Scenarios as a Tool in Water Management: Considerations of Scale and Application

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ABSTRACT: In recent years, the use of scenarios for creative visioning of potential futures for planning and strategy testing has become increasingly popular. Water management has not been excluded in this trend and many case studies of scenario application can be identified. Three scenario exercises are considered in this paper – the regional Societal and Institutional Responses to Climate Change and Climatic Hazards (SIRCH) project in southern England, the UK Environment Agency Water Resources Strategy and the World Water Council's World Water Vision. The paper discusses the role of scale in scenario approaches with regard to impacts, decision-making, participation and scalability. Scenarios are also compared with respect to their approaches and outcomes relative to issues in water resources planning, specifically demand management, extreme events and climate change. Conclusions point to the potential for innovative scenario approaches that consider adaptation, participatory interaction and local clustering.

1. INTRODUCTION

In recent years, the use of scenarios for creative visioning of potential futures for planning and strategy testing has become increasingly popular. Water resources management is a field where a variety of scenario approaches have been undertaken for diverse purposes. This paper outlines three case studies of water scenarios to examine how scale affects scenario development, outcomes and applications: the SIRCH (Societal and Institutional Response to Climate Change and Climatic Hazards) project funded by the European Union to understand process of drought and flood risk management in southern England; the UK Environment Agency's (EA) Water Resources Strategy scenarios developed at national and regional levels; and the World Water Council's World Water Vision global scenarios. The Thames Region in southeast England is used as a basis for comparing the case study scenarios.

The paper, in Section 2, introduces scenarios in general, the specific case of the Thames Region and a framework for developing and applying scenarios in the region. Section 3 sets out the three case studies individually. Section 4 compares the case studies considering issues related to scale including: impacts, decision-making, participation and the transfer of knowledge between scales. Section 5 discuses how the case studies relate to water resources issues of concern in the Thames Region, specifically demand management, extreme events and climate change. Finally, the paper proposes innovative approaches for future approaches scenarios in water resources management.

2. SCENARIOS AS A PLANNING TOOL IN THE THAMES REGION

2.1. What are scenarios?

A scenario may be defined as a coherent and systematic description of a 'possible future', expressed as a narrative about future environmental and socio-economic conditions. Scenarios usually have qualitative 'storylines' associated with quantitative indicators (for instance see Nakicenovic and Swart, 2000).

Scenarios can be used as a tool for delineating possible futures, which differ in crucial ways from the present. Rather than taking a predictive approach, scenarios are used to picture the future in an exploratory way, with the aim of identifying factors that will need to be taken into account in planning. More than one scenario is usually developed in a scenario-building exercise because

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the range of possible outcomes is of interest, rather than a 'best guess' trend projection. The scenario methodology is particularly applicable in cases in which new factors may prove to be significant, or in which there is much uncertainty or disagreement about the future. Scenarios are also useful when adaptive time scales are longer than those used in conventional planning, or when the "worst case" needs to be planned for as well as more probable, expected, or central outcomes.

Scenarios can develop considering the current situation and drivers that propel the present into the future or by designing a snapshot of a future time and backcasting (working backwards, to determine how that state can be achieved) (Robinson, 1990). The consideration of 'branch points' (Gallopin et al., 1997), are predominantly associated with the former approach. Branch points represent critical decision points, or periods of instability in the system, where conventional beliefs in 'structural invariance' do not necessarily apply and constraints on the system are relaxed. At these points individual and collective decisions regarding the forward directions have more power to affect great transitions (Gallopin et al., 1997).

To frame our discussion of the application of scenarios to different issues and situations we make reference to the work of Ringland (1998). Ringland classified scenario exercises into three main categories: scenarios for learning (by those involved in the scenario building process), scenarios for building of a common vision to influence public attitudes outside of the business environment, and scenarios for strategy evaluation or development. As a result of his analysis of various scenario building case studies, Ringland concludes with what he sees as the two main advantages of scenario building: the unfreezing of the intellect to plan in an atmosphere of great uncertainty; and the creation of a scenario 'wind tunnel' to test strategic plans and ensure that they will 'stand-up' to different potential futures. In examining the water resources scenario case studies presented, Ringland's scenario classifications (which are not necessarily mutually exclusive) and the key advantages he has identified are helpful in clarifying the purpose, strengths and weakness of the different approaches undertaken. The goal of this discussion, as Ringland suggests, is to make useful observations and recommendations for scenario building and its application in water resources without detailing a prescriptive approach that would stifle the creative and innovative aspects of scenario development and use.

In relation to water resources management, planning for resource development and supply management is often predicated on assumptions about the stability of social and ecological systems which are actually highly variable short time scales and the rigidity of management paradigms that are open to evolution or change. Given the unreliability of projections over the medium-term (decades) and long-term (generations), and our limited understanding of the interrelationship between human and ecological processes, conventional trend projection methodologies seem particularly unsuited to the task of strategic adaptation.

As a process in water resources management, scenario building can facilitate creative engagement between different actors in the hydro-social cycle. A scenario-building exercise can also provide a forum for discussion, and can contribute to the creation of a shared framework within which alternative planning responses can be identified. On the other hand, scenarios may be taken as forecasts, or used for purposes for which they are not appropriate.

2.2. Water resources in the Thames Region

The Thames Region (shown in Figure 1) is the catchment area of the River Thames and its tributaries. There are 5,330 km of main river in the region 12 900 km^2 in area (Environment Agency, 1999). The region is located in the south east of England with the city of London at the down-stream end of the catchment. The region represents less than ten percent of the land area of England and Wales but contains twenty-three percent of the population, generates just over twenty-seven percent of GDP, and has a similar percentage of all construction work (Environment Agency, 1998b). The region continues to attract high levels of growth (Environment Agency, 1998) and further housing

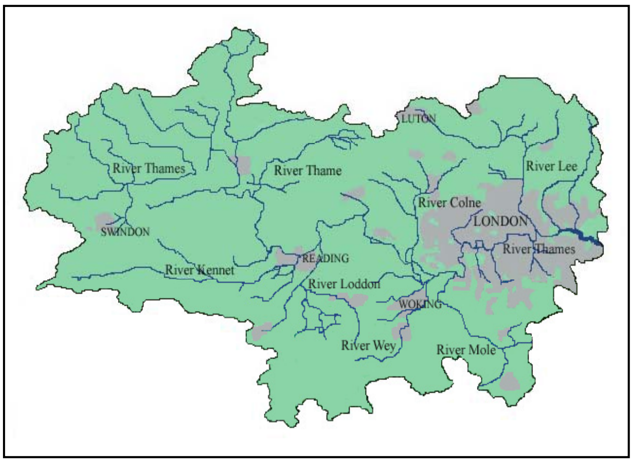

Figure 1. The Thames Region (Adapted from Environment Agency, 2001b).

development will place heavy demands on existing infrastructure networks (Council for the Protection of Rural England, 1999).

The Thames Region is amongst the driest in the UK; annual effective rainfall is 235 mm (338 mm in west and 116 mm in east) with the northeast part of the region most at risk of drought (Environment Agency, 2000). Approximately 55% of the effective rainfall within the catchment every year is abstracted annually with 86% of this water going to public water supply (Environment Agency, 2001b). The majority of public water supply is abstracted to provide domestic water supply to the 12 million people living in the region mainly concentrated in the major population centres -- such as London and surrounding satellite cities. In recent years, rapidly growing urban centres in the upper Thames, have placed a strain on local water supply. Overall, the rate of water demand in the Thames Region has risen by over 50% since the early 1960's but until recently, water resources were not seen as a constraint on development in the region. Recent groundwater droughts and an increase in peak demands have raised awareness regarding the seriousness of the situation. Future developments in drought prone areas will have to be staged to coincide with new water resources. Potential shortfalls in the water supply-demand balance are already foreseen under the growth levels predicted for certain areas (Environment Agency, 2001b).

Development in the Thames Region is also constricted by land use restrictions. Over 40% of the Thames region is classified as 'Areas of Outstanding Natural Beauty' (26%), 'Green Belt' or has some other form of protection. The headwaters of the Thames' smaller groundwater-supported (or 'chalk') tributaries dry progressively through the summer as the water table falls, sometimes exacerbated by water abstractions; such persistent 'low flow' rivers in the region are one of the prime concerns of the environmental regulator (Environment Agency, 2001b). Additional pressure is placed upon resources through pollution of both ground and surface water, and through increasingly stringent environmental restrictions (which address, for example, low flows in rivers and water quality).

A remarkable variability in hydrological conditions has been witnessed in the Thames Region in the last decades (Institute of Hydrology and British Geological Survey, 1995; Marsh, 1995). Throughout the 1990s several hydrological systems set new records (e.g. flow and water levels), extending the average reporting range for system levels (Arnell et al., 1994). By the mid-1990s, meteorological events began to show a broad consistency with some climate change scenarios (Arnell et al., 1994, Department of Environment, 1996) prompting the water industry to question the resilience of its water resource management strategies (Marsh, 1996).

The UK, as a whole, has experienced four major dry periods in the last twenty years (Brown, 1992; Institute of Hydrology and British Geological Survey, 1995, Centre for Ecology and Hydrology, 1998). However, as water resources are groundwater-supported, single-season meteorological droughts affect water resources in the Thames region less than in other regions in the UK. The most recent groundwater drought, running over consecutive seasons from 1995 to 1997, is the most severe since records began; many boreholes were at or below historic minima in 1997 and the early months of 1998 (Centre for Ecology and Hydrology, 1998, 1999).

Fourteen counties, fifty eight district councils, and thirty three local planning authorities in London lie wholly or partly within the region, which is a planning and regulatory unit only for the Environment Agency (National Rivers Authority, 1995). Privatised water service companies operate to boundaries that do not match any other geographical or political boundaries. The Thames Region is a planning and regulatory unit only for the Environment Agency Thames Region, one of eight regions in England and Wales (National Rivers Authority, 1995).

The key stakeholders for water resource management in the Thames Region can be listed as:

- Water service companies - commercial enterprises with a natural monopoly (at present) to provide water to domestic, corporate and municipal users. There are five water service companies operating in the Thames Region.
- Environment Agency (EA) - the environmental regulator of the water industry in England and Wales is responsible for water resources planning, the issuing and management of abstraction licences as well as water quality and some aspects of nature conservation.
- Office of Water Services (Ofwat) - the economic regulator, set up at privatisation of the water industry in 1989 to stimulate competition and set prices for water and allowed capital expenditure.
- Department of the Environment, Food and Rural Affairs (DEFRA) - oversees both the Environment Agency and Ofwat, political representation in setting policy.

- Local authorities - planning and service level of government, with little direct representation in water issues other than planning approval for new development and major infrastructure.

2.3. A context for scenario development in the Thames Region

Though scenarios are receiving increasing attention as a tool for water resources planning (Gallopin and Rijsberman, 2000, Environment Agency, 2001a, 2001b), they are building upon a more established framework of climate and socio-economic scenarios being used in environmental policy and research forums. Figure 2 shows the case study scenarios in the context of other scenario approaches used in the UK.

In 1996, the Intergovernmental Panel on Climate Change (IPCC) convened a Special Report on Emissions Scenarios (SRES), as a follow up to their earlier greenhouse gas emissions scenarios (called IS92) (Nakicenovic and Swart, 2000; see www.sres.ciesin.org). The four narrative storylines and families were labelled A1, A2, B1 and B2 (corresponding to quadrants along governance/sustainability axes), with 40 scenarios as realisations of the narratives. Six modelling teams implemented the scenarios (sometimes with alternative variants). Four scenarios were harmonised across the modelling teams to create marker scenarios that are now widely used in climate change studies. The panel involved a writing team of some 40 experts, widespread review and submission of storylines (the 'open process') and review and adoption by government representatives to the Panel on Climate Change. The scenarios were expressly oriented to provide a benchmark for greenhouse gas emissions and related climate forcing. While they cover a range of driving forces (population, economy, technology), they did not focus on water, vulnerability or climate impacts. For instance, disasters and surprises were excluded, and all regions experience significant economic growth (a 10-fold increase in global economic welfare in the 'poorest' scenario).

The Panel on Climate Change process overlapped with an independent panel, convened by the Stockholm Environment Institute in 1995. This "Global Scenario Group" produced four scenarios, each with two variants (Raskin et al., 2002); see www.gsg.org):

- Conventional Worlds—Market ('don't worry, be happy') and Policy Reform ('grown, environment, equity through better technology & management')
- Barbarization—Breakdown ('the end is coming') and Fortress World ('order through strong leaders')
- Great Transitions—Eco-communism ('small is beautiful') and New Sustainability Paradigm ('human solidarity, new values, the art of living')

The scenarios are different visions of the future represented by the first variant. The second variant illustrates a response to the scenario trend—a branch point for social, economic and political policy. These scenarios cover a wider range than most global projections-including bleak scenarios of increased inequitable development and

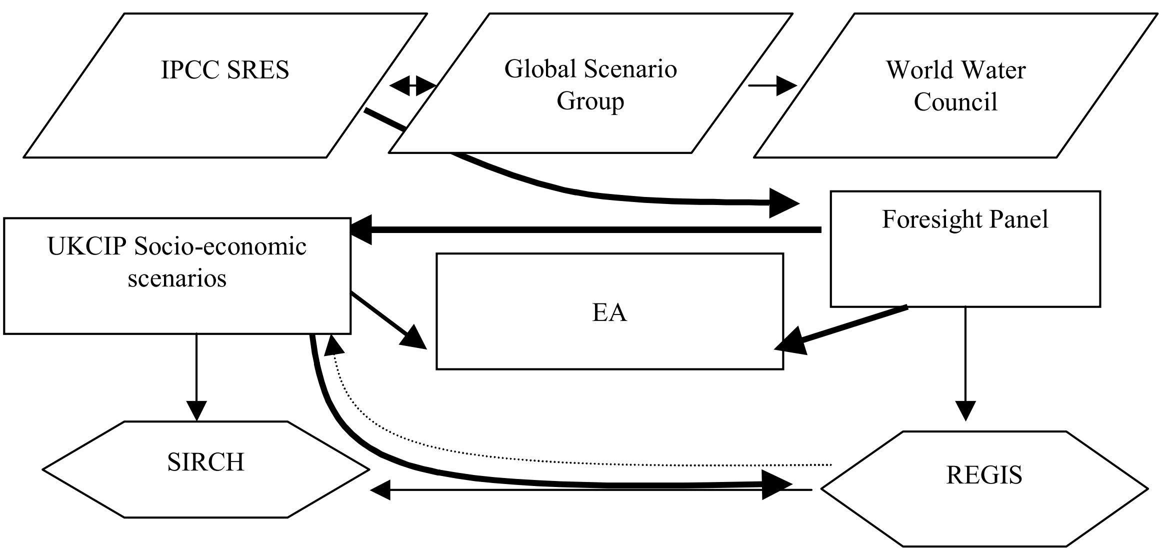

Figure 2. Socio-economic scenarios in the UK. Top row are international scenarios, middle row are national scenarios and bottom row are regional scenarios. Boxes in bold are compared in this paper. Arrows indicate downscaling processes and inter-relationships, with the width of the arrow reflecting the strength of the relationship.

fragmentation. Although water is included, the scenarios are holistic and do not provide great detail into water issues. The Global Scenarios Group is comprised of 14 experts drawn from around the world.

The other global effort, by the World Water Council, is described below in Section 3.3.

In the UK, the Department of Transport and Industry (DTI) Foresight Programme on Environmental Futures scenarios (www.foresight.gov.uk) provided a key link between the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (see www.rivm.ni/env/int/ipcc) and other scenario programmes at the national and regional levels.

The Foresight Programme was begun in 1994 to identify future challenges for the UK, bring together diverse expertise to meet these challenges and encourage public debate about the future (http://www.foresight.gov.uk). The Environmental Futures programme, in particular, aims 'to inform and stimulate debate among businesses, regulators and Government departments about the environment and to encourage them to develop strategies and policies that will prove robust to a range of environmental futures' (Department of Trade and Industry, 1999). The Foresight process involved a round-table to brainstorm ideas concerning possible futures, the sorting of ideas into scenario groupings and the creation of storylines and indicators for each of the scenarios. Four scenarios for a future United Kingdom were the result. The scenarios, Provincial Enterprise, World Markets, Global Sustainability and Local Stewardship, were developed in the quadrants of two axes representing changes in social values (consumerism to community) and governance (globalisation to regionalisation) (Figure 3). The scenarios describe possible UK futures between 2010 and 2040.

The UK Climate Impacts Programme initiated a process to create socio-economic scenarios, following on from the Foresight Programme (see www.ukcip.org.uk). The UK Climate Impacts Programme scenarios were developed by the same team as used in the Foresight Panel—they had also been involved in the IPCC SRES process. The UK Climate Impacts Programme scenarios are similar to the Foresight scenarios (Figure 3). After extensive review (particularly among government departments), quantified indicators were developed. One of the UK Climate Impacts Programme projects, Regional Integrated Assessment of Climate Change Impacts in the North West and East Anglia (REGIS), implemented the UK Climate Impacts Programme scenarios-indeed the project was instrumental in developing regional versions and involving extensive local stakeholder involvement (see Holman and Loveland, 2001).

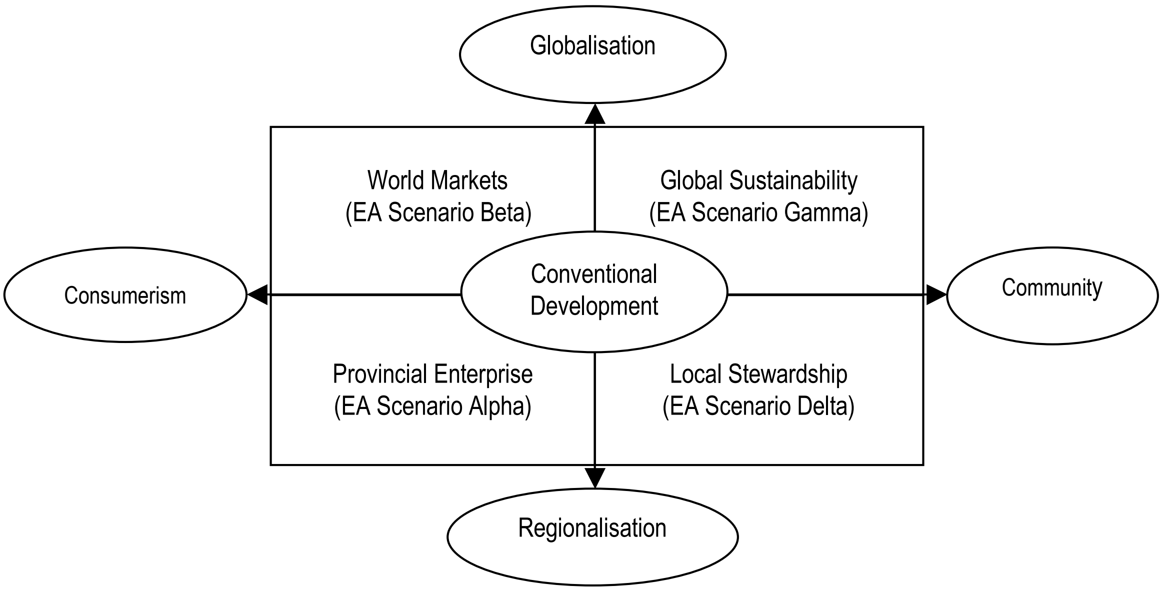

Figure 3. Classification of Foresight Socio-Economic Scenarios (Adapted from DTI, 1999).

3. SCENARIO CASE STUDIES

3.1. Coping with drought in the Thames Region - The Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios

Building on the recent interest within the water industry in future droughts, the Social and Institutional Responses to Climatic Change and Climatic Hazards project, European Commission's Environment and Climate Programme (DGXII) Ref ENV4CT97 0447) initiated a participatory scenario development process in early 1998. This project included a case study, conducted by authors of this paper, on vulnerability and adaptation to drought hazard in the Thames Region of the United Kingdom. The case study used a scenario building process to identify possible futures and explore adaptation mechanisms under different institutional developments (Downing et al., 2001).

The Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios were developed and assessed via a participatory methodology over the course of two workshops. Prior to the first workshop, in-depth interviews were conducted with key water managers and regulators in the region. The interviews provided information on current drought management strategies, and 'lessons learnt' from the most recent drought in the Thames Region (1984-1998 groundwater drought). The first scenario workshop involved sixteen water resource management experts from the region. The goal of the workshop was to identify factors that should be considered in evaluating adaptive capacity. Participants developed three plausible scenarios that described the possible development of social, economic and environmental drivers over the course of the 50 year time horizon.

One storyline involved Trend Projection and Conventional Wisdom - the experience of the last ten years projected forward, with increased wealth and consumer demand in a mixed regulatory regime. The other two scenarios were consciously extreme: Economic Growth and Market Enterprise -- high economic growth increases wealth, raises expectations, elevates demand for water, increases willingness-to-pay for water-related amenities, and also creates conflicts between water users; and Environmental Stewardship and Regulation -- a high general awareness of environmental issues, increased wealth and a more egalitarian society leads to a balance between water use and the environment. The three scenarios are related to the Foresight Panel scenarios (discussed in Section 2.3), to the extent of having similar orientations. However, two of the SIRCH scenarios (that is not the trend projection) were constructed be more extreme interpretations, and did not rely on the formal indicators developed by the Foresight Panel.

After the first workshop, storylines (the qualitative, overarching narrative element) were further developed, by the research team, into detailed scenarios with quantitative indicators. This process was aided by a four-part typology considering resources (i.e. hydrological indicators), institutions (the rules and norms which govern water management and planning), stakeholder influence, and key roles and issues for stakeholders. These socio-economic scenarios were mapped against four climate scenarios developed by the UK Climate Impacts Programme (Figure 4).

In the second Social and Institutional Responses to Climatic Change and Climatic Hazards workshop, participants were asked to explore the capacity of drought management institutions to adapt to the changes described by the socio-economic scenarios and the pattern of extreme events generated in the

		Climate scenario *increasing climatic risk*			
Qualitative differences ↕	Socio-economic scenario	Low	Medium low	Medium high	High
	Market enterprise	Increased demand and increasing climate risk, but likely to be met through economic adjustments			High demand and climate impact could exceed economic management
	Trend projection	Moderate demand, risk management required		Increasing risk of supply/demand crises	
	Environmental stewardship	Lowest demand, little risk of adverse impacts		Potential climatic risk to environmental management	

Figure 4. Qualitative socio-economic scenarios related to increasing risk of climate change.

context of the climate change scenarios. Results of three models (showing dynamic behaviour, agent-based household consumption behaviour and game theoretic economic behaviour) developed during the course of the project were also presented to assist the participants.

The scenarios used in the Social and Institutional Responses to Climatic Change and Climatic Hazards project were developed to focus on a specific issue-- institutional capacity to manage future drought risk. That is, they are bottom-up analytical devices rather than global, alternative futures. The scenarios used were chosen on the basis of prior research within the project and for their capacity to capture and illustrate institutional and stakeholder capacity to adapt to plausible, but extreme, changing circumstances. The scenarios were not intended to span a range of all possible futures nor to select a preferred future for drought management and determine how that future could be achieved.

The planning horizon for the scenarios was the 50 years to 2050. This compares with the water company planning horizon of 2016 and the planning horizon of 2025 for the environmental regulator of the water industry (although both include longer views at some levels).

The project found that the "Economic Growth and Market Enterprise" scenario was unsustainable under mid-to-extreme climate change pointing to the need for a reconsideration of current policy goals of increased liberalisation in the water sector. The scenario exploration also provided possible support for a move away from 'predict-and-build' to risk-based water resources planning

Participants in the Social and Institutional Responses to Climatic Change and Climatic Hazards project were an expert group of stakeholders (including senior water company managers, representatives of regulatory agencies and a small number of academics and NGO representatives), specifically selected for the task of scenario building. The project was not conducted as an open, public exercise. The workshops drew upon an established community of water resource managers and regulators who are accustomed to working with each other at various scales. The process was participatory in nature. The project facilitators provided a general outline of several scenarios to facilitate discussion, while the storylines and full scenarios were developed in small working groups. This approach was undertaken to promote learning in the individuals involved and potentially influence drought management policy and approaches to implementation.

The Social and Institutional Responses to Climatic Change and Climatic Hazards project was undertaken almost immediately subsequent to an unprecedented drought in the Thames Region when stakeholders, primarily in the national government, were making decisions regarding the future management of drought in England and Wales. Indeed, the process was intentionally placed between two regulatory reviews, to explore research methods and long-term perspectives rather than to directly intervene in water management in the UK. In many cases, the recommendations of the project have been in line with recent developments (e.g. the increasing focus on demand management as a sustainable strategy for water management (Environment Agency, 2001b)) but no work has been undertaken to determine what linkages exist between the project and the generation of these outcomes. The most likely impact, if any, was indirect benefit to stakeholders involved in the 'unfreezing of the intellect' associated with scenario building in an atmosphere of uncertainty.

3.2. Water Resources for The Future - Environment Agency Scenarios

The scenarios that are playing a major role in water resources management in England and Wales are those generated through the Water Resources Strategy process undertaken by the Environment Agency (Environment Agency, 2001a). The scenario building process was undertaken as part of an integrated water resources planning process to secure the proper use of water resources in England and Wales (Environment Agency, 2001a). The scenarios use a national framework for the development of regional scenarios and are used by the environmental regulator to develop water resources strategies for the future. The Thames Regional strategy is developed for roughly the same area as the Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios (see Figure 1).

The scenarios developed by the Environment Agency examine the uncertainties related to the future demand for water. As a basis for this examination, the Environment Agency adopted the Foresight Programme Environmental Futures scenarios developed by the UK Department of Trade and Industry (DTI, 1999) as the framework for socio-economic change over the planning horizon. Scenario work undertaken by the Environmental Agency focussed on developing additional narrative and indicators for water demand that are consistent with the economic and social changes described in the Foresight scenarios. The augmented scenarios were relabelled as Alpha (Provincial Enterprise), Beta (World Markets), Gamma (Global Sustainability) and Delta (Local Stewardship) (see Figure 3) to distinguish the EA narrative and indicators from the base Foresight scenarios.

In the Environment Agency scenarios, water demand was broken into 4 key components: household demand; industrial and commercial demand; spray irrigation demand and leakage. For each component, key water policy, technology and sector-specific drivers of demand were identified and discussed relative to the socio-economic factors detailed in the Environmental Futures Scenarios. Different methods of calculating scenario demand were then used for each of the demand components.

Household demand under scenario conditions was calculated using a micro-component analysis. This method involved breaking aggregate household demand into its component uses and forecasting the Ownership, Volume and Frequency (OVF) of use for each component. Industrial and commercial demand was classified by selected Standard Industrial Classification codes and company size and examined relative to average water use per unit production or employee and uptake of water saving technology. Spray irrigation demand was forecast considering the relationship between optimum demand (determined by the crop and soil type, local climate and recommended irrigation plans) and economic demand (determined by cost, price and constraints on irrigation). Leakage was calculated for each scenario using scenario-specific assumptions concerning the regulatory, political and economic aspects of leakage. Full details of demand scenario development are available in Environment Agency (2001c). In general, assumptions regarding the components of demand were made nationally and applied to the unique conditions (climate, population projections, scenario descriptions of growth etc.) found in each water resource area to determine incremental demand over the elapsed scenario period.

The published result of the scenario exercise was the calculation of changes in water demand levels for the four scenarios at two snapshot dates in the future (2010 and 2025) for each of the eight Environment Agency Regions in England and Wales (see Table 1 for scenario results for the Thames Region). Regional results were then broken down for additional reporting by water company resource zones.

At the Environment Agency, the development of national and regional water demand scenarios was considered a first step in developing water resources strategies. Strategies were seen to consist of different options, or groups of options, for managing the supply-demand balance. In developing the strategies the goal was to 'identify mechanisms and management measures for achieving society's present aims within the constraints that the scenario presents' (Environment Agency, 2001a). Scenario constraints were seen, first of all, to consist of the quantitative levels of demand that would have to be balanced with supply through the implementation of various supply and demand management options. The options available to the Environment Agency were then subjected to a sustainability analysis based on present sustainability criteria to determine the recommended strategy. The robustness of the final strategy, its appropriateness and projected impact, under all scenarios was examined on a regional basis.

Strategy options for the Thames Region included demand management and water efficiency options, surface water yield improvements, groundwater developments, abstraction recovery to protect the environment and the potential for new reservoir storage or bulk transfers, contingent upon further investigation and developments. The full list of options is presented in Environment Agency (2001b).

Scenarios were not used to examine the impact that potential environmental, economic and social aspects of the scenario futures could have on the importance or definition of the sustainability criteria used. Neither was the resilience of the Agency itself (and therefore its ability to fully implement the strategies) examined as part of the strategy process. Therefore, scenarios were not used, in this instance, to envision potential futures for water resources management in England and Wales but to examine how options developed under current water resources management systems and values can potentially cope with future water demand.

Work on the Environment Agency demand scenarios was conducted in-house with reference to literature, expert opinion and widespread, but ad hoc, consultation with members of the water industry (Environment Agency, 2001c). The EA water demand scenario process contributed to learning within the Environment Agency resulting in the development of many key indicators useful for considering water demand levels under future conditions. However, learning was generally restricted to a small group of Environment Agency staff. Therefore, it remains to be seen whether or not the scenarios will result in a shared vision between the Agency and other key stakeholders in the water industry or environmental protection even though the details of scenario development and strategy findings have been published and widely distributed. The approach taken assumes that sufficient learning and creation of shared vision is already an intrinsic part of the Foresight scenarios, leaving the Agency to focus strictly on the extension and application of these scenarios to suit their strategic needs. However, the common vision and learning process generated through Foresight was not necessarily specific-to nor shared-within the water resources community.

With respect to strategic application, the scenario approach used created an effective 'wind tunnel' for strategy development and evaluation. The scenarios were used in a nationally consistent way to explore demand. The resilience of options to scenario conditions could then be explored in a regional manner. However, the use of demographic forecasts that were not a part of the Foresight scenario process and the informal nature of resilience testing do lead to some internal inconsistencies within the process and the results.

An additional point to note regarding the water resources strategies developed is that the scenarios were developed considering the demand on an annual basis. Annual variations in demand were accounted for by considering annual demand in a 'dry year'. The impact of climate on annual household water consumption was considered by adjusting micro-component levels to reflect dry-year demand and the impact of climate on spray irrigation was considered using a more complex analysis of optimum demand, economic demand and irrigation constraints. Seasonality in water supply was discussed relative to some of the strategy options discussed and the current differences between winter and summer surface water availability were shown in maps of the region (Environment Agency, 2001b). The heightened impact of drought on resource availability and demand was not considered in any detail.

To address the potential impact of climate change on water supply, the strategy document states that current research supports the conclusion that within the planning horizon of the strategy, 'public water supply systems will retain their existing yields' (Environment Agency, 2001a) though individual systems will respond in different ways. With respect to demand, climate change was considered in impacts to garden water use on a sample scenario and a preliminary assessment of climate change impact on spray irrigation demand was undertaken. The strategy also considered drought and the potential for climate change impacts through the sustainability appraisal of strategy options. Preference is given to strategy options that provide maximum security of supply during drought and are resilient to climate change. Drought is addressed in the Drought Management Plans (e.g. Environment Agency (2001d)) that are produced for every Environment Agency Region apart from the scenario building and strategy process.

3.3. Global Water Scenarios - World Water Council (WWC)

The scenarios developed under the auspices of the World Water Council will be an important reference for the global water industry for some years to come (Gallopin and Rijsberman, 2000). The World Water Council scenarios were developed as part of the World Water Vision (World Water

Table 1. Percentage change from 1998 baseline in components of demand under scenario conditions (figures from Environment Agency, 2001b).

Component	Scenario: Alpha 2010	Alpha 2025	Beta 2010	Beta 2025	Gamma 2010	Gamma 2025	Delta 2010	Delta 2025
Household	+14	+26	+13	+14	+4	-29	+7	-21
Industrial and Commercial	+10	+5	+18	+38	-2	-32	-12	-43
Spray Irrigation	+24	+47	+24	+35	+12	-6	-6	-12
Leakage	-32	+143	-32	-33	-62	-72	-32	-49
Total	0	+53	+1	+5	-16	-42	-9	-34

Vision) programme. The ultimate aim of the WW Vision exercise is 'to generate global awareness of the water crisis that women and men face and of the possible solutions for addressing it' (Cosgrove and Rijsberman, 2000). The exercise is predicated on the belief in a crisis in the current management of water resources around the world and the need for action at all levels to create a sustainable future. The World Water Council's World Water Vision is a call to action, or in the words of Cosgrove and Rijsberman (2000) 'this is not an academic exercise – it is the start of a movement'. The global scenarios developed are key both to the formation of the World Water Vision and the development of strategies to achieve the World Water Vision.

The World Water Council's global water scenarios are based on 'alternative evolutions of major forces driving the global water situation: economic, demographic, technological, social, environmental and governance' (Gallopin and Rijsberman, 2000). The process began with a broad set of global drivers and a list of 'critical uncertainties' (factors which have an important role in shaping scenarios but have future values or outcomes difficult to determine at present) at a global scale. Critical uncertainties to be addressed at a global scale can be listed as

- water productivity trends
- expansion of irrigated agriculture
- massive increases in food production from rainfed agriculture
- dematerialisation of the economies
- national food self sufficiency vs. global food security
- availability of cheap water-purifying technologies
- public acceptance of genetically modified crops in the south and the north
- public opposition to large dams
- fundamental scientific discoveries
- scientific changes in human values and lifestyles

Source: (Gallopin and Rijsberman, 2000)

Three World Water Vision scenarios were developed. The first scenario was entitled "Business-as Usual" and was based primarily upon the projection of current trends. The second and third scenarios were built around the consideration of 'branch points'. The "Technology, Economics and the Private Sector" scenario is optimistic about uncertainties related to market systems, new technologies and regulatory control, in a context of decentralization of decision-making. The final scenario, "Values and Lifestyles" describes a future in which concerns over sustainability motivate a new ethic of water conservation, enacted by governments as well as civil society. The scenarios are meant to represent a wide span of plausible futures and to highlight issues that will need to be addressed if global water management is to become sustainable. The "Values and Lifestyles" scenario is put forward as the path to the most preferred future and it is used to define both the World Water Vision for 2025 and the process for achieving the Vision (Cosgrove and Rijsberman, 1998). The "Technology, Economics and Private Sector" and "Values and Lifestyles" scenarios are used to show the magnitude of change required (in investment or social change, respectively) to divert from the "Business as Usual" outcomes.

The scenarios were initially developed by a Scenario Development Panel consisting largely of academics, consultants and employees of multi-lateral lending and development institutions concerned with water management. They were subjected to four iterations of development through consultation and discussion with others involved in the World Water Vision process (modellers, reviewers and people working on regional and sectoral World Water Vision scenarios). Computational models were used to ensure scenario consistency and fill gaps. The World Water Vision process as a whole has a broader participatory component which has involved 15,000 people at various scales of engagement in various regions around the world (Gallopin and Rijsberman, 2000).

Climate change is not considered in the World Water Vision scenarios but drought frequency is anticipated to change over the course of some scenarios as a result of other factors. Drought frequency is not seen to be a determining factor in the scenario outcomes except in the final phases of the "Business as Usual" scenario where severe drought could tip the scenario into breakdown.

The World Water Council scenario process focuses strongly on the building of a common vision to influence attitudes in water resources management. Learning has also been promoted through the breadth of the exercise and publications generated by the programme. The question becomes the translation of that learning and influence into policy and its implementation. This raises the further question: who is the audience for the global scenarios and what influence does they hold? Of course, every citizen can act in the water polity through their consumption activities but the ability of global scenario building published in academic and practitioner forums to influence changes in public behaviour is questionable. However, as a framework engaging regional stakeholders and creating regional scenarios the global WW Vision may be more effective in prompting change.

4. A DISCUSSION OF SCALE

In the formulation of a scenario exercise, consideration must be given to the scale of impacts, the scale of decision-making required to enact outcomes and the scale of stakeholders to be engaged. Where these issues cannot all be addressed at one scale, consideration must also be made of how to enact the process or transfer knowledge between scales.

In the three case studies discussed, a variety of scales are used to examine water resources issues. The World Water Council takes a global approach, the Social and Institutional Response to Climate Change and Climatic Hazards project focuses on the Thames catchment area and the Environment Agency applies a national approach to scenario building to each of it's eight regions in England and Wales. In each of these cases, scale affects the questions being asked in scenario building, the stakeholders involved, the possible futures generated and the potential applications for the results.

Gallopin et al. (1997) discuss the need for examination at different scalar levels to fully understand the entire system of socio-ecological interactions and to address the problem of sustainability. They also propose a division of different topics between the different geographical scales: a global scale to illuminate world changes in economic, cultural, demographic and environmental phenomena. A regional perspective is required to analyze the problems of acid rain, water allocation, and certain migration patterns. A national focus sheds light on many policies, trade patterns and security issues. A local view often is appropriate for evaluating land-change patterns, biodiversity and ground level pollution. In this framework water allocation is listed as an issue to be addressed at regional scale, however, no other aspects of water resources management are specifically discussed. The question therefore becomes 'what are the global, regional, national and local aspects of water resources management?'

4.1. Environmental Impacts

Water is a local resource, given not only the constraints of the hydrological cycle, but also of the hydro-social cycle (in which water is cheap to store but heavy to transport, limiting the spatial extent of water distribution systems in most parts of the world).

When looking at the issue of scale in the case studies, it is interesting to note that none of the scenarios are set at a sub-catchment scale where local environmental problems can be acute. However, water transfers between communities and catchments often make the relationship between supply and demand an issue that is larger than the area that is suffering the physical consequences of low flows. The challenge therefore becomes an issue of identifying a scale that encompasses the catchment-based impacts and the demand serviced by the supply network.

The Environment Agency case study tries to overcome the offset of demand and supply by focusing on balances in water company supply zones. Strategy options are put forward to meet the supply demand balance considering additional resources needed to meet current or potential environmental constraints to water provision as well as resources required to meet the scenario demands.

The Social and Institutional Responses to Climatic Change and Climatic Hazards project was conducted at catchment scale but due to the size of the catchment and the focus on management issues occurring across the region, or even nationally, local variations in demand and water management were not addressed.

Unlike the climate change problem, it is difficult to identify the global environmental commons in relation to the water debate. However, Gallopin and Rijsberman (2000) address this issue explicitly in the World Water Vision case by listing environmental drivers as: water-related diseases; soil salination; groundwater; and ecosystem health. In the "Business as Usual Scenario" a situation of stress and vulnerability evolves. However, this vulnerability generally only tips into crisis in the developing world where stress is greatest and fewer adaptive mechanisms are in place. In the "Technology, Economic and Private Sector" scenario new technology and economics are applied to reduce or eliminate environmental impacts, where it is economic to do so, while incurring some social costs. Again in this case, developed countries experience the greatest environmental improvement at the lowest social cost. However, environmental degradation and social impacts are more unevenly distributed between countries in the north and south. In the "Values and Lifestyle Scenario" a crisis prompts social and technological change that tackles environmental and social challenges in a sustainable manner.

Table 2: Scales of Water and Land Management Activities for the Thames Region.

	National	Regional	Supply Zone	Local
Department of Environment Food and Rural Affairs (DEFRA)	Water and Land Policy			
Environment Agency	Policy development with DEFRA	Policy implementation - strategy development	Policy implementation and operations - catchment management	
Ofwat	Policy (with DEFRA) and implementation	Some differentiation of policy		
Water Companies	Trade associations and consultation		Operations	
Secretary of State	National (Development) Planning Policy	Regional (Development) Planning Guidance	Public enquiries and development control	
Local Authorities		Input to Regional Planning Guidance Process through planning fora	Local Development Plans	

4.2. Decision Making

If scenarios are designed to prompt changes in a management system, the scale of the scenarios must consider the relevant scale of decision-making. This is not always as straight forward as it may sound. Decision-making for different aspects of a single system can be led by a variety of actors spread across various scales. This is certainly the case for water resources management in the Thames Region. Scales of decision making for land and water resource management activities are given in Table 2.

Above the national level, the UK, and therefore the Thames Region, are also subject to European Legislation. Article 130r of the Treaty of Rome place water quality issues under the environmental policy competency of the European Union (allowing decisions to be taken by a majority in the Council of Ministers and co-decision between Parliament and Council). In contrast, measures concerning town and country planning, land use and water resources planning (among others) require unanimity within the Council of Ministers under Article 130s (Kraemer, 1998). This distinction reflects the views of many European Union Member States that strategies related to regional development and infrastructure policy are of a national importance such that a veto to European legislation is required in these areas (Kallis and Butler, 2001). But more than answering questions concerning how to address water quality issues, the decision-making powers dictated by the Treaty of Rome raise questions regarding the appropriate scale of decision making for water resources management within the UK. The physical relationship between quality and quantity means that this division of power is not always uncomplicated. The European Union Water Framework Directive (2000/60/EC) which came into force on 22nd December 2000 is primarily a water quality document but concerns water quantity to the extent that it impacts quality.

The clear demarcation of water quality as a supra-national issue fits well with the issues addressed by the three case study scenario programmes. The World Water Vision programme, set at a global scale, was the only programme designed to examine water quality issues to any depth.

In England and Wales, water resources, and related land planning policies, are developed nationally and implemented nationally, regionally and locally through various public and private bodies of various levels of accountability (see Table 2). Policymaking occurs at a national level, water companies operate to supply zone boundaries (unrelated to any other planning or management boundaries) and regulators, Ofwat and the Environment Agency bridge scales. In the case of Ofwat this is translation of national policy to water company level. In the case of the Environment Agency bridging occurs between the national policy level, regional strategic level and local environmental protection and between all of these levels and water companies.

The Environment Agency scenarios can be seen as an example of the Environment Agency's need to cross scales. The scenario process was established nationally for regional application with outputs at regional and water company scales for the consideration of strategic action at all levels. The scenarios were used by Environment Agency decision makers to develop strategies for resource management. The majority of actions proposed through the strategy are to be carried out by the Agency, either independently or in partnership with other organisations. Externally, the strategy programme was focussed on communicating the Agency's strategic plan to specific decision makers, usually related to the national, regional and water company scales used in scenario development.

Scenario development was conducted at a regional scale in the Social and Institutional Responses to Climatic Change and Climatic Hazards project. However, many of the issues raised related to decision making at various scales. Environmental regulation and water resources planning are conducted by the Environment Agency at a regional level. However, this is set within a national framework for environmental regulation and planning set out by Environment Agency Head Office and Central Government. Water companies operate within the regional scale according to their own water company boundaries, but again within a framework set nationally by Ofwat. Therefore, the institutional capacity to manage drought risk at a regional level is limited. Tackling issues of national importance at a regional level may be ineffective in influencing the national debate on drought management unless a case can be made for the representative nature of the case study or the inordinate severity of regional impacts.

The appropriateness of these divisions in decision-making powers within and across scales can, in one way, be assessed through the examination of what capacity exists for visioning, strategising and creating cohesive, adaptive and effective water management futures. The inclusion of private companies and new regulatory agencies in water management and the institutional scales and structures developed through the privatisation of the water industry in England and Wales have added increased complexity to the water management polity. However, none of the scenario processes discussed have fully undertaken the challenge of examining this capacity or even explicitly acknowledging this problem.

4.3. Participation

Scenario building is an essential process of many participatory methods (van Asselt et al., 2001). It is a key means to build a group identity, to evaluate potential conflicts and to foster 'out of the box' thinking about complex issues. Indeed, personal experience by scenario 'facilitators' (based on informal discussions with several scenario teams in Europe) indicates that this is the true benefit of the technique, rather than the final report and quantified set of indicators. The scale of a scenario process can be related to both the size of the scenario building group and the individuals or groups involved.

What is the relationship between group size and creative processes of visioning? Do larger (and multi-national?) groups tend to create less extreme scenarios, or more variants? The Foresight and UKCIP 'official' national scenarios are less diverse than the Social and Institutional Responses to Climatic Change and Climatic Hazards 'small group' regional scenarios. And, the IPCC SRES process (Nakicenovic and Swart, 2000), with a large panel and governmental review, resulted in 40 scenarios from four narrative storylines. The broad participation programme undertaken by the World Water Vision programme resulted in three scenarios.

Scenarios of what for whom? Are there differences in the legitimate constructions of futures? The sense of ownership is a function of group size, as well as the structure of the process. The SIRCH workshops and WW Vision programme were driven by stakeholder issues, whereas the Environment Agency process was 'imposed' on stakeholders, although there was widespread consultation. A regulator's scenarios may imply restrictions in how the future is portrayed, and certainly raises questions of how the scenarios are to be used. If scenarios are meant to infer wisdom leading to action, this issue is critical.

Who is best placed to develop these scenarios? Should a water regulator formulate scenarios regarding the future of water supply? Is their use of the scenario approach limited by their regulatory role of private enterprise? Who facilitates the process—an independent entity or one of the leading stakeholders? To what extent are citizens involved and is their involvement substantive? At what scale do citizens feel they can best engage in scenario building and work towards building any normative futures envisioned. If the process is intended to alter long-term futures, build political support for different regulatory regimes or raise awareness among consumers, for instance, then citizen participation (including the institutions that affect the public) might be considered essential. For instance, one conclusion of the SIRCH project is that consumers, advocacy groups and the media are poorly represented in the water planning process, although they are key to dynamic demand management.

4.4. Transferring knowledge between scales

In the three examples of scenario building and application, various scales of analysis have been encountered – from the global to the regional. Each scale has its strengths and weaknesses. What recommendations can we offer for future scenario building and its role in water resources policy and application in regulation, operation and management?

As illustrated in Figure 2, past exercises in transferring scenario outputs between scales has focussed on the down-scaling of results (although the REGIS project was used to test the UKCIP scenarios (indicated by the dotted arrow)). This pattern is reinforced by the case study scenarios.

The World Water Vision scenarios address possible futures at a global scale, and are intended to be 'scaled-down' as required. National climate change scenarios were downscaled to regional impacts in the analysis of the Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios (Downing, 2002).

In their scenario exercise, the EA works downwards from a national framework to a regional strategy. The Agency also sums its regional plans to produce a national strategy but this is predominantly an exercise in summation as opposed to a formulation of an independent national vision that takes regional inconsistencies into account.

Downscaling, however, is not always a straightforward adjustment of scenario results to another scale. The UKCIP socio-economic scenarios, they based in part on the Foresight Panel, were 'downscaled' to the regional level in the REGIS project (Regional Climate Change impact and Response Studies in East Anglia and North West England, DETR Project CC0337). So, both the Social and Institutional Responses to Climatic Change and Climatic Hazards and REGIS scenarios have the same orientation. However, the two market-led scenarios have diverging interpretations of the changes to the supply/demand balance. Both indicate that increasing wealth and commodification of water leads to higher demand. However, In the Social and Institutional Responses to Climatic Change and Climatic Hazards 'vision' this is met through a variety of market mechanisms—that is drought risk is reduced through the ability of water companies to price water at its marginal value and develop new resources, leading to a healthy supply/demand balance although with some environmental impacts. This comparison illustrates the point that the interpretation of broad storylines, in the final analysis, rests with the stakeholders and analysts involved in the process—there is not a 'necessary' relationship between global driving forces and their interpretation at the local, sectoral level.

The possibilities for up-scaling scenario results were demonstrated in the project Integrated Visions for a Sustainable Europe (see http://www.icis.unimaas.nl/visions/) where scenario results were integrated across several sectors and scales. The Visions process involved the development of detailed and diverse regional scenarios in each of the project's case study regions along with research into global issues and futures (Rotmans et al., 2001). Global information was then down-scaled and regional scenarios up-scaled to guide and enrich scenarios built with stakeholders at the European level. The final scenarios addressed similarities and tensions between the regions under a European Framework (that did not necessarily include the maintenance of the European Union). The process of scenario building across these scales resulted in multi-dimensional scenarios with different regional winners and losers under the same European scenario conditions. The process also allows for learning across the scalar divide (how the tensions and interactions between different regional visions can work together or apart to form a cohesive vision with positive and negative aspects). At both the regional and European levels stakeholders were incorporated into various stages of the scenario building process.

In the water management polity in England and Wales, upscaling of scenarios would be most productive in areas were the potential for diverse regional, local or water company impacts needs to be accommodated within a national management plan.

5. WATER RESOURCES ISSUES

This section explores some of the water resources issues that have been explored by the different case studies to see if the scenarios progress our understanding of the issues or have other practical application.

5.1. Demand management

Domestic demand for water is one of the key concerns for future water management in the Thames region. As all of the case studies dealt with changes in water demand, to some extent, comparisons between the different scenarios are informative in a discussion of scenario outcomes and applications.

The Social and Institutional Responses to Climatic Change and Climatic Hazards and World Water Council processes independently began their scenario-building processes with similar qualitative storylines upon which to base scenario development. The rubrics of the three Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios (Trend Projection and Conventional Wisdom, Economic Growth and Market Enterprise, and Environmental Stewardship and Regulation) are broadly comparable to those of the World Water Vision scenarios (Business-as Usual; Technology, Economics and the Private Sector; and Values and Lifestyles). Both projects initiated a participatory process of scenario-building on the basis of these scenarios. However, differences emerge upon closer comparison of demand scenarios related to each project; for example, the Social and Institutional Responses to Climatic Change and Climatic Hazards "Trend Projection" and the World Water Vision "Business as Usual" projections differ on the degree to which efficiency measures will be implemented (the World Water Vision assuming increased efficiency of water use, the Social and Institutional Responses to Climatic Change and Climatic Hazards scenario arguing that customers will continue to demand no restrictions in demand or reductions in use). The 'grounding' of the Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios in a particular region, in consultation with water management stakeholders, thus leads to very different specifics of each scenario despite the similar overall rubric. This leads us to question the applicability of the World Water Council scenarios at regional scales, and thus to question their robustness when applied to the Thames region.

Extending comparisons to the Environment Agency scenarios for water demand, points to further differences between scenario outcomes that result from the scenario building process, the stakeholders involved and the scaling of outcomes. In the Social and Institutional Responses to Climatic Change and Climatic Hazards project the Thames stakeholders, working at a regional level, envisioned that an "Economic Growth and Market Enterprise" scenario would result in an increase in domestic consumption by 200% for indoor use and 300% for outdoor use as householders would have an increased willingness to pay for water-related amenity. The Environment Agency's national assumptions for the "Beta" scenario (based on the "World Markets" socio-economic scenario) offset increases in discretionary water uses (power showers, swimming pools) with improved water efficiency of appliances through technical innovation and increased turn-over of home appliances (due to enlarged personal wealth) to arrive at a more modest 13% increase in household water demand in the Thames region. The Social and Institutional Responses to Climatic Change and Climatic Hazards "Environmental Stewardship and Regulation" scenario is similar to the Environment Agency "Gamma" and "Delta" ("Global Sustainability" and "Local Stewardship", respectively) scenarios with respect to in house water consumption. However, the Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios translate environmental stewardship into increased garden water use while the Environment Agency carries water saving beliefs and behaviours into the garden as well as the home with the increasing prevalence of rainwater collection for garden watering.

The differences between demand in the Social and Institutional Responses to Climatic Change and Climatic Hazards and Environment Agency scenario programmes could possibly be explained by a variety of factors including: the Social and Institutional Responses to Climatic Change and Climatic Hazards project explicitly set out to create extreme scenarios so extreme possibilities for consumption are reasonable; the scenario building process involved a varied group of stakeholders (including private water companies) and interpretations were neither controlled by one stakeholder nor scrutinized by the participants; consumptive demands in Thames region could differ from other regions in England and Wales and the application of some national demand assumptions may be inappropriate; and the more detailed micro-component approach undertaken by the Environment Agency to calculate scenario demand may have resulted in more realistic results.

Scenarios are different from predictions and there is no correct answer for domestic demand within a scenario process. A more appropriate way to evaluate the demand scenarios is to look at their fitness for purpose within their individual scenario processes. The Social and Institutional Responses to Climatic Change and Climatic Hazards project sought extreme scenarios to test institutional adaptability. The EA makes more detailed, less extreme, scenarios in line with national socio-economic predictions as a basis for making strategic decision regarding water supply. In this case, an extreme variation in scenarios could have severe repercussion for the over design of supply systems.

Though the scenario results must be looked at within the context of the scenario building process and the proposed application, this does not mean that the different scenarios should always stand separately. Global views on the possibilities for technological development of water saving appliances could inform the narrower national and regional views on water saving possibilities. The willingness of households to take up new technologies, however, is better assessed on a regional level were stakeholders have a hands-on feel for potential impact. It is also informative to break any demand prediction into detailed micro-components, as was done in the Environment Agency case study and some of the modelling conducted for the Social and Institutional Responses to Climatic Change and Climatic Hazards project, to ensure that numbers generated in visioning exercises have a basis in the realities of water consumption.

5.2. Connecting the Present to the Future: Pathways and Extreme Events

Two key issues in the development of scenarios are the timeline over which the scenario is developed and the method of development. These two factors work together to make the present into a possible future or to map a possible future back to the present. Development methods can be described in part by the extent to which behavioural or dynamic pathways are considered in moving from the present to the future. For example, extreme events may initiate step changes in innovation and institutional norms.

Extreme hydrological events such as droughts and floods pose significant challenges to water resource managers, and threats to water resource and supply system security. There is increasing evidence supporting the hypothesis that climate change will result in an increasing frequency and amplitude of extreme meteorological and hydrological events (Hulme et al., 2002). There is thus an increasingly pressing need for an examination of adaptive capacity, and planning for adaptive responses to crisis events.

In looking at the time element of the scenarios used, the Foresight scenarios are seen to describe potential futures in the UK between 2010 and 2050. The Environment Agency adaptation of these scenarios are assumed to gradually unfold over time starting from the present, however, the differing consequences of the four scenarios do not become immediately apparent due to the lead-in time required for many water resources projects and behavioural changes.

The Environment Agency scenarios do not consider the potential power of extreme events to effect changes in water supply or consumption. A dry-year scenario is used to calculate scenario water-demand levels but no dynamic between wet and dry years and how this might impact behaviour is discussed. Drought is seen to be a controllable event outside of resource planning (through drought management plans – for example see (Environment Agency, 2001d)) In the Water Resources Strategies, the Agency does point to on-going and future studies where the links between climate change and demand and will be further explored. The outcomes of these studies will be considered in annual reviews of the water resources strategies.

The Social and Institutional Responses to Climatic Change and Climatic Hazards scenarios were not time dependent in that they looked at future possibilities to 2050 but did not tie these events to a specific time line. The Social and Institutional Responses to Climatic Change and Climatic Hazards project uses hazards as natural laboratories for water management in the belief that crises can provide insights into normal operations and the assumptions and priorities that support them. The Social and Institutional Responses to Climatic Change and Climatic Hazards report discusses how real events can promote, or even force, change as part of a systematic learning process, by working in the direction of macro societal trends, by providing new opportunities for leadership, or working as a chain of events - for example the floods of autumn 2000 after the Easter floods of 1998. However, as the report points out, events can also be harnessed to prevent change or shift blame. Use of crisis or extreme events as a starting point for analysis may also detract from comprehending the human ecology of everyday situations (Downing et al., 2001).

In the Social and Institutional Responses to Climatic Change and Climatic Hazards example, changes to the frequency and severity of drought conditions are predominantly a result of climate change. Changes to the frequency and severity of drought impacts are a result of adaptation in the management of supply and demand.

The World Water Vision scenarios consider the unfolding of three possible scenarios from a branch point in 2005, a date chosen to reflect system lags and inertia. The branch point is a result of different human actions and beliefs culminating to pull society in a single direction.

The World Water Vision scenarios do consider water scarcity but do not discuss the possibility that the frequency or severity of drought events could occur as a result of changing climate patterns. Climate is not seen as a driver or critical uncertainty related to change in these scenarios. Drought is seen to occur mainly as a combination of deteriorating environmental quality, depleted groundwater levels and the difficulty and cost of establishing new sources of supply. The potential for drought to act as a 'sideswipe' (Gallopin et al., 1997) to the system trajectory is only mentioned in the later stages of the "Business as Usual" scenario. Differences in drought response (wither anticipatory or reactive) are not seen as branch points.

To deal with the potential for hazards adequately in scenario building, key drivers and uncertainties related to hazards, and the scales at which they occur, must be identified. One of the main purposes of pursuing a scenario approach is to explore a variety of futures and therefore it seems natural to explore a variety of risk, hazard event and adaptation scenarios. The occurrence of different degrees of hazard and resulting impact and adaptation can be examined through various scenarios.

In its integrated scenarios for Europe, the Visions project considers the ability of events (including flood events) to have significant impact on population patterns and water resource management strategies in Europe. The scenario 'Living on the Edge' was used to explore a 'period of chaos, crisis and crisis management. At both the European and regional levels coping with chaos was the rule. The patterns of coping, however, differed among regions and sectors.' (Rotmans et al., 2001). The Visions programme shows the advantage of the scenario approach where diverse scenarios covering crises and non-crises situations can promote further learning and communication regarding strategy robustness and similarities and tensions between changes prompted by hazard occurrence and those that develop as a result of more gradual societal change.To relate the discussion of events to the use of scenarios being discussed by this paper, we can refer back to Ringland's ideas of using scenarios for learning, building a common vision and developing strategy. Though learning and promoting common visions regarding hazard events are important, strategy development and testing is the key area where the consideration of events is vital to water resources scenarios. A strategy that is not robust to event occurrence could be fatally flawed.

5.3. Toward Scenarios of Vulnerability and Adaptation to Climate Change

The volatility of environmental change poses a challenge to traditional demand projections and industry design standards.

The conventional approach to climate change impact assessment relies on climate change scenarios to drive impacts models, working through a chain of linkages ending with an assessment of autonomous and planned adaptation. This climate scenario-driven impacts approach of linked models results in a cascade of uncertainty to the point where insight is lost.

More recently, people have sought to integrate socio-economic scenarios and climate change scenarios, with both following similar lines of construction. Scenarios of future greenhouse gas emissions are driven from global assumptions of economic growth, population growth and consumption. This translates fairly readily into global emissions, atmospheric concentrations, global climate change and regional to local climate scenarios (of course this chain is grand and entails significant uncertainties). A parallel track downscales the regional and global driving forces to local sensitivities to climate impacts.

The main problem with this approach is that the coarse regional scale hides the interesting issues of regional and local vulnerability. Local institutions, lives and livelihoods at risk cannot be easily located in the driving forces at a continental scale. As indicated above, the global-local link is not a unidirectional, necessary hierarchical relationship. In fact, it is almost entirely indeterminate. One would expect large local diversities even in a more uniform global economy.

An alternative is to cluster scenarios and regions according to the dominant axes of concerns. This is similar to the approach taken in the Foresight Panel (Figure 3), but involves axes of immediate concern to the analysis (rather than the large scale driving forces behind the scenarios themselves).

As a means of characterising risk and adaptive capacity, a simple matrix may be insightful (Figure 5). The qualitative 'vision' of future socio-economic conditions indicate the nature of vulnerability to climate change impacts, and the range of adaptive capacity. Climate impacts over the time scale of climate change (i.e., several decades and more into the future) are not themselves predictable, and should be considered impacts scenarios.

Figure 5 indicates how such a matrix of socio-economic scenarios of adaptive capacity and impacts scenarios can differentiate between regions and populations at-risk. For example, semi-arid

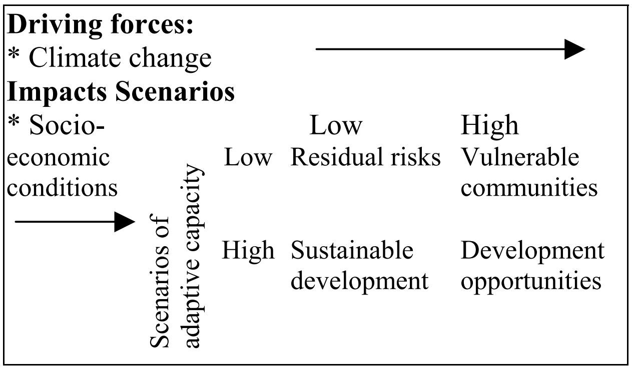

Figure 5. Matrix of scenarios of adaptive capacity and climate change impacts.

urban areas already short of water and without adequate infrastructure or economic bases (regional towns in the Sahel come to mind) are almost certain to fall in the upper right quadrant of potentially high climate impacts and low adaptive capacity (which might be labelled 'adapt to survive'). Where impacts could be high but adaptive capacity is also high - coastal tourism resorts in Antigua for example—development assistance could lead to new opportunities and a sustainable strategy to cope with increased risks (perhaps, 'adapt and thrive'). Where impacts are low, further information on the nature of climate change may be warranted, although a precautionary approach to situations of low capacity may be suitable to be prepared for surprises (such as a rapid increase in damaging extreme events) (corresponding to 'mainstreaming adaptation').

6. CONCLUSIONS

The three examples discussed in this paper can be seen to engage different decision-makers at different scales to differing degrees on different topics – all of which are productive and informative. However, the usefulness of these distinct scenario processes could potentially be improved if they were set into a framework where one set of scenarios could relate to and inform the development or interpretation of another scenario exercise or examination process. Explicitly discussing and comparing the differences in scale, engagement, learning, issues addressed and application of three examples of scenario building is a first step in this process. Though no two scenario processes or results will be the same (nor should they be), the discussion of these issues and the placement of the work within a larger common context will help to illustrate the key outcomes and findings that will frame work at smaller geographical scales or inform work at larger scales and higher levels of decision making.

Motivating effective adaptation to socio-institutional and environmental change requires participation across a broad spectrum of stakeholders and citizens. Scenario exercises tend to be static—initiated by a small group of experts (and stakeholders), developed in diverse ways with larger groups, then recorded, usually in reports and various visioning media (e.g., mock newspaper cuttings). More participatory interaction is necessary. For instance, a short-form of scenario development might be encouraged among user groups, leading to families of scenarios that take off from common themes. This would lead to more diversity and less control over the 'official' scenario, but that may be inevitable in any case (as concluded in the UKCIP process—(UK Climate Impacts Programme, 2000)).

Drawing upon our own background in integrated assessment, qualitative scenario building must blend the formalisms of models with the expert knowledge of institutional change. This is generally done off-line—by research teams that translate the qualitative storylines into quantitative indicators and test them in a range of models. More promising are ways to open up access to scenario models and exercises. Simple rule-based games available on the internet, for example, provide a new means to engage the public and key users over extended periods (for example, see FIRMA project water game at http://www.cpm.mmu.ac.uk/firma/).

A stakeholder-driven and public access exercise in scenario building is likely to lead to a large number of scenarios, particularly if regional and local variations are included. The IPCC resolved this issue by indicating marker scenarios that are typical of a family of scenarios. This is relatively tractable if the outcome of the family of scenarios has a singular identity-in the case of the IPCC greenhouse gas emissions leading to global climate change.

A more enterprising analysis would be to derive clusters, of regions and scenarios, by sampling across the population of plausible scenarios posed by diverse stakeholders. Of course, this requires consideration of the size of regional clusters (villages to nations?), the interpretation of clusters (e.g., common responses to globalisation?), and the link between local clusters and national and global processes. The analysis would at least show the diversity of plausible futures at different scales.

7. REFERENCES

Arnell, N. W., A. Jenkins, and D. G. George. 1994. The Implications of Climate Change for the National Rivers Authority. NRA Research and Development Report, 12, NRA, Bristol.

Brown, A. 1992. Inland water quality and pollution. Pages 87-105 *in* A. Brown, editor. The UK Environment. HMSO, London.

Centre for Ecology and Hydrology and British Geological Survey, 1998. Hydrological Review of 1997.

Centre for Ecology and Hydrology and British Geological Survey, 1999. Hydrological Review of 1998. Centre for Ecology and Hydrology and British Geological Survey.

Cosgrove, W. J., and F. R. Rijsberman. 1998. Creating a vision for waterlife and the environment. Water Policy 1: 115-122.

Cosgrove, W. J., and F. R. Rijsberman. 2000. World Water Vision. Earthscan Publications Ltd, London.

Council for the Protection of Rural England, 1999. Hungry Housing, London.

Department of the Environment, 1996. Review of the Potential Effects of Climate Change in the United Kingdom. HMSO, London.

Downing, T. E. 2002. Domestic water demand in southern England: Sensitivity to climate change and drought. Water Policy (submitted).

Downing, T. E., J. Handmer, K. Bakker, K. Lonsdale, and E. Crook, 2001. Hydrological Risk in the Thames Region: Prospects for Adapting to Climate Change. Environmental Change Institute, Oxford University, Oxford.

Department of Trade and Industry, 1999. Environmental Futures. Office of Science and Technology, London.

Environment Agency, 1998. Thames Environment 21: The Environment Agency Strategy for Land-use Planning in Thames Region. Thames Region, Reading.

Environment Agency, 1999. Environment Agency Website - Thames statistics. *in*. http://www.environment-agency.gov.uk.

Environment Agency, 2000. Tony Lawton, Hydrometry Information Group - pers. comm.

Environment Agency, 2001a. Water Resources for the Future: A Strategy for England and Wales, Bristol.

Environment Agency, 2001b. Water Resources for the Future: A Strategy for Thames Region, Thames Region, Reading.

Environment Agency, 2001c. A scenario approach to water demand forecasting, National Water Demand Management Centre, Worthing.

Environment Agency, 2001d. Thames Region Drought Plan, vol.3.

Gallopin, G., A. Hammond, P. Raskin, and R. Swart. 1997. Branch Points: Global Scenarios and Human Choice. Stockholme Environment Institute, Stockholm.

Gallopin, G. C., and F. Rijsberman. 2000. Three global water scenarios. International Journal of Water 1: 16-40.

Holman, I. P., and P. J. Loveland, editors. 2001. REGIS: Regional Climate Change Impact Response Studies in East Anglian North West England. Soil Survey and Land Research Centre.

Hulme, M., J. Turnpenny, and J. Jenkins. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Briefing Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich.

Institute of Hydrology and British Geological Survey, 1995. Hydrological Data United Kingdom: 1994 Yearbook, Wallingford, Oxon.

Kallis, G., and D. Butler. 2001. The EU water framework directive: measures and implications. Water Policy 3: 125-142.

Kraemer, R. A. 1998. Subsidiarity and water policy. *in* F. N. Correia, editor. Selected issues in water resources management in Europe. A.A. Balkema, Rotterdam.

Marsh, T. J. 1995. Drought Returns to the United Kingdom. Drought Network News 7:5-6.

Marsh, T. J. 1996. The 1995 UK Drought - a signal of climatic instability? Proc. Instn Civ. Engrs Wat., Marit. & Energy 118: 189 - 195.

Nakicenovic, N., and R. Swart, editors. 2000. Special Report on Emission Scenarios. Cambridge University Press, Cambridge.

NRA. 1995. Thames 21 - A Planning Perspective and a Sustainable Strategy for the Thames Region. National Rivers Authority, Reading.

Raskin, P., T. Banuri, G. C. Gallopin, P. Gutman, A. Hammond, R. Kates, and S. R. 2002. Great Transitions: The Promose and Lure of the Times Ahead. Stockholme Environment Institute, Boston.

Ringland, G. 1998. Scenario Planning: Managing for the Future. John Wiley & Sons, Chichester.

Robinson, J. 1990. Futures under glass: a recipe for people who hate to predict. Futures October 1990.

Rotmans, J., M. B. A. van Asselt, C. Anastasi, D. Rothman, S. Greeuw, and C. van Bers. 2001. Integrated Visions for a sustainable Europe: Summary of Project Results and Visions. ICIS, Maastricht.

UK Climate Impacts Programme. 2000. Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme. UKCIP, Oxford.

van Asselt, M. B. A., J. Mellors, N. Rijkens-Klomp, S. C. H. Greeuw, K. G. P. Molendijk, P. J. Beers, and P. van Notten. 2001. Building Blocks for Participation in Integrated Assessment: A review of participatory methods. working paper I01-E003 ICIS, ICIS, Maastricht.