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The United Nations World Water Assessment Programme

Insights

Building a 2nd Generation of World Water Scenarios

Joseph Alcamo and Gilberto Gallopín

United Nations World Water Assessment Programme (WWAP)

United Nations Educational, Scientific and Cultural Organization

World Water Assessment Programme

The United Nations World Water Development Report 3
Water in a Changing World

Coordinated by the World Water Assessment Programme, the *United Nations World Water Development Report 3: Water in a Changing World* is a joint effort of the 26 United Nations agencies and entities that make up UN-Water, working in partnership with governments, international organizations, non-governmental organizations and other stakeholders.

The United Nations' flagship report on water, the WWDR offers a comprehensive review of the state of the world's freshwater resources and provides decision-makers with the tools to implement sustainable use of our water. The WWDR3 represents a mechanism for monitoring changes in the resource and its management and tracking progress towards achieving international development targets. Published every three years since 2003, it offers best practices as well as in-depth theoretical analyses to help stimulate ideas and actions for better stewardship in the water sector.

Water in a Changing World has benefitted from the involvement of a Technical Advisory Committee composed of members from academia, research institutions, non-governmental organizations, and public and professional organizations. To strengthen the scientific basis and potential for implementation of its recommendations, interdisciplinary expert groups were also created for a number of topics, including 'Indicators, Monitoring and Databases', 'Business, Trade, Finance and Involvement of the Private Sector', 'Policy Relevance', 'Scenarios', 'Climate Change and Water', 'Legal Issues' and 'Storage'. An accompanying case studies volume, Facing the Challenges, examines the state of water resources and national mechanisms for coping with change in 23 countries and numerous small island developing states.

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Table of Contents

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Building a 2nd Generation of World Water Scenarios

*Joseph Alcamo and Gilberto Gallopín**

United Nations World Water Assessment Programme (WWAP)

Summary

This document briefly discusses the uses of qualitative and quantitative scenarios, then reviews the status of global water scenarios. It points out some of their major shortcomings: (i) the absence of scenarios that examine the combined impact of changing climate, land use and socio-economic factors on continental or global water resources; (ii) the lack of quantitative scenarios dealing with ecological issues; (iii) the weak treatment of water governance and water pricing issues.

We recommend that new scenarios be developed that are targeted to a broad audience – including the scientific community concerned with changes in the earth system, international organizations concerned with water, and the general public and students. To address the needs of this broad audience, the scenarios will have to be more comprehensive than previous scenarios, and cover, in addition to the new factors mentioned above, the following specific topics: changing average (annual) water availability, frequency of hydrological extreme events (floods and droughts), average water use, river connectivity (dams and reservoirs), river morphology, ecological (biological and chemical) condition, land use, and water governance.

We also recommend the 'SAS approach' (Story and Simulation) using to develop new scenarios. This is an iterative procedure that ensures the engagement of both stakeholders and experts in the scenario-building process. SAS involves three stages: (i) the development of qualitative 'storylines' by a group of stakeholders and experts, (ii) the use of models to produce quantitative scenarios which provide needed numerical data and enable a consistency check of the storylines, and (iii) the harmonization of the qualitative and quantitative scenarios through an iterative process relying on interaction between scenario writers, experts, global modelers and stakeholders. The SAS approach has the advantage of ensuring the participation of stakeholders in the actual development of the scenarios, and of engaging modelers and other experts directly with stakeholders and decision makers. The involvement of scientific experts along with stakeholders increases the chances that both scientifically-credible and politically-relevant scenarios are produced.

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1. Introduction

This paper describes what scenarios are and how they contribute to decision-making, and why new scenarios are needed now and what they might contain. It also provides examples of past scenarios related to water resources, and gives a brief summary of an approach to carrying out such an exercise.

Interest in the future of the global water system has grown rapidly over the last few years, stimulated by an awareness that widespread changes are occurring in the system that could have major implications for nature and society. Examples of these transformations are given in Table 1 (overleaf). These and other changes are associated with major demographic, social, economic and political processes (i.e. globalization, national security, international conflicts over water access, and population growth and displacement).

Our awareness of the extent of changes in the global water system is fairly recent, and many critical, unresolved questions remain, such as: Will changes in the system continue at their current level over the coming several decades? If so, at what intensity, pace and location – and what impacts will they have? What new technological breakthroughs are plausible? Will new types of changes emerge? And further, what social, economic, institutional and environmental impacts will these changes have?

Researchers have begun addressing these questions through a growing number of global water scenario studies that examine future trends in water abstraction, wastewater loadings and water availability from both continental and global perspectives. Many international organizations have encouraged the scientific community to build scenarios in order to address outstanding questions about the global water system.

The Global Water System Project (GWSP) has argued that scenarios are critically important for describing 'the global water system under different levels of global change' (GWSP, 2005 – the GWSP is a Joint Project of the International Geosphere-Biosphere Programme, the World Climate Program, the International Human Dimensions Programme of Global Change, and Diversitas). Scenarios are needed to identify 'future areas of critical change in the global water system', and 'as a departure point for scenario analysis on the local or river basin scale' (GWSP, 2005). Scenarios of the future of the global water system are also needed to understand future developments in the entire earth system, because of the many connections between the dynamics of freshwater and the rest of the earth system.

Motivation for building global water scenarios also comes from the policy and business communities. At the First World Water Forum in Marrakech, Morocco in 1997, these groups called for scenarios of a 'World Water Vision' that would 'convince the world of the urgency of the water crisis and of the need to involve many more people in the development of water policy' (Cosgrove and Rijsberman, 2000*a*).

This document has four main objectives: first, to review the basic elements of the 'scenario approach' as it applies to world water futures; second, to briefly review existing global water scenarios and identify their deficits; third, to emphasize the need for a new family of global water scenarios, to discuss what they should include and to describe the potential audience for them, and finally, to suggest a general approach for implementing the new scenarios.

2. The Scenario Approach

Special challenges arise when we try to incorporate water as an issue in sustainable development. We need a long-term perspective in order to account for the slow unfolding of hydrologic and social processes and the necessary time for a new water infrastructure to yield its fruits. However, there are methodological problems in developing this long-term perspective. It would seem logical to use forecasting techniques to estimate future water use and water resources, but this runs into problems; although forecasts may be reliable over the short-term, they become untrustworthy as the time horizon expands from months and years to decades and generations. Forecasts necessarily incorporate a fundamental uncertainty, because of our limited understanding of human and ecological processes, and because of the intrinsic indeterminism of complex dynamic systems. The third challenge comes from the fact that the future of water resources depends at least partly on human decisions that are yet to be made (Gallopín et al., 1997).

How are we to address these challenges? One way is to take a scenario approach. The term 'scenario' has been introduced into the planning literature to mean 'a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points' (Kahn and Wiener 1967). It is important to emphasize that scenarios are not projections, forecasts or predictions. Rather, they are stories about the future with a logical plot and narrative governing the manner in which events unfold (Schwartz, 1991; Cole, 1981; Miles, 1981), Scenarios usually include images of the future – snapshots of the major features of interest at various points in time – and an account of the causal flow of events leading from the present (or the base situation) to such future conditions.

Scenario analysis provides a method for contending with inherent uncertainties of the future – water scenarios provide information that supports decision makers and other stakeholders in their evaluations of future policies for managing water resources. They provide them with pictures of the world under a variety of qualitatively different evolutions, ranging from futures in which no major changes in water policy or behaviour take place, to futures in which society actively grapples with its water problems. Scenarios help identify for them the possible dangers of some undesirable trajectories, as well as the

Table 1	Examples of major changes transforming the contemporary global water system
Biodiversity loss	Destruction of habitat and pollution have caused widespread loss of species.
Climate change Impacts	Global surface temperature continues to rise throughout the instrumental record, with new evidence of an accelerated hydrologic cycle. Regional increases in extreme precipitation, systematic reductions in snow cover and mountain ice, and more frequent and intense quasi-periodic events (e.g. ENSO, AO) have been tabulated over the past few decades.
Erosion	Sediment load to aquatic systems has increased by a factor of 3–4, due to poor land management inducing erosion.
Eutrophication	Due to development and increasing use of water, the eutrophication of inland waterways continues to increase; impacts persist in the coastal zone, where they cause anoxia and toxic algal blooms, and endanger fisheries
Groundwater contamination	Groundwater resources have been contaminated with salts, pesticides and other substances from agricultural activities, and with chemicals and pathogens from industrial activities and settlements.
Intensive water abstraction	In heavily populated regions, water withdrawals sometimes exceed natural river flow and the rate of groundwater recharge (mining of aquifers; currently, water tables are falling on all continents); water is reused many times, with concomitant public health and pollution problems.
Interception of sediment flux	Dams trap 30% of global sediment flux, with downstream impacts influencing many coastal zones of the world. Reservoir siltation from upland erosion results in substantial economic loss in many parts of the world.
Introduction of exotic species	As a result of increasing world trade, invasive species are replacing native species and changing the character of natural ecological systems.
Land-coastal linkages	Because of water diversion and evaporative (irrigation) losses, connections between the land and coastal zones are being severed with respect to water, nutrients and sediment. Well-known examples include the Yellow and Colorado Rivers, among many others in arid regions.
Loadings of micropollutants	The loadings of micropollutants in water systems are on the rise in many parts of the world including natural (e.g. arsenic and other metals) and engineered (e.g. pesticides) species.
Nitrogen loadings	Global nitrogen loadings of rivers have increased by a factor of 2 to 3 compared to pristine conditions, with 10-fold increases in some regions
Salinization	Intensive and prolonged agricultural activity has led to large-scale leaching of salts from cultivated areas and caused elevated salinity concentrations in groundwater and surface waters.

Source: GWSP (2005).

critical decision points where action is needed to gain a desirable future and avoid an undesirable one.

In addition to their role in supporting decision-making, scenarios can also provide common frameworks to map and address the critical concerns of diverse stakeholders and to identify alternatives, and they can serve as a forum for discussion and debate. A summary of the advantages of the scenario approach is given in Box 1.

The scenario approach typically involves the following elements:

The development of scenarios generally begins with the characterization of the *current situation*. An important initial step in scenario construction is the definition of the critical dimensions of the scenarios. Collectively, these define the multidimensional space within which scenarios can be mapped or constructed. Dimensions do not necessarily imply causal assumptions; rather, they are defined in terms of their relevance – they are descriptors of the most important attributes of the images of the future. Examples of possible dimensions are economic growth, social progress, environmental quality conflict level.

Box 1 The need for a scenario-approach to understanding the future of world water resources

The need for a long-term view. Understanding the role of water in sustainable development requires a long-term view in order to account for the slow unfolding of hydrologic and social processes, and to factor in the necessary time for investments in water infrastructure to yield their fruits.

The high uncertainties about the system. Decision-makers in the water sector must decide on water management policies against a backdrop of a rapidly changing environment and increasing uncertainty. Fundamental uncertainty is introduced both by our limited understanding of human and ecological processes, and by the intrinsic indeterminism of complex dynamic systems. Moreover, water futures depend on human choices yet to be made.

The need to include non-quantifiable factors. The world water system includes, and is influenced by, many factors that are extremely difficult to quantify (e.g. cultural and political variables and processes), as well as some factors that can be quantified and modeled mathematically (e.g. hydrologic and climatologic dynamics, and economic factors). Qualitative scenario analysis can cope with these situations in which simulation models cannot be used, and can complement quantitative analysis.

The need for integration. To ensure its sustainability, water must be viewed in a holistic manner, including both its natural state and the competing demands upon it – domestic, agricultural, industrial, and environmental. Decisions about land use affect water resources, and conversely, decisions about water management affect the environment and land use. Decisions about our economic and social future affect the hydrologic systems and ecosystems upon which we depend. In sum, sustainable management of water resources requires systemic, integrated decision-making that recognizes the interdependence of decisions; scenarios are particularly valuable for dealing with this interrelatedness.

The need for perspective. Qualitative scenarios provide input and context for quantitative scenarios, while quantitative scenarios provide consistency and feasibility checks for some elements of other scenarios, as well as numerical estimates of some scenario variables. Also, global scenarios provide a global perspective for scenarios on a smaller geographic scale (local, watershed, country, regional), while local and national scenarios are necessary to zoom in to the level at which practical, place-based solutions can be found.

The need for input to decision-making. It is not practical for decision-makers to pick up the elements from different studies that are most relevant to their decisions. Scenarios in this case are useful for decision-makers because they can be built with decision-making in mind. They are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points, directing attention to the unfolding of alternatives and to branching points at which human actions can significantly affect the future.

Providing an arena for conversation among stakeholders. In addition to their role in supporting decision-making, scenarios also provide common frameworks to map and highlight the critical concerns of diverse stakeholders and to identify alternatives, and they are also an excellent arena for discussion, debate, and negotiation.

Next the major *driving forces* are identified; these represent the key factors, trends or processes which influence the situation, focal issue, or decisions, and actually propel the system forward and determine the story's outcome. Some of these forces are *invariant* over all scenarios; that is, are to a large extent predetermined. Some of the driving forces may represent *critical uncertainties,* the resolution of which fundamentally alter the course of events (Schwartz 1991). Those drivers influence, but do not completely determine, the future. Thus, while the initial drivers are the same in all scenarios, the trajectory of the system follows a different course in each of them.

The current state, driving forces, strategic invariants, and critical uncertainties form the backbone of the scenarios. In addition, all qualitative scenarios unfold according to an internal logic which links the elements into a coherent *plot.*

The end point of the scenario is an *image of the future* resulting from the unfolding of the scenario[1].

Another important point is that scenarios come in different forms. They can be qualitative, in which case they take the shape of stories about the future with a logical plot and narrative governing the manner in which events unfold, often complemented with cause-and-effects digrams (Schwartz, 1991; Cole, 1981; Miles, 1981). They can also be quantitative, in which case they generate numerical calculations about the sequence of states leading to the future. The advantages and disadvantages of qualitative and quantitative scenarios are explained in Box 2. Since they both have indispensible characteristics and complement each other, the next generation of global water scenarios needs to have strong elements of both.

3. Review of Existing Global Water Scenarios

A number of global water scenarios have already been produced and published.[2] The scenarios differ greatly in character: some are quantitative as in the case of model estimates of future changes in runoff responding to climate change); others are qualitative, including those that describe how changing socio-economic conditions will affect water resources over

1 This is true for the so called *exploratory scenarios,* which probe the future starting from the present; *normative* (also called *backcasting) scenarios* begin with a description of the desired image and work backwards to the present.

2 In this document we refer interchangeably to 'global water scenarios' and 'scenarios of the global water system.' These are scenarios that have either continental or global coverage and describe long term (usually longer than two decades into the future) changes in the global water system, either qualitatively or quantitatively.

the coming decades. Some are model-based, while others have been derived by scenario panels through a collective scenario-building process. Still others have been developed through an iterative procedure involving both models and scenario panels.

Global scenarios of changes in water resources have been published by Alcamo *et al.* (1997, 2003, 2005), Arnell (1999, 2004), Döll *et al.* (2003), and Oki *et al.* (2001). The combined impact of climate and population scenarios on global water resources has been analysed by Oki *et al.* (2003) and Vörösmarty *et al.* (2000). Alcamo *et al.* (2007) analysed the impact of climate, population and other economic factors on changes in global water resources. Alcamo *et al.* (2003) analysed the impact on withdrawals of a 'business-as-usual' scenario driven by changes in socio-economic variables.

Shiklomanov and Rodda (2003) presented global scenarios of water use for the period up to 2025. Gallopín and Rijsberman (2000) and Rijsberman (2001) presented integrated qualitative scenarios including economic, social, technological, environmental, demographic, and governance drivers affecting future global water resources. Alcamo & Henrichs (2002) presented areas of particularly rapid changes in water stress due to changes in water withdrawals and climate. Henrichs *et al.* (2002) analysed the water stress situation in Europe by bringing together aspects of future climate change and changes in water use due to socio-economic development, but did not explicitly identify the importance of climate change versus other socio-economic factors. In a global-scale study. Döll (2002) analysed the impact of climate change on the net irrigation water demand for areas that were equipped for irrigation in 1995.

Recent global environmental assessments have produced comprehensive global environmental scenarios which include future global water use and availability, e.g. the Global Environmental Outlook of the United Nations (UNEP, 2007) and the Millennium Ecosystem Assessment (Carpenter et al., 2005; Alcamo et al., 2005).

Much less work has been done on the global scale on future trends in the ecological condition of waters. The only published global scenarios of aquatic biodiversity are given in Xenopoulous *et al.* (2005).

5. The World Water Vision Scenarios

In reviewing past scenarios we give special attention to the World Water Vision (WWV) exercise of the World Water Commission, which was the first and remains the largest international effort to develop global water scenarios (Cosgrove and Rijsberman, 2000a and b; Gallopín and Rijsberman 2000; Rijsberman 2001).

The motivation for the scenarios can be traced back to the First World Water Forum in Marrakech, Morocco in 1997 which brought together many private, governmental, academic and advocacy groups concerned with world water issues. One of the important outcomes of the Forum was the call for a 'World Water Vision' to raise global awareness about global water problems and solutions. The main objective of the Vision, and the process to develop it, was to 'convince the world of the urgency of the water crisis and the need to involve many more people in development of water policy' (Cosgrove and Rijsberman, 2000a). It was declared that the Vision should be expressed in the form of scenarios that describe the world freshwater situation in 2025. Further, the scenarios should be primarily qualitative in order to maximize transparency to stakeholders and inclusion of important non-quantifiable factors.

The World Water Council set up two bodies to oversee the activities of the World Water Vision and these groups also had a major influence on the development of the World Water Scenarios. The first was a 'Vision Management Unit' which managed the day-to-day activities of the World Water Vision Exercise. The second body was the World Commission on Water for the 21st Century consisting mostly of water experts and decision makers. These two bodies set up a Scenario Panel of 17 technical experts and stakeholders to provide the creative input to the scenario construction.

The scenario exercise initially focused on development of qualitative scenarios, to allow incorporation of the many social, economic, environmental and cultural factors that play a major role in shaping the water future, but which cannot be modeled in detail. The development and discussion of qualitative scenarios served as a platform for consultation among many stakeholders from different disciplinary backgrounds. Mathematical models were subsequently incorporated to analyse the consistency and coherence of the qualitative scenarios, explore some of the consequences and to help fill in some of the gaps.

Early in the process, the Panel identified six major driving forces that they believed covered all key factors, trends or processes that influenced the situation, focal issue, or decisions, and actually propel the system forward and determine the story's outcome. The clusters of driving forces identified by the Panel were:

- Demographic (population growth in developing countries; migration pressures; urbanization in developing countries).
- Economic (economic output; trade; increasing prosperity in developing countries; water works investment).
- Technological (high-tech expansion; water use efficiency; water pollution; adoption of new crops; sanitation investment; desalination plants).
- Social (personal lifestyles; poverty; inequity).

- Governance (power structure; level of conflict; globalization).
- Environmental (water-related diseases; soil salinization; groundwater; ecosystem health).

The qualitative scenarios described the unfolding of events related to the future world water situation, as well as important direct drivers (e.g. the future extent of irrigated land or the level of water supply infrastructure) and indirect drivers (e.g. changes in population and economic growth)

The scenarios were developed in an iterative fashion, starting with a 'zero order draft' of a storyline crafted by the Scenario Panel, which was then converted using best judgment into quantitative driving forces that could be used as model inputs. The quantitative scenarios (model calculations) reinforced the storylines in two ways. First, model output was used to assess the validity and consistency of the storylines– for example, to check if the population and economic assumptions were consistent with statements about future levels of water use. Second, they provided numerical information on water use and availability to supplement the qualitative information contained in the storylines. The scenarios evolved in four rounds of development, discussion, feedback, and subsequent improvement, and in interaction between the scenario developers, modelers, reviewers and the groups working on visions for sectors and regions.

When completed, the storylines and quantitative scenarios were posted on the World Water Vision website and discussed at several regional meetings worldwide. Comments were incorporated into the final storylines. Three scenarios were developed:

Business-as-Usual (BAU), representing the future trajectory in which major crises are avoided and no major policy or lifestyle shifts take place.[3]

Technology, Economics, and Private Sector (TEC), which results from an emphasis on market forces, the involvement of the private sector, and mainly technological solutions. Actions are taken mostly on the national/local or basin-level.

Values and Lifestyles (VAL), which emerges through a strengthening of humanistic values, increased international cooperation, and heavy emphasis on education, international mechanisms, international regulations, increased solidarity and changes in lifestyles and behavior.

More information about the development of the scenarios is given in Cosgrove and Rijsberman, 2000a and b, and Gallopín and Rijsberman (2000).

It can be argued that the scenarios contributed to the goals of the World Water Vision exercise by helping to raise public awareness about water issues. They did so by being an effective and credible method to communicate the main messages of the World Water Vision in numerous publications and public presentations (Cosgrove and Rijsberman, 2000b). The three global scenarios provided inspiration for water professionals and also for regional groups to think about local or regional 'drivers,' to develop their own scenarios, and to generate shared ideas about what a Water Vision for the 21st century could be.

6. What are the Shortcomings of Current Global Water Scenarios?

Qualitative scenarios

In discussing the shortcomings of qualitative scenarios we will use the WWV scenarios as a reference point. First of all, the WWV dealt with a very comprehensive set of driving forces, and this set should be a starting point for the next generation of scenarios. However, two changes are needed. First, the numerical values of the driving forces have to be updated, because a large amount of work has been done since 2000 on projections of population, economic growth, and other socio-economic driving forces. Second, new driving forces should be added to the original set. The following drivers should be considered:

Climate Change. The WWV Scenario Panel did not include climate change because many climate experts thought that the major impacts of climate change would be felt beyond the time horizon (2025) of the scenarios. Since then, however, the impact of climate change has already become evident and current. It is critical, therefore, to include climate change as a driver in the next generation of scenarios.

Trade and Globalization. Although the WWV scenarios incorporated the influence of free trade and globalization as indirect factors, these issues have intensified and should be included in the next generation of scenarios as major driving forces.

Security. The issue of security did not play a central role in the WWV scenarios. However, security concerns have of course taken a central place on the international agenda since 2001, and security considerations have a pervasive influence on diplomatic and military international negotiations. Security concerns even threaten to displace other priorities such as international cooperation in the fight against poverty. Whether and how security should be included in new scenarios is an issue that needs to be examined in a new scenario exercise.

Energy. Energy use and production did not play an important role in the WWV scenarios, but should be considered as a major driving force in the next set of scenarios.

3 Not to be interpreted as a static scenario, but one where the current trends and dynamics continue.

Logic of the Drivers. More generally, the evolution of the drivers, and even the logic behind the storylines, should be examined and possibly redone in the light of developments since the year 2000, both within and without the water sector.

Policy Initiatives. New policy initiatives have been adopted since 2000, such as the acceptance of the Millennium Development Goals, which explicitly includes the target to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. This and other important policies must be taken into account in the next set of scenarios.

Quantitative scenarios

Quantitative, model-based scenarios also have some major deficits. Among these are:

- Few global water simulations take into account socio-economic drivers of changes in global water use.
- Few quantitative (or qualitative) scenarios have been developed that account for the impact of land use change on water resources on the *continental or global scale*. (There is, however, a literature on current impacts of land use change on water resources, and on scenarios of land use impacts on future water resources on the *local and river basin scale*.)
- No quantitative (or qualitative) global water scenarios have considered the *combined impact* of changing climate, land use and socio-economic factors on continental or global water resources.
- Virtually no global quantitative scenarios deal with the ecological aspects of the global water system.
- Water governance issues have been included in global quantitative (and qualitative) scenarios in only a very simplistic manner.

7. Why New Scenarios?

What is the justification for new scenarios?

The first argument is obviously to address the long list of deficits of current global scenarios given above. In particular, most current global water scenarios neglect, or inadequately represent, important driving forces such as climate change, security concerns, globalization, and free trade considerations. These driving forces need to be incorporated in new scenarios.

Second, current global scenarios do not take into account the future impact of important new policy initiatives such as the Millennium Development Goals for water, and the imminent new international agreement on climate change. These initiatives must be included in new scenarios.

Third, current scenarios do not provide a sufficiently holistic view of the water system. New scenarios must provide a more comprehensive integrative perspective to scientists and stakeholders about likely or possible changes in the global water system. Up to now quantitative global water scenarios have taken into account only one or a few factors (e.g. climate change). Therefore they have been unable to examine the combined effects of future changes in demography, economy, land use, and climate. They have also barely begun to explore the impacts of changing governance structures on the global water system.

Fourth, new global scenarios are needed for providing a global perspective/context to scenarios on a smaller geographic scale (local, watershed, country, regional). Many of the important changes occurring in a river basin are determined by 'external' factors, i.e. drivers from outside the basin. For example, the demand for irrigation water within a particular river basin is likely to be strongly influenced by world prices of various agricultural commodities. Likewise, water demand in some river basins is strongly affected by the immigration of people into a river basin, and this stream of people is determined by demographic or economic factors that transcend the river basin. Global scenarios can provide information about some of the 'external' factors that will influence the future condition of river basins.

8. What Should New Global Scenarios Include?

As stated above, the new scenarios should incorporate relevant information about the driving forces used in the WWV together with other new driving forces such as free trade, security, globalization, energy and climate change. But the final list of driving forces should be selected by an international scenario panel as part of the scenario building process. (See 'Implementing New Scenarios.')

The driving forces that are difficult to quantify will only appear in the qualitative scenarios. The other driving forces will be incorporated in the quantitative scenarios, either calculated explicitly by the model (i.e. water availability, population variables) or included implicitly (i.e. water uses efficiency, technological progress, changes in consumption patterns) in the form of parameters of the equations of the mathematical models.

Apart from elaborating new driving forces, the new scenarios should also incorporate a new set of water variables/indicators critical to the future state of the water system and important for making decisions about water management. These specific water variables will be computed as part of quantitative scenarios (if feasible) and include:

- Changing average (annual) water availability as affected by changes in climate, land use, and water abstractions

Table 2 **Feasibility of including particular topics in new quantitative global water scenarios**

More feasible	Less feasible
Changing average (annual) water availability	Changing river connectivity (dams and reservoirs)
Changing frequency of hydrological extreme events (floods and droughts)	Changing river morphology
Changing average water use	Changing ecological (biological and chemical) conditions of aquatic ecosystems, including aquatic & riparian biodiversity
Changing land use	Changing forms and impacts of water governance

- Changing frequency of hydrological extreme events (floods and droughts)
- Changing average water use
- Changing river connectivity (dams and reservoirs)
- Changing river morphology
- Changing ecological (biological and chemical) conditions of aquatic ecosystems including aquatic & riparian biodiversity
- Changing land use
- Changing forms and impacts of water governance

While special efforts should be made to include the above information in new scenarios, it must be recognized that it may be very difficult to include some of these topics because of the lack of data or understanding about future developments.[4] Table 2 estimates the feasibility of covering particular topics.

In addition to the range of information described above, new scenarios should also have the following design goals:

- They should be developed by a participatory process involving a wide range of different interest groups. (For details, see 'Implementing New Scenarios' overleaf.)

They should have two time frames:

- *short* (up to 2015 or 2020) in order to address the issue of the Millennium Development Goals and other policies relevant to the next decade
- *long* (up to 2100) to take into account the impacts of long term changes in climate, land use and socio-economic driving forces.[5]

They should employ state-of-the-art models for simulating the global water system

They should reflect the most up-to-date understanding about future driving forces, including changes in demography, economic growth and technological change. If possible, these drivers should be specified by a single model (for consistency) and checked against other driving force scenarios.

They should incorporate the latest thinking on future trends and impacts of water governance.

They should be much stronger in their treatment of water pricing and other economic factors than previous scenarios.

If feasible, they should be multi-scale, i.e. a set of global-scale scenarios should be developed. Parallel to the global scenarios a consistent set of scenarios should be developed on the river basin scale for selected river basins.

The scenarios, at all scales, should aim to be policy relevant, *scientifically credible, and to be perceived as* legitimate *by the different stakeholders*

9. What is the Audience for New Global Scenarios?

New global water scenarios should be targeted to a wide audience, including:

Decision-makers at different levels. Decisions regarding water availability and water use are being made everyday at the local, national, and international scales.

4 However, where data are insufficient, consultations with experts may mitigate the problem by using their best judgements in an organized way.

5 The year 2025 was chosen for the WWV scenarios because when they were developed (in 2000) it was far enough in the future to stimulate thinking about the future, but not too far to be irrelevant for decision makers. At the time, 2050 was considered too far in the future to be useful to stakeholders, even though groups such as the Intergovernmental Panel on Climate Change had used even longer time horizons for their scenario analyses. Given the inherent time-lags in the construction of water infrastructure, and the long time scale of important hydrologic and climatic processes, a time horizon of 2100 is needed for the next generation of qualitative scenarios.

Scenarios can provide information about long-term consequences of those decisions, and about alternative pathways into the future, as well helping to identify some crucial decision points and issues.

Stakeholders. Many people around the world are affected (positively or negatively) by changes in water accessibility and use, and many different social and economic actors (governmental, non-governmental, and private) are involved in water issues. Scenario exercises can provide a neutral arena for identifying and discussing water issues from different viewpoints and interests.

The scientific community concerned with changes in the earth system. The future condition of the global water system will be affected by climate and other global changes. In turn, changes in the global water system will have a profound impact on other parts of the earth system such as global patterns of climate, vegetation and land use. Scenarios can provide a vehicle for better anticipating future changes in the global water system.

International organizations concerned with water. Since the lifetime of some water infrastructure is several decades, decisions today must factor in expected long-term changes in the global water system. Scenarios can provide information about the magnitude and nature of these changes and global 'hot spots' of change.

General public and students at the university- and other levels. Global water scenarios provide an excellent device for envisioning the future and understanding the many complicated factors that will influence future changes in the global water system. They can be used very effectively to communicate complex ideas about future water resources to a broad general and academic audience.

10. Implementing New Scenarios

Global scale

We propose that the 2nd generation of qualitative-quantitative global water scenarios be developed using the 'SAS approach' (Story and Simulation), first used by the World Water Vision exercise. This is a procedure for combining state-of-the art complex scientific knowledge with local knowledge in a form useful for developing policies. SAS is an iterative procedure that ensures the engagement of both stakeholders and experts in the scenario-building process. The process involves the harmonization of the qualitative and quantitative scenarios through an iterative process relying on interaction between scenario writers, data and sectoral experts, global modelers and stakeholders. (Alcamo, 2008, Cosgrove and Rijsberman, 2000b). The interactive process encourages communication and discussion between these different actors.

This was the basic approach used in the World Water Vision exercise, as well as by the Intergovernmental Panel on Climate Change and Millennium Ecosystem Assessment for developing scenarios. The procedure is described in detail in Alcamo (2008).

The SAS approach

At its core, the SAS approach involves the work of a Scenario Panel made up of stakeholders and experts from around the world. The process begins with an in-depth discussion amongst the Scenario Panel about existing scenarios, followed by the development of qualitative 'storylines' by a group of stakeholders and experts. A storyline in this case is a narrative description of future events that lead to different future world water conditions. These storylines provide an understandable and transparent basis for understanding scenario assumptions, and a more interesting method for communicating the substance of the scenarios than numerical data, and represent the complex views of the individual members of the stakeholders and experts.

In the next step, the scenario coordinating team uses information from the storylines to derive a consistent set of quantitative driving forces for model inputs. A special methodological problem is how to convert the qualitative information of the storylines into the quantitative inputs needed by models. One method for doing so is to use 'fuzzy sets' to translate the linguistic statements in the storylines ('population growth is medium') to numerical model inputs ('population growth is 1 percent per year').

The quantified driving forces are then used by the modeling teams to build and run models and compute a wide range of future indicators of the global water system. (e.g. changing water availability, frequency of droughts and floods, and water use.) These calculations provided needed numerical data and are used to make a consistency check of the storylines.

The modeling teams then report their results to the Scenario Panel. In particular the modeling teams will report inconsistencies in the storylines indicated by model calculations, as well as additional information provided by the modeling analyses that can be incorporated into the storylines. The Scenario Panel revises the storylines based on the model calculations and other new information.

Steps b, c, and d are repeated at least twice in order to achieve a comprehensive and consistent set of qualitative scenarios (storylines) and quantitative scenarios (model calculations).

In the last step, the scenarios are sent out for wide review, final revisions are made to them, and they are published, widely distributed, and presented to policymakers, stakeholders and researchers involved with water issues.

The SAS approach has the advantage of ensuring the participation of stakeholders in the actual development of the scenarios, and of engaging modelers and other experts directly with stakeholders and decision-makers. This was an important element of the World Water Vision exercise (Cosgrove and Rijberman 2000b, Alcamo 2008). Moreover, the iterative process results in a rich combination of both qualitative and quantitative information having a high level of consistency and scientific credibility. The use of modeling, and involvement of top scientific experts along with stakeholders in the Scenario Panel, promotes the development of scientifically-credible scenarios.

Sub-national and local scales

At the sub-national and local scales (e.g. the watershed and the urban levels), the same general approach applies, with the difference being that the scenario construction process, and the scenario findings, can be more directly connected to real, specific actors and decision-makers and thus can be made more realistic and usable. At this scale, the global scenarios can provide valuable input by suggesting a general tendency of change, and by providing a picture of the global driving forces that will influence changes at the national or sub-national scale.

The local scenarios, on the other hand, can also provide substance and specificity to the whole scenario exercise, and demonstrate the diversity of situations involved in the water issue. The disadvantage of focusing on the local scale is that insights and lessons gleaned from this scale are usually not easily transferable to other locations or to the global scale.

At the national and sub-national levels, the establishment of good communication systems between the groups preparing scenarios will be important in order to stimulate exchange of experiences, mutual learning and reciprocal capacity-building. The development by the World water Assessment Programme (WWAP) Secretariat of a scenario tool-box and training material to be made available to the interested scenario groups would greatly facilitate the task and increase comparability of the efforts.

11. Concluding remarks

Scenarios can thus be an important tool in decision-making. We hope that this paper has demonstrated that a new set of scenarios in which driving forces create pressures – either directly on the resource, or indirectly through human activity – is required. These scenarios will lead to new understanding of the various pathways connecting processes and decisions in the water and non-water sectors, and so help us to cope with the great global water uncertainties and make better choices about our future.

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World Water Assessment Programme side publications, March 2009

During the consultation process for the third edition of the World Water Development Report, a general consensus emerged as to the need to make the forthcoming report more concise, while highlighting major future challenges associated with water availability in terms of quantity and quality.

This series of side publications has been developed to ensure that all issues and debates that might not benefit from sufficient coverage within the report would find space for publication.

The 17 side publications released on the occasion of the World Water Forum in Istanbul in March, 2009, in conjunction with *World Water Development Report 3: Water in a Changing World*, represent the first of what will become an ongoing series of scientific papers, insight reports and dialogue papers that will continue to provide more in-depth or focused information on water–related topics and issues.

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by Ruth Vollmer, Reza Ardakanian, Matt Hare, Jan Leentvaar, Charlotte van der Schaaf and Lars Wirkus for UNW-DPC

Global Trends in Water-Related Disasters: An Insight for Policymakers
by Yoganath Adikari and Junichi Yoshitani at the Public Works Research Institute, Tsukuba, Japan, for the International Center for Water Hazard and Risk Management (ICHARM), under the auspices of UNESCO.

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