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Envisioning the future of water in Europe – the SCENES project

Abstract

The aim of this article is to describe the background and main elements of the SCENES project (Water Scenarios for Europe and Neighbouring States) together with the approach for selecting, constructing and evaluating water scenarios up to 2050. SCENES is a multi-faceted integrated project that aims to address the complex questions about the future of Europe's water resources. It takes an integrated approach by combining and balancing the many dimensions of Europe's water futures, including hydrological, ecological, economic, cultural, social, climatic, financial and other dimensions. The project is implemented in three phases. In the first phase (fast-track) largely extant scenarios are selected, and readily available information on drivers and policies information assembled and run through an existing quantitative model of pan-European water availability. In the second phase more refined scenarios are developed at both the pan-European and regional scales, with scenario panels providing 'enriched' scenarios. The third phase involves a synthesis of the information and dissemination of the project outputs to external stakeholders and end-users. In the SCENES project an evaluation of the participatory scenario processes is carried out giving us new information on the functioning of the science-policy interface, and on the challenges the European water management may confront in the future.

Keywords
Scenarios, pan-Europe, water resources, water use, water availability, water quality

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1 Introduction

1.1 Key issues

The future of Europe's waters will be influenced by a combination of many important environmental, social, political, and policy drivers, such as global (incl. climate) change, population changes, land use change, as well as economical and technological developments. Political developments, such as the enlargement of the European Union and relationships between EU member states, accession countries and non-member states, will also have an impact on Europe's waters. Amongst the most important policy drivers are the current and future agricultural, industrial, energy, trade, transportation and environmental policies.

One of the most important policy drivers is the implementation of the EU Water Framework Directive (WFD). The WFD promotes sustainable water use based on long-term protection of water resources, in particular, by mandating that Member States develop river basin management plans for each river district in the light of the national and EU development strategies. Since many basins are trans-boundary in nature, the WFD encourages a European approach to river basin management. The requirements for these basin plans will have a great influence on water planning. For example, the plan must include a report of how various water users are contributing to the recovery of costs of water services, based on harmonized datasets and reporting protocols. Moreover, they must address the multitude of dimensions of water use (domestic, industrial, agricultural sectors) and the water requirements of aquatic ecosystems. These plans have also taken a broad view of water availability, including the quantity and quality of surface waters and groundwater, and not exceeding the regenerating capacity of the various water resources in the long-term. Finally, it is explicitly mandated that European citizens should play an active role in developing these plans and in implementing the WFD, as well as paying more attention to water issues in general ("developing the attitude").

Several major tasks need to be carried out to achieve the goals of the WFD. First, water authorities need a better understanding of the nature of problems having to do with too much water (flooding) or too little water (scarcity). Second, stakeholders in charge of managing water (authorities, water boards, other entities) need tools and knowledge to manage the current status (quantitatively and qualitatively) of European waters according to the principles of integrated watershed management and joined/common resource perspective, especially for trans-boundary catchments to have a shared vision on the common resources. A third important task is to assess the future state of waters in Europe in order to anticipate and plan for the problems of future water use, availability and quality. This will allow water authorities, water companies, and other stakeholders to devise better strategies for achieving the goals of the WFD.

This paper describes a pan-European project for developing water scenarios. The working hypothesis of this project is that a multi-dimensional scenario process, with a strong foundation in science and broad participation of stakeholders, can provide new ideas about managing the future of water in Europe. Further, that these new ideas can help achieve both a better sharing and a higher ecological integrity of Europe's waters.

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1.2 Objectives of SCENES

SCENES project is a *four year project* focusing on the issues of freshwater use and availability in Greater-Europe, that is all of Europe up to the Caucasus and Ural Mountains, including the Mediterranean rim countries, are covered. SCENES takes a comprehensive view of Europe's water resources, and be consistent with the requirements of the Water Framework Directive. The project considers:

- **Water use:** This project improves estimates of water use at pan-European and regional scales. Furthermore, scenarios are developed that take into account the various cultural, social, ecological, financial, political, and economic dimensions of water use.
- **Coping Capacity***:* The project assesses changes in the future coping capacity of society in dealing with future water-related risks, and how this capacity can be enhanced.
- **Quantity of Surface Water:** As with other assessments, the pan-European availability of surface water is estimated in SCENES. However, the project will go further as illustrated by the next two points:
- **Quantity of Groundwater:** Water resources in Europe depend not only on the exploitation of surface runoff, but also its groundwater resources. Hence the availability of groundwater is taken into account in the water scenarios.
- **Water Quality:** While it is clear that the scenarios must describe the volume of surface and groundwater available, they must go beyond this and also describe the *quality* of available water, and *ecological water requirements*. In this project first steps are taken at a pan-European scenario analysis of future water quality and ecological flow requirements by compiling an inventory of wastewater discharges, estimating future wastewater discharges, and carrying out calculations of water quality.

There are different kinds of scenarios for different purposes. To fulfil the needs of this project it is planned to develop *combined qualitative and quantitative* scenarios. The *qualitative* scenarios (storylines) provide an understandable way to communicate complex information, and can incorporate a wide range of views about the future. The *quantitative* scenarios are used to check the consistency of the qualitative scenarios, to provide needed numerical information, and to "enrich" the qualitative scenarios by showing trends and dynamics not anticipated by the storylines. Taken together, the qualitative and quantitative scenarios provide a powerful

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combination that compensates for the deficits of the other. Furthermore, they are *interactive/adaptive* scenarios, in the sense that they can be updated to better address the requirements of decision makers and stakeholders.

The *qualitative scenarios* (storylines) provide an internally-consistent picture of how water resources in different parts of Europe will develop up to 2025 (to address more immediate policy issues) and 2050 (to deal with longer term challenges such as climate change). The storylines will portray in words, pictures or diagrams the step-by-step developments of changes in Europe that affect water use and availability, and vice versa, how changes in water use and availability will affect Europeans. By developing storylines with different themes, we explore the uncertainties that future water managers and stakeholders may have to face (changes in irrigation withdrawals, climate, technology, infrastructure etc) and robust strategies for dealing with these changes. The storylines explore, for example, how social, financial, economic, and cultural changes will modify the future demand for water in Europe, and how the coping capacity of people in various parts of Europe to drought can be increased over time.

The *quantitative scenarios* complement the storylines by providing numerical information about key issues. For example, the quantitative scenarios provide estimates up to 2050 of changes in the frequency of droughts due to climate change, changes in irrigated agriculture, changes in water withdrawals because of the transformation of the energy sector, and changes in domestic water demand owing to changes in human behaviour. Using models to make these estimates helps to maintain consistency in the estimates.

In summary, the SCENES project has four major objectives:

1. To evaluate different methodologies for developing scenarios of Europe's waters with the aim of improving these methodologies, involving different pan-Europe scale, regional and pilot area scale modelling efforts.

2. To develop and analyse a set of comprehensive scenarios of Europe's fresh waters up to 2050. These scenarios provide reference points for long-term strategic planning of water resource development in Europe, alert policymakers and stakeholders to emerging problems related to water use (e.g. new water quality and ecological problems, new regions of water scarcity); and allow river basin managers to test their regional and local water plans against uncertainties and surprises which are inherently imbedded in a longer term strategic planning process.

3. To evaluate the socio-economic, environmental and ecological impacts of the different water scenarios. This is accomplished by analysing and assessing the complex relationships between water availability, water demand and water use to provide a basis for strategic planning and technological alternatives.

4. To help launch an on-going process in Europe of scenario-development. At the end of the project a plan is devised for institutionalising the on-going development of water scenarios in Europe.

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1.3 Project set-up

The activities of the project are in essence organized following the DPSIR framework (Drivers, Pressures, State, Impacts, Response), used widely for demonstrating and reporting on the issues of human influence on the environment, e.g. by the European Environment Agency (see Figure 1). The work package on **drivers and pressures** (WP1) compiles and specifies the driving forces and pressures that are needed as input to the development of scenarios at both the European and regional scale. The work package for scenario development (WP2) together with the modelling activity (WP3) provide alternative future **states**, both qualitative and quantitative, of the European waters. In WP4 the consequent **impacts** expected to be caused by the various futures for waters, as depicted by the different scenarios, are assessed. Finally, the work package for support for policies (WP5) organises the pan-European participatory processes for scenario building, synthesizes the comprehensive and complex results of the project, disseminates them to specific users and the general public, gives training and support for planning of water issues on a European and regional levels, and plans for an on-going effort at scenario analysis in Europe. This activity can be seen as facilitating the potential actions in **response** to the various scenarios developed in earlier work packages.

1.4 Iterative approach for constructing scenarios

Scenarios are descriptions of possible futures that reflect different perspectives on past, present and future developments. Scenario development aims to combine analytical knowledge with creative thinking in an effort to capture a wide range of possible future developments in a limited number of outlooks [1]. Scenarios should be based on coherent and inherent and internally consistent set of assumptions about the key relationships and driving forces. Scenarios are particularly useful in cases where the time scales are longer than those used for conventional planning, and great uncertainty prevails for the development of the phenomenon.

To produce a set of policy relevant scenarios it is necessary to focus on three spatial scales, the pan-European scale, the regional scale, and a water management unit scale, to test the processes on a number of case studies. Because of its unique *European perspective*, the project should focus on the interdependency of water resources in different parts of Europe and on the pan-European future of water resources. However, many important details only become visible at the regional and management unit scales. Hence this project must have a *multi-scale focus.* In SCENES we develop parallel and consistent scenarios on three different scales i) on the pan-European scale, ii) on a regional scale, and iii) on a pilot area scale.

The pan-European analysis provides an overview of the interconnections between water resources in different parts of Europe, as well as identifying future “hot spot” problem areas. The resolution is a spatial grid covering all river basins in Europe. The pan-European scenario analysis provide boundary conditions for the regional studies and also help to maintain the consistency of the four case studies.

By working at the regional and pilot area levels (as compared to the pan-European level) it is easier to include a wider range of stakeholders (local industry, farmers' organizations, environmental groups) because these groups tend to be organized locally. Second, it is possible to address issues at a more local level that are difficult to characterize at the pan-European scale, e.g. the future vulnerability of different social groups to water scarcity, or the effect of different catchment-level water management institutions on long-term sustainable management of water resources. To address these issues it is useful to work with specific examples within the regional scale. Finally, results from the regions are used to enrich the pan-European scenarios, and to check the plausibility of these pan-European visions.

The project is implemented in three phases, (see Figure 2).

1. Phase I being a 'fast-track' exercise at the pan-European scale whereby largely extant scenarios are selected, and readily available information on drivers and policies information assembled and run through an existing quantitative model of pan-European water availability;
2. Phase II involves more refined scenario development at both the pan-European and regional scales, with scenario panels providing 'enriched' scenarios through back-casting that will feed back into a second analysis of drivers and policy issues that feed into an enhanced water availability model, and;
3. Phase III involves a synthesis of the information and dissemination of the project outputs to external agencies.

2 Drivers and pressures

2.1 Driving forces

The scenarios developed and used should be based on coherent and internally consistent sets of assumptions about all the external factors that might influence future water demands. Many of these factors will relate to socio-economic developments, such as changes in population and migration within Europe, agricultural development and land use change, technological development which may increase water efficiency, and economic growth which may lead to increased water withdrawals and wastewater discharges. However, pressures will also be policy- or legislation-driven, with the EU WFD previously mentioned and reform of the Common Agricultural Policy (CAP) being just two of the recent pieces of legislation that are likely to have a major impact on Europe's water future. Also influential will be global scale environmental pressures including climate change, with predictions of more extreme hydrological events, and political pressures, such as those imposed by enlargement of the EU, and ever-changing relationships both between Member States and with Accession Countries and non-member states.

Drivers for change are often of a long-term nature, such that there are many long-term impacts on the water environment (e.g. it takes many years to reverse pollution from nutrients such as phosphates), that the substantial investment in the changes needed requires long time scales for both planning and execution, and that behavioural change is likely to take time to be fully achieved (e.g. by households to reduce water use. Hence, the specification and quantification of the key issues and driving forces that underpin the development of the future scenarios are central to the success of the SCENES project.

An investigation of the dynamics of water use involves a review of changes in general socio-economic variables, key sector policies that influence water use, economic growth and planned investment linked to existing water regulation, as well as assessment of how important water is to the economy and socio-economic development of the basin, and investigation of likely trade-offs between socio-economic development and water protection. During the Phase I fast-track pan-European study, a database of driving forces information from existing published sources will be assembled. Analysis of these factors may reveal trends that can be factored in to provide inputs to the Phase II study, where the scenarios will be enriched at regional and pilot area scales. However, it will also be necessary to analyse this information together with European legislation to assess the possible impacts of policy measures on water demands, water quality and ecology in order to quantify those impacts and, thereby, inform the qualitative storylines developed by the Scenario Panels. Individual driving forces and pressures may each decrease or increase water demands in the future. Thus, it is difficult to predict all the likely changes that may take place from combined forces and pressures between now and the 2025 -2050 time horizon, or even by 2015 when the WFD's environmental objectives must be achieved.

The primary drivers for change likely to influence water demand in the near future comprise population, industrial output, agriculture and climate change. The impact of the latter in 2050 is likely to be difficult to detect or model, with there still being considerable uncertainty in global climate model outputs of impacts for this short future horizon. Whilst the link between population and levels of domestic water use is clear, it is also necessary to consider number of households, the trend in many countries being towards a larger number of smaller households, increasing both water demand and development pressure. Abstraction and flow-related pressures, including many point sources of pollution and morphological changes, are also linked to economic activity. Analysis of trends in industrial output and employment levels enables identification of the areas of the economy that have expanded or contracted in recent years which, in turn, allows an appreciation of the key sectors that are driving a country's or basin's economy and are likely to remain significant in the future.

Links between economic activities and diffuse pollution pressures are more difficult to determine, particularly for diffuse pollution from non-agricultural activities. In the agricultural sector, the impact of the CAP and associated agricultural intensification, such as increased stocking, fertiliser use and pesticide use, has resulted in increased pressures and impacts on the environment, though this has slowed in recent years. The growth of organic farming and CAP reform are expected to consolidate this trend and, thereby, provide some landscape, water quality and biodiversity benefits. However, another pressure that can result in loss of natural biodiversity and have significant economic impact is alien species i.e. non-native organisms that establish themselves in, and subsequently disrupt, native ecosystems.

2.2 Data management within SCENES

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The trend towards holistic approaches to environmental management and multidisciplinary science research projects such as SCENES requires the coordination and harmonisation of data from the different disciplines involved and the creation, either virtually or actually, of a single integrated database [2]. The approach that will be taken to the acquisition, management, dissemination and long-term security of the wide range of spatially and temporally referenced data collected for the SCENES project must consider both managerial issues such as data storage and exchange, as well as scientific issues such as how best to hold such data so that the researchers in the four case study regions can access them with ease. The following tasks will be carried out as part of data management in SCENES:

- Acquire quality-controlled data sets from other SCENES partners and third parties
- Provide data to SCENES scientists
- Set standards for data storage and exchange
- Develop appropriate techniques and tools necessary for the management of the data
- Receive the data and model output of the scientific elements of the project (e.g. WaterGAP results and impact indicators)
- Enable the dissemination of data within and outside the SCENES project

Table 2.1 provides a list of some of the data types that will be handled during the SCENES project, described in more detail in the SCENES Data Plan[9].

In order to create the required integrated database of environmental information, the challenging task of assembling and matching data types from many different sources and countries must be addressed. Currently, there are few standard data definition or encoding systems across the environmental agencies and academic institutions [2]. This means that researchers requiring specific information on, for example, nitrate concentrations in surface and groundwater sources across Europe, cannot be sure that they are comparing data of similar analytical origin or quality. Therefore, one of the first tasks is to harmonise the data from the individual suppliers, as far as is possible, to facilitate both loading to the SCENES database and data exchange between work packages. The various data formats established to ensure a consistent and efficient flow of data and information are described by the SCENES Data Exchange Format[10].

Table 2.1 Examples of the range of data types handled during the SCENES project

Hydrological data	Water use data (national)	Water quality data
Rainfall	Domestic water demand	Nitrogen
Temperature	Domestic water use	Phosphorus
River flow	efficiency	Total dissolved salts
Groundwater recharge	Manufacturing water use	Biochemical oxygen

[9] Fry, MJ. 2007. SCENES Data Plan.
[10] Gijsbers, P. & Fry, MJ. 2007. SCENES Data Exchange Format.

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Land use	efficiency	demand
Lakes & reservoirs	Electricity generation water use	Water temperature
Wetlands	Power station cooling types	Total coliform bacteria
Wastewater discharge points	Electricity production	
Type of sewage treatment	Crop types & irrigated areas	**Socio-economic data**
	Irrigation water use	Population (national)
	Livestock numbers	GDP (national)
	Livestock water use	

3 The scenario development process

The four main objectives of this part of the project are:
(i) To develop innovative cross-scale scenario development methodologies.
(ii) To create a set of multi-scale European water scenarios up to 2050.
(iii) To link qualitative scenario development with analysis and model operation.
(iv) To strengthen scenario use through direct experience.

In short, the activities revolve around the development of multi-scale scenarios with a high level of stakeholder involvement. The scenarios will be primarily qualitative or semi-quantitative in nature and will be linked to the modelling results at pan-European and Pilot Area level. At this early stage in the project we can most clearly describe the initial activities that are related to the selection of the fast-track pan-European scenarios and the development of the scenario methodology.

3.1 Innovative scenario development methodology

SCENES is tasked to consider existing scenario development methods and innovate to improve them in a "learning-by-doing" participatory process. The starting point for deriving a new scenario development method is the Storyline-And-Simulation method (SAS; see Figure 3) as proposed in [3]. This method involves the development of narrative storylines during a series of stakeholder workshops. These qualitative scenarios are subsequently translated to a set of quantified parameters that are the input for a quantitative model, in this case WaterGAP. Key to the method is an iterative procedure during which storylines and models are improved. Here we focus on the qualitative scenario development.

The development of narrative storylines has a high level of stakeholder involvement. Within SCENES, stakeholder panels will be formed on pan-European level, in most of the 8-10 Pilot Areas, as well as for at least one of the four regions (see Figure 4). The largest challenge will be to provide a tool-box of methods that is sufficiently flexible to be applicable at local and pan-European scale, and that can cover a broad range of issues from irrigated intensive agriculture in

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the south of Spain to water quality and flooding in new access countries in the Baltic region. At the same time, however, methods need to be sufficiently similar to enable meaningful downscaling and up-scaling as well as comparison across different regions. The scenario tool-box will encompass three methods that serve three different goals: Conceptual modelling; Narrative storyline development; and Back-casting.

3.1.1 Conceptual Modelling

Conceptual modelling (CM) can be defined as the activity of formally describing related aspects of the physical and social world around us for purposes of understanding and communication, not prediction. Being formal and structured makes it complementary to storyline development that emphasises creativity and flexibility. Each type of CM invokes its own discipline that, like a graphic language, reveals different kinds of causal structures implied in a narrative. Therefore, the initial narrative phase creates an open and expansive atmosphere to help participants venture into uncertain futures. Facing all the underlying assumptions and causal relations might stifle narratives at the start, but can deepen understanding on which narratives are improved in subsequent stages.

Several types of CM will be employed, namely – in order of increasing degree of quantitativeness – Qualitative System Dynamics Models (such as Causal Loop Diagrams (CLD), Stocks and Flows Maps) and Fuzzy Cognitive Mapping (FCM). The approach to develop FCMs is highly intuitive, and it can quickly be explained and applied to any new situation (see [4,5]). FCMs will therefore be developed for most of the Pilot Areas. FCMs can be used to structure the outcomes of the participatory processes by introducing system thinking. FCMs will force the participants to make the systems from which they reason explicit, and therefore more transparent. This will facilitate an objective translation and will increase the reproducibility of the scenarios as developed by stakeholders. Complementarily used Qualitative System Dynamics Models like CLDs and Stocks and Flows Maps (described i.e. in [6]) are more formalised and take a longer time to develop. For all four regions Qualitative System Dynamics Models will be developed. They are very structured models that are able to capture the feedback loops and non-linear influence between variables. They are good for presenting and therefore for the better understanding of dynamism of the feedback loop relations as well as they can be the base for constructing Quantitative System Dynamics Models.

3.1.2 Narrative storyline development

In the initial phases of the project, we will develop narrative storylines during stakeholder workshops. Based on a number of fast-track European scenarios, a group of 20-25 key stakeholders will develop 3-4 scenarios for each level where stakeholder panels will be assembled, including all Pilot Areas. The method that will be followed resembles that as used during the Millennium Ecosystem Assessment [7,8]. The emphasis is on the creative process of developing long-term visions for local regions, based on certain higher-level developments, such as international trade, agricultural policies, or climate change. The resulting scenarios at Pilot Area level will be linked to European and global scenarios (and thus to models such as WaterGAP). An additional advantage of this kind of method is that focusing on long-term possibilities will stimulate social learning and reduce potential conflicts between participants.

3.1.3 Back-casting

Back-casting is a technique where reasoning from a desired future situation a number of different strategies and policy options are offered to overcome obstacles and reach this situation. The initial stage of scenario development tries to encourage creative thinking in a very "positive" atmosphere that is open to possibilities, even far-fetched ones. Barriers and delays that might derail or stall a scenario might not easily surface in such early attempts to be inclusive. Back-casting can then be applied to rigorously re-examine each narrative for potential obstacles and to explore ways to neutralize or avoid them. Back-casting scenarios can link the structured understanding of the current system (from the various types of Conceptual Models) to the set of long-term scenarios (from the narrative storyline development) that are linked to European development. This step is crucial in the process of scenario development.

3.2 Scenarios for Europe's freshwater

Key to the SAS approach is the iteration between qualitative storylines and quantitative models. To maximise the number of iteration loops, we have opted to use existing qualitative and quantitative scenarios to build a first set of European scenarios. These fast-track scenarios will serve as an input to the first series of stakeholder workshops, both at Pilot Area and pan-European level.

3.2.1 Scenario selection for fast track

A large number of scenarios studies exist both at the global and at the European levels including several useful applications of down-scaling these global scenarios. However with the exception of the WaterGAP applications and a few of the sub-global assessments of the Millennium Assessment, none of these focus on water issues. Yet, they are of comparable pedigree and constitute a pool of credible, large-scale scenarios from which to choose. We can basically distinguish three types of scenario studies:

- Global integrated scenario studies that are very complete and normally have elaborated storylines. These studies usually do not focus specifically on water. These studies are IPCC/SRES; GEO-3/GEO-4; MA. [9,10,11]
- Scenario studies that focus specifically on water. These studies usually are far less elaborate and include only sketchy storylines. These studies are World Water Vision; Global Water Outlook; EEA European Water Outlook. (see [12,13,14])
- Studies that are specific for Europe. These include Visions/MedAction and the various downscaling studies from IPCC-SRES (ATEAM, EURuralis, PRELUDE)

Table 1 lists the criteria that were used to select the best set of scenarios and the resulting scores for each assessment. More weight was given to the role of storylines, the specificity for Europe and a number of other factors such as the information on water.

Table 1. Scoring table of main characteristics and weighting factor for some of the selected scenario studies.

Criterion	IPCC (down-scaling)	MA	GEO4	WWV	Visions/ Med-Action	EEA Eur Water Outlook	Global Water Outlook	Weighting Factor
Storyline elaboration + creativity + complexity	4	8	6	4	7	1	4	3x
European specificity (including downscaling exercises)	6 (8)	4	7	3	9	9	4	3x
Time horizon	4 (8)	6	6	8	7	9	8	1x
Availability of gridded driving forces	8	8	8	8	2	9	5	2x
Scientific acceptance	9	7	7	5	5	5	5	2x
Policy acceptance for water	1	4	4	4	4	6	4	1x
Information on water	2	6	6	6	6	8	6	2x
How current?	6	8	8	4	7	5	6	2x
Date of publication/ Current availability	9	9	4	9	8	8	9	1x
Total Score	94	104	**107**	79	99	99	80	

From the table it is clear that the water-specific studies had the lowest scores, mainly due to the lack of storyline elaboration and the global focus. Scores for the Millennium Assessment and GEO-4 were very comparable and both sets could serve as fast-track scenarios. The GEO-4 scenarios however are specific for Europe and the most current of all studies, which turned out to be the decisive factor. Thus, GEO-4 was selected as the most relevant set of scenarios, and therefore the set that was selected as input for the fast-track procedure.

Figure 5 shows the four GEO-3/GEO-4 scenarios positioned along two main uncertainties 'Global versus regional development' and 'Economic versus Environmental focus', which are the two main uncertainties that are underlying many of the scenario studies. Note that this figure is showing the GEO-3 scenarios, in anticipation of the official publication of the GEO-4 scenarios. This set of scenarios will form the basis for the development of water-relevant fast-track storylines as well as fast-track WaterGAP runs for Europe.

4 Quantifying scenarios by modelling

4.1 Why do we need quantitative scenarios?

While the storyline-writing described in the previous section provides a valuable and rich description of the future, storylines also have important shortcomings. First of all, nearly all storylines have inconsistencies. This is expected because it is very difficult for storyline-writers to maintain complete consistency when constructing a story about the influence of complex and interacting factors (demographic, economic, technological, climatological) on water use in Europe over the coming decades. To help maintain the consistency of storylines, it is useful to employ models. For instance, models can be used to check if assumed driving forces of the scenarios lead to the intended outcomes described in the storylines. (e.g. if lower population growth leads to decreasing water use).

Another, and more important, shortcoming of storylines is that they do not provide the numerical information needed by researchers for assessing the future state of water resources nor by managers for making decisions about water management. While storylines can describe the trend of water resources in a general sense, there are many questions about the future of water in Europe that require a quantitative answer: Will the future ecological condition of Europe's waters comply with the aims of the Water Framework Directive? By how much will water use increase in various water use sectors and countries? In which river basins in Europe will water shortages be a particular problem? To address these and other issues we need a model or models to provide a numerical estimate of the response of Europe's waters to the driving forces specified in the storylines. In other words, we need quantitative scenarios to complement the qualitative scenarios provided by the storylines.

In the SCENES Project, models will be used to generate quantitative scenarios about the following aspects of future water in Europe:

- The volume of water withdrawn and consumed in the domestic, thermal electrical generation, hydroelectric, manufacturing, agricultural, and tourism sectors of each European country (annual average).
- The water availability in all catchments in Europe (annual renewable water resources).
- The discharge of Europe's rivers during low flow years (monthly average low flow).
- The water quality of most river stretches in Europe (for various average monthly indicators – see below).

4.2 WaterGAP: The Main Instrument for European Modelling

The main instrument used in SCENES to compute pan-European water resources is the WaterGAP model (Water – Global Assessment and Prognosis) [15,16]. In its new version, WaterGAP computes both water use and availability on a 5 minutes by 5 minutes (geographical longitude and latitude, respectively) European grid (approximately 10 x 10 km). The grid-scale calculations are then aggregated to the river basin scale as has been done in previous regional and global studies [15,16,17]. WaterGAP is made up of two main components -- a Global Hydrology Model and a Global Water Use Model (see Figure 6):

- *The Global Hydrology Model* simulates the characteristic macro-scale behaviour of the terrestrial water cycle to estimate water availability. This model has been used for numerous assessments of large-scale hydrology including an analysis of the impacts of climate change on the future occurrence of droughts and floods in Europe [18].
- *The Global Water Use Model* consists of different modules that compute water use for the sectors households, manufacturing, thermal electricity, and irrigation for each country in Europe. (Depending on the sector, calculations are either at the country-scale and downscaled to a grid, or computed directly on a grid). Both water availability and water use computations cover the entire land surface of Europe. The model has been extensively documented in the literature [15, 16,17]. WaterGAP has been used extensively, including for a comprehensive analysis of future trends in European water use and part of the most recent European Environmental Outlook [14,19].

4.3 Improving the Estimation of Future Water Resources

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As part of SCENES, the WaterGAP model will be improved in two major ways to make it a better tool for answering questions about the future of Europe's waters.

4.3.1. Improving the Water Use Model

The aim here is to improve the capability of WaterGAP to compute future water use in the main water use sectors of each country in Europe. Because irrigation water requirements are of great importance in Europe (especially Southern Europe) we will improve the current irrigation water use model in WaterGAP by making it crop-specific (it now differentiates only between rice and non-rice crops). The model used to compute future water use in the domestic sector will also be improved by adding information about the relationship between household water price and domestic water use (where these data are available). The models used to compute water use in the thermal electrical generation and manufacturing sectors will be improved by creating better <data bases for the location of power plants and manufacturing facilities in Europe. Two new sectors will also be added to the Water Use model - water requirements for tourism and hydroelectricity in Europe.

4.3.2 Constructing a Water Quality Model

Estimates of future water quality in Europe are needed for assessing the future state of aquatic ecosystems, and for determining the suitability of available water for different water users (e.g. water supply for households and many industries must be relatively low in total dissolved solids). Hence in SCENES we will extend WaterGAP and make it capable of computing many important water quality parameters. The first steps towards continental-scale water quality modelling has already been taken under the Millennium Ecosystem Assessment in which the WaterGAP model was used to compute wastewater flows on a continental-scale grid for the first time [20]. In SCENES, WaterGAP model will be extended to compute total dissolved solids (a measure of the suitability of water for household , industrial and agricultural use), coliform bacteria (an indicator of the suitability of water for swimming and other water contact activities); biochemical oxygen demand and dissolved oxygen (indicators of the level of organic pollution and overall health of aquatic ecosystems), chlorophyll *a* (an indicator of phytoplankton level and the level of eutrophication in rivers and impoundments), and "toxic pollutants" (an indicator for the levels of various dangerous chemical substances present in water). All of these indicators except for "toxic pollutants" will be explicitly modelled in the new WaterGAP water quality model. For "toxic pollutants" we will compute a proxy indicator based on an estimation of the dilution capacity of water bodies and the load of toxic pollutants into water bodies.

4.4 Linking Storylines and Modelling

The storyline-writing and modelling will be very closely linked in the SCENES Project. The inputs to the model calculations will be based as far as possible on driving forces (demographic, economic, technological, and other) derived from the first draft of the storylines. These driving forces will be used to run WaterGAP and produce quantitative scenarios of water use, water availability and water quality. The computed quantitative scenarios will then be presented to the

Scenario Panel and used as input to the storyline-writing process. Specifically, the model results will be used to check the consistency of the storylines and to provide numerical information that fits to the storylines. It is expected that the first draft storylines will then be revised based on the modelling input. The revised driving forces from the storylines will then be used as new input to WaterGAP, which will then produce a new set of model runs. This iteration of storyline-writing, model runs and presentation of model results is expected to be repeated three times. The iterative procedure will ensure that the qualitative and quantitative scenarios will be well integrated, and that the project in the end will produce a set of rich, comprehensive and realistic scenarios about the future of Europe's water resources.

5 Impacts

5.1 Impacts – water system services and dimensions

In SCENES, the state of the water resources system in Europe resulting from the various scenarios is further translated in impacts for society, economy, environment and ecology. Because water policies are often sectoral, these impacts are quantified separately for four water system services: 1) water for food (agricultural water use), 2) water for people (domestic water, direct health threats, and recreation), 3) water for utilities (energy production, industries and navigation), and 4) water for nature (rivers, wetlands and lakes).

Although certain water system services may at first sight have a stronger link with either economy, society or environment and ecology, impacts for all four of these dimensions will be considered. The main distinction is between impacts on the water system service itself, and impacts through the water system service on other water system services. Some examples of impacts are presented in Table 5.1, in which the dimensions economy & society and environment & ecology are grouped.

Table 5.1 Examples of indicators for the four water system services

Impact dimension / **Water system service**	**Economy & society**	**Environment & ecology**
Water for Food	change in agricultural production	change in area of polluted ground water resources, eutrofication of lakes and rivers
Water for People	change in access to sufficient water for domestic purposes and change in quality of bathing waters	health risks related to algae blooms and toxic substances in sediment and water.
Water for Nature	change in the provision of ecosystem goods and services	change in quality of aquatic and wetlands ecosystems and habitat availability
Water for Utilities	changes in cooling water capacity in dry, warm periods, resulting in limitations of energy production	change in water temperature and the consequences for ecosystem production and habitat quality

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As can be seen in Table 5.1, for the water system services Water for Food, Water for People and Water for Utilities the indicators regarding economy & society focus on the water system service itself, while the indicator for environment & ecology consider impacts on other water system services. For Water for Nature, this is the other way around. The environment & ecology indicators will focus on the Water for Nature sector itself, while the impacts on the other sectors are shown through economy & society indicators.

5.2 Indicators – definition and selection

Quantification of impacts requires the identification and selection of indicators for these impacts. An indicator is an objectively quantifiable variable that has a significance beyond its face value [21]. The component variables themselves do not have such a wider significance.

The framework of water system services and dimensions, which should be regarded a further specification of the Impact component of the DPSIR framework, is the basis for the development of indicators, to provide a balanced view of impacts for Europe.

In various European and global studies many indicators for water and environment have been defined. In SCENES, a limited number of indicators will be selected based on two main criteria: i) relevance to policy objectives; and ii) calculability. The first criterion is a direct link with the drivers. From the policy objectives which drive the scenarios, indicators can be deducted to check to what extent policy objectives are met under the various scenarios. To make the indicators policy-relevant they should be closely related to the policy objectives, and preferably show the actual impact for society.

The second criterion, calculability, implies that the quantitative relationship between the change in the water resources system and the indicator is known. Indicators that can only be quantified using monitoring data are therefore not suitable. Calculation therefore refers to quantification for future scenarios using quantitative relationships in contrast to calculation based on monitoring data.

5.3 Indicator calculation

European scale data will be used to calculate the indicators. Comparison with regional scale situations will show to what extent European scale assessments make sense at smaller scales. This is an important question from a scientific point of view, and also in view of the institutionalization of scenario development within Europe.

For SCENES, the European scale constrains the available data, and indicators are adjusted accordingly. An important source of information for indicator calculation is the WaterGAP output. In fact, one could say that the indicator quantification consists of further processing WaterGAP results. However, other information will be used separately or combined with WaterGAP results to quantify impacts.

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To calculate the indicators, the HABITAT software is used. HABITAT is a GIS-based tool in which various calculations with maps (ASCII grids) can be performed [22, 23, 24]. This software is ideal for transparent post-processing of the WaterGAP output and other data. When new insights appear, calculation rules in HABITAT can be easily adjusted to instantly provide adjusted maps of indicator values.

An example of the calculation rules to calculate an indicator from WaterGAP output is provided in Figure 7 The presented indicator for domestic water availability for each river basin is defined as the frequency of occurrence of water shortage (supply below demand) in any part of a river basin. In the calculation it is assumed that domestic water use always has the first priority of all water use, which means that the total amount of water available in the basin can be considered available for domestic use. For lower priority use, the amount of water used by higher priority users first has to be abstracted from the total water availability to find the amount of water available for the particular use. Similar calculation rules for all other indicators will be defined and implemented to calculate impacts for all scenarios.

6. Support for policies

6.1 Participatory scenario building process

SCENES aims at building an effective and integral science-policy interface, that would allow a better management of water resources. Water Scenarios produced by SCENES are, in fact, very specific type of scientific advice since they are co-produced in a concerted effort by researchers, decision-makers and stakeholders. The framework underlying SCENES work acknowledges the complex embedded role of science in our society [25] and tries to create new methodologies in order to open up the scientific practice to public and increase the policy relevance of science. In SCENES we take the position that scientific advice is very much rooted in the context and the setting in which it is produced. The methods of knowledge production used have a performative role on the ontologies science produces. In fact, we see that that these two cannot be separated: they are co-produced (see in particular [26,27,28]).

In building the science-policy interface in SCENES we put special emphasis on both policy-relevance of the scenarios as well as deliberative context of scenario making. Two challenges arrive from here. Firstly the scenario methodology should find its place within the existing management and planning practices – and be aware of the constraints and potentials that arise from there. Secondly, the participatory scenario-building itself is a communicative process, of which success is dependent on how information is generated and communicated within and between groups of stakeholders and experts within SCENES and, ultimately, with key decision makers outside of SCENES.

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6.2. Identification of stakeholders

The approach chosen in SCENES requires that a special attention is paid on the selection of scenario panel members at the pan-European, regional and pilot area level. The main criteria for selecting organizations for Pan-European panel is their characteristics in covering European or wider regional extent and their connection to the main themes of the project: water, environment, planning or policy. Additional criteria for selecting certain persons to the panel was their particular expertise in scenario development.

Between the case study areas there is great variability in drivers, problems, needs and institutional backgrounds. Therefore on a regional and a Pilot Area level the identification of participants is based on a systematic context and stakeholder analysis. We identify the participants along two major axes: first based on their importance on water use and water quality, and second, based on their influence on decisions. We also aim at identifying those water users that may have a crucial role in the future, although not yet today. The regional and Pilot Area panels will consist of participants from the following stakeholder categories:

- Authorities and public officials (from all important policy sectors: e.g. water, agriculture, energy, industry, tourism)
- Political decision-makers
- Interest groups (e.g. farmer's unions, chamber of commerce)
- Firms, business representatives (e.g. water companies, energy production, farming, fishing, tourism)
- Non-governmental organizations and local associations (e.g. irrigation co-ops, rural and village development, environment)
- Research (natural and social science)
- Media and journalists
- Laymen
- Other (according to local specifics)

6.3 Evaluation of the participatory scenario-making process

In SCENES we will carry out a systematic evaluation of the participatory scenario-building process. We will analyse how scenarios are co-produced in these collaborative settings and critically evaluate how they can support river basin management. The evaluation will also provide material for developing methodologies of participatory scenario-making.

The criteria for evaluating the scenario processes consist of *information management, social learning* and *legitimacy.* The criteria have been adapted from [29, 30]. The criteria put special focus on evaluating the participatory process in order to understand its effects. Thus the focus is on *how* questions. When evaluating information management, we put special focus on assessing how different types of knowledge were elucidated and integrated during the different phases of the process. We also look at how boundaries between different types of knowledge were made visible or created, upheld or broken. Special attention is also put on how uncertainties and complexities were processed.

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The criterion of social learning focuses the relationships between actors during the scenario-making process, how participants, while working together, learn from each other and from different ways of perceiving the problem. We will assess how the framing of the problem evolved during the process. We will also ask how did the roles and positions between different actors evolve.

If successful, the scenarios produced can help to improve the river basin management and implementation of WFD, for instance. One evaluation factor is, thus the legitimacy of scenario-process. Legitimacy refers to the degree that the scenario process is heard, respected and accepted. Legitimacy of the process has four building blocks: a) compatibility with the management structures and practices, b) acceptance by the stakeholders, c) transparency, and d) representation and inclusion of actors.

7 Upcoming activities

With the completion of the fast-track scenarios, as well as the methodology to develop participatory multi-scale scenarios, the first series of stakeholder workshops can be conducted. The results of these workshops are expected to be available halfway through 2008. In other words, within the timeframe of the project we can realistically aim for at least two iteration loops between (pan-European) models and (Pilot Area) storylines. Consequently, discussions on short-term policy options in the back-casting exercise will be based on a multi-scale qualitative, semi-quantitative, and quantitative understanding of issues of water quality and water quantity. This will maximise the possibilities to link local, regional, and European solutions to a better management of Europe's freshwaters.

8 Acknowledgements

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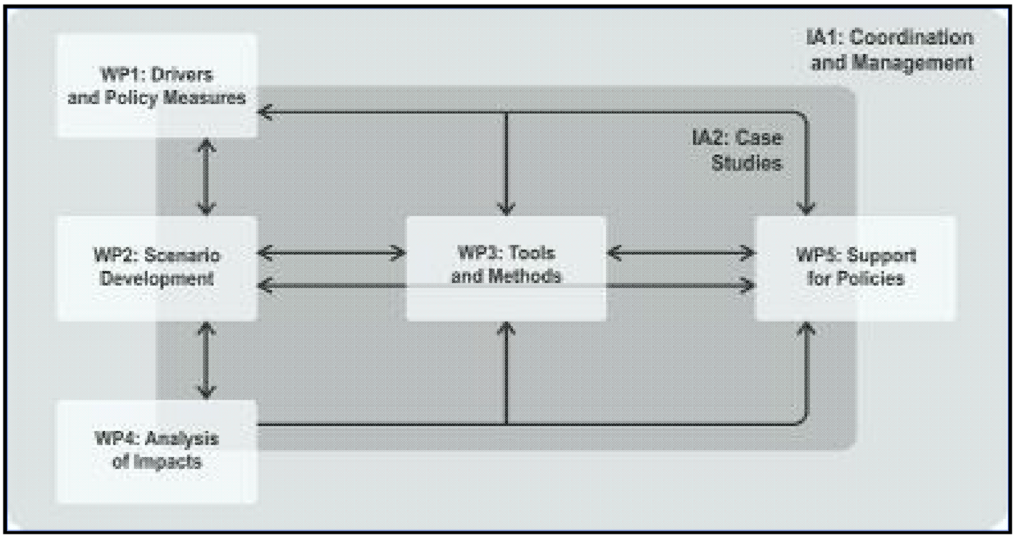

Figure 1. Basic organisation of activities in SCENES project

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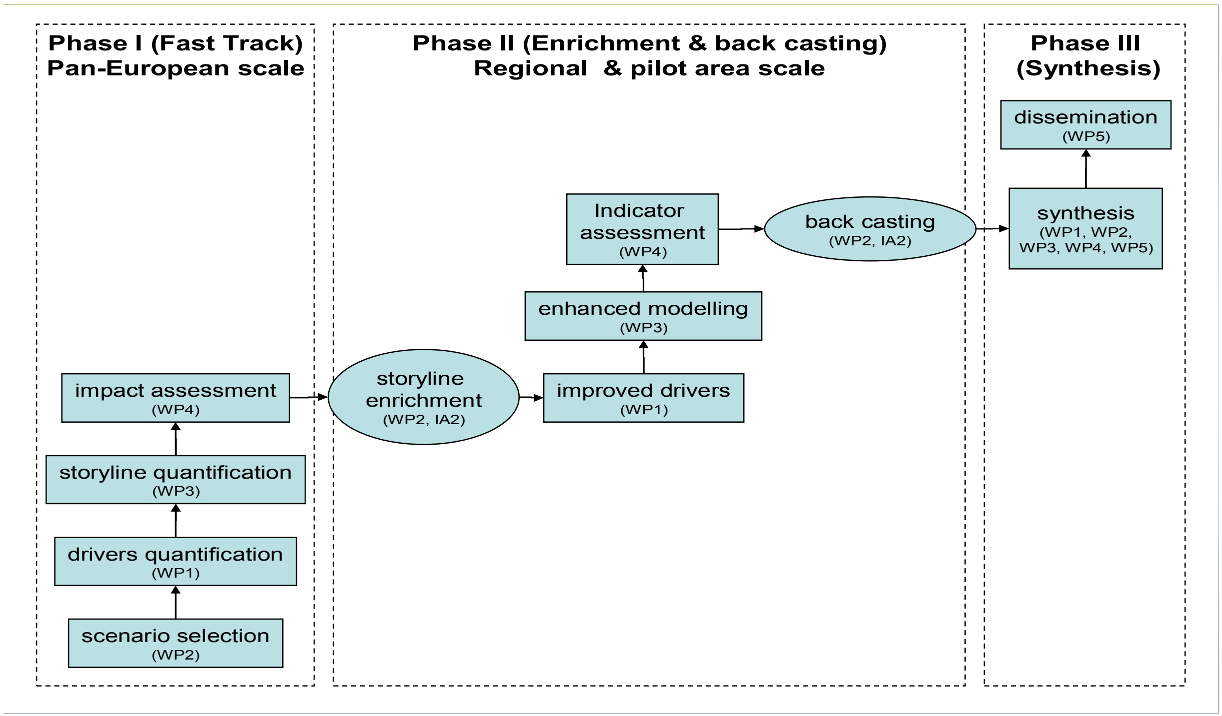

Figure 2. The three phases within the SCENES project.

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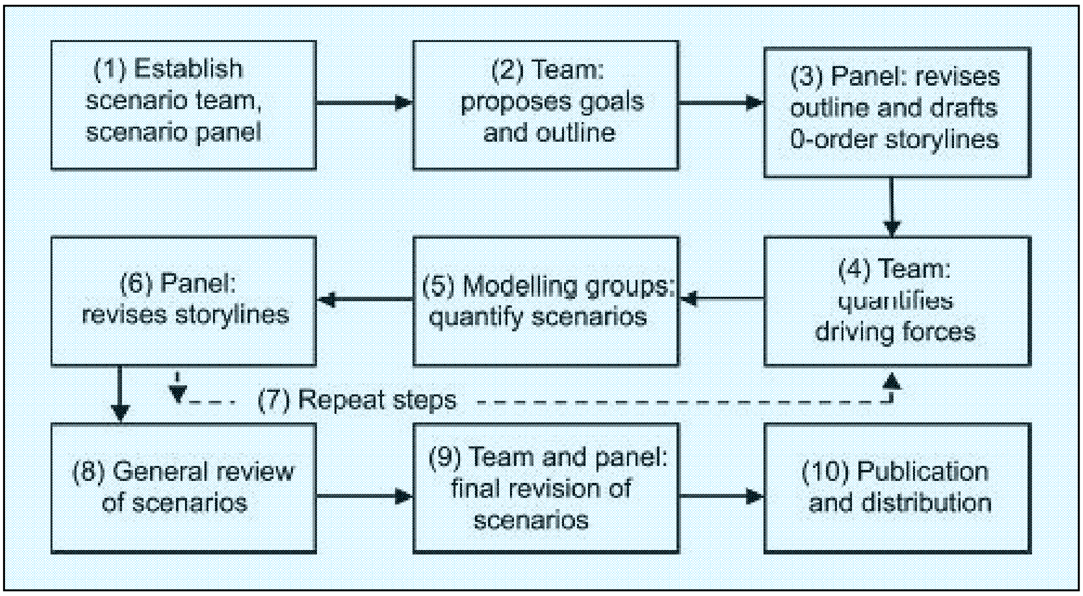

Figure 3. The Storyline-And-Simulation methodology.

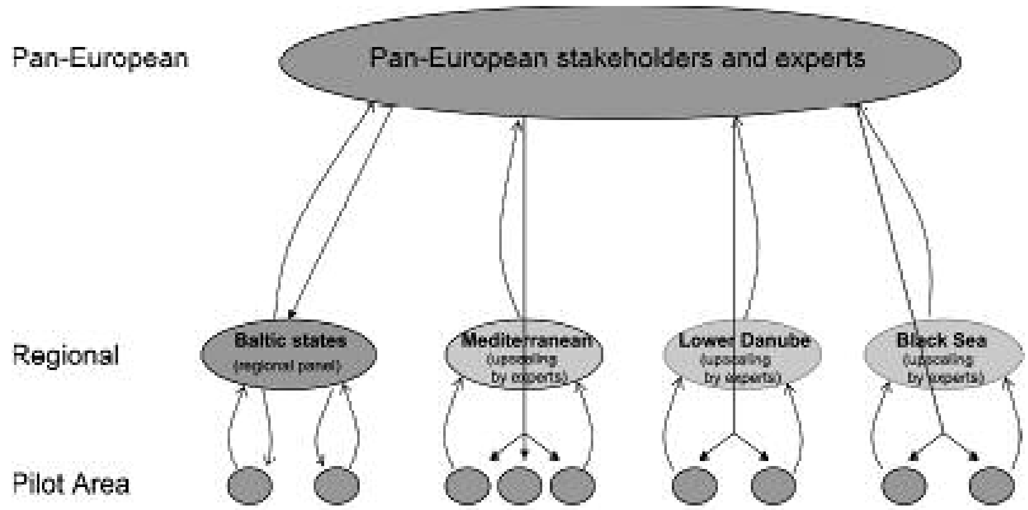

Figure 4. Overview of the scenario panels in SCENES at pan-European, regional, and Pilot Area level. Circles indicate levels at which SCENES meetings will take place. The dark grey shade indicates levels at which stakeholder panels will be assembled and stakeholder workshops will be organised. The light grey shade indicates levels with expert meetings.

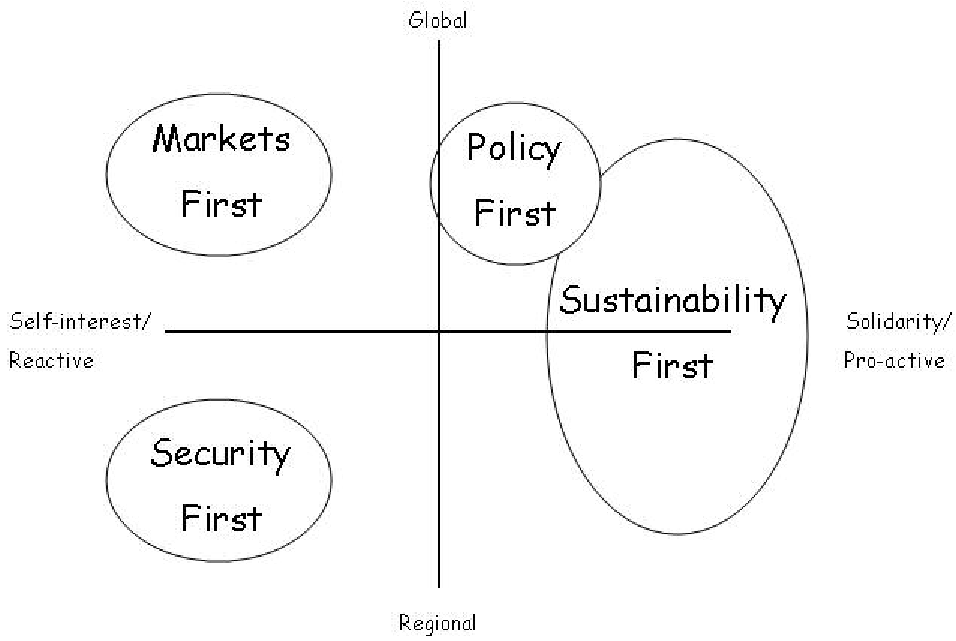

Figure 5. The GEO-3 scenarios positioned along two main uncertainties, Global/Regional development and Reactive/Proactive attitude towards environmental problems.

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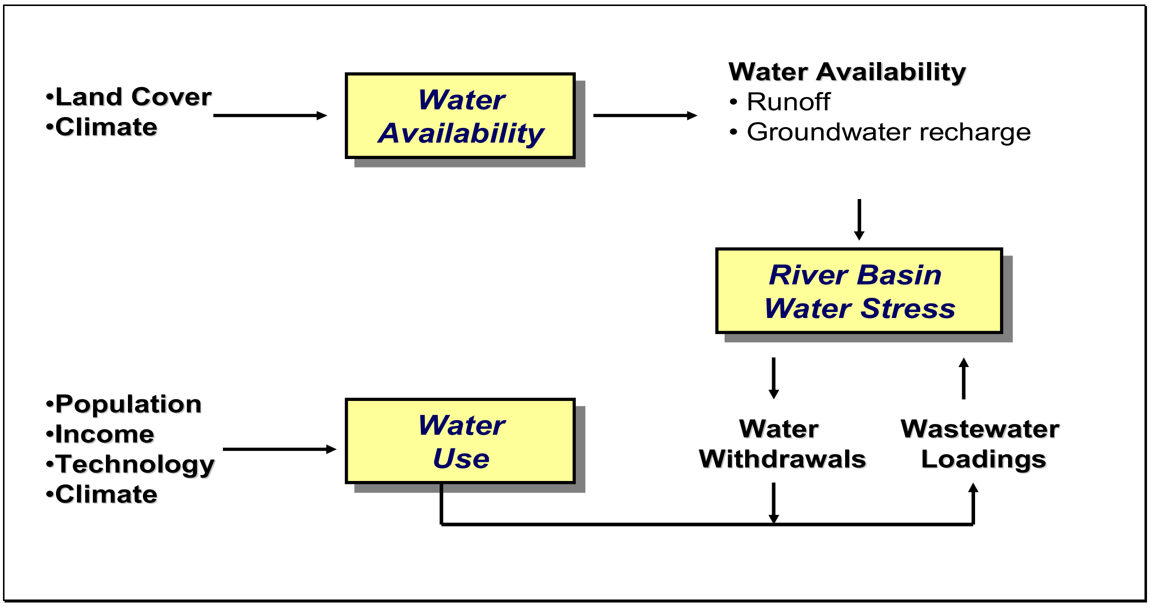

Figure 6. The drivers and basic components of the WaterGAP model (Alcamo et. al. 2003a)

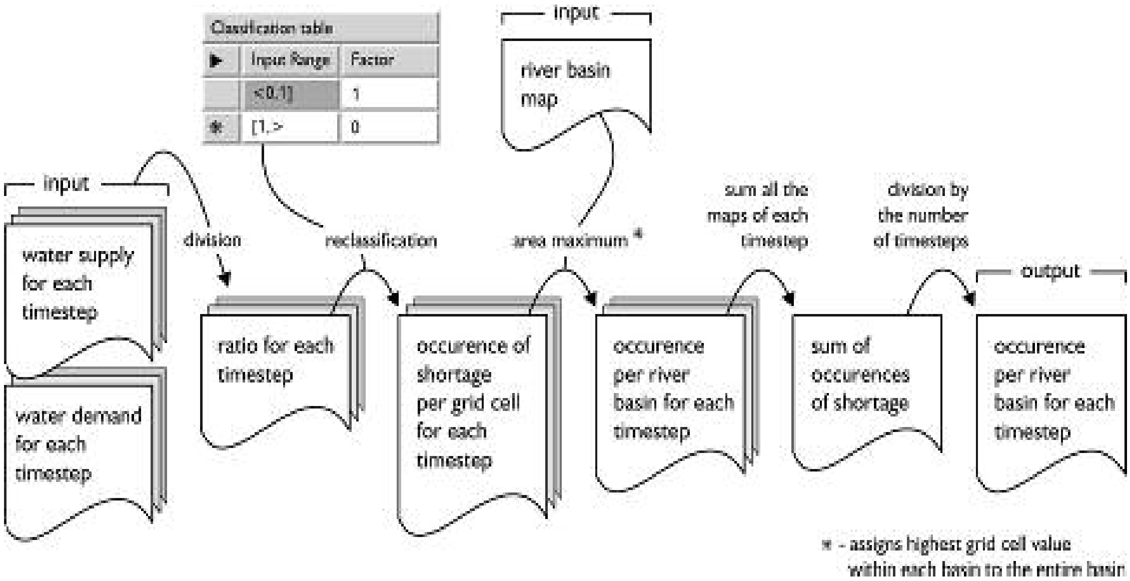

Figure 7. Example of flow chart for map based calculations with HABITAT