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GLOWA-Elbe II

GLOBAL CHANGE IMPACTS ON THE WATER CYCLE IN THE ELBE RIVER BASIN – RISKS AND OPTIONS

GLOBAL CHANGE AND SUSTAINABLE WATER USE IN THE GERMAN ELBE REGION – A REVIEW OF SIMULATION RESULTS OF THE GLOWA-ELBE PROJECT

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Abstract

The German Elbe basin is characterised by low water availability and high nutrient loads in its river system. Due to low average annual rainfall and high probability of further reductions in coming decades, the basin appears to be particularly exposed to potential climate change effects. The GLOWA-Elbe project carried out various model simulations for a range of scenarios in order to examine climate change effects and to assess the vulnerability of water users in the Elbe region. Results are discussed with important stakeholders and used as a starting point to develop appropriate strategies for water resource management to mitigate or even reverse recent detrimental developments – such as high levels of diffuse nutrient emission loads from agriculture and artificially increased runoff in the many parts of the basin.

For most scenarios, climate change itself would not lead to a reduction of diffuse nitrogen emissions. Therefore, further specific measures like, e.g. taxation of mineral nitrogen fertilizer are needed to decrease the nitrogen surplus of farms and, hence, reduce emissions to the river system and the North-Sea. The sensitivity of runoff to climate change was explored in detail for the Spree-Havel sub-basin. There, the flooding of 12,000 ha of abandoned open pit coal mines is creating a new artificial lake chain (with land shares in South-Brandenburg and North-Saxony), including several new water reservoirs to regulate runoff. Following the results of several simulation studies it would be favourable to accelerate the flooding of pit mines, given the possibility of further decreased precipitation in the future. Otherwise, meeting water demand downstream, which competes with the flooding of pit mines, will become an increasingly complicated endeavour in the coming decades. The consequences become apparent during summer month with insufficient Spree flows in order to remain the wetland area Spreewald – a nature reserve and national attraction for boat tourism – and to match the surface water demand of the Berlin area. Alternatively, the Spree-Havel surface water regime could be stabilised by water imports from the neighbouring Oder basin or by extending the remaining life of lignite mining activities. However, both alternatives could create substantial environmental problems elsewhere.

1. Facts and trends for the Elbe basin

The German Elbe basin (Figure 1) coincides with large parts of East-Germany (Table 1). Its total German territory share amounts to 33% and is thus at the same order of magnitude as the Rhine basin. In contrast to the Rhine and also to the Danube basin, water availability in the Elbe basin is very low (Table 1), the second lowest compared to other major European rivers. The main reason for the low water availability is the low yearly precipitation total (Table 2), which lays markedly below German average (789 mm for 1961-1990).

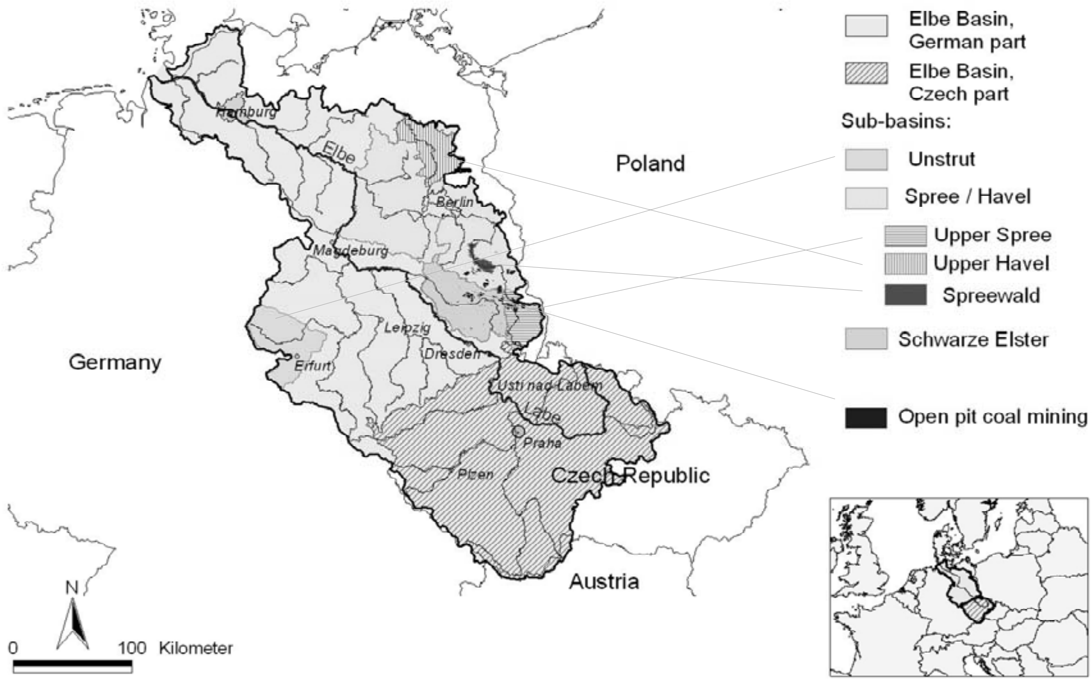

Figure 1: The Elbe basin

The already low precipitation today can be expected to make the region vulnerable to climate change, as soon as the latter is associated with reduced rainfall. Recent climate change (Table 2) is characterised by two trends: increasing mean annual temperatures and a shift in precipitation patterns towards a rise of winter precipitation and a decrease of total precipitation in the central parts of the basin. In Western Germany, in contrast, precipitation increased between 10-20% during the last 30 years. A continuation of the current trends in the central part of the Elbe basin would most likely lead to aggravated water conflicts and to the emergence of new ones.

The political agenda for water management is set by the European Water Framework Directive (WFD), which is strongly oriented towards the sustainable use of water resources. In the German Elbe basin as well as elsewhere, achieving its standards for water use involves addressing existing sustainability deficits and adjusting to challenges regarding water-relevant aspects of climate and socio-economic change. Considering the past, at least three anthropogenic interventions in the water cycle are particularly important for the design of future management strategies in the basin:

- the loss of wetlands and floodplains due to river canalisation, artificial drainage and river embankment,
- pollution of surface water by nutrient emissions (nitrogen and phosphorus) from point and non-point sources, causing high nutrient loads to the North Sea,

- intensive pumping of ground water for lignite mining in the upper Spree region (Lusatia), which artificially increased surface water discharge and its benefits for ecosystems and cities, especially Berlin, downstream.
- All three interventions are in contradiction to sustainable use of water resources and need to be increasingly addressed in the future. Two strategies are of major relevance in this context:
- further decrease of nutrient emissions from point and non-point sources,
- alleviation of landscape runoff and an increase in the residence time of surface water in the basin.

Tab. 1 Elbe basin facts

Length of the main stream [km]	1.091
Area [km²]	148.286
Administrative affiliation of major parts	Schleswig-Holstein, Niedersachsen, 88% territory share of the East German states
Population density* [capita/km²]	193
Urbane area [%]*	7.3
Agricultural land [%]*	61.3
Arable land [%]*	49.4
Forest [%]*	27.1
Water [%]*	1.4
Specific runoff [l/km²·s]*	5.3
Total water availability including the Czech part**	680 m³/(capita year)

* from Behrendt 2004 for 1993-1997,
** Stanners & Bourdeau 1995

Tab. 2: Recent climate characteristics and trends for the German Elbe basin

1951-2000	Median basin values [1)]
of 50 year averages in	
• yearly mean temperature [°C]	8.6
• yearly precipitation total [mm]	616
• yearly climatic water balance [mm][2)]	22
of 50 year linear trend changes in	
• yearly mean temperature [°C]	+1.1
• yearly precipitation total [mm]	-1
summer	-46
winter	+50
• yearly climatic water balance [mm]	-34

1) Median of basin means and linear trends (significant to more than 80%) from 369 climate station
2) Difference between precipitation and potential evapotranspiration calculated following Turc-Ivanov

Tab. 3: Developments in surface water parameters of basin wide relevance

Loss of wet lands in the low land areas (Spree-Havel, state Brandenburg) and of flood plains in the German Elbe basin
- Since the 1800's, the wet land area decreased steadily from 280.819 ha to 21,408 ha in the state Brandenburg
- 80% of current water channels are artificial in the state Brandenburg
- Floodplain area decreased from 617.000 ha to 83.654 ha in 1990 in the German Elbe basin

Improvement of water quality in the German basin part
- within 15 years the water quality changed from heterotrophic to autotrophic again
- Phosphorus and Nitrogen input to the North sea decreased by 53 and 26% between 1983-87 and 1993-97
- However, Chlorophyll-a concentration in many river sections is still higher than 20 µg/l

Flooding of remained brown coal mining pits in Lusatia (states Brandenburg and Saxony)
- Brown coal mining activity decreased from 195 Mill t per year in 1989 to 55 Mill t in 2000
- Ground water exports to surface water decreased and are further decreasing, Berlin has to adjust to a decreased surface flow, which approaches zero during the summer in warm and dry years
- Water demand for flooding of abounded mining pits to 12000 ha lake site conflicts with water needs downstream (Berlin; flood plain forests, grasslands and peats in the Spreewald area)

Tab. 4: Facts and trends for the transition in the East-German basin part since 1989

Welfare
- Increase of average per capita annual income from 9.780 € (1991) to 16.057 € (2002)
- Net loss in working places of 3 Mill.
- Decrease in birth rate from 1.6 to 0.77, currently approaching national level (1.4) again with 1.3
- Emigration of young women twice as extensive as those of young man

Water sector
- Oversized Infrastructure for a shrinking population
- Decrease in the water consumption per capita and day from 142 l to currently 93 l
- High increase rates for boat tourism

Economy
- Providers of gas, energy and water have an over-proportional share at the economic activity (35% of total revenue)
- GDP Share of agriculture is 2.1%, double as high as in West-Germany

Beside second order interactions between first order consequences of both measures, the first one of these is water quality the latter more quantity oriented. The measures above shape already the water-related trends in the region (Table 3). The water quality –although still not satisfying for many parameters - could be improved remarkably in recent years and flooding of abandoned open pit coal mines can be seen as a contribution to increase the residence time of surface water in the lowland part of the basin.

In the GLOWA-Elbe project, the above strategies were further specified, their potential to resolve existing problems was tested and explored in the context of climate and socio-economic change processes. Comparable to climatic changes, socio-economic changes can be deduced to a certain extent from global and regional trends. An overview about major trends is given in table 4. All sources not explicitly referred to in the tables can be found in Wechsung (2005).

2. An integrated heuristic concept for the exploration of regional water use perspectives under conditions of global change

In GLOWA-ELBE two major aspects of sustainable water use were explored: first, nitrogen entry from non-point sources, and second, surface water regulation.

For these two policy areas conflict analyses were executed and management strategies to adapt to the challenges of global change were developed in co-operation with stakeholders and policy makers. As one result of the GLOWA Elbe studies and simulations policy recommendations will be delivered to political and public actors.

In GLOWA-Elbe, a heuristic concept called Integrated Methodological Approach (IMA) was developed and applied, which substructures the research process in tasks. The IMA contains categories and notions to formulate the research tasks and conventions, which ensure coherence and convergence of all sub-processes. It enables researchers from different disciplines as well as researchers and stakeholders to communicate in a common language and to integrate results in a final assessment (Messner et al. 2005; Wenzel 2005a). In a simplified form, the concept is depicted in Fig. 2. It consists of the following steps:

1. Compilation of a catalogue of so-called developmental scenarios, which combine frames of development, including a set of global change scenarios on climate, demographic, economic, and societal developments, and possible policy actions at the regional scale (land use, policy etc.).
2. Identification of context-relevant indicators and corresponding criteria for the evaluation of different developmental scenarios.
3. Analysis of the scenario impacts with respect to the selected indicators and criteria, using all available data, models as well as expert and literature knowledge.
4. Multicriteria analysis and equity analysis to assess the results, and especially the policy strategies, in face of current policy objectives and actor preferences.

All steps are executed in close co-operation with stakeholders and policy makers in order to include local and expert knowledge and to ensure applied research with close contact to the existing problems at the study sites.

The steps 1 and 2 introduce the problem solving categories (alternative strategies, scenarios, indicators) and use them to define the task. Steps 3 and 4 in the lower part of Fig. 2 refer to specific methods to explore and evaluate the impact of the considered scenarios. Beside a strong participatory moment at every level, the categories in Fig. 2 are linked mostly top-down. However, as indicated by the loop backwards from problem exploration after step 4 to step 1 of the definition part, research following IMA might need several iterations before a satisfying result emerges.

The IMA process can be sub-structured (Fig. 3) into parallel or hierarchically arranged daughter processes, which give special emphasis to regional (sub-basins, states, cities) and thematic aspects (quality, quantity). The water quality oriented investigations within GLOWA-Elbe for the Elbe basin in total, its German part and the German sub-basin Unstrut were arranged in a parallel mode, only loosely coupled by the assumptions for the global change scenarios (Fig. 3, upper right site). In contrast, the quantity related investigation of the post-mining surface water regulation in the German sub-basin Spree-Havel followed a hierarchic approach (Fig. 3 lower left site). Here, results from an aggregated analysis for the whole sub-basin shaped IMA steps 1 to 3 and was complemented by more detailed studies subsequentially carried out for the sub-areas Spreewald and Berlin.

The IMA sub-processes have to be initiated and integrated again by a central control process as depicted in the centre of Figure 3. Contrary to grid-oriented approaches for integrative analysis of the water cycle, variables, scales, units and time slices need not be homogenous in the IMA sub- and control processes. The IMA enables the use of different levels of abstraction and aggregation for global change scenarios and management strategies. Some fundamental processes such as water flow can be modelled very explicitly with a high spatial and temporal resolution. Other processes such as the economic factor allocation in a region can only be formalised in an idealized way at a coarse time and spatial scale. However, a minimum of coherence is also needed in this case in order to allow aggregation and interpolation of information for the assessment level in step 4. The IMA guides the information streams from different levels of abstraction to the areas, points and time scale that are of interest and concern by the stakeholders and decision makers involved. In tables 5 and 6, an overview is given about the most important simulation models that are used in step 3 for exploring the impacts of global change on the water cycle and its manifold functions in the Elbe, their underlying basic calculation units, the requested assessment level and the model interdependencies.

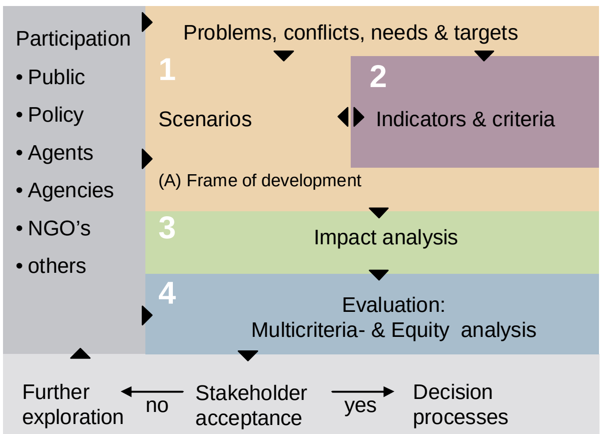

Fig. 2: The Integrated Methodological Approach (IMA) used as meta-model in GLOWA-Elbe

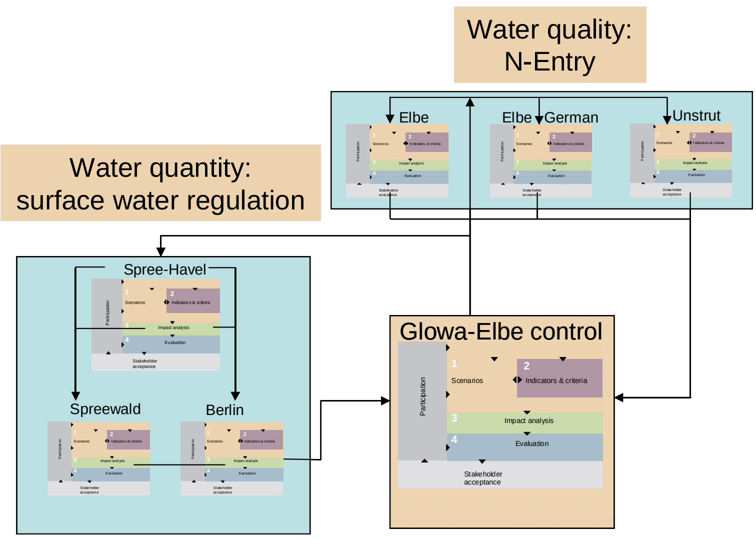

Fig. 3: The IMA process in GLOWA-Elbe consisting of a central control process and several doughter processes with thematic (water quality and quantity) and regional emphasis (Elbe, German Elbe, Unstrut, Spree-Havel, Spreewald, Berlin)

Tab. 5: Water supply and quality related GLOWA-Elbe models their basic level of information processing, the number of processed units and the assessment level to which information were aggregated

simulation task	model	units processes	basic level of temporal and spatial information processing	other than basic assessment levels
			Spree-Havel	
water supply	EGMOD		daily simulations of water-flow in	input for WBALMO
		170	sub-basins	
balancing water demand and water supply	WBALMO		monthly simulation of probability for matching supply thresholds in five year planning periods for	gauging stations water user group mean monthly values of a five year period
		400	water users	
		14	Reservoirs	
		170	with local balances/ sub-basins	
			Spreewald	
	WBALMO	197	local balances/ sub-basins	as above
			Berlin	
water supply	ARCEGMO		daily simulations of water flows for	local input for WBALMO
		40	sub-basins	
	WBALMO	120	Users	as above
		40	local balances/ subbasins	

Tab. 6: Selection of water regulation related GLOWA-Elbe models their basic level of information processing, the number of processed units and the assessment level to which information were aggregated

simulation task	model	units processes	basic level of temporal and spatial information processing	other than basic assessment levels
			German Elbe	
climate scenario	STAR		daily measurements and 100 simulations of scenario climate	grid; day, month, summer, winter, year
		369	stations	input for SWIM and EGMOD (table 8)
water supply	SWIM		daily simulations of water flows and biomass growth	
crop yields		11651	hydrotopes in total	basin, district; day, month, summer, winter, year
		3143	hydrotopes on arable crop land	
			interpolated climate x 52 soil types x 15 land use types x land use specification (9 crops)	
agricultural land use	RAUMIS		yearly simulation of agricultural land use and production intensity	districts, state, basin input for MONERIS
		112	districts	
nutrient entry for seven pathways	MONERIS		monthly simulations of nitrogen entries in	
		184	sub-basins	basin, export to the North-Sea

3. Global change scenarios

3.1. Climate

Scenario selection is crucial for any impact simulation. Although the different climate models applied to the region generally concur with regard to the simulated temperature increase due to increases in the atmospheric concentration of CO_2 and other greenhouse gases, there are large differences in the model-based regional projections for precipitation change. Taking this into account, the scenario selection was based on two criteria: First, the plausibility of the supposed climate change given current regional climate trends; and second, the particular regional vulnerability to possible climate shifts. Following these both criteria a regional climate scenario produced with the statistical model STAR was chosen for further impact analysis. In comparison to all others, the most likely statistical realisation of the scenario (see below) suggests a temperature rise, which is associated with a tendency towards a dryer climate. This is consistent with the observed 50 year trends in the basin (Table 2). Linear trend analysis indicate that past temperature increases were linked with precipitation increases at the luff site of the mountain areas, and precipitation decreases in the mountain lee areas, particularly during the summer half of the year (May-October). Furthermore, the plausibility of a climate shift following the most likely realisation of the STAR scenario was also emphasised by a modelling exercise undertaken within the frame of the GLOWA-Elbe scenario analysis. Assuming different boundary conditions, the two statistical models STAR (Gerstengarbe & Werner 2005) and NEURO-FUZZY (Reimer et al. 2005), which were compared in this exercise, simulated both a precipitation decrease for the next degree temperature increase when averaging the results of 100 statistical realisations per scenario.

Both scenarios describe a transient climate change from 2001 to 2055. The STAR model postulated a general temperature increase of 1.5 degree C for the central basin station Magdeburg up to 2055, following mean results of the ECHAM4-OPYC3 climate model for the basin and extrapolated from that single trend the temporal and spatial climate characteristic. The scenario procedure works as follows: First, the random year to year variation of temperature was sampled from de-trended daily temperature records for the period 1951-2000 at Magdeburg. The same concrete order of de-trended historical years (i.e. 1999, 1954, 1971 …) was afterwards used for all other stations as basis for specific temperature scenarios. The day to day temperature variation in the scenario years followed those in the sampled years with one exception. The absolute level from where the changes occurred was increased according to the temperature trend. The temperature trend (1.5/55°K/year) was added equally as a mean increase to all temperature days of a year. Finally, all other climate variables were derived from the daily temperature data using historical analogies determined with a cluster analysis per station. Statistical realisations of the STAR climate scenario were produced by replicating the stochastic sampling process in the temperature record for Magdeburg described above. In this case it was repeated 100 times.

The NEURO-FUZZY model converted coarse spatial outputs for the period 2020-2050 delivered by the regional climate model REMO into a finer resolution and extrapolated the change signal to the period 2001-2055. The climate model output was converted using empirical correction functions determined for recent weather records of the period 1990-1999. As well as by the model STAR 100 scenario realisations were produced, but here by random parameter variation instead of year sampling.

The authors of both scenarios declared one realisation as the most likely one, but this is only meant in comparison to all other realisations simulated by the according model. This should not be misunderstood as the most likely direction of climate change. It is ‘most likely’ only in comparison to the 99 other realisations of the scenario and for the criteria used. In the case of STAR, this ‘most likely’ realisation is the one with a precipitation trend for 2001-2055 at Magdeburg that is consistent with the slight negative trend observed for the last 50 years at this station. The most likely NEURO-FUZZY realisation comes from a simulation run with the mean parameter constellation of all 100 used. Averaging across the whole German basin part, the 100 realisations of the STAR scenario are less dry than the NEURO-FUZZY scenario during 2020 to 2050, when both precipitation records were normalized by the degree temperature increase. However, for the Spree-Havel basin, the normalised STAR-precipitation was lower than the one from NEURO-FUZZY. Taken the high vulnerability of that sub-basin with regard to further decreases in precipitation in the context of the post-mining flooding of pit lakes as discussed above, the STAR scenario was chosen for the following impact assessment. Three of the 100 STAR realisations are depicted in Fig. 4, whereby the realisations are characterised in summary by the climatic water balance – the difference between precipitation and potential evapotranspiration.

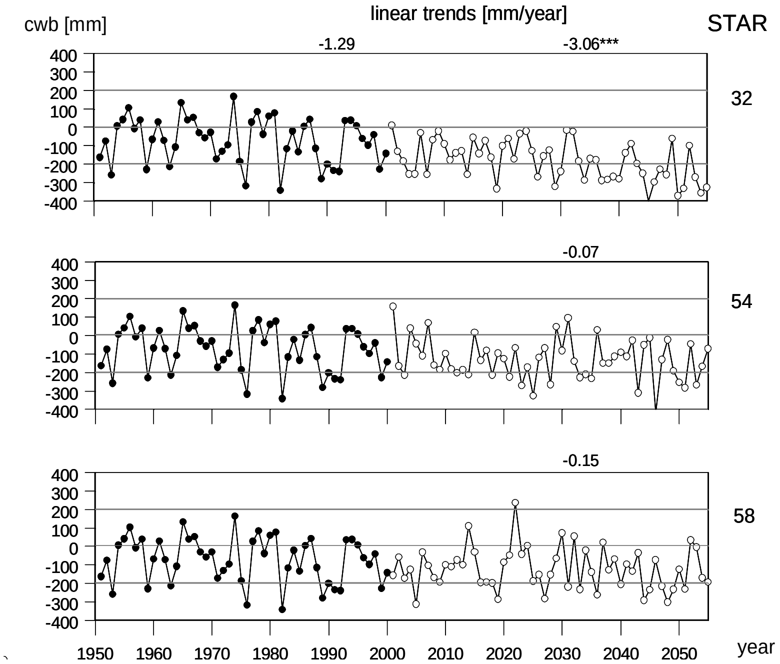

Fig. 4: Series of basin medians of the climatic water balance (cwb, calculated as described in table 2). The values were calculated for the recent climate (1951-2000) and three selected realisations (32, 54, 58) of the STAR100 scenario (2001-2055). The significance of linear trends of cwb for the two climate periods (recent, scenario) was tested at probability values lower 0.1; 0.05 and 0.01 and depicted accordingly with *,** and ***.

3.2. General socioeconomic development and perspectives for agriculture and lignite mining

Impact studies were carried out for two selected future pathways of socioeconomic development. In order to consider the uncertainty connected to socioeconomic future developments, we chose two story lines for the frames of development, which refer to quite opposite policy paradigms. The first one, A1, supposes a dominance of economic thinking in future decisions and implies further globalisation of processes and weak priorities for environmental policy issues. The second, B2, suggests a higher public attention towards sustainable development and is associated with a higher regional diversity. Both strategies are described more extensively in the IPCC SRES report (IPCC 2000), from where the abbreviations stem, too. From the general story lines for each SRES scenario, regional assumptions for the alternative frames of development A1 and B2 were derived relating to trends for economic growth, population change, operating margins of single sectors (tourism, fish farming) and sector policies.

The case of agricultural policy can be used to exemplify this procedure of deriving socioeconomic global change scenarios for the frames of development A1 and B2. Two policy scenarios were formulated: *partial liberalisation* and *nitrogen tax for mineral N* (*N-tax*). The *partial liberalization* scenario is consistent with the A1-SRES story line. It assumes that all production-related subsidies will be transferred to production neutral payments that are linked to environmental safety standards. The mineral fertiliser tax scenario is a regional complement of the B2-story line. Following this scenario the current price for nitrogen fertilizer would be tripled by a 200% state tax on the current value.

Regarding lignite mining, it was generally assumed that mining activities would last only until about 2035.

4. Scenario impacts on major water quality and quantity problems

4.1. Agricultural land use and nitrogen entry to the basin

Agriculture is a main source of nutrient emissions (nitrogen, phosphorus) to the Elbe basin and thus to the North Sea. Further reductions of nitrogen emissions are still necessary. Moderate climate change as a reduction in the climatic water balance by 27 mm from currently 2mm does not lead to a significant reduction of nitrogen entry (Table 7).

Tab. 7: Simulated impacts of partial changes in agricultural policy and climate on crop yields, arable land use, nitrogen (N) surplus and N-river entry in the German Elbe basis

Year	1999	2020			
	status-quo *	status-ex *	partial liberalization*	N-TAX*	STAR 32**
			change [mm] to status-ex		
cwb [mm]	2	2	0	0	-27
			change [%] to status-ex		
yields[1] [dt/ha]					
Cereals		8.13	5.2	-28	-7.3
Oilseeds		5.23	3.1	-36	-6
arable land[2] [thousand ha]		4.093	-34	-11	-1
farms N-surplus[2]	74	69	-13	-65	0
		change [%] to status-quo (=100)			
N-entry[3]		-6			
			change [%] to status-ex		
			-4	-19	0

simulated by [1]) SWIM, Hattermann et al. (2005, Kapitel II-2.2.2), [2]) RAUMIS, Gömann et al. (2005, Kapitel I-2.1.1), [3]) MONERIS, Behrendt et al. (2005, Kapitel I-2.2)
* recent climate 1996-1999, ** scenario climate 2016-2025

Tab. 8: Sensitivity of central basin values for actual evapotranspiration (Et), total runoff and groundwater recharge to changes in the climatic water balance (cwb as described in table 2)

		2046-55	
	1961-1990 [1]	simulated [1]	interpolated [2]
	[mm]	change [mm] to 1961-1990	
cwb	17	-160	to -27
		change [%] to 1961-1990	
Et	527	2	-
total runoff	171	-41	-7
groundwater recharge	95	-50	-8

1) simulated by SWIM for STAR100, Hattermann et al. (2005, Kapitel II-2.2.2)
2) linear interpolated by the author to cwb=-27 mm as in Tab. 7

Tab. 9: Multi-criteria exploration of water management strategies for climate change adjustment in Spree-Havel (Messner et al. 2004, II-2.2.2). The frames of development for the SRES-story lines A1 and B2 had no extra influence on the ranking.

climate	Spree-Havel management strategy	net use calculated at a discount rate of 2%: water supply	Fishery	water conditioning	tourism at the new lake sites	Water availability: industry	ecosystems	inflow: Spreewald	Berlin	rounded mean of ranks
		Ranking[1)]								
recent	basis	3	5	4	4	2	4	3	4	4
STAR100[2)]	basis	3	4	3	5	3	3	3	4	4
recent	advanced flooding	5	2	5	1	5	1	2	2	3
STAR100	advanced flooding	5	2	5	1	5	1	2	2	3
recent	reduced creaks	4	1	3	2	2	2	5	5	3
STAR100	reduced creaks	4	1	4	3	3	3	5	5	4
recent	Oder BrB	1	3	1	3	1	2	1	1	2
STAR100	Oder BrB	1	5	1	2	1	2	1	2	2
recent	Oder Bln	2	4	2	4	2	4	3	2	3
STAR100	Oder Bln	2	3	2	4	2	3	3	1	3

[1)] strategy is the better the lower the rank (1- best, 5-worst)
[2)] analysis across all 100 realisations of the scenario

Development frame	difference in total net use [Mio €]: 0% Discont rate	5% Discont rate
	Spree-Havel basis	
A1	31.1	-156.9
B2	-413.2	-267.2
	advanced flooding	
A1	72.3	-146.6
B2	-389.7	-264.8

Tab. 10: Differences in total net use (water supply, fishery, water conditioning, tourism at the new lake sites) between two selected water management strategies and the current *basis*-strategy at two discount rates whereby climate change is assumed to follow the STAR100 scenario and socioeconomic change the SRES story lines A1 and B2 (Koch 2004)

Potentially, a decrease in the climatic water balance (cwb) might involve the stimulation of retention processes in soil, groundwater and surface water due to extended residence times and decreased runoff. The residence time might increase as consequences of reduced water flows. In fact, simulations carried out with the Model SWIM (Table 5, 8) for a drastic climate change scenario reveal that a warmer and dryer climate would mainly reduce runoff and groundwater recharge and alter actual evapotranspiration only at minor extent. However, a further simulation exercise with the agro-economic model RAUMIS, the Model SWIM and the Nitrogen emission model MONERIS has shown that in order to reduce nitrogen entry to the river system by one relative unit, the nitrogen balance surplus of farms had to be reduced by three relative units under current climate conditions (Table 5, 7). An increase of the residence time and decreases in surface runoff as supposed for warmer and dryer climate were not sufficient. The higher mineralisation rates act here as counterbalancing effects due to increased temperatures. On the other hand, specific simulation studies with the MONERIS model have shown that also in case of a possible increase of precipitation the nitrogen entry would not dramatically elevate (Behrendt et al. 2005). Although the residence time would decrease, a stimulated microbial activity would keep the retention level quite stable under these circumstances (results not shown). Regardless of the direction of precipitation changes, only a major reduction in the nitrogen balance surplus will significantly diminish the nitrogen entry level. From the two policies investigated, *partial liberalization* and *N-tax*, the latter resulted in the most significant reduction of simulated Nitrogen entries for 2020.

4.2. Water availability in Spree-Havel

Management strategies are usually explored with water management models that balance supply and demand under different regulation strategies for the use of reservoirs and weirs. Here, the water management model WBALMO was applied to analyse the consequences of global change in the sub basin. The WABALMO model was applied at three levels: first, for the whole Spree-Havel sub-basin with an emphasis on the impact of upper-part management strategies regarding the flooding of pit mines and overall water use prioritising rules; second, for the Spreewald wetland; and third for the city of Berlin. The both latter applications, which correspond to a nested mode, have taken the management strategies defined for the whole basin as given and looked for further adjustment variants at their local level. All three studies were based on 100 regional runoff simulations delivered by the models EGMOD and ArcEGMO for the 100 STAR realisations.

The water management situation becomes particularly difficult when the natural water supply from basin precipitations (climate change!) and the ground water pumping activities in the mining areas (socioeconomic change!) shrink at the same time. As a consequence of a decrease in precipitation from 574 mm (1990-1990, Q_{25}-Q_{75} basin quantiles: 488-653 mm) to 545 mm (2020-2050, Q_{25}-Q_{75}: 476-619 mm) and a temperature rise from 9.8 °C (1990-1990, Q_{25}-Q_{75}: 9.1-10.6 °C) to 10.3 °C (1990-1990, Q_{25}-Q_{75}: 9.7-11°C) the minimum inflow to Berlin of 8m^3/s from the Spree river could not be guaranteed anymore during the summer of a dry year. It would sink below 5m^3/s in the next decade (2011-2020). The inflow would cease even during summer time from 2030 on. As further consequences, the duration needed for flooding the mining pits would increase by about 6 month and the acidity degree of flooded pits would increase, creating an extra demand of 1000 t calc hydrate for neutralisation treatment (Kaltofen et al. 2005). Further downstream at the Spreewald wetland region the warmer and dryer climate leads to decreased ground water levels (Dietrich 2005) and, hence, to losses in peat volume (Lorenz et al. 2005) and to changes in species composition (Bangert et al. 2005, Chapter II-2.3.3). Of the currently dominating semi-terrestrial biotope types 19 to 36% would change to the terrestrial type. Alder forests would change to mixed alder-ash forests in many marginal areas. The percentage of endangered species would increase between 9-19%. The bulk economic water use efficiency for agriculture, fishery, boat touring, tourism, carbon sequestration and nature preservation would decrease. In other words, even a constant water inflow to the sub-basin would result in a decrease of economic values created in the region (Grossmann 2005). For Berlin, the lower Spree inflows would lead to decreased supply securities at a series of gauges. The aggregated index-value of water plant supply security would decrease from 0.99 to 0.93 and that of power plants from 0.94 to 0.64 (Wenzel 2005, Chapter II-2.4.1). The consequences for water quality indexes of trophy and toxicity would be negligible, assuming that nutrient inputs will generally decline over the considered period by 24% (Bergfeld et al. 2005).

5. Effects of alternative management strategies for adjusting to global change in the Spree-Havel basin

The simulated effects of the chosen climate change scenario revealed a high vulnerability of the Spree-Havel water supply security to decreasing precipitations particularly after 2030. Thus, management alternatives to reduce this vulnerability were examined. As result of a stakeholder dialogue process, four relevant strategies for water regulation were suggested to mitigate water scarcity in the overall basin (Messner et al. 2004, Messner et al. 2005): two alternative strategies relating to the flooding regime of mining pits (*accelerated flooding* of the pits and *reduced creeks* nearby the pits) and two strategies for resolving the water deficit by means of water imports from the neighbouring Oder basin (*Oder Brb* – import via Oder-Malxe canal to the Spreewald in the state of Brandenburg, *Oder Bln* – import via the Oder-Spree canal to the city state Berlin).
The first two strategies have the advantage of low water supply costs and an earlier availability of the new lake sites for tourism, but the disadvantage of a reduction in fish pond area and earlier emergence of costs for pit lake water treatment. The latter variants improve the conditions for local fish farming and include lower costs for water treatment, but involve disadvantages as regards high water supply costs and delayed pit lake use by tourism (Table 9).

If in addition to the net costs for the four factors discussed above - the water supply security for ecosystems and industries and the minimum inflow security are taken into account, the *accelerated flooding* strategy and the two strategies for using water from the Oder basin (*Oder Bln*, *Oder Spree*) generally appear to be more robust with respect to climate change as the currently intended *basis* strategy. If we take into account the unavoidable transboundary effects of a water transfer from the Oder basin, then the *accelerated flooding* strategy seems to be the first choice in case that only national water resources are available. However, a sensitivity study for the four economic criteria and two discount rates revealed that the advantage of the *accelerated flooding* strategy shrinks with an increasing discount rate (equal to long term trend growth rates of the gross domestic product) and disappears at a rate of 5% (Table 10).

Adjustment strategies were also formulated at the local scale for the Spreewald region and Berlin. For the Spreewald, a strategy named *peat conservation* was alternatively explored under current climate conditions and STAR100 climate change. From the five possible inflow variants only the *Spree-basis* variant was chosen to test the amelioration potential of *peat conservation*. The *peat conservation* strategy is becoming advantageous only then, if the willingness to pay for such a service exceeds 500 €/ha*year. Below that threshold the currently applied *Spreewald basis* strategy is preferable (Grossmann 2005, Chapter II-2.3.4).
For Berlin, two alternative strategies to the currently favoured *Berlin basis* strategy were formulated and explored in combination with the three inflow scenarios *Spree basis, accelerated flooding*, *reduced creeks* and *Oder Bln* set for the overall basin. The *Berlin-basis* strategy and the two alternative strategies are described in table 11. Water supply security indices were calculated for evaluation based on water discharge simulations at several gauges within the Berlin area (Rachimow et al. 2004, Chapter II-2.4.2). The highest rank across all considered inflow scenarios takes the *energy- and water policy* (Wenzel 2005).

Tab. 11: Berlin's Water management strategies for adjusting to global change

Berlin strategy	Description
Berlin-basis	no further changes in water consumptions, full usage of installed capacity for the processing of sewage water, power plants will be used around its optimum working mode complementing power imports from power plants in the mining area Lusatia
Energy- and water policy	introduction of water saving technologies, which lead to capacity reduction and earlier suspension of water and sewage water stations, local energy productions will be partly substituted by energy imports, the water consumption of remaining power stations will be reduced after applying more efficient cooling technologies
Water re-directing	fresh water from sewage plants will be micro-filtrated and lead directly in the Spree-river instead of the Teltow-canal as currently practiced

The effects on water quality were exemplarily assessed for the lake Müggelsee, a Spree lake of 7.3 km^2 size in the southeast of Berlin. The mean residence time of Spree water in the lake with approximately 60 days is relatively low. Thus, water quality of this lake is an integrative measure for the impact of inflow scenarios on Berlin's water quality. For characterising water quality, the bathing freshwater suitability (BFS) was used. The BSF was quantified using an index combining a trophy and a toxicity term. The first depends on the concentration of chlorophyll-a, the second on the concentration of blue-green algae. The simulations for a mean year in the scenario period 2048-2052 indicate that the inflow conditions resulting from *accelerated flooding* lead to the best index values. The *Oder Bln* strategy is classified as worst variant with the lowest index values. The latter can be explained by the higher native nutrient concentrations expected for water imports from the Oder basin (Bergfeld et al. 2005 Chapter II-2.4.3; Wenzel 2005, Chapter II-2.4.1). Simulations were limited to the most likely realisation 32 of the STAR scenario, which is supposed to be one of the driest among the available 100 realisations. Complementary investigations regarding the water quality effects of the three local management strategies *Berlin basis*, e*nergy and water policy* and *water re-directing* suggest a low sensitivity of the mean Berlin water quality to local management strategies (Bergfeld et al. 2005 Chapter II-2.4.3). These complementary simulations were restricted to the *Spree-basis* inflow scenario and considered the water quality in the two major linear sections of the Berlin river network (Spree: 27 km, Tegel-canal: 30 km) below the Müggelsee. Thus, a combination of the inflow scenario *accelerated flooding* with the Berlin strategy e*nergy and water policy* appears to be particularly favourable for Berlin under the conditions of the explored global change scenario.

6. Conclusions

The German Elbe basin is particularly vulnerable against a further decreasing regional in water availability. The outcome of different climate studies confirmed the indication that the regressive precipitation trend observed in the past may continue. Such a development has different consequences for water quality and quantity-related problems in the basin. Nitrogen entry to the Elbe river and finally to the North sea seems to be robust with respect to climate change. Reducing the nitrogen surplus of agricultural land is needed for further progress towards acceptable entry levels from anthropogenic nitrogen sources.

The most severe water quantity problem of the German Elbe basin potentially occurs in the Spree-Havel sub-basin. Successive reduction of lignite mining up to 2055 in combination with decreasing precipitations could lead to a more frequent appearance of water shortage periods during the summer months in the lower part of the sub-basin, particularly in Berlin.

Accelerated flooding of abandoned coal pits and the earlier introduction of water saving technologies can reduce water scarcity and its consequences. Here, the mining and energy producing company Vattenfall Europe as owner of the power plants in Berlin and one of the main actors involved in the flooding of Lusatian mining pits plays a central role. Although energy production on lignite basis contributes to climate change by increasing the CO_2 emissions to the atmosphere, the current lignite mining activity mitigates the vulnerability of surface water supply to decreasing precipitations. However, this happens at the cost of unsustainable uplifting of ground water. Further investigations are necessary to identify and explore strategies that may limit or compensate groundwater losses by policy measures inside and outside the mining region, respectively.

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References

Bangert U., Vater G., Kowarik I. & J. Heimann (2005) Vegetationsentwicklung im Spreewald vor dem Hintergrund von Klimaänderungen und ihre Bewertung aus naturschutzfachlicher Sicht. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.3.3

Behrendt H., Bach M., Opitz D. & Pagenkopf W.-G. Massgebliche anthropogene Enflüsse auf die Gewässerqualität (2004) S. 42-58. In: Wasser- und Nährstoffhaushalt im Elbegebiet und Möglichkeiten zur Stoffeintragsminderung Herausgeber: Alfred Becker/Werner Lahmer (Hrsg.) Berlin September 2004, 520 Pages; ISBN 3-89998-007-7

Behrendt H., D. Opitz, M. Venohr & M. Soukup (2005) Mögliche Auswirkungen von Änderungen des Klimas und in der Landwirtschaft auf die Nährstoffeinträge und –frachten. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter I-2.2.1

Bergfeld T., Strube T. & V. Kirchesch (2005) Auswirkungen des globalen Wandels auf die Gewässergüte im Berliner Gewässernetz. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.4.3

Dietrich O. (2005) Das Integrationskonzept Spreewald und Ergebnisse zur Entwicklung des Wasserhaushalts. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.3.1

Gerstengarbe F.-W. & P. C. Werner (2005) Simulationsergebnisse des regionalen Klimamodells STAR. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter I-1.3

Grossmann M. (2005) Berücksichtigung des Wertes von Feuchtgebieten bei der ökonomischen Analyse von Bewirtschaftungsstrategien für Flussgebiete: Beispiel der Spreewaldniederung. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.3.4

IPCC (2000) Emissions Scenarios. 2000, Summary for Policymakers IPCC, Geneva, Switzerland. pp 20.

Kaltofen M., Koch H. & M. Schramm (2005) Wasserwirtschaftliche Handlungsstrategien im Spreegebiet oberhalb Berlins. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.2.1

Koch, H. 2004, Wasserbewirtschaftungsstrategien in vom Bergbau überprägten Einzugsgebieten im Kontext des globalen Wandels und deren integrierte Bewertung, BTUC-AR 1/2005, ISSN 1615-7818

Lorenz M., Schwärzel, K. & G. Wessolek (2005) Auswirkungen von Klima- und Grundwasserstandsänderungen auf Bodenwasserhaushalt, Biomasseproduktion und Degradierung von Niedermooren im Spreewald. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.3.2

Messner F., Wenzel V., Becker A. & F. Wechsung (2005) Der Integrative Methodische Ansatz von GLOWA-Elbe. In: F. Wechsung, A. Becker & P. Gräfe (2005)

Messner F., Kaltofen M., Zwirner O. & H. Koch (2005) Exemplarische Umsetzung des Integrativen Methodischen Ansatzes am Oberlauf der Spree. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.1.4

Messner F., Zwirner O., Karkuschke M. (2004) Participation in multi-criteria decision support for the resolution of a water allocation problem in the Spree River basin. *Land Use Policy*, available online since December 2004

Rachimow C., Pfützner B. & W. Finke (2005) Veränderungen im Wasserdargebot und in der Wasserverfügbarkeit im Großraum Berlin. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.4.2

Reimer E., Sodoudi S., Mikusky E. & Langer I. (2005) Klimaprognose der Temperatur, der potentiellen Verdunstung und des Niederschlags mit Neuro- Fuzzy Modellen. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter I-1.2

Stanners D. & Bourdeau P. (eds) (1995) Europe's Environment: The Dobris Assessment. European Environment Agency, Copenhagen 1995.

Wechsung F., A. Becker & P. Gräfe (2005) Integrierte Analyse der Auswirkungen des globalen Wandels auf Wasser, Umwelt und Gesellschaft im Elbegebiet, PIK-Report 95, ISSN 1436-0179

Wechsung F. (2005) Herausforderungen des globalen Wandels für die Elbe-Region In: F. Wechsung, A. Becker & P. Gräfe (2005), p. 13-62

Wenzel V. (2005a) Der Integrative Methodische Ansatz im stringenten Sprachkalkül. In: F. Wechsung, A. Becker & P. Gräfe (2005)

Wenzel V. (2005) Integrierende Studien zum Berliner Wasserhaushalt. In: F. Wechsung, A. Becker & P. Gräfe (2005), Chapter II-2.4.1

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Project duration: 01.10.2004 - 30.09.2007 Report period: 01.10.2004 - 31.12.2004

GLOWA-Elbe II

Project I: Project integration and coordination

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Keywords: integration approach, ecosystems, socioeconomy, sustainable development, global change, impact assessment, EIbe river basin, water management, water balance

Abstract:
The aim of the project GLOWA-Elbe is the "analyses of regional impacts of the global change in the Elbe region and the resulting strategies for the water management". The research is dedicated to the entire Elbe basin including the German and the Czech part. The project will deliver management strategies for partial and integrated conflict treatment of surface water availability and quality.
The GLOWA-Elbe project combines five projects: project I: project integration and coordination, project II: regionalisation, project III: field of conflicts: surface water availability, project IV: field of conflicts: surface water quality and project V: scenario analyses on multiple conflicts. Nine subprojects fulfil the subtasks of the projects.

Mission and Results
The original research goal of GLOWA-Elbe is the development of integrated strategies for sustainable management of water availability problems, water use conflicts and resulting environmental and socioeconomic problems in the Elbe basin. The first phase of GLOWA-Elbe focused on investigations of hot spots in the German part of the Elbe basin. The results of the studies are reviewed and discussed in the first paper of the GLOWA-Elbe section. A book with the title 'Integrierte Analyse der Auswirkungen des Globalen Wandels auf Wasser, Umwelt und Gesellschaft im Elbegebiet' will be published in 2005 (Weissensee publishing house, Berlin).
The regional scope of the project is expanded to the entire basin. For the second phase the research goal is specified to the exploration of global change impacts in respect to surface water management and possible adjustment strategies is focused only for the German basin part.

Beside climate change, particular emphasis is given to other non climate components of global change as the spread of new technologies in the region and socioeconomic changes. Taking into account the complex nature of global change, regional frames of development will be derived from general global story lines. Within the frame of development alternative, management strategies will be identified, characterised regarding their impact and evaluated taking into account multiple sustainability criteria and different stakeholder interests.

Specific research questions are:
- What is the possible change in regional temperatures, precipitation and extreme meteorological events?
- What are the regional consequences of socioeconomic change for water demand and nutrient and pollutant emissions into surface water bodies?

- What are the combined impacts of climate and socioeconomic changes on water supply, water demand and surface water availability?
- What are the direct and indirect impacts of global change on surface water quality?
- Which alternative management strategies exist for the German part of the basin for global change adjustment, what is their value and which strategies should be preferred taking into account the relevant stakeholder interests?

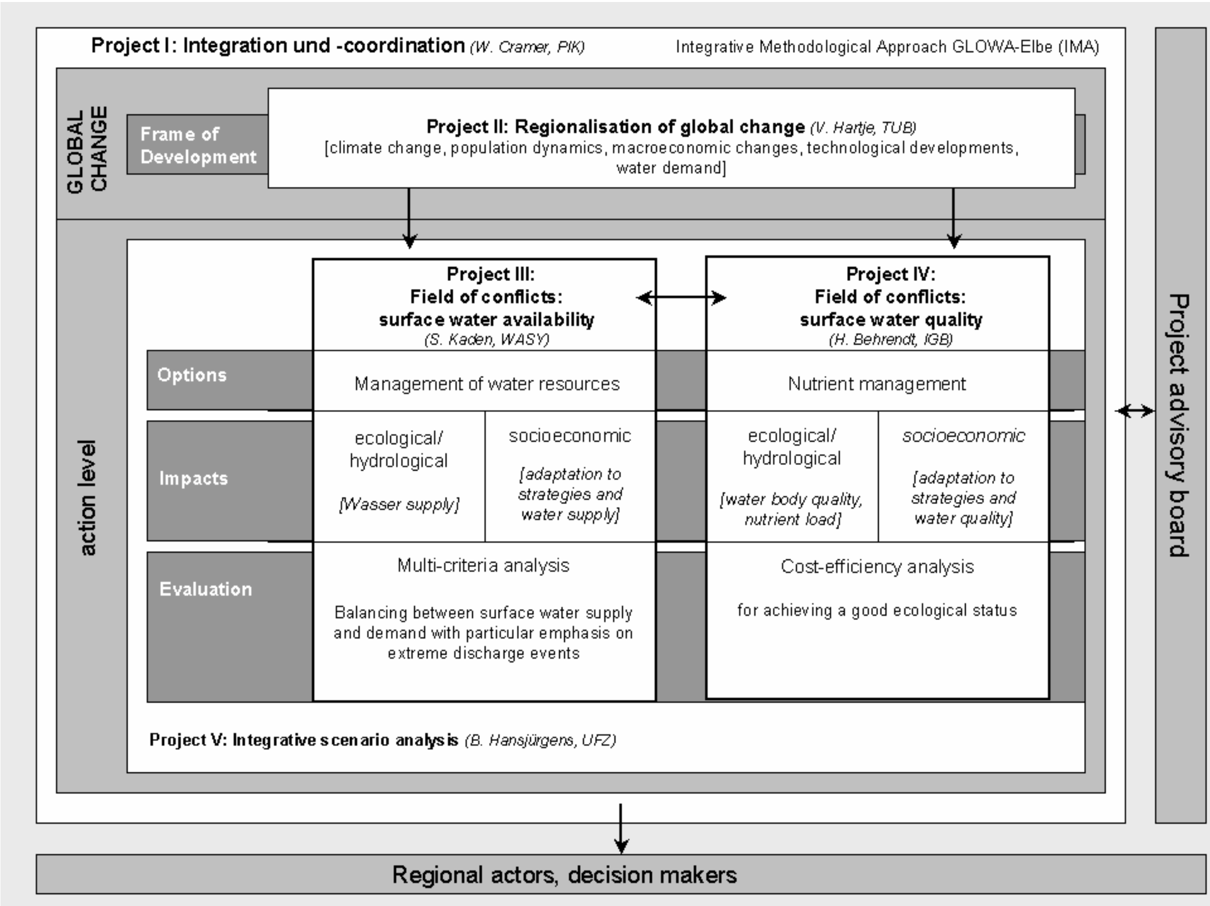

Figure 1: Structure of GLOWA Elbe in its second phase

The research questions are addressed by five projects (Figure 1), which supervise nine subprojects (Table 1). The course of research activities, its scientific harmonisation and the integration of results is coordinated by project I 'Coordination and Integration'. The downscaling of given global change story lines to the Elbe basin is realised by the project II 'Regionalisation'. The projects III and IV determine global change consequences for the conflict fields 'surface water availability' and 'surface water quality'. The conflict analysis, the identification of management strategies and its partial evaluation is supported by the project V 'Scenario analysis on multiple conflicts'. The integrative exploration of management strategies considering both conflict fields is the final product of project V.

Table 1: Organisation of subprojects within the projects

projects	subprojects
project I: project integration and coordination	**subproject 1.** Project integration and coordination (Potsdam-Institute for Climate Impact Research, PIK)
project II: regionalisation	**subproject 1.** Climate and water availability (Potsdam-Institute for Climate Impact Research, PIK) **subproject 2.** Global change and the water cycle in the Elbe river basin: Regionalisation of socioeconomic development

	pathways (Technical University of Berlin, Institute for Landscape and Environmental Planning, TUB) **subproject 3.** Projection and diffusion of water relevant technologies as well as analysis of resulting effects (Fraunhofer Institute for Systems and Innovation Research, ISI) **subproject 4**. Analysis of strategies of agricultural landuse for prevention of water amount- and water quality problems in the Elbe river basin (Institute for Rural Studies of the Federal Agricultural Research Centre, FAL) **subproject 5**. Application of the Integrated Methodological Approach (Centre for Environmental Research Leipzig-Halle, UFZ; Research Centre Jülich, FZJ)
project III: surface water availability	**subproject 2**. Global change and the water cycle in the Elbe river basin: Regionalisation of socioeconomic development pathways (Technical University of Berlin, Institute for Landscape and Environmental Planning, TUB) **subproject 5**. Application of the Integrated Methodological Approach (Centre for Environmental Research Leipzig-Halle, UFZ; Research Centre Jülich, FZJ) **subproject 6.** Water resources management and water availability in the Elbe river basin under conditions of global change (Institute for Water Resources Planning and Systems Research Ltd., WASY) **subproject 7**. Water resources management and water availability in the Elbe river basin under conditions of global change (Brandenburg University of Technology Cottbus, Faculty of Life Science and Technology, Hydrology and Water Management, BTU; Leibniz-Centre for Agricultural Landscape and Land Use Research, ZALF) **subproject 9**. Impacts on the river Elbe due to variations in nutrient inputs and water availability in the river Saale sub-basin as a consequence of global change (German Federal Institute of Hydrology, BfG)
project IV: surface water quality	**subproject 2**. Global change and the water cycle in the Elbe river basin: Regionalisation of socioeconomic development pathways (Technical University of Berlin, Institute for Landscape and Environmental Planning, TUB) **subproject 8.** Potentials for the changes of matter inputs and ecological impacts Leibniz Institue of Freshwater Ecology and Inland Fisheries, IGB) **subproject 9.** Impacts on the river Elbe due to variations in nutrient inputs and water availability in the river Saale sub-basin as a consequence of global change (German Federal Institute of Hydrology, BfG)
project V: scenario analyses on multiple conflicts	**subproject 1.** System analyses (Potsdam-Institute for Climate Impact Research, PIK) **subproject 5**. Application of the Integrated Methodological Approach (Centre for Environmental Research Leipzig-Halle, UFZ)

All projects follow the same general methodological approach called IMA (Integrated Methodological Approach, see project V). Intensive stakeholder interaction is an immanent part of this general methodology.

Three organisation units within GLOWA-Elbe are important: (1) the working group “AG GLOWA-Elbe” with the five project leaders and co-worker of project I, (2) the advisory board consisting of scientists and representatives of the federal states bordering the Elbe region (see table 2) and (3) the working group “Integration” as executive organ of the “AG GLOWA-Elbe” built by members of project I and V.

Table 2: members of the GLOWA-Elbe advisory board

member	**institution**
O. Univ. Prof. Dipl.-Ing. Dr. Dr. h.c. Helmut Kroiss	Vienna University of Technology, Institute for Water Quality, Resources and Waste Management
Prof. Hans Joachim Kujath	Institute for Regional Development and Structural Planning
Dipl.-Ing. Sven Schulz	River Basin Community Office Magdeburg chairperson
Prof. Dr.-Ing. habil. Hartmut Niesche	Ministry of Rural Development, Environment and Consumer protection, State of Brandenburg department 7: Water protection and water management
MR Klaus-Dieter Liebau	Ministry of agriculture and Environment, State of Saxony-Anhalt department of water protection, water management and water framework directive
MR Helmut Telscher	Thuringian ministry of agriculture, nature protection and environment department 54: water landscape
Dr. rer. nat. Slavomir Vosika, Petr Kurìk	International commission for the protection of the Elbe river (IKSE)

Project ID: 01 LW 0304A, 01 LW 0307, 01 LW 0308, 01 LW 0308, 01 LW 0310

Project duration: 01.10.2004 - 30.09.2007 Report period: 01.10.2004 - 31.12.2004

GLOWA-Elbe II

Project II: REGIONALISATION. PROJECTION OF SOCIO-ECONOMIC AND CLIMATIC EFFECTS OF GLOBAL CHANGE TO THE RIVER BASIN SCALE

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Involved sub-projects:

Subproject 1: Climate and water availability

Subproject 2: Global change and the water cycle in the Elbe river basin: Regionalisation of socio- economic development pathways

Subproject 3: Projection and diffusion of water relevant technologies as well as analysis of resulting effects

Subproject 4: Analysis of strategies of agricultural land use for prevention of water amount- and water quality problems in the Elbe river basin

Subproject 5: Application of the Integrated Methodological Approach (IMA)

Keywords:

regional effects of global change, climate change, regional economic development, agricultural land use, diffusion of water technologies, land cover change, regional population development, water availability, water demand, nutrient emissions, modelling, River Elbe, river basin management.

Abstract:

The primary aim of the project "Regionalisation" is to analyse the socio-economic and climatic dimensions of global change on a regional scale. The work of GLOWA Elbe follows the Drivers Pressure State Impact Response concept to analyse effects of global change on water availability, water demand and nutrient emissions. The central task of the project "Regionalisation" within the overall concept is to identify changes in driving forces and quantify the resulting environmental pressures. The methodological approach being developed to address these issues is of high practical relevance, because the current process of river basin planning in the context of the European Union Water Framework Directive explicitly requires long term projections of water availability and demand. The innovation of the developed approach is in bringing together well established modelling instruments for long term projections of regional socio-economic development which have not had any direct reference to spatial dimensions of river basins and transforming the generated projections to the river basin scale in a consistent manner. Key characteristics of the GLOWA Elbe approach are (a) primary integration (b) a two step approach - regionalisation of global change and projection to dimensions of river basin and water users (c) a modular concept, with loose linkage of independent and well established modelling approaches.

Mission and results:

There are essentially two scale transformations necessary for this approach to succeed: analysing the effects of global climatic and economic change on regional development patterns and transformation of projections for regional, primarily administrative spatial units, to the spatial dimension of river basins and water users. Central research questions to be answered are:

- How do regional climate patterns change?
- How do regional settlement and land use patterns change dependent on regional economic, agricultural and population development?
- How do changes in climate and land use pattern affect run-off and surface water availability?
- How does water demand develop as a result of changes in economic, population and land use development?
- How do nutrient emissions change as a result of changes in economic, population and land use development?

The methodological approach being developed to address these issues is of high practical relevance, because the current process of river basin planning in the context of the European Union Water Framework Directive explicitly requires long term projections of water availability and demand. The innovation of the developed approach is in bringing together established modelling approaches for long term projections of regional socio-economic development and transforming the generated projections to the river basin scale in a consistent manner. Key characteristics of the GLOWA Elbe approach is a combination of (a) primary integration of spatial and temporal resolution (b) a two stage approach: assessment of effects of global change on a regional level with subsequent projection to dimensions of river basin and water users (c) modular concept of modelling, with a loose linkage of modelling approaches.

The concept of primary integration requires that models are delineated in such a way that there are well defined interfaces for the exchange of metric scaled data. A central requirement is that there is a common definition of spatial and temporal resolution. The specification of a common spatial topology and typology is the focus of the joint efforts currently underway in the project. The project uses two spatial concepts: hydrological response units and water users. Hydrological response units are heterogeneously structured entities having a common climate, land use and pedo-topo-geological associations controlling their hydrological transport dynamics. On the basis of the hydrological response unit concept, processes of land use changes driven by socio-economic changes can be transferred to the analysis of water and nutrient flows. While the concept is primarily important for analysing process of agricultural land use and diffuse nutrient emissions, it is also of importance for modelling runoff and diffuse nutrient emissions of urban areas. Here the characteristics of urban drainage systems and the sealing rate of urban land are relevant characteristics. The second concept is that of water users and direct nutrient emitters. These are characterised by their specific upstream / downstream location in the river basin and their monthly water withdrawal and return flows as well as their yearly nutrient emission. They are the basic elements of modelling the surface water resource use system. The water users are aggregated according to the detail need for characterising their water withdrawal and nutrient emission characteristics and data availability. Important direct water users such as industry or thermal and hydro-power plants are considered individually, whereas household and commercial water uses and emissions are aggregated according to water supply districts or waste water treatment plant catchment areas.
The GLOWA Elbe approach follows a two stage approach to develop projections of the effects of global change on a river basin scale. In the first stage, key parameters of scenarios of global change (stemming for example from global climate and global trade models) are used to drive models with a regional perspective. Specifically this a model of regional economic and population development (REGE; cf. Gornig et al., 1999), a model of regional agricultural development (RAUMIS: cf. Gömann et al., 2003), a model of the development of the energy sector (IKARUS: Wagner & Stein, 1999) and a regional climate model (STAR:

Werner & Gerstengarbe, 1997). In the second stage, the results are translated into the dimension of river basins using the concept of hydrological response units and water users. Land use demands projected from the agricultural and regional economic and population models for administrative units level are consistently integrated and projected in space using a land use model (LAND USE SCANNER: cf. Hilferink et al., 1999). The resulting land use projection together with the climate projection are an input for the eco-hydrological model (SWIM; Krysanova et al., 1998), which generates times series of water availability as a boundary condition for the analysis of surface water management in Project 3. The land use model is also to be used to project population development to catchments of water supply and waste water treatment infrastructure. Household, commercial and industrial water demand and as well as nutrient emissions are then to be estimated based on an analysis of diffusion of water technologies (cf. Hissel et al., 2003) and econometric analysis of water demand (cf. Renzetti, 2002 for discussion of approaches). Water demand for power generation is to be estimated using a power plant model directly linked to the energy sector model (KASIM: cf. Wagner & Stein, 1999).

The GLOWA Elbe approach is based on a modular modelling concept, with loose linkage of modelling approaches. The concept of primary integration combined with clearly defined input and output data structure allows repeated cascading analysis of various sets of scenarios of global change and of national and European policies on water demand and nutrient emissions. Most of the models are well tested and their results have been widely used for policy analysis in their specific sectors. Only “missing links”are currently being newly developed in GLOWA Elbe, especially related to projecting the water demand at a water user level.

References:

Gornig, M., Görzig, B. & Schulz, E. (1999): Perspektiven der Beschäftigungs- und Bevölkerungsentwicklung in Deutschland und in den Bundesländern. In: *Informationen zur Raumentwicklung*, Heft 11/12.

Hilferink, M. & P. Rietveld (1999): Land Use Scanner: An integrated GIS based model for long term projections of land use in urban and rural areas, In: *Journal of Geographical Systems*, 1(2): 155-177.

Gömann, H.; Kreins, P.; Kunkel, R. & Wendland, F. (2003): Koppelung agrarökonomischer und hydrologischer Modelle. In: *Agrarwirtschaft* 52 (4): 195 – 203.

Wagner, U. & Stein, G. (Eds.) (1999), *Das IKARUS Projekt: Klimaschutz in Deutschland. Strategien für 2000 –2020*. Springer: Berlin.

Krysanova, V., D.I. Müller-Wohlfeil & A. Becker (1998) Development and test of a spatially distributed hydrological / water quality model for mesoscale watersheds. *Ecological Modelling* 106 (1-2): 261-289.

Hiessl, H. & Toussaint, D. (2003): *Alternativen der kommunalen Wasserversorgung und Abwasserentsorgung*. Physica-Verlag, Heidelberg.

Renzetti, S. (2002), *The Economics of Water Demands*. Springer, Berlin.

Werner, P. C., & Gerstengarbe, F.-W. (1997): Proposal for the development of climate scenarios. Climate Research, Vol. 8, No. 3: 171-182

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GLOWA-Elbe II

Project III:
SURFACE WATER AVAILABILITY

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Involved sub-projects:

Subproject 2: Global change and the water cycle in the Elbe river basin: Regionalisation of socio- economic development pathways

Subproject 5: Application of the Integrated Methodological Approach (IMA)

Subproject 6: Water resources management and water availability in the Elbe river basin under conditions of global change

Subproject 7: Water resources management and water availability in the Elbe river basin under conditions of global change

Subproject 9: Impacts on the river Elbe due to variations in nutrient inputs and water availability in the river Saale sub-basin as a consequence of global change

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Keywords:
Global change, sustainable development, water resource management, modelling, economic evaluation, multi-criteria evaluation, integrated assessment, participation

Abstract:
The key question for the project is how climate change and socio-economic development will affect water resources, water demand and surface water availability in the whole Elbe river basin. The analysis is based on a detailed water resources management model, which is under development at present. In parallel the simulation software package WBalMo used within the project is enhanced to meet the needs of water management modelling in large basins, i. e. consideration of travel times as well as sub-basins. The state of work in 2004 is described in the following.

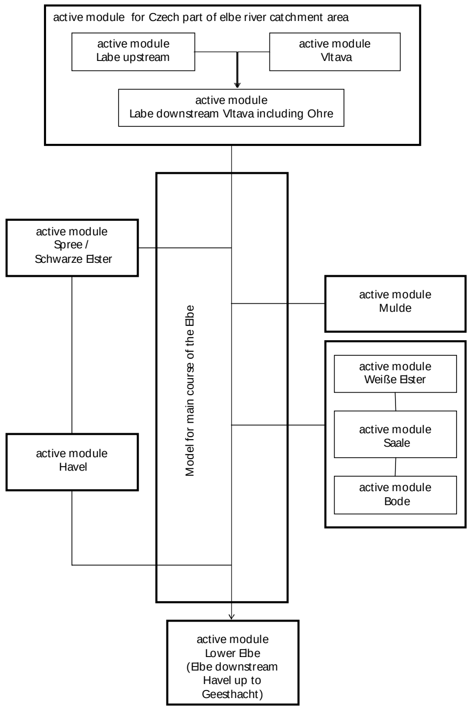
Mission and results:
The project work in 2004 was concentrated on preparatory methodological and organizational work for the development of the water resources management model WBalMo Elbe. This model is planned to be developed in a modular way, taking into the account already available sub-models of similar type as well as the interests of regional water authorities. The latter are both, suppliers of necessary modelling data and information, and partners in model development and use.

As a first step contacts to all relevant water authorities in the Elbe river basin were deepened or established, including the relevant authorities of the Czech part of the Elbe river basin. For the potential German partners a first project workshop was held in December 2004. At this workshop the goal, structure and basic methodologies of the project GLOWA Elbe with special regard to water resources availability were presented. Based on a short presentation of results of the first project phase GLOWA Elbe I, the main working steps and the potential results of GLOWA Elbe II were discussed.

The main focus of discussion was the data requirements and availability for detailed water resources management modelling in the Elbe river basin. These data comprise all kinds of water resources management components and water usage, e. g., permits by water law, water transfer, rules for the management of reservoirs, etc.

Based on this information it will be possible to structure the model in detail, defining sub- basins and balance profiles to which the water uses will be linked.

As a first draft of the planned partition of the Elbe river basin into sub modules for the detailed design of the water resources management model, a rough module structure scheme was developed (see figure right hand).



It is planned to develop the model in a modular structure, integrating models of sub-basins (so-called active modules or sub-models). The active models of sub-basins shall also be used independently of the overall model by the responsible regional authorities. Some of the modules will be based on already existing water management models. Another major point of the workshop was the consideration of wetland areas. On the basis of information about ground elevation, soil parameters etc., special wetland sub models will be developed.

The water distribution facilities and their management in wetlands will be used to derive the water demand or release of wetlands into the river system.

For the Czech part of the Elbe river basin, three major alternatives for cooperation/ support between the German research team and Czech water authorities are under discussion:

1) Joint development of the active sub-models or the Czech part of the Elbe river basin using WBalMo.
2) Development of a simulation model for the Czech part of the Elbe river basin by Czech water authorities on their own with WBalMo, estimation and delivery of simulated discharges at the cross section Dečin/ Labe
3) Development of a simulation model for the Czech part of the Elbe river basin area on their own with another model. There might be even the possibility to integrate that model into the overall model system.

The model design and use will be based on the simulation software system - the long-term water resources management simulation model WBalMo (WaterBalanceModel, former ArcGRM). Stochastic management modelling according to WBalMo encompasses the following aspects:

- stochastic simulation of system inputs (precipitation, runoff, etc.),
- deterministic simulation of water usage in the river basin according to a water user priority ranking,
- registration of interesting system conditions (incl. reservoir water levels, discharge in comparison to minimum discharge rates at user-defined points in the river basin).

For details see http://www.wasy.de/english/produkte/arcgrm/index.html or Kaden et. al. 2004.

WBalMo will be enhanced for this sub-project. The enhancements concern:

1) Consideration of the flow (travel) time

Usually in WBalMo it is assumed that with one time step (one month) both, the runoff processes and the effects of water usage and management are effective. If the spatial extension of the system to be modelled is large, as for instance is the Elbe river basin, the flow times have to be taken into consideration in relation to the balance time step (generally a month) of the balance model.

If one shifts the time interval for each individual process in the system according to the total flow time valid at the respective balance profile, then all processes are synchronized. Now again the WBalMo assumption of the simultaneousness of runoff and water utilisation balance applies. The computation of the input data of the model objects then takes place via interpolation between the months, which limit the synchronous interval.

In the model so-called regions can be specified, for which it is accepted that no flow time influence is relevant internally. Within these regions in the process of water balancing priorities can be considered, a strong point of the model WBalMo. In structuring the overall model into regions, the definition of the regions can take place not only by considering the flow times but also by hydrologic aspects or on the basis of administrative criteria.

2) Model structuring by so-called active modules

The Elbe river basin is characterised by a large number of sub-areas, for which separate management models already exist or for which the development of such models is desired.

The result of the model design (Elbe main module with linked modules) is a pool of co-ordinated sub-modules, which are also separately executable. All the sub-modules in the model system are active ones (White box Model). Therefore it is not necessary to parameterize the sub-models relating to the main model. In this way, reactions from management requirements within sub-modules downstream, e.g. releases from the Saale reservoirs for the augmentation of low water in the Elbe, are possible.

Another important aspect is the joint work with the socioeconomic partners in GLOWA –Elbe II. On the input side of the water resources model they have to quantify water demand for different socioeconomic scenarios. On the output side they will develop routines for economic evaluation of the calculated water availability. At a first workshop, organized by the socioeconomic partners, model properties, specifics of their input and output data were discussed.

For including climate change scenarios in the water resources management model, the output data of the so-called SWIM-Model will be used (Subproject 2; PIK). Based on first discussion about the information needed for SWIM modelling and what results are required for Subproject 6 and 7, it was agreed as the next steps to transfer the results of the design of sub-basins and balance profiles into a geographic database. Based on this information SWIM will generate discharge at required balance profiles for the related basin borders. These data will be used as the input of natural runoff by WBalMo Elbe.

References:

Kaden, S., Schramm, M., Redetzky, M., ArcGRM: interactive simulation system for water resources planning and management in river basins, in: Research Basins and Hydrological Planning, Xi, Gu & Seiler (eds), 2004 Taylor & Francis Group, London

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GLOWA-Elbe II

Project IV:
SURFACE WATER QUALITY

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Involved sub-projects:

Subproject 2: Global change and the water cycle in the Elbe river basin: Regionalisation of socio- economic development pathways

Subproject 8: Potentials for the changes of matter inputs and ecological impacts

Subproject 9: Impacts on the river Elbe due to variations in nutrient inputs and water availability in the river Saale sub-basin as a consequence of global change

Keywords:
Global change, sustainable development, surface water quality, diffuse and point inputs of substances, modelling, economic evaluation, multi-criteria evaluation, integrated assessment, participation

Abstract:
The key question for the project is how climate change and socio-economic development will affect surface water quality in the Elbe river system. The analysis is based on different established water quality models reaching from the estimation of matter inputs into the river systems to the response in different freshwater ecosystems and which are related to the water resource modelling in Project III.

Mission and results:

The aim of the project is the spatial distributed analysis of the impacts of Global change on the matter inputs and the ecological state of the surface waters in the Elbe catchment area. Furthermore the economic consequences will be analysed to establish the ecological good state within the different water bodies of the Elbe river systems. The results are the base for the evaluation of different options of action. The framework of project IV is based on the improvement and linkage of different established models focused on modelling of matter inputs into the surface waters and the ecological state of different ecosystems. One of the main tasks will be the coupling of the models and the establishment of the scenario capability including the linkages to the water quantity and socio economic models developed in the other projects of the framework of GLOWA Elbe II.

The special focus is the modelling of nutrient inputs and the ecological responses due to the eutrophication one of the main problems within the Elbe river system. Furthermore the sources and impacts of other substances on the ecological state of the freshwater systems in the Elbe catchment will be investigated e.g. Bisphenol A.

The project work in 2004 was concentrated on preparatory methodological and organizational work for the development of the water quality models MONERIS and QSIM to the Elbe river systems. MONERIS (matter inputs) is prepared for modelling individual years and the reconstruction of the historical changes of nutrient inputs into the Elbe river system after finishing historical data collections.Case studies for the modelling of the responses of different lake types on climate changes were selected and data collection for these lakes was begun.

Improvement of QSIM for the better modelling of the water quality in the main stream of Elbe was started.

A literature study on the sources and impacts of Bisphenol A was started.

One of the main task in the first phase of the project was the identification of the linkages between the matter input model MONERIS and the socio economic analysis. These linkages were identified and discussed within the socio-economic group.

Next steps will be the establishment of the linkages between the ecological and input models within the framework of the water quality project itself and especially the establishment of the needed transfer functions.

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GLOWA-Elbe II

Project V: SCENARIO ANALYSES ON MULTIPLE CONFLICTS

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Involved sub-projects:
Subproject 1: System analyses
Subproject 5: Application of the Integrated Methodological Approach (IMA)

Keywords:
Scenario analysis, global change, integrated assessment, stakeholder involvement, conflict analysis, economic evaluation, multi-criteria evaluation, interdisciplinary environmental research

Abstract:
Project V deals with the integration of research work as regards the existing and uprising conflicts on water quantity, water quality and, partly, flood protection in the Elbe River basin. The research work of the other projects is coordinated and results are to be connected in order to enable a comprehensive and integrated analysis of multiple water use conflicts in the context of global change in the Elbe River basin, including stakeholder involvement and multi-criteria evaluation of combined policy measures. Based on results of GLOWA Elbe I the hot spots of multiple water conflicts in the whole basin are identified and analysed by means of the Integrated Methodological Approach (IMA) of GLOWA Elbe. A major research focus lies on the analysis of policy trade-offs between water quantity, water quality and flood protection objectives. Close cooperation with research projects on flood protection in the Elbe River basin funded by the BMBF and the European Union will ensure the inclusion of conflicts linked to flood protection policy.

Mission and results:
Compared to GLOWA Elbe I the information basis for the analysis of water conflicts in the Elbe River basin has obviously improved due to the compilation and delivery of A, B and C reports by the River Basin Community (FGG) Elbe and the German federal states to the EU in 2004 in the context of the report obligations of the Water Framework Directive. Initially, these reports form the basis of the conflict analysis. Later on stakeholder involvement will complement the analysis to improve the understanding of current and future multiple water conflicts and to identify and evaluate measures to mitigate or resolve them. It is a preliminary result of conflict analysis regarding the most important issues linked to multiple water conflicts in the Elbe river basin that two topics will be at the centre of integrated research in project V.
First, the major interrelations of water quantity and quality problems are currently visible in the Spree River basin. Water quality problems relating to nutrient emissions and acidity are aggravated by limited discharge and reduced water availability. Based on the research results of GLOWA Elbe I concerning mainly the water quantity problems, the focus of the current research involves the analysis of the trade-offs of water quantity regulations and nutrient

emission reduction strategies. The question of whether water bodies with low water quality should be improved by means of water quantity or water quality measures or a combination of both will be a major topic in project V.

Second, another issue of multiple water conflicts in the Elbe river basin refers to the interrelation of drinking water provision, hydro-electric power generation, tourism and flood protection measures in the management of barrages. If droughts and floods will increasingly occur in the coming decades, less water might be available for drinking water provision, tourism and hydro-electricity power generation, because barrages might more and more be used for water quantity regulations. This might bring about new conflicts about water use of barrages and reservoirs in general and might increase pressure on ground water.

The integrated and interdisciplinary analysis of these topics is only possible if research on water quantity, quality and floods is linked from the beginning. This is ensured by the integrative activities of project V. Members of this project take part in all major working group meetings of the other GLOWA Elbe II projects in order to take care of appropriate consideration of multiple conflicts in the application of the IMA. Close cooperation with the BMBF-project VERIS and the EU-project FLOOD*site*, both focussing on flood research and evaluation of flood measures in the Elbe river basin, will be the basis for the inclusion of flood research in the analysis of multiple water conflicts in GLOWA Elbe II.

References:

Messner, F., Kaltofen, M. (Eds)(2004), Nachhaltige Wasserbewirtschaftung und regionale Entwicklung – Analyse und Bewertung von Szenarien zum Wassernutzungskonflikt im bergbaubeinflussten Einzugsgebiet der Oberen Spree. UFZ-Report 1/2004, Leipzig and Cottbus, 95 pp.

Messner, F., Wenzel, V., Becker, A., Wechsung, F. (2004), Der integrative methodische Ansatz von GLOWA Elbe, in: Wechsung, F., Becker, A., Gräfe, P. (Eds.), Integrierte Analyse der Auswirkungen des globalen Wandels auf Wasser, Umwelt und Gesellschaft im Elbegebiet, Schlussbericht zum Vorhaben GLOWA Elbe I, S. 63-70.

Messner, F., Zwirner, O., Karkuschke, M. (2004), „Participation in Multicriteria Decision Support for the Resolution of a Water Allocation Problem in the Spree River Basin“, in: *Land Use Policy (available online since 2004, print version will be published 2005).*

Koch, H., Kaltofen, M., Grünewald, U., Messner, F., Karkuschke, M., Zwirner, O., Schramm, M. (forthcoming), „Scenarios of Water Resources Management in the Lower Lusatian Mining District, Germany”, in: *Ecological Engineering (in press, accepted in January 2004).*

Messner, F., Koch, H., Kaltofen, M. (forthcoming), „Elbe – Integration of Economic Evaluation into the Water Management Simulation Model WBalMo”. In: Erickson, J., Messner, F., Ring, I. (Eds), *Sustainable Watershed Management in Theory and Practice,* (ch. 6), Elsevier Science *(accepted by external review in August 2004).*