are used on a large scale for the drinking water supply. Hence there is particular need to know about the impacts of hydraulic engineering measures on the ground water budget and mass balance, as well as about the in- and exfiltration of material (mechanisms of water dispersal).

A further problem is the severe reduction in natural retention areas, e.g. in the district of Magdeburg from about 220,000 ha to about 35,000 ha. In order to protect settlements and agricultural areas, flood protection structures have been erected along extensive stretches, in a few cases dating back to the 12th century, and more intensively since the start of large-scale Prussian dyke construction. On behalf of some of the federal states bordering the Elbe, redevelopment concepts for dykes requiring maintenance are currently being developed. In addition to conventional maintenance measures, it is planned to reposition or breach the dykes in some stretches with the aim of restoring former inundation areas and regenerating flood plains to establishing ecological flood protection. For this purpose, available data on hydrological, hydraulic or morphological changes within the restored retention areas and in the river are insufficient and must be extended.

2.1.2.3 Interfaces with other issues

The extent to which lowered ground water levels affect the flora and fauna in the flood plains and the possible ways of land use (cf. subconcept "Flood-Plain Ecology") must be analyzed and assessed.

Access to spawning and growing grounds with a certain morphological structure is a pre-condition for the reproduction of fish species. Hydraulic engineering measures may alter the neccessary structures in the Elbe to the detriment of the fish populations (cf. subconcept "Ecology of Flowing Waters", section "Fish Fauna").

The river bed and the interstitial system are the habitat for many organisms, which metabolize various matter and thus contribute to the self-purifying capacity of the water body. Changes to the balance of transported solids thus have a direct impact on this biocoenosis (cf. subconcept "Ecology of Flowing Waters", section "Structure-bound turnover processes").

In accordance with the interfaces outlined above, work on ecomorphological issues imposes demands on the disciplines of hydraulic engineering, hydrology, geomorphology, flood plain ecology, limnology, fish ecology etc. For this reason, these disciplines should be integrated in collaborative research projects with common or complementary topics.

2.1.3 Priority research tasks

The morphological structures of a river and their development directly influence the biotic functions and processes of a stream ecosystem. The wide range of interventions in the Elbe river basin, whose impacts on the ecosystem cannot generally be assessed yet, indicate the urgency and thus the high priority of ecomorphological research within "Elbe Ecology" (cf. Section 2.1.2),.

2.1.3.1 Problem-oriented assessment of available research findings

Available data sets for developing large-area models to cover the flow and morphodynamics as a basis for biotic studies in the river and flood plains must be assessed and validated in a problem-oriented manner. This is particularly true for geometric, hydrological and morpho-

logical data with different spatial and temporal resolutions, including data on transsects through the river bed and its forelands with the dykes, water levels, hydrographs, transport of suspended matter, bed load etc. Deficits must be identified and eliminated on a project-oriented basis. Requirements have to be listed and updated for future data collection with respect to data management. The available literature must be examined, compiled and assessed concerning the problem in hand to analyze, for example, the historical course of the river and bed.

2.1.3.2 Development of ecological *Leitbilder*

The lack of information, which necessary for the analysis and evaluation of morphological structures and their ecological functions, is in particular due to the fact that as yet no uniform parameters have been defined for the description of large rivers. In order to develop evaluation standards and ecological *Leitbilder* (cf. Framework Concept, Section 1.3.1) we must

- examine historical documents etc. on the course of the river and bed as well as
- identify and document near-natural stretches of the river as reference states.

Thus stretches with ecological deficits can be indicated and defined as the ecological *Leitbild* for the maximum approximation to the near-natural state possible under present conditions.

Based on existing methods and tools, e.g. the map of the structure quality for small flowing waters by the ***L****änder-****A****rbeitsgemeinschaft* ***Wa****sser* (LAWA), an evaluation procedure is to be developed for large flowing waters. Abiotic parameters and biotic indicators must be selected in such a way that morphological structures and ecological functions, as well as natural or anthropogenic changes to them, can be assessed. This applies particulary to the significance of:

- structures in the range between low and mean water, typical river-bed and flood plain structures (interstitial, ripple marks, flood plain forests, backwaters etc.; cf. subconcept "Ecology of the Flood Plain" and subconcept "Ecology of Flowing Waters", section "Structure-bound turnover processes"),
- the impact of natural solids transport and that due to shipping on recolonization of the bed (cf. subconcept "Ecology of Flowing Waters", section "Structure-bound turnover processes") and
- the bed structures, bed load transport and sedimentation or silting for the reproduction of fish (cf. subconcept "Ecology of Flowing Waters", section "Fish Fauna").

An important goal in the development of ecological *Leitbilder* for the morphology of the Elbe is the establishment and the synthesis of biotic indicators and abiotic parameters, such as flow diversity, variation in depth and width, bed substrate type and composition, profile, profile depth, and water-covered proportion of the profile, depth and width erosion, longitudinal and transverse banks, river bank structures, longitudinal structure of the river bank as well as residence times.

2.1.3.3 Development of instruments for analysing the morphodynamics and predicting the impacts of interventions

Tools for analysing the dynamics of flowing waters are based on topographic models covering the river as well as the forelands (inundation areas) with its dykes in transverse and longitudinal profiles. The available data sets on profiles must be processed according to the issues of concern, and supplemented if necessary. As a basis, in particular for biotic research, a large-scale topographical model should be elaborated covering the entire river Elbe and tributaries as required.

The supra-regional flow model for the Elbe and the confluence regions of its tributaries will serve in studying the runoff dynamics (changes in water level and flow rate) and displaying the impacts of river engineering work and water management on the flowing water and the inundation areas.

Morphological models must be compiled on a section-specific basis in order to cover bed instabilities and depth erosion phenomena and to allow the development of measures for bed stabilization wherever they are regarded as urgent from the perspective of flood plain development.

Available ground water models for the forelands and flood plains are to be developed to such an extent that the impacts of interventions in the fluvial system on the ground water dynamics and quality become visible (cf. subconcept "Ecology of the Flood Plain", section 3.2). In particular, the processes of in- and exfiltration and dispersal are to be covered (e.g. of pollutants in the bank-filtered water).

Models that couple the three items river, ground water and vegetation are to be developed to such a state, that the interactions between abiotic parameters and biotic indicators can be shown.

The aim is to estimate subsequent impacts of use and intervention in the stream ecosystem. This involves the

- examination of the variability in space and time of the transport of suspended material and solids; mass balancing and differentiation of suspended material and bed load;
- analysis of
  - the impacts of bed instability on abiotic factors, e.g. grain size distribution,
  - ground water dynamics in the forelands, as well as biotic functions and processes in the river and its flood plains, e.g. colonization of the interstitial, development of flood plain forest;
  - the interaction of the primary causes of present and expected depth erosion;
  - natural self-stabilization of the flow on the basis of near-natural river bed morphology;
- large-area analysis of the runoff dynamics, with respect to the
  - impacts of river engineering work concerning depth erosion, flow dynamics, water levels, colonization potential, achievement of economic expansion goals,

  - consequences of repositioning, breaching and repairing the dykes, e.g. on flood diversion as well as on the flood plain biocoenosis and
  - ecologically compatible possibilities of shaping the river bank;
- studies on the impacts of use, e.g. shipping, and individual hydraulic engineering measures, e.g. filling in potholes, groynes, on ecomorphological structures;
- impacts of hydraulic engineering measures on the in-/exfiltration of (harmful) substances into the aquifers of the bank regions;
- development of economically and ecologically sustainable measures for engineering interventions in the river basin, e.g. river-bed stabilization;
- development of tools to control the performance of implemented measures.

2.2 STRUCTURE-BOUND TURNOVER PROCESSES

2.2.1 Anticipated research tasks

The subconcept "Ecology of Flowing Waters" will be supplemented by the addition of a section on "Structure-bound Turnover Processes". The *Projektgruppe Elbe-Ökologie* has organize a workshop on this subject in July 1996. Notwithstanding the results of this workshop, priority will be given here in advance to those processes which are converting matter on the river bed and in the interstitial. The rates of substrate-bound conversion have been less extensively researched than processes in the flowing wave. This issue is expected to reveal many links with research issues in the other subconcepts:

- Bed substrates are particularly influenced by the dynamics of runoff and morphodynamics. Their biological functions may be impaired by anthropogenic interventions in the stream ecosystem, e.g. river regulation measures. This item represents interlinks with the issue "Ecomorphology".
- The impact of pollutive matter on the development potential of fish is described by an interface with the section "Species and Biocoenosis".
- Furthermore, cross-references can be established to chemical or toxicological sediment studies performed, for example, by the ***B****undesanstalt* ***f****ür* ***G****ewässerkunde* (BfG), the *Forschungszentrum Geesthacht* (GKSS) or the ***U****mwelt****f****orschungs****z****entrum* (UFZ).
- The assessment of turnover and retention of material in flowing waters and flown-through lakes of the lowland touches issues of the water and material balance in the river basin (cf. subconcept "Land Use in the Catchment Area").

2.3 SPECIES AND BIOCOENOSIS

2.3.1 Fish fauna

2.3.1.1 Introduction and objectives

Fish stocks make both specialists and laymen interested in understanding the ecosystem of waters, as they are used as a food resource. A drop in the environmental capacity of fish waters shows usually immediate economic consequences. For this reason there is more widespread and more detailed knowledge on the mode of life and habitat requirements of fish, particularly of commercial species, than it is the case for other groups. Scientific knowledge and economic exploitation complement each other and will have to continue to cooperate in future if permanent protection and restoration of near-natural habitats is to succeed.

Species, populations and biocoenoses of fish are considered to be ideal biological indicators. They can be used to achieve both special and also integrating insights into the functions of stream ecosystems, selected stretches of flowing water or the interrelations between river and flood plains. It is even suggested that fish represent the most suitable indicator for ecological interrelations of stream ecosystem.

The Elbe has a special significance for approaches, concentrated on fish ecological, as a major fraction of the pristine biocoenoses is still retained in spite of considerable deterioration of the water quality. This is attributed to the many and diverse morphological structures of the river. Users as well as scientists must therefore concentrate on elucidating the interrelations between the morphological or structural factors of the ecosystem and their functions for the fish stocks. Against this background, fish ecology and fisheries biology of the Elbe research programme have the following goals in common:

- conservation of a riverine ecosystem typical of the natural region as a whole and in detail,
- sustainable reproduction of all autochthonous species,
- preservation of the genetic potential,
- promotion of threatened species and those returning to the Elbe,
- elaboration of general, transferable and practically applicable findings and methods,
- promoting the situation for migrating species in the Elbe and its tributaries.

The issues of fish ecology are regarded as particularly suitable for ensuring the holistic approach of the research project. To this end the following principles must be observed:

- Research is to be confined to the potential distribution range of the fish stocks. Equal consideration must be given to the stream of the Elbe, the flood plains and the interrelations between the flowing wave and water bed, i.e. to the longitudinal, lateral and vertical component.
- Research work is to be oriented to interfaces with other issues such as "Ecomorphology", "Ecology of the Flood Plain" and "Structure-bound Turnover Processes".

Research on fish ecology takes place under acute pressure time. The previous situation of the Elbe was characterized by an increasing deterioration in water quality. At the same time, the structural quality of the river improved due to the dilapidation of the hydraulic engineering structures in the former German Democratic Republic. Today both lines of development are reversed. A perceptible improvement in water quality is contrasted with possible structural impoverishment caused by rapid repair to the river regulation structures to maintain the Elbe´s function as an inland waterway. Hence fish ecology has to pursue the most urgent goal of forecasting possible impacts of individual or combined river engineering measures on fish communities.

2.3.1.2 Problems and knowledge deficits

In comparison with other countries, e.g. USA, Canada, UK, France, Eastern Europe, low significance is attributed to professional and leisure fishing in Germany, and research on fish ecology in flowing waters is underrepresented. Large rivers are neglected by ichthyology, mainly due to the methodological problems of acquiring quantitative data on populations.

Findings on maintaining, restoring and also managing migratory fish populations in continuous or interrupted systems, which are available in other countries, shall be taken into consideration for the Elbe. However, the Elbe as a so-called "sand river" differs much from other rivers in Central Europe already investigated in detail, e.g. Rhine or Danube. Correspondingly, there is little knowledge about the significance of riverine structures, e.g. sand and gravel banks, groynes, as habitats for fish fauna, above all with respect to the rheophilic species. Precisely these findings are, however, decisive for all further measures leading to a change in the Elbe basin.

An up-to-date qualitative study of the species composition is available for most of the Elbe main river (ARGE ELBE 1995). However, as yet quantitative surveys and data on the stock dynamics as well as information on the qualitative and quantitative composition of the fish fauna in the flood plain waters and tributaries of the Elbe are scanty. Specific studies of the tributaries have begun within the frame of fish mapping in *Mecklenburg-Vorpommern* (1991) and in *Sachsen-Anhalt* (1992/93) but have not yet been completed. On the whole, the species composition in the entire course of the Elbe, and also in some tributaries, seems to be currently subject to extreme change. Previously extinct or very rare species are being sighted again, however, their origin is unknown.

Most fish species living in flowing waters require several different habitats to complete their life cycle from the spawn to the adult. Each habitat must be accessible in sufficient quality and quantity. The migrations of many fish species (up- or downriver or into the standing waters of the flood plains) clearly show the biocoenotic interrelations between catchment area, flood plains and river. Sustainable reproduction of all autochthonous species and the conservation of their genetic potential is only possible if these relationships can be sustained. The assessment of the present situation, the threats and the potential hazards require to know about the demands to the habitat at all developmental stages of fish. Considerable

deficits concern type, extent, site and number of spawning grounds, as well as the frequency of use. This is valid for the gravel-spawning species as well as for those having no special demands to the substrate or preferring vegetation close to the bank or else inundation areas for spawning.

Studies on juvenile fish are generally rare and have not yet been carried out in the Elbe. Shortly after hatching fish larvae behave largely sedentary. Juvenile fish, however, frequently change location and habitat. In addition to the quality of the spawning habitats, number, site and accessibility of growth habitats are decisive criteria for a stream ecosystem.

Further, the role of the interstitial system underneath the river bed is not yet understood (hyporheic interstitial). Available studies mainly refer to small flowing waters, which are easier to survey, but underline the decisive significance of this habitat. The extent to which this concerns also spawn and juvenile fish in large rivers remains unknown at present.

Apart from the accessibility of the various habitats required for growth and development, the migration facilities offered to adult fish are essential. Findings from the Austrian Danube and the Middle Elbe demonstrate the great significance of lateral migration, i.e. diverse interrelations between the river and the flood plain waters. The conditions that trigger migrations between individual subhabitats and their extent remain as yet unknown.

Long-distance migrants, such as salmonids (salmon, sea trout) are comparatively well studied, and they are commonly used as indicators of migration obstacles. However, knowledge on migrations of short-distance migrants, e.g. burbot, orfe or bluenose, is very scant. Short-distance migrants shift only between certain sections of flowing waters, the conditions of which are decisive for their survival of the species. Better knowledge about these potamodromous species would improve the bioindication of the ecological status of river sections.

2.3.1.3 Research priorities

2.3.1.3.1 Problem-oriented assessment of available research findings

The impacts of hydraulic engineering measures on typical Elbe ichthyocoenoses and on individual developmental stages in the life cycle of selected indicator species should be evaluated by reviewing the available literature as soon as possible so that interventions in the morphology of the River Elbe can be assessed. Priority is given to assessing the impacts of groynes and headworks, or repairs to them, on the bed and bank structures, although attention should be paid to existing transverse structures, too. At the same time, the evaluation of the literature serves to collate existing knowledge on the autecology of typical Elbe fish species in order to define *Leitbilde*r (cf. section 2.3.1.3.2).

2.3.1.3.2 Development of ecological *Leitbilder*

The draft of ecological *Leitbilder* requires to extend the available know-how by:

- describing the requirements of autochthonous species to those habitats, which play a decisive role in their life cycle, using qualitative and quantifiable parameters and

- reconstructing the near-natural state including spawning, growth and migration areas in the Elbe tributaries and in flood plain waters.

The pristine abundance of fish species typical of the Elbe as well as the current biodiversity is well-known, so that deficits concerning certain species can easily be identified. Also, the quantitative composition can be approximated. Now, species-specific *Leitbilder* must be drawn up and any deficits in knowledge pinpointed. The parameters necessary to describe the autecology of individual species must be clarified. In small flowing waters, certain parameters have proved valuable: variance of width and depth, sheltering facilities per considered stretch, grain sizes, oxygen saturation of the interstitial etc. Comparable data are not yet available for large rivers. The deliberate definition of parameters and indicators, relevant both for fish ecology as well as for other disciplines is a premise for compiling *Leitbilder*. For example, hydrological, hydraulic and morphological parameters must be appropriate to describe the habitat conditions required by selected indicator species and ichthyocoenoses.

2.3.1.3.3 Biocoenotic studies

Collecting new data for characterizing the Elbe system must be oriented both towards deficits as well as to the issues required for the *Leitbild*, its evaluation and the measures to be compiled. A further goal is to complement the methods for future data acquisition programmes by the federal states and to improve the evaluation of findings, for example with respect to the threat and protection of fish stocks and their utilization. Limited inventories may be necessary to forecast the population dynamics and to improve the bioindication function:

- **Survey and evaluation of the spawning and growth grounds, in particular:**
  - a cartographic survey of the present spawning and growing grounds for representative sections of the Elbe catchment area
  - assessment of the spawning and growing grounds with respect to their significance for the reproduction of individual species or of fish stocks. The limitation of spawning populations by space, food or predators is of secondary interest
  - a list of criteria for assessing ecomorphological structures concerning their suitability and significance as spawning or growth areas
  - significance of the Elbe interstitial for the reproduction and production of fish
  - evaluation and forecast of the impacts of hydraulic engineering interventions on the quality and quantity of known spawning and growth area, e.g. habitat forecast models
  - impacts of dynamics of floods (in time and space) on the suitability of inundation meadows as spawning grounds
  - drafting of proposed measures for selected stretches concurring with the objective and the *Leitbild*
- **Local movements and migration, in particular:**
  - significance of the runoff dynamics for the access to and from flood plain waters

- recording and weighting the most important spawning and food migrations (longitudinal, lateral, vertical)
- recording and characterizing the habitat needs of short-distance migrants in representative stretches of the Elbe
- bioindication of the ecological status of river sections by means of short-distance migrants.

- **Methods of recording populations**

As experience on the fish fauna of the Rhine has shown once more, quantitative inventories of fish populations require the combination of different fishing methods in order to achieve reliable results. This is essential for scientific statements as well as for the conception and implementation of monitoring programmes. The data, that are required for long-term surveys or for continuous monitoring of the status of the fish fauna, must be harmonized, i.e. comparable in time and space, i.e. the fishing strategies must be standardized. Fish ecological research on fish therefore also has the task to conceive concepts and sampling strategies for future monitoring programmes including:

- elaboration and evaluation of the potentials and limits of specific fishing methods
- combination and optimization of fishing methods considering limited funds and staff
- suggestion of study areas to be covered on a standard basis in long-term programmes
- proposals for optimizing monitoring programmes in time and space.

Subconcept
„Ecology of the Flood Plains“

3 SUBCONCEPT „ECOLOGY OF THE FLOOD PLAINS“

3.1 INTRODUCTION AND OBJECTIVES

3.1.1 Flood plains and their threat

Intensive abiotic and biotic interrelations characterize and closely link river and flood plains:

- dynamics of the runoff regime and the ground water in the inundation area and the
- morphodynamics of the river, i.e. the development of its route and transverse profile.

The geological situation in which the river valleys are embedded, both with respect to their genesis and present state, leads to differences in the character of the river basins and flood plains. Their characteristic features are unmistakable so that one can speak, for example, of the "Rhine", "Danube" or "Elbe" flood plains. Due to the "morphodynamic force" of pristine rivers, all flood plains have in common an extraordinary diversity of site factors as well as of plant and animal life. About 12,000 plant and animal species live in near-natural flood plains on the lower reaches of rivers plus a large number of migratory species who use the flood plains transiently as step stones for feeding, resting or breeding. Thus flood plains are among those European ecosystems with the greatest biodiversity.

The situation of flood plains can be described by the theory of "steady state". The continuity and stability of conditions for life in flood plains result from a large number of successions taking place simultaneously and being interrupted by natural interferences at different stages in their development ("cyclic succession"). The pattern of natural interferences is shaped by the dynamics of the runoff and morphology of the river. The understanding how flood plains function is challenged by the complex interrelations. Flood plains must be considered in four dimensions:

- longitudinally (paths of dispersion, i.e. "river corridors" for plants and animals),
- transversally (aquatic, semi-terrestrial, terrestrial region; main channel, side branches, flood channels, backwaters, banks and bluffs bordering the flood plains etc. as well as their various interrelations),
- vertically (interrelations with the ground water of the flood plains) and
- time, particularly the long-term periodicity of runoff dynamics.

The following pristine functions are decisive for the balance of water and matter in the flood plains and thus also for human use:

- retarding flood water runoff (flood retention, flood protection),
- retaining and sedimenting matter transported with the flowing wave (sink function, soil formation, increase in nutrient content, pollutant accumulation),
- filtering the water contributing to the ground water recharge (filter and purification function, drinking water supply).

Pristine or near-natural rivers and flood plains have become rare, as man continuously interferes with the dynamics of rivers and flood plains to ensure economic exploitation, e.g. ease of navigation, utilization for hydropower, agriculture, particularly arable farming, water supply, gravel mining, settlement, transport as well as tourism and recreation. All these human activites require quenching or excluding natural dynamics. These alterations of the temporal and spatial dynamics have considerably impaired pristine functions, they

- impoverish pristine structures and habitats associated with great losses in the diversity of typical species,
- restrict dispersal routes for organisms, i.e. the longitudinal permeability, resulting in genetic impoverishment of the animal and plant populations (island effect),
- lower the ground water level leading to dessication as a consequence of soil melioration, river straightening, deepening and bed erosion,
- decrease the biological self-purifying capacity of the rivers as well as
- constrict natural retention areas thus increasing the risk of flooding.

3.1.2 Situation of the Elbe flood plains

The present ecological state of the Elbe is beyond its pristine situation. The course of the river has been fixed and some stretches have been shortened. The morphodynamic power of the river can therefore no longer shape the flood plain, the river cannot alter its course, meanders cannot be formed nor oxbow lakes cut off, neither can new standing waters be created, nor the flood plain relief reshaped. Suppression of the natural morphological dynamics means that a decisive factor is eliminated from the steady state of the flood plains.

In the upper reaches of the Elbe and its tributaries, the transport of bed load is interrupted by numerous barrages. The addition of bed load has been ruled out due to erosion of the banks along the entire course of the Elbe. Reducing the length of the course and confining the river bed by river regulation structures has increased flow velocity and has intensified erosion of the bed. In some sections, the Elbe has deepened its bed by about 2 m in 50 years. This lowers the water levels in the river and entails a drop in the flood plain aquifers, where the ground water level directly depends on the water level of the Elbe. These effects are still regionally restricted, but potentially can occur along the entire course of the Elbe. Particularly affected are the reaches at km 150 (near Torgau), between km 183 and km 245 (between Torgau and Rosslau), km 325 to km 355 (from Magdeburg to below Niegripp) and at km 525 (downstream the Elbe mouth).

In addition, the original inundation area of the Elbe has been confined by embankments. Large areas of the "morphological flood plain" have been taken out of the inundation regime and are utilized for agriculture or settlement. For example, approx. 600 km^2 of the natural flood retention area on the Middle Elbe between the confluences of the Saale and Sude (km 266) has been lost since 1850. The average width of the inundation areas has been reduced from approx. 10 km to approx. 1 km. Furthermore, the confluences of some tributaries (e.g. Löcknitz and Sude) have been shifted upriver and confined by embankments. These measures prevent the Elbe from flowing into backwater areas as the floods rise and pre-

vent the tributaries from overflowing their banks. Frequency and duration of inundation, both decisive for the flood plain biocoenosis, have changed radically in comparison with pristine conditions.

However, the entire middle reaches of the Elbe from Usti nad Labem (Czech Republic) to the Geesthacht weir upstream of Hamburg (Germany) are less affected by engineering measures than other German rivers. The length of the river has been reduced only at a few sites, and its free flow has been fully retained in the above-mentioned stretches. Formerly installed regulation structures, e.g. groynes, have fallen into disrepair as they were not maintained adequately by the former German Democratic Republic. Typical features of the river could reestablish such as sand bars, broad beaches, forelands with varied relief, extensive percolation water biotopes or large dune fields. The natural runoff fluctuations between low and high water levels have a largely unimpeded impact on the water balance of the recent flood plains as well as in places on the formation of the river banks and flood plain relief.

The mosaic of different coexisting habitats in the Elbe flood plains has been retained, e.g. dry dunes and moist dune valleys. The variety of biotopes is reflected in a diverse flora and fauna, rich in species. Along the Middle Elbe between Wittenberg and Magdeburg the largest continuous flood plain forests are found in Central Europe demonstrating the rich near-natural habitats in the flood plains. These biotopes are surrounded by an open landscape largely used for agriculture. The scene is characterized by intensively farmed meadows, pasture land and arable fields. This farm land with little outstanding relief, influenced by the runoff dynamics of the Elbe, is an area of nation-wide and international importance for the brooding, resting and migration of numerous bird species, such as the crane or Bewick´s swan. The landscape along the Elbe with its pattern of pristine or cultivated habitats is of paramount importance for nature conservation in Germany and in Europe, but its future existence is threatened by:

- interference with the runoff dynamics of the Elbe, particularly by lowering the levels of the river and the aquifer as well as by changes to the inundation dynamics,
- suppression of the existing morphodynamics, particularly in the land/water transition zone,
- interference with the ground water balance, particularly by large-scale gravel mining
- levelling of the flood plain relief by intensive agriculture increasing erosion
- occupation of further areas by settlement, industry or tourism, as well as the
- restrictions to the biological permeability along the river, particularly by main traffic routes crossing the valley.

3.1.3 Objectives

As a consequence of the specific dynamics between the runoff regime and surfaces as well as the ground water balance, the conditions for the vegetation and fauna typical of the Elbe flood plains have to be elucidated with the aim to improve the existing tools for the evaluation of interventions (environmental impact assessments). This aim is approached by developing reasonable procedures for the evaluation and ecological *Leitbilder* specific for the

region to provide the basis for compiling *Entwicklungsziele* that can be implemented. In the long run, the scientific findings should contribute to the pursuit of the *Bundesnaturschutzgesetz*, i.e. to balancing between the conservation of and the interferences in the pristine situation. The executive authorities in nature conservation, water economy, agriculture, urbanization planning etc. should receive support in:

- development and maintenance schemes,
- planning of renaturation measures,
- evaluating the conservation value of flood plain biotopes and
- documentation of the current status and changes to it.

3.2 PROBLEMS AND KNOWLEDGE DEFICITS

3.2.1 Structural diversity and biocoenosis

The morphology of the Elbe flood plains, particularly of the Middle Elbe, results from three successive processes, that have superimposed in space and time. The stream channel was shaped 12,000 to 10,000 years ago by melt water from the Vistula glaciation. The currently visible rough relief of the valley is due to aeolic sedimentation (fine sands deposited as dunes). The morphodynamics of the River Elbe came about by interaction with this relief. Numerous meanders arose, were cut off, superimposed and interlinked, creating a wide variety of morphological structures. Even today, together with the runoff dynamics, they represent highly differentiated habitats. Just as important as the different habitats is their spatial configuration. The coexistence of wet and dry habitats with steep gradients in microclimate over a small area is particularly characteristic of the Elbe flood plains, and their biodiversity may be largely attributed to this. Rise and natural restoration of bifurcations, backwaters or the microrelief were gradually suppressed, when hydraulic engineering and embankment construction started in the Middle Ages. In some stretches, however, embankments led to the formation of new biotopes, such as percolation water zones within the dykes.

Even under natural conditions, the biotopes of the flood plain are becoming senescent, backwaters are silting up, the microrelief is being worn down etc. It is now a major issue of concern in ecology and nature conservation, that such decaying systems are not being regenerated or newly created by natural processes. Unfortunately, these processes are even accelerated by anthropogenic factors including eutrophication, lowering of the ground water level or mechanical soil working. Uncontrolled progression of theses processes will cause a loss of structural and, along with that, biological diversity. Our knowledge on interactions between the morphological structures and the water budget of the flood plains is scant. Issues of concern are:

- impacts of slight changes in inundation frequency and duration, as well as fluctuations of the ground water, on the climate of the microrelief and on the specialized flora and fauna;
- significance of small-scale patterns and gradients for the composition of biocoenoses;
- the time necessary for back waters to silt up in relation to fluctuations of the ground water and to the frequency and duration of inundations;

- ecology of percolation water zones and consequences of changed inundation dynamics.

3.2.2 Assessment of the ecological status of the flood plains and river-bank structures

The issues discussed in the following sections 3.2.3 to 3.2.7 require scientifically established and reproducible evaluations to deal with them. In the past, evaluation procedures for flowing waters and their flood plains have frequently been developed and tested. However, these procedures usually apply only to the present situation. The nature of evaluation procedures capable of assessing dynamic processes in both space and time, e.g. inundation frequency and duration, still remains largely unclear. A major concern is the transfer of available assessment systems to the special situation of the Elbe.

3.2.3 Changes in water budget

Most problems in the Elbe flood plains arise from a disturbed river/flood plain interaction already occurring or to be feared in future.

In the first place, river bed instability has become apparent in considerable stretches of the Middle Elbe (depth erosion with alarming consequences) caused by interdependent factors affecting runoff dynamics, water level and thus the ground water table in the flood plains:

- lack of bed load due to the transverse structures in the upper reaches of the Elbe and its tributaries,
- reduction in course length,
- restrictions in width due to groynes and headworks or restrictions in lateral erosion.

Investigation and description of the causal relations is an essential task of ecomorphological research, cf. subconcept "Ecology of Flowing Waters", section "Ecomorphology". The extent to which interrelations between water levels and ground water tables affects soils or vegetation and their faunal elements, is largely unknown for the Elbe.

3.2.4 Ecological flood protection

A further issue of concern is the severe reduction in natural inundation areas as a consequence of land use, in particular for settlement and agriculture. From the ecological perspective and in view of existing restrictions on dynamics, it is necessary to restore large inundation areas in their original location. This would make a decisive contribution to the sustainable development of biotopes typical of the flood plains and its water budget. Concrete plans on repositioning embankments are already in place in Brandenburg, Sachsen-Anhalt, Mecklenburg-Vorpommern and Niedersachsen, frequently as part of the necessary dyke repairs. As yet no experience has been gathered in the large-scale repositioning of embankments or in the breaching or demolition of dykes in Germany. Hence information is needed on:

- impacts of the runoff dynamics newly establishing on the biotopes inside and outside of a modified dyke, in particular on the various types of flood plain forest, surface waters of the flood plain and percolation water zones,
- methods of flood plain forest restoration,
- remobilization of pollutants from contaminated soils (in some areas heavy metal pollution is up to 10 t/ha).

3.2.5 Gravel mining

Gravel mining directly impairs the morphology and ground water dynamics of the flood plains. It may show considerable consequences in the flood plains far beyond the actual site of intervention. Gravel pits are artificial structures in the flood plain. Although, from the aspect of nature conservation, flooded pits may take over some functions of natural waters, nevertheless they cannot replace structures created by natural dynamics, e.g. backwaters. The federal states bordering the Elbe plan gravel extraction for up to several thousand hectares per district. Hence we need criteria for the:

- approval or rejection of gravel mining projects,
- selection of sites and the extent of gravel extraction, as well as
- subsequent use of gravel pits.

3.2.6 Agricultural use

Flood plains have been considerably affected by agriculture measures which, as a rule, destroyed matter cycles that were tightly closed under pristine conditions. Agriculture has damaged the filter and accumulation functions of the flood plains in many places and shows further severe impacts:

- levelling of the flood plain relief,
- impairment of structures and elements of the landscape,
- promoting inundation-related erosion, particularly in the case of arable farming and intensive grassland management,
- eutrophication of flood plain waters, e.g. as a consequence of intensive or inadequate animal production, and
- lowering of the ground water table through soil melioration measures.

The impact characterization, diagnosis and assessment of agricultural produktion in the flood plains has been focused on the eutrophication-relevant nutrients nitrogen and phosphorus, as well as on the toxicology of pesticides. From the present perspective, this approach of evaluation is not adequate in the cleared flood plains, but should include the biotic and abiotic structural elements of the flood plain (macro- and microrelief), forests, hedges,field shrubs etc.

There is a knowledge deficit concerning

- the restoration of a range of relief typical of the flood plain,

- the management of contaminated sites and also
- retention areas regained by repositioning dykes.

3.2.7 Other issues of concern

More intensive exploitation of the flood plains is associated with economic development including above all the allocation of development areas for settlement, industry and tourism, as well as the development of transport routes. Problems particularly arise in regions with a poor economic infrastructure where the river previously formed the national border. Concepts are required permitting economic development without impairing the ecological value of these comparatively pristine landscapes.

3.2.8 Interfaces with other issues

Research on the subconcept "Ecology of the Flood Plain" is mutually interdependent on the issues "Ecology of Flowing Waters" and "Land Use in the Catchment Area". Overlap with other disciplines in subject matter and site must be established in order to compile ecological *Leitbilder*, i.e. in identifying parameters and indicator species. The transfer of information and appropriate data processing must be ensured. Interfaces with the subconcept "Ecology of Flowing Waters", section "Ecomorphology", arise for the following topics:

- preparation of a digital topographical model,
- assessment of the impacts of dyke repositioning on the runoff dynamics,
- estimating the impacts of progressive depth erosion as well as various measures designed to counteract it,
- evaluation of the subsequent effects of the planned levelling of the flow rates at low and medium waters on the dynamics of the ground water close to the river,
- estimates of the impacts of groyne and headwork construction or repair on the runoff dynamics in the case of mean or high water.

The major interfaces with the subconcept "Ecology of Flowing Waters", section "Fish Fauna" are:

- fish migration in the waters of the flood plain and
- assessment of backwaters..

An essential interface with the priorities of the subconcept "Land Use in the Catchment Area" is the reduction of material discharges by changes in land use.

3.3 PRIORITY RESEARCH TASKS

3.3.1 Problem-oriented evaluation of available research findings

According to a study by ÖKON GmbH more than 1600 publications from the most varied disciplines are available on the Elbe and its flood plains, their functioning and biocoenosis (scientific publications and other data, obtained for example in environmental impact assessments). The literature review serves the preparation of:

- establishing an Elbe-specific file on target species classified to natural regions,
- the parametrization of the habitat demands by target species and biocoenoses,
- selecting indicator species and indicator biocoenoses,
- integrating findings from other river basins and verifying their transferability to the Elbe system.

3.3.2 Relations between river and flood plains

Most urgent, priority must be given to identifying, analysing and describing the interrelations between the runoff dynamics of the river and the dynamics of the floods and ground water in the the flood plain. Moreover, the knowledge about these interrelations provides the indispensable basis for further research, which has to include the topics:

- differences in the pristine and the anthropogenically altered runoff dynamics of the river and the impacts on the water budget of the flood plains, particularly on the periodicity and duration of inundations and on the shifting depth of the ground water table;
- influence of the runoff and ground water dynamics on the ecological status of the tributaries, backwaters, flood channels, small bodies of water and percolation water zones,
- significance of the microrelief for the flood plain biocoenosis, particularly in connection with changes in the dynamics of ground water, flow and morphology of the flood plain.

3.3.3 Development of ecological *Leitbilder*

In order to determine the near-natural state, the development of the flood plain habitat under pristine conditions after the last ice age is to be examined. The interactions between the dynamics of morphology, runoff and ground water, soils and soil formation as well as the influence of the natural vegetation on the water budget are of particular significance. In addition to the low-water situation typical of the Elbe, mean and high water situations must also be considered.

When establishing ecological references, particular attention must be paid to the origin in space and time of pristine open lands and successions (reconstruction of the pristine landscape).

The way in which the natural boundary conditions have been changed by anthropogenic interference must also be indicated. Changes in water budget must be identified, e.g. water level, flow conditions, aquifers. In order to characterize drastic changes in the flood plain ecology, points or periods must be selected in which major technical or economic innovations were introduced. Economic boundary conditions must also be taken into consideration. On this historical basis, it must be clarified which of the natural boundary conditions

- have been irreversibly damaged,
- can in principle be reconstructed,
- must be restored at all events,
- must be protected against damage,

in order to allow the existence, viability and sustainable use of the flood plain.

The development of *Leitbilder* shall provide a list of parameters and targets capable of being depicted cartographically for concrete, representative areas along the course of the river. Parameters describing the water budget and the morphodynamics, as well as indicative species or biocoenoses are to be preferred.. Research has to select appropriate parameters from the known ones or to propose new ones, for example:

- Ground water: depth of the ground water table and its fluctuations etc.
- Soils: available field moisture capacity, compactness, root penetration, air capacity etc.
- Runoff dynamics: residence times, duration of seasonal inundation, inundation levels, flow rates, flow patterns etc.
- Morphodynamics: river bank structures, stratification stability, soil texture, surface relief etc.
- Flora and fauna: species and biocoenosis indicating single or several parameters.

The *Leitbilder* should initially be elaborated on the basis of available documents, cartographic information, historical and current literature etc. It may be useful to add informations from other German and European rivers and their flood plains to those specifically concerning the Elbe.

3.3.4 Assessment and bioindication

Most evaluation procedures in use today for flowing waters and flood plains make use of a multistage scale enabling the current ecological status of biotopes and biocoenoses to be classified in comparison with the pristine state. Further development of this method proven in practice must pay greater attention to previously neglected geomorphological structures. Furthermore, new procedures must be developed to additionally cover the dynamic interactions between the river and flood plain, as well as between the flood plain biotopes. In preparing new evaluation procedures, or developing those available, one has to evaluate the:

- flood plain relief as a site factor for biocoenosis
- location of different biotope types in their function as habitats
- flood plain development considering the dynamics of site factors
- development and ageing processes of flood plain biotopes
- deficits in autecology and population ecology of the indicator species selected for the *Leitbilder*, particularly those species allowing to distinguish natural from anthropogenic changes in flood plains and their biocoenoses.

3.3.5 Management concepts

Drafting of management concepts for future sustainable use and development of inundation areas, including the interests of water resources, agriculture, tourism and nature conservation. In particular, the potentials for agriculture and forestry in the flood plain should be examined with respect to maintaining and expanding near-natural biotopes, as well as large-

scale extensive land use. The concepts must be assessed with respect to their ecological and socioeconomic effects.

3.3.5.1 Gravel mining

Gravel mining is a major intervention in nature. It is subject to provisions of the federal and state conservation legislation, in particular to mining law, which is superior to the legislation of the federal states. The obligation to perform an environmental impact assessment merely refers to individual projects, and not to the impacts of several mining projects for which different project managements are responsible. However, a large-scale regional analysis is indispensable from an ecological perspective, since the individual projects do not merely add up, but may cause much greater damage. So, gravel mining comprises several priority issues:

- short- and long-distance impacts of gravel mining on the ground water table,
- dynamics of runoff and ground water,
- modification of the regional climate due to the emergence of large evaporation areas,
- ground water quality and
- development of the affected flora and fauna.

3.3.5.2 Flood retention and flood plain renaturation

Priority is given to research concepts supporting existing plans on restoring natural retention areas by repositioning or breaching dykes. The aim is to initiate pilot projects on a 1:1 scale in order to record the ecological consequences of a changed flood situation. Flood plain renaturation is to be dealt with, including the ecological functionality of backwaters and flood plain forests, as well as their renaturation. Attention should be paid to locational and biological interrelations between the flood plain and the adjacent terraces, as well as to the functions of tributaries and their flood plains as a pool, or refugium, for species recolonizing restored stretches of the river.

3.3.5.3 Farming in the inundation region

Research on the issue of farming in the flood plain should primarily accompany the concrete implementation of plans, as in the catchment area. Existing or planned model projects should receive scientific support and be assessed with respect to their ecological and socioeconomic impacts. Priority is given to those projects that go beyond purely material considerations, e.g. discharge minimization of eutrophying substances, or that indicate ways in which structural damage can be mitigated or reversed or, e.g. land fragmentation, sealing of the soil, levelling of relief, drainage, river straightening. The studies should cover the

- potentials and limitations of transferring model projects to other scenes with a different natural and socioeconomic frame (cf. subconcept "Land Use in the Catchment Area", section 4.3.2),
- assessment of the European, federal and state programmes on promoting extensive land management with respect to their ecological and economic efficiency in the flood plains,

- forecast of economic and business consequences of area-wide extensive grassland farming in the flood plains
- scope for diversifying the sources of income for farmers including tourism, landscape conservation, nature conservation by contract, or production of regenerative materials
- assessment of various uses with respect to their ecological compatibility, especially concerning the culture of regenerative materials in the flood plains
- forecast of the consequences of changed agricultural use on plants and animals in naturally open landscapes
- potential uses, or alternative uses for products grown on contaminated soils.

Subconcept "Land Use in the Catchment Area"

4 SUBCONCEPT "LAND USE IN THE CATCHMENT AREA"

4.1 INTRODUCTION AND OBJECTIVES

4.1.1 Flowing waters and their catchment area

Riverine ecosystems are characterized by the specific natural conditions in their catchment area. The tributaries mediate between the terrestrial component (landscape) and the main river. The contact between the large number of small rivers and their surrounding area is particularly intensive, the length ratio of small tributaries to large rivers can exceed 100:1. Hence the water budget and mass balance of large rivers depends on the contribution of pristine or near-natural compartments to the catchment area and the way they are used. Therefore, as a premise only a holistic consideration of the catchment area can achieve an adequate understanding of the natural functions and interactions in the stream ecosystem. This is the basic precondition for solving the problems arising from land use, in particular from agricultural practice. This point of view is underlined by the National Report of the Federal Republic of Germany at the United Nations Conference on Environment and Development in Rio, 1992: *"In spite of [...] positive environmental achievements [...] no sign of a sustained trend reversal in stresses imposed on nature by agriculture can yet be perceived. The environmental and agricultural ministers of the federal and state governments are in agreement that there is a considerable need for action here. [...] The situation in the new federal states will play a decisive role".*

4.1.2 The Elbe catchment area

The Elbe is one of the largest river basins in Central Europe (length approx. 1100 km, catchment area approx. 148,000 km^2, see map in the Appendix). The river system imposes its water regime on large regions of the Czech Republic and Germany (approx. 34 % or approx. 65 % of the total catchment area, resp.). Until recently, the Elbe was one of the most polluted rivers in Europe. Economic restructuring, especially in the new federal states, i.e. the area of the former German Democratic Republic, which covers 73 % of the Elbe catchment area, and the erection of sewage water treatment plants has considerably reduced discharges from point sources. Hence present attention is increasingly focused on diffuse immissions. A major fraction of the diffuse discharge is attributed to agricultural activities. Currently, the Elbe contributes 12% to 13% to the total load of nitrogen and phosphorus of the North Sea. Time series of eutrophying elements in the German Bight still indicate steep rises in nitrate concentrations which correlate with Elbe flood events. The input of nitrate into the North Sea from the Elbe can be reduced significantly only by the immediate implementation of holistic concepts for water pollution control in the catchment area. Otherwise the commitment of reducing the nutrient input by 50 % in the period from 1985 to 1995, undertaken by Germany at the International North Sea Protection Conferences, cannot be achieved for nitrogen. At the same time, the measures to be implemented will serve to protect the ground and drinking water against excessive immission of nitrogen.

A joint position paper by the scientific societies and associations of agriculture and water management on intensified water conservation in the agricultural sector states in 1993: *"Scientific know-how on efficient avoidance measures is already very extensive. The major deficits continue to be found in implementing these measures in agricultural practice."*

The key concept of *"sustainable development"* of Agenda 21 at the 1992 United Nations Conference on Environment and Development requires to combine ecological, social and economic development factors for future development targets. This interdisciplinary approach is also supported by the ***S**achverständigen**r**at für **U**mweltfragen*: *"Sustainable development thus includes an environmentally compatible coordination of economic processes oriented towards the environmental capacity of the ecological systems, as well as corresponding social compensatory processes…."* (*Umweltgutachten* 1994).

The current structural changes in the new federal states allow to create the preconditions for a long-term sustainable economy on an ecology-based conception of land use in the Elbe catchment area.

4.1.3 Objectives and approaches

The major objective within the "Elbe Ecology" research programme is to support projects which will indicate ways in which, together with the responsible authorities, concepts of sustainable land use can be realized in practice in different natural or economic regions in the Elbe catchment area. Management concepts must be developed permitting the area-wide implementation of socioeconomically acceptable forms of use adapted to the environmental capacity of the sites. In order to achieve these goals the following approaches must be considered (cf. framework concept Section 1.3.1):

- The present status of land use has to be documented.
- Existing know-how on sustainable land use must be elaborated.
- Based on existing information, the entire catchment area must be classified according to natural region and socioeconomic criteria.
- Assessment standards must be established and on this basis regions with ecological deficits are to be identified.
- Ecological models must be drawn up for the classified areas.
- Concrete implementation projects for representative areas must be realized to remedy ecological defects. In designing these model projects, use should be made of EU, federal or state activities which conform to the *Leitbilder*. The implementation of these projects must be scientifically supported, and their results analysed and assessed with respect to the ecological and socioeconomic targets.
- Results from representative model projects are to be transferred to corresponding natural or economic areas.

4.2 PROBLEMS AND KNOWLEDGE DEFICITS

4.2.1 Water budgets and mass balances of the landscape

The ecological load capacities of near-natural ecosystems, expressed as critical levels or critical loads, have in part been considerably exceeded. This increasingly leads to environmental problems, e.g. eutrophication, especially of aquatic ecosystems or impairment of drinking water quality.

The contribution of eutrophying matter originating from agricultural practice to the total pollution of the Elbe and its tributaries, as well as its immission paths and conversion processes are well-known. The fraction of diffuse inputs by agriculture amounts to more than 80 % for nitrogen, mainly via ground water passage, and more than 85 % for phosphorus, largely via surface erosion. For the paths of diffuse input of nitrogen we must differ between regions with loose rock (approx. 75 % of the Elbe catchment area in the new federal states) and those with exposed rock. Knowledge concerning the concrete regional allocation or the quantification of diffuse input of nitrogen in flowing waters is scant. This becomes evident by the discrepancies when comparing the potential emission from the surface and the actual immission observed as load in the flowing water. Possible reasons are:

- great regional differences in space and time for the nitrogen transport via the ground water, particularly in loose rock so that the immitted nitrogen is subject to very different conversion conditions;
- retention by accumulation in certain regions of the catchment area (sinks), e.g. in wetlands, intact fen sites or river valleys;
- retention and conversion in flowing waters and flown-through lakes, particularly under lowland conditions with little runoff, e.g. the basins of Spree and Havel.

The correct evaluation of the current situation is difficult due to the obsolete data from the new federal states, which reflect the status of the late eighties. Since the reunification of the two German states, considerable changes have taken place in land use, and topical data on the current pollution situation are still missing for many regions. The diffuse fraction of nitrogen input can be better quantified by comparison with the perceptible reduction in discharges from point sources. New data on discharges from point sources are currently being gathered on behalf of the ICPE, as a basis for future studies.

Furthermore, there is a lack of knowledge on the concrete impacts on water budgets and mass balances in different regions. Such impacts are caused by large-scale changes in land use, mainly due to market policy as a consequence either of the European agrarian reform (extensive management, set-aside programmes, reafforestation) or of various ordinances and guidelines. We need a comprehensive ecological and socioeconomic evaluation of these changes.

A major goal of the federal states bordering the Elbe is to maintain agriculture as a structurally decisive element in economy, particularly in economically weaker regions. At the same time, diffuse immissions to the Elbe and its tributaries are to be reduced. Against this back-

ground, model projects are required to test available land use concepts in order to analyse and evaluate the ecological and socioeconomic impacts by means of supporting scientific studies.

The current discussion is drawing attention to the greatly increased immisson of mineral matter to flowing waters over the past few decades. Particularly base cations were released as a consequence of drastic drainage measures. These losses have to be balanced in order to ensure the principle of sustainability. Knowledge on the extent and the regional significance of this phenomenon is insufficient.

The flooding of the abandoned open-cast pits originating from brown coal mining in the basins of the rivers Black Elster, Mulde, Saale, Spree and Havel will dramatically reduce drainage and will retain ground water as well as water from flood events. This will perceptibly influence the flow rate and water quality of the Elbe for several decades, above all during low water situations. There is a need for more research into the impacts on the balance of water and matter throughout the whole area and on low water situations of the Elbe.

The specific runoff as well as runoff characteristics are essentially influenced by the water budget of the region, and thus by the type and intensity of land use in the catchment area. Flood events can thus be counterbalanced by creating or maintaining natural retention areas. Information on the effectiveness of existing retention structures, or those to be restored is badly needed.

4.2.2 Indication and assessment of interventions in the morphology of the landscape

Large parts of the Elbe basin are still characterized by the agricultural structures of the former German Democratic Republic. The interventions in part had extremely negative ecological effects, for example, destruction of surface morphology to create fields of enormous size, soil erosion promoted by inappropriate farming methods, one-sided crop rotations, unsuitable large-scale livestock production, severe interference with the regional water budget (complex melioration), with serious consequences above all for natural material sinks, e.g. fen sites.

As yet, major attention for the indication and evaluation of the impacts of land use in the catchment area has focussed on agriculturally related inputs of nitrogen, phosphorus, and also pesticides, into the waters. These approaches must be expanded by indicator systems providing information on critical structural changes in ecosystems, for example, changes in surface fragmentation, drainage, rezoning, reparcelling of agricultural land, agriculture and forestry, tourism, as well as sealing of the soil surface by roads and highways, settlement and industry. There is a lack of information on possible indicators, evaluation procedures, *Leitbilder* and on the definition of *Qualitätsziele.*

4.2.3 Obstacles to implementation

There is a sharp decline in agricultural producer prices as a consequence of current national and European boundary conditions. This situation is a major obstacle to realizing water pollution control, if the latter interferes with the farmers´ economic interests. Losses of income as a consequence of less intense land use can hardly be balanced by higher producer prices, apart from the cultivation of special products in limited areas, e.g. by ecological farming. Economic support programmes, as yet primarily directed towards reducing farm surpluses, must be replaced by environmental and water conservation concerns.

Ground water is the main path of nitrogen input into the Elbe, and thus into the North Sea. Approx. 2/3 of nitrogen from diffuse sources enters via the ground water. Hence, an area-wide protection of the ground water against inputs of all matter must be aimed at, requiring a higher degree of precautionary pollution control in the entire catchment area. This higher level of precaution is currently being realized in particularly sensitive areas, e.g. (drinking) water conservation zones, by close cooperation between agricultural and water management. Economic losses on the part of individual farmers due to competitive disadvantages by restrictions on use are financially compensated. Whether this limited-area approach can function as a model for large sections of the catchment area or as a general way in which economic disadvantages can be compensated, is one of the most important issues in this subconcept. Little experience is available with the solution of these problems. There are only few examples where mesoscalic implementation of measures is supported by ecological and socioeconomic studies.As a further difficulty, the success of the implemented measures can be evaluated only after a considerable period of time. Hence the exemplary realization of available water conservation concepts in cooperation with the competitive authorities must be initiated as soon as possible and be supportet by scientific studies, e.g. the concept on ***E****ffiziente* **u***nd* ***u****mweltverträgliche* ***La****nd****nu****tzung* (EULANU), ***K****ritische* ***U****mweltbelastungen* ***L****andnutzung* (KUL), or findings from the collaborative research project on remediation concepts for small flowing waters (by BMBF). Since the testing of concepts for environmentally compatible and sustainable farming in rural areas depends upon the availability of appropriate areas, biosphere sanctuaries are especially suitable as model regions.

4.3 PRIORITY RESEARCH TASKS

4.3.1 Problem-oriented evaluation of available research findings

Existing know-how on methods and concepts for sustainable land use must be compiled:

- data on the assessment of the present hydrological, material, structural and biocoenotic, as well as on the social and economic *Ist-Zustand* are to be evaluated and deficits identified;
- suitable simulation models are to be selected, e.g. for forecasting the impacts of changes in use on water budgets and mass balances;

- governmental programmes concerning environmentally compatible land use in various regions, are to be assessed with respect to their ecological and socioeconomic targets, their efficiency and their success.

4.3.2 Classification of the catchment area

The area-wide implementation of measures in the catchment area and the development of management concepts is only possible if the heterogeneity of the natural and economic site factors is considered. The entire catchment area with its flowing waters must be appropriately broken down into manageable ranges according to natural and socioeconomic criteria. Classifications of subareas based on natural regions, biotope types, land use, landforms or land registers, which are available from state authorities or research institutions, are to be used and expanded to achieve a uniform classification of the entire catchment area. Attention is drawn to the extensive preliminary work on the "Typology of Flowing Waters in the Elbe Catchment Area" (TIMM *et al.*, 1995; in German).

A first survey on the data from natural regions a well as on the data processing situation in the Elbe catchment area is being prepared by the *Projektzentrum für Ökosystemforschung* at the University of Kiel and will be ready by the end of 1996. Additional data in this sector and on socioeconomic aspects will be collected on this basis making use of further sources.

The *Qualitätsziele* will be defined in the frame of the ecological *Leitbild*. The area-wide realization of a more sustainable land use is to be socially harmonized and will be described under the category *Entwicklungsziel*. The achievability of both the *Qualitätsziele* and the *Entwicklungsziele* depends, amongst other aspects, on the legal and socioeconomic boundary conditions, e.g. economic and demographic conditions, different legislatures in the different federal states. The differences relating to natural regions must therefore be harmonized with the regional and local socioeconomic boundary conditions, preferably on a mesoscale level, e.g. subregions of the catchment area. There is a need for research concerning the

- definition of socioeconomic criteria for the spatial differentiation of the catchment area, e.g. average farm size, gross output of agricultural produce, input and output quantities, market prices, special regional factors on the input and output markets,
- application of these criteria to the Elbe catchment area,
- combination of socioeconomic and regional criteria, and
- determination of model regions or model farms for scientifically supported implementation projects (cf. Section 4.3.4).

The allocation of defined economic units and natural region units should form a basis for the development of models as well as for the selection of representative model areas typical of the natural region in order to implement measures in conformity with the model.

4.3.3 Development of ecological *Leitbilder*

The *Leitbilder* are to be developed in accordance with the approach discussed in the frame concept in Section 1.3.1. Selected parameters and indicators should describe relevant morphological, hydrological and material factors, as well as faunistic and vegetational aspects. Parameters should be harmonized between the federal states bordering the Elbe in order to facilitate comparison and aggregation of the findings. This requires to

- establish ecological references via suitable parameters and indicators for the classified areas, e.g. with respect to the load in the near-natural state;
- to assess the ecological *Ist-Zustand* according to the specific natural region and to identify regions with ecological deficits, e.g. high material outputs;
- to compile ecological *Leitbilder* for the different natural regions, i.e. to find the maximum approximation to the near-natural state achievable under present conditions, e.g. with respect to material outputs). Targets are expected to be represented as tables or maps for specific regions; e.g. for the water and material balance;
- to identify possible ways of land use for different natural regions, oriented towards the environmental capacity of the land and thus ensuring sustainable development. Future use should aim at the regeneration of the land´s natural functions, e.g. for water budget, accumulation, retention, production or habitat, as well as of the dependent functions for the people working there (recreational and socioeconomic functions).

4.3.4 Research in model projects

The major aim of research in the present subconcept is to give scientific support to the concrete realization of proposed measures for land use accommodating environmentally compatible and socioeconomic requirements. The concepts must be tested and further developed in different natural regions and economic areas. The studies must be documented in such a way as to permit a performance review so that the projects may serve as reference examples. Model projects which can be incorporated into the above-mentioned classification in the course of realization can already be funded at short notice. This procedure corresponds with the goal of the UNESCO programme ***M**an **a**nd the **B**iosphere* - MAB: *"… drawing up models for a careful management of the biosphere oriented towards the principle of sustainability and of developing, testing and realizing these models in representative landscapes by way of example"*. Therefore, within the framework of existing or planned federal or state activities and in cooperation with the competent authorities,

- model projects should be initiated and designed scientifically,
- scientific studies should accompany projects which are implemented in conformity with this goal and
- the ecological success and the socioeconomic impacts of the measures implemented should be assessed.

In order to facilitate the acceptance of such measures, those involved on the spot, e.g. farmers, associations, authorities, are to be included in the projects from the beginning. Goals,

working hypotheses, realizability of research findings, data bases and requirements, time schedules, evaluation methods as well as the compilation and synthesis of results must be defined as precisely as possible in an interdisciplinary manner. Above all, the consequences of changes in land use are to be studied in the model projects, e.g.

- the water budget of the landscape, e.g. impacts of restoring natural retention structures on the area runoff and water retention with respect to the natural ground water recharge, matter retention and flood protection;
- the mass balance of the landscape, e.g diffuse pollution of the ground water and surface waters in the Elbe catchment area;
- the biodiversity typical of the natural region;
- the income situation of those affected. Concepts must be developed for alternative income, e.g. by way of compensation. So-called "ecological bonuses" must be analysed and assessed ecologically and economically to develop a basis for a remuneration system to acknowledge "ecological services";
- business and economic factors. Holistic cost-benefit analyses for various types of management must be compared (eco-audit).

Furthermore, studies are also required with the goal of

- applying and further developing simulation models for forecasting and assessing the impacts of changes in regional land use with respect to their ecological and socioeconomic efficiency, as well as instruments for the performance review of environmental policy measures;
- determining the supra-regional impacts of structural changes in open-cast brown coal mining on the available water resources and their quality.

If the implementation of measures in the model projects is seriously hindered by a lack of basic knowledge, the following issues can also be dealt with:

- quantification of fluxes from the various sources and input paths to clarify the discrepancy between emission and immission of matter (concentrations and loads),
- analysis and quantification of the retention mechanisms of water-mediated matter transport in different compartments, e.g. in unsaturated and saturated soil zones of various regions, retention in natural sinks such as fens,
- studies on the dynamics in space and time of matter emission via soil and ground water as a function of hydrological process sequences and their modelling,
- further development of tools for use by authorities, e.g. mesoscale simulation of the water budget in soils or of lateral and vertical material fluxes.

Matter retention in flowing waters and flown-through lakes touches the issue "Structurbound dynamics" in the subconcept "Ecology of Flowing Waters" and is defined there as a research task.

Appendices