Water Supply and Management

in the APEC Region

Summary Report

Vol. I

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FOREWORD

The APEC Center for Technology Foresight was launched in Bangkok on 3 February 1998. The objectives of the Center are:

- Promote the adoption of technology foresight across APEC member economies.
- Provide a means for comparison of technology foresight exercises and implementation in APEC member economies and across the world, with a view to stimulation of Best Practice in appropriate methodologies for Foresight in APEC economies.
- Conduct technology foresight exercises on an APEC-wide basis, and between relevant member economies.
- Improve the quality and effectiveness of technology-related planning and development and priority-setting for research, across APEC member economies.
- Develop a technology foresight research and application capability available to APEC member economies and International agencies.

The Center has adopted the following definition of Foresight:

> *'Foresight involves systematic attempts to look into the longer-term future of science, technology, the economy, the environment and society, with a view to identifying emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic, social and environmental benefit'*

As its initial project, the Center chose the topic of 'Water Supply and Management' with a time horizon of 2010. The aim was to involve as many APEC economies and their Experts as possible to produce an outcome relevant to all APEC economies. The approach was to have an Issues Paper prepared by a consultant and then draw together a group of Experts to analyse the issues and develop scenarios. Based on these scenarios, a set of inputs for a Delphi Survey was constructed and distributed widely to Experts in the APEC economies. The results of the Delphi Survey were combined with the scenarios to produce a report for policymakers, which is published as Volume 1.

As contribution to stimulating debate in APEC member economies, Volume 2 reproduces the Issues Paper and sets down outcomes of the Experts' Meeting held at Hua Hin on 12-14 May 1998. These outcomes include the issues identified by the Experts, the uncertainties identified for future water supply and management and three scenarios based on groupings of these uncertainties. Using these scenarios the Experts identified a preliminary list of topic statements for the Delphi Survey, which were refined and expanded and then distributed. The analysis of the Delphi studies is reported in Volume 2.

The Experts' Meeting drew together 10 experts from 9 economies and we are particularly grateful to them for giving their time and experience and to their economies which supported their attendance. We are also very grateful to Professor Ron Johnston for preparing the Issues Paper, for carrying out the demanding role of facilitator and for preparing the policy makers' report. Dr Taeyoung Shin on whom fell the burden of the Delphi Survey ably assisted him.

To our knowledge, this is the first multi-economy Foresight project and the process has provided to be an intensive learning exercise both for the Experts and for the Center staff. We are indebted to Monthida Sitathani, Tamsin Jewell, Mayuree Vathanakuljarus, and Nalinrat Sirikantraporn for their dedicated support.

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Executive Summary

This report describes the first multi-country foresight study, on the subject of Water Supply and Management, conducted by the APEC Technology Foresight Center located within the National Science and Technology Development Agency in Bangkok, Thailand. A process of literature review, issue identification, scenario development and analysis, and Delphi survey, involved experts and stakeholders in water supply and management from sixteen APEC member economies.

Fourteen key issues were identified for the future of water supply and management:

- Water supply
- Water demand
- Water quality
- Current and new water technologies
- Water in economic development
- Application of market forces to the supply and management of water
- Water and the environment
- Water and human health
- Water resource assessment
- Integrated water resource management
- Geopolitics and international laws for water
- Infrastructure and structural safety
- Water use and management enforcement
- Energy costs.

Scenarios identified three different futures in which conflict and global epidemics dominated, in which APEC member economies had adopted common regulations for water management and trade, and in which major advances in desalination and low water use crop technologies provided a huge breakthrough in water availability and use.

The Delphi survey found that half of the most important issues in the development of water supply and management to 2010 could be categorised as policy, regulation or management issues, with the rest evenly divided between systems capability and technological advance issues. Dates of realisation were bunched together in the relatively close future of 2005-2010.

The project has revealed the many challenges involved in effective multi-country foresight studies, and there is much to be learnt in both conceptual and practical terms. There are a very substantial range of technological opportunities, but their advances need

to be effectively anchored in addressing the technological needs identified in this report, and in establishing the necessary broad scientific, technological and managerial expertises necessary to underpin these advances.

Finally, it is apparent that there is the need for a new paradigm to guide the further development of water supply and management. This paradigm will be based on the recognition of water as a precious and valuable resource, which needs to be used economically and socially to maximum advantage, and hence requiring the adoption and acceptance of demand, and integrated water resource, management. Defining and promoting this paradigm, and encouraging its application, appears to be a worthy and important task for the APEC community.

1. Introduction

The APEC Center for Technology Foresight, was established in February 1998 with the objective of serving and involving all APEC member economies in diffusing technology foresight expertise across the APEC region[1]. However, the aim is not just to assist member economies with their own foresight efforts, but also to conduct research at a multi-economy level. Technology foresight may be able to contribute to issues which cross national boundaries - from air pollution, to chicken virus, to electronic information distribution.

Prior to the selection of topics for multi-economy study, the Center developed a number of criteria which any foresight study should meet: the issue must be of concern to most economies, with at least four agreeing to participate in the study; the issue must transcend national boundaries, so that it can go beyond what might be achieved by a national or bi-lateral study; there must be potential for sharing the results with all the APEC members; the issue should be of general, public concern or benefit and not one that is likely to be dealt with by the private sector; and finally, the issue will have important technological components but not necessarily 'high-tech' ones.

The first subject for a multi-APEC economy technology foresight study was chosen after wide consultation throughout APEC. A survey of APEC members identified a list of more than 50 possible topics of concern, which were then prioritised at a Technology Foresight Symposium attended by over one hundred participants from sixteen different countries[2]. The topic 'Water Supply and Management' that was eventually selected at the inaugural joint meeting of the Center's Steering Committee and International Advisory Board was considered to meet all the criteria outlined above for a multi-economy study. Its importance and relevance to the region cannot be disputed. Water problems are not limited to developing countries:

> *Current patterns of water use in developing countries, countries with economies in transition and industrialised countries alike are often not sustainable. There is mounting evidence that the world faces a worsening series of local and regional water quantity and quality problems, largely as a result of poor resource management, including ill-adapted allocative mechanisms, wasteful use of the resource, unregulated effluent disposal and weak institutional frameworks. There is also a close interaction with declining biodiversity, desertification and pollution of the marine environment.* (UN Economic and Social Council, Geneva, June 1997)[3]

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1 More information about the APEC Center is provided in Y. Yuthavong and C Sripaipan, 'Technology Foresight as a Tool for Strategic Science and Technology Planning and Policy Development', delivered to ASEAN Fifth Science and Technology Week, Hanoi, 1998, NSTDA, Thailand.

2 Proceedings of APEC Symposium on Technology Foresight, Chiang Mai, Thailand, National Science and Technology Development Agency (1997).

3 cited in the Introduction to the Issues Paper: Water Supply and Management in the APEC Region, prepared for the APEC Technology Foresight Center by Professor Ron Johnston FTSE, Executive Director, Australian Center for Innovation and International Competitiveness, University of Sydney, Australia, http://www.nstda.or.th/apec/html/water_supply___management_i.html

…and cannot be addressed only at national level:

> *Of more than 200 international river basins, 148 are shared by two countries, 30 by three countries and 22 by four or more... apart from island countries, almost all countries are involved in the problems of international river basins to some extent...Over a third of these major international river basins are not covered by any international agreement...Pollution, impoundment and diversion of water by upstream nations is likely to be a growing source of international tension and insecurity* (Union of International Associations, April 1998) [4]

In examining the issue at the symposium, participants recognised that:

> *Beyond 2000 there will be great need of supplies of water for domestic, agricultural and industrial uses while excessive water supplies cause seasonal flooding and global warming may start to increase the sea level causing flooding of low lands. Clean water will become ever-increasingly more scarce. Technologies include water management, remote sensing, irrigation with environmental concerns, and recycling and conservation technologies. Other technologies to purify water such as membrane filtering are needed.* [4]

The objectives of this first multi-country foresight study in APEC were defined as:

1. To develop a strategic and coherent view of the challenges, threats and opportunities associated with water supply and management in and across APEC economies.
2. To provide an APEC-wide demonstration of the application and value of technology foresighting techniques in addressing an issue of great and long-term significance.

2. Key Issues in Water Supply and Management

Through an examination of the extensive literature on the issue of water supply and management, and preparation of an Issues Paper that was subjected to detailed assessment and review by 'water experts' from the nine APEC member economies involved in this project, a total of fourteen issues were identified.

1) *Water Supply*

The supply of freshwater in a region is limited by the dynamics of the hydrological cycle. The renewable supply of water is determined by the surface run-off from local precipitation, the inflow from other regions, and the groundwater recharge that replenishes aquifers. As water can, in principle, be re-used many times, the availability of water for human use depends as much on how it is used and how water resources are managed, as on any absolute limits. Apart from human use, water is also needed to sustain the natural ecosystems found in wetlands, rivers, and the coastal waters into which they flow.

Based on the data that about 42,700 cubic kilometres of water that falls on the Earth flows through river systems, it is estimated that about 9,000 cubic kilometres per year are readily accessible for human use, plus a further 3,500 cubic kilometres that is captured and stored by dams and reservoirs.

However fresh water resources are very unevenly distributed, and subject to substantial cyclic variation. Thus, within the APEC region, the countries in tropical regions are normally subject to very high rainfall, and availability is largely determined by capture. However, the most recent El Nino cycle has demonstrated that even these countries can be subject to severe limitations of rainfall. At the other extreme, countries such as the USA (western region), China (northwest), Chinese Taipei, Hong Kong and Australia (all except southeast), have normally very low rainfall, and hence have to concentrate on the effective use of the limited available resource.

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4 Ibid

A crucial problem affecting supply in many regions is leakage. While 'official' estimates tend to play this down, unofficial estimates are invariably much higher. In Chinese Taipei, official leakage is 30%, but estimates put it as high as 50%; Korea acknowledges a "very high" leakage from its distribution system. Thus, a significant proportion of the water that has been captured, at some expense, is lost to supply.

2) ***Water Demand***

Despite recent improvements in the efficiency of water use in many developed countries, the demand for water has continued to rise as the world's population and economic activity has increased. From 1940 to 1990, withdrawals of freshwater have increased by more than a factor of four, more than double the rate of population growth. Current total human usage is about half of the total available water identified above. With a 50% increase of the total world population forecast for the next twenty-five years, this alone unchanged would approach the limit of water availability.

One important consequence of the growing demand is the increasing reliance on essentially non-renewable water resources in the form of groundwater. In a number of countries, excessive extraction of groundwater has led to subsidence (eg Chinese Taipei).

The uneven distribution of water resources has already led to this stage of scarcity in a number of regions. There is an accepted benchmark of 1000 cubic metres per capita per year to avoid chronic water scarcity on a scale sufficient to impede economic development and harm human health. Twenty countries have already fallen below this level, mostly in Africa and Western Asia. However it is worth noting that Israel supports its population, its growing industrial base and extensive irrigation with less than 500 cubic metres per person per year.

Irrigated agriculture takes about 70% of water withdrawals, rising to 90% in the dry tropics. In total, agriculture consumes 87% of total water. Industry is also a growing user of water. Traditional manufacturing industries such as textiles, food production, and chemicals, as well as power production and mining, consume large quantities of water, but largely in localised operations. The newer industries, such as electronics, much of the production of which has been established in developing and emerging economies, are also critically dependent on a reliable water supply.

3) Water Quality

Contamination by pollutants has seriously degraded water quality in many rivers, lakes and groundwater sources, effectively reducing the supply of freshwater for human use. While the increase in population alone has increased the challenges to water management, particularly in the area of sanitation, the greatest threats are from a wide variety of industrial, municipal and agricultural sources. While there has been significant progress in developed nations over the past 30 years in controlling water pollution, it has continued to rise in most developing nations and in transition economies.

One important factor is the rapidly growing and industrialising cities of the developing world, where pollution control is still in its infancy and domestic sewage and industrial effluence have left many urban rivers and groundwater sources heavily contaminated (eg Korea). This widening penumbra of pollution around the 'mega-cities' exacerbates the problem of extending minimal freshwater and sanitation services to the residents, many of whom live in considerable poverty.

The nature of pollution problems vary by region, but include bacterial pollution, largely through inadequate sanitation (it is estimated that 90% of wastewater is discharged without treatment in the developing countries), algal blooms fertilised by the phosphorus and nitrogen contained in human and animal wastes, detergents and fertilisers, chemicals, heavy metals, salinity caused by widespread and inefficient irrigation, and high sediment loads resulting from upstream erosion resulting from deforestation.

4) ***Current and New Water Technologies***

A range of technologies is currently available for water supply and management. They include:

- detection and access - largely drilling supply bores into groundwater
- capture and storage - dams, etc.; loss reduction, quality management of stored water
- distribution infrastructure - pipeline construction and maintenance, leakage detection and control
- wastewater treatment - biological, chemical, recycling
- irrigation - supply, application, monitoring
- sanitation - variety of filtration and purification techniques and processes, centralised and decentralised.

There is a considerable range of new technologies either presently under development, or that could emerge over the next ten years, which could make a substantial contribution to the many challenges to effective water supply and management. Prominent candidates include:

- greater use and re-use of waste water for appropriate domestic, rural and industrial applications (Hong Kong has a dual supply system to households, one providing freshwater, the other saltwater)
- more efficient delivery and application of irrigation water
- lower water requirement crops
- reduced evaporation
- non-water based sanitation disposal
- desalination
- technologies of demand management
- new plant nutrition systems
- new cropping patterns
- water harvesting
- inland valley swamp development
- low-lift pump schemes
- peri-urban irrigation with treated urban wastewater
- bio-solid management and disposal
- application of smart technologies and intelligent systems to urban and domestic water use
- closed cycle industrial water usage systems.

5) ***Water and Economic Development***

Water is an essential input or infrastructure resource to much agriculture, energy production, industrial manufacture, mining, water transport, and water recreation industries. The increasing pressures of international competition, and the emergence of newly industrialising economies, are producing ever increasing demands for the supply and management of this commodity. The availability of this commodity is a very real limit-to-growth upon economies.

This is leading to conflict over usage priorities for human direct consumption and sanitation needs, agricultural (particularly irrigation) and industrial demands, and the environmental requirements of a healthy functioning of water-reliant ecosystems. It is now recognised that this is not important only for ethical or ‘visual amenity’ reasons, but also because ecosystem health underpins the production of food, the reduction of flood risk, and ‘natural’ filtration of contaminants.

In addition, inappropriate or inefficient use and management of water is having directly deleterious effects upon these systems of production. Thus excessive or inappropriate irrigation is a primary cause of salination, leading to enormous degradation of land resources. Polluted run-off can have a very damaging effect on marine resources, including fishing, both directly and through producing the conditions for algal blooms and ‘red tide’. Contaminants can render water unusable for manufacturing use, as in for example the food industry, and in extreme circumstances, even for cooling purposes.

6) ***The Application of Market Forces to the Supply of Water***

Water is often wasted because it is under-priced. There is a need for a widespread understanding of water as an economic as well as a social good. The cost of use or mis-use of water is paid for either by the user, by the community at large, or, commonly, by a depletion of the existing ‘natural capital'. As water demand continues to increase, it becomes ever more important to see that it is directed to high-valued economic or social uses.

Thus, a removal of the direct and indirect subsidies, especially for agricultural use, currently operating in many countries, would provide an incentive for more effective use, for conservation, and for the investment in and diffusion of more effective technologies and systems. Allocation of water rights not on a historical basis, but amore transparent market or administrative system based on full cost accounting and benefit analyses, can substantially reduce distortions and inefficiencies.

This points the way for governments at national, provincial and municipal levels to shift progressively away from being providers of water services to being the creators and regulators of an environment that allows communities, the private sector, and non-governmental organisations to engage in the supply of water and sanitation services. The introduction of water pricing and market mechanisms can encourage the private sector to apply financial and management resources towards more effective water supply and management service delivery.

7) ***Water and The Environment***

The importance of maintaining an adequate supply of water to maintain the health of rivers has already been mentioned. In addition, there is a growing concern about the negative consequences and economic balance of dam construction and river impedance as a mechanism to increase water supply. Strong opposition, largely on environmental and, to some extent, wilderness protection grounds, have emerged in a number of, particularly industrialised, countries.

Wastewater disposal is another major environmental issue, with different considerations being applied to urban, rural, industrial and mining outputs. The problem is at its greatest, and most visible, in the environment, where the consequences of inadequate treatment and disposal systems have become increasingly obvious. However, some more far-reaching and ultimately more damaging consequences may be associated with a long history of inattention to rural waste disposal.

Substantial progress has been made in recent years in dramatically improving best practice in waste disposal levels in both manufacturing industry and mining, particularly through the concept of 'total containment'. This has been achieved by a mix of regulation and market competition. However there is enormous scope for the diffusion and further development of these waste-reducing practices.

8) ***Water and Human Health***

Water represents an enormous potential threat to human health. It was only about 150 years ago that the crucial role of the provision of clean water and effective sanitation was recognised as the basis for effective public health. Since then there have been great advances, and the industrialised countries have largely enjoyed a century of freedom from the threat of water-borne diseases.

However that situation is changing, with population growth, and the decline of public investment in infrastructure. It was never the case in the economically less-developed countries. WHO estimates that more than five million people die each year from diseases caused by unsafe drinking water and a lack of sanitation, and water for hygiene. An estimated one-half of the population of developing countries suffers from water-associated diseases caused either directly by infection through the consumption of contaminated water, or indirectly, by water dependent disease carrying organisms. Improved water and sanitation can reduce morbidity and mortality rates of some of the most serious of these diseases by 20-80%.

Problems are also developing in the industrialised nations where urban sewage infrastructure constructed over the past century is collapsing (Australia, Canada, US), and where urban development is encroaching on, and polluting catchment areas (Australia, Hong Kong's supplies from China).

9) ***Water Resource Assessment***

A critical element in more effective water supply and management is more effective policy and planning, based on accurate information on the state (quantity and quality, stocks and flows, usage patterns, hydrological and demographic data, information on forestry and land management, etc.) of water resources.

The capability to provide accurate water quantity and quality data, and to interpret it, is lacking in many countries. Few, if any developing countries have a significant capability in water quality monitoring, which would provide important health-related information. Data on water resource management, irrigation, land degradation, and environmental quality are generally sparse and poor.

Moreover, there is evidence that this capability is in decline. In many industrialised nations, the pressures of competitiveness policies, privatisation, and shrinking public sector budgets, have seen a cutback in what are perceived ‘public good’ activities such as hydrological measurement, observing networks, and consequently in expert staffing. In the developing countries, the pressures of economic development have reduced such long-term approaches to the lowest priority.

10) ***Integrated Water Resource Management***

A crucial component of an effective approach to addressing the challenges identified above, and to improve water supply and management, is through an approach based on integrated water resource management. Such an approach rests on integration, and effectively coordination, of policies, programs and practices addressing the issues identified above.

Such an approach will need to include issues such as the efficiency of water use, long-term resource protection, the economic effects of deterioration in water quality, national, or where appropriate, river basin-based management of groundwater and wastewater, and data collection and model development.

In addition, it needs to be recognised that it is no longer adequate to treat water problems as, essentially, a local issue. Even when comprehensive water management plans have been devised, many developing countries lack the financial, managerial and political capacity to implement them. In developed countries, it is not uncommon that interest-based opposition to ending subsidies or implementing a regime which includes wider considerations undermines the political will for change.

Almost all APEC member economies are struggling with this, essentially political problem. Thus in Thailand, 38 different government agencies in 9 different ministries have a water responsibility. Attempts to introduce comprehensive water legislation has been stymied by the different interests of the many agencies.

11) ***Geopolitics and International Law of Water***

About 300 major river basins, and many groundwater aquifers cross national boundaries. The potential for conflict, as scarcity, and the economic value of water grows, is considerable. While regional and international legal mechanisms can reduce water-related tensions these mechanisms have never received much support. Indeed existing international water law may be unable to handle the strain of future problems.

Under conditions of conflict water resources may become economic or military goals in the same way that oil has been in the past. Water resource systems could be military targets; in addition water resources can in fact be used as military means given the ability to control the flow of water to another nation. Riparian countries will need to develop mechanisms for cooperation over the development and management of trans-boundary water sources. It would seem appropriate to develop processes for negotiation and non-violent resolution of these differences.

12) ***Infrastructure and Structural Safety***

The very high cost of traditional dam construction, now running at approximately US$1000 per tonne of freshwater, is making water capture through storage an extremely expensive option. In addition, there is considerable environmental, and rural opposition to dam construction. This operates not only at the local, but also the international level. There is also a growing concern about the safety of dam structures, as a result of a number of failures.

The distribution infrastructure is another area of concern, with decaying pipelines leading to leakage and pollution, occasional subsidence, and bacterial contamination.

13) ***Water Use and Management Enforcement***

There is a growing tension between the traditional role of water authorities to serve the public, and the increasing need to regulate and police public use of water. Environmental control authorities are commonly provided with significant powers to fine polluters, and even close down plants. However there may be a growing need also to police access, and to develop better mechanisms for identifying illegal diversion of water.

14) ***Energy Costs***

The energy costs of transporting clean water and treating wastewater are considerable. Currently in industrialised countries about half a tonne of water is moved, per person. Increased energy costs will necessarily raise the price of water. The traditional urban water system is proving both unsustainable and ineffective, particularly as cities grow. This will place great pressure on reducing the transport of water by moving to decentralised water collection and effluent treatment, by a much higher level of recycling within the home (and total recycling in industrial premises), and by substantially reduced reliance on water as a transport system for effluent.

3. The Future for Water Supply and Management

3.1 Scenario-based Futures

A number of foresight exercises addressing various aspects of water supply and management have used scenarios to project possible futures.

In this project, three scenarios were developed. (They are presented in full in the Companion Volume). In '**Danger! Water Ahead'** a pessimistic future was characterised by a water-borne disease epidemic, a consequent dramatic increase in the price of water, and the outbreak of conflict between nation states over access to water. Governments and international bodies were paralysed, and world trade was substantially diminished, leading to a much higher recognition of the central role of water in economic and political, as well as human survival, matters.

In '**Water Rules**' APEC member economies agreed on mutual binding regulations for water quality and trade, and established integrated water management as accepted practice. As a consequence, by 2010 the APEC economies enjoyed a substantial advantage in economic performance and water quality. Important new underpinning technologies were electronic access to models and databases on the total water cycle, satellite monitoring of water use, and improved transport and storage systems.

In '**APEC Turns on the Tap**' the devastating impact of a prolonged 'El Nino' event catalysed the introduction across APEC member economies of a series of appropriate emergency short-term measures including highly controlled irrigation, domestic water saving through redesigned plumbing, mandatory use of recycled water by industry and setting of market prices for water. However, the major advances resulted from an APEC investment in longer term R&D which established the basis for economically competitive desalination plants, linked to the genetic design of salt-resistant, low water use crops.

As a comparison, an Australian study[5] used the scenario technique to develop four possible futures:

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5 ASTEC, 'Curbing Our Thirst: Possible Futures for Australia's Urban Water System in the 21st Century', Partnership Study of 'Matching Science and Technology to Future Needs', Canberra,1995.

- ‘**Market World**’ in which the water industry has been fully privatised, with enforceable service delivery performance requirements; the emphasis on cost reduction leads to a neglect of 'public good' issues;
- ‘**Eco-Event’** in which the steady build-up of ecological disasters, requiring all infrastructure to be designed, constructed, operated and maintained according to ecologically sustainable principles; all environmental costs are fully internalised, leading to a rise in the price of water, but this has been offset by successful demand management and innovative technology for water re-use;
- ‘**Public Health Crisis**’ in which the future is driven by the rapid spread of global epidemics and a failure of public health management systems; this leads to a strong shift of R&D towards health issues, a booming private market in ‘pure water’ , and restrictions on pets and recreation;
- ‘**Slow Deterioration**’ in which a lack of public funds and triggering crises leads to a steady decline in the quality of water services.

3.2 Delphi-based Futures

The other commonly used technique for foresighting and creating the future is the Delphi survey. Experts and stakeholders across the APEC member economies were surveyed for their views on a series of ‘topics’ identified by the Workshop experts, arising from the scenarios and their own experience. (Table 1 - they are presented in full in the Companion Volume).

Table 1 Key Delphi Results

Topic	**High Importance %**	**Mean Year of Realisation - APEC Region**	**High Need for APEC Cooperation %**
Scientific methods for flood forecasting, warning and management to protect important areas at high risk in practical use.	88.2	2005	38.6
Technology to detect/locate leaks of over 10% from the distribution system developed.	87.9	2005	43.6
90% of people have easy access to safe water for domestic use.	87.5	2008	40.0
‘User Pay’ and ‘Polluters Pay’ policies are enforced.	85.7	2004	33.3
Pricing system that encourages water users to recognise water as a finite and valuable resource in operation.	82.9	2007	26.4
Water pricing systems used to control demand.	82.9	2007	23.1
Nationally coordinated approach to water supply and management implemented.	79.4	2005	30.9
Systems for monitoring water source contamination in widespread use	79.4	2007	37.0
70% of water used in industry recycled for further use.	75.8	2009	33.3
Accurate rain and precipitation water-balance forecast, aiming at effective utilisation of rainfall in widespread use.	74.3	2007	48.3

Integrated water resource management plan linked with other natural and human features implemented for every major river basin.	74.3	2009	30.9
Nationally determined priorities of water usage/sharing among the sectors (domestic, industrial and agricultural) enforced.	73.5	2006	22.6
Irrigation systems exceed 75% efficiency	72.7	2008	30.9
International standards for dam safety are enforced	72.2	2005	48.1
50% of natural run-off is captured and stored for use	68.8	2010	25.0
Rainfall prediction accurate enough to allow effective flood control using dams in widespread use.	67.6	2006	42.1
Water information (quality, quantity, usage) readily available to the public.	67.6	2006	29.1

Table 1 lists the seventeen topics, in descending order, from the 64 surveyed, that more than two-thirds of respondents (in the second round) considered to have a high degree of importance – presumably the most important changes needed or possible in APEC water supply and management systems. They constitute an interesting, and rather mixed, set of issues.

Eight of them fall into the category of policy, regulation or management issues (eg user pays, pricing systems, nationally coordinated approaches). It would appear that the most significant changes are needed at this level. Five topics describe a level of performance of the water system (eg 70% of water used in industry is recycled, irrigation systems exceed 75% efficiency). Obviously achieving this level of performance would require advances in both technology and management practice. Just four topics are substantial advances in science and technology (eg scientific methods for flood forecasting, technology to detect and locate leaks).

The mean year of expected realisation within the APEC region for each of these topics is bunched tightly in a six-year time span between 2005 and 2010. The policy, regulation and management issues and the science and technology events average realisation in 2006, whereas the system performance events are not achieved, on average, until 2008. Perhaps this last category is seen as requiring the uniting of a greater range of forces. It is important to note that none of these important issues were seen as not being achievable within a reasonably immediate time frame of ten years; they are all seen as practically achievable.

The level of cooperation required within APEC to achieve these outcomes was much lower than the rating of importance. Among these 17 'high importance' events, the average proportion of respondents who rated cooperation within APEC as being of high importance to their realisation was only 34.3% - just over a third. The level of cooperation was lowest for policy and regulation issues – 30.6%, which are viewed as more a national matter, than system performance issues – 33.2% and science and technology issues – 43.2%. The traditional role of cooperation in achieving scientific and technological targets is evident. The highest level of cooperation was necessary in achieving accurate rain and precipitation forecasts, and in international standards for dam safety.

Relatively few topics were seen as of little importance. Only two had a rating of high importance by less than 10% of respondents in the second round – techniques to transport icebergs cost-effectively, and water containers for large-scale long distance transport across oceans in practical use.

4. Implications for Water Supply and Management in the APEC Region

4.1 Challenges of Multi-Country Foresight

This project has revealed many of the challenges associated with the conduct of an effective multi-country foresight study. The relatively simple issue of engaging a range of national experts and stakeholders in a project whose genesis lies entirely outside their own structures and systems, and of conducting a challenging exercise in a single language presents many practical obstacles.

The establishment of the necessary legitimacy and credibility which has been shown to be crucial in achieving a consensual commitment to creating a future[6] presents considerable difficulties. As managers and participants in this project have written:

> A major aim of the overall study is to achieve coordination at an APEC-wide level, and it is hoped that all those who participated in the study, and their agencies, will have increased understanding of each other, and the relevance of an APEC wide perspective. By working with key institutions in each economy, the study should be able to contribute to the development of new working relationships and networks, and this supports the previous suggestion that multi-country studies should focus on working through agencies in each country, rather than trying to contact experts directly, since these relationships and networks might remain once the Center itself has moved on to other research topics.
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> 'Commitment' (generating a sense of commitment to the results among those who will be responsible for implementing changes in the light of the foresight exercise) is a key concern of the Center and this will depend very much on the authority, legitimacy and credibility of the study. While recognising that authority, legitimacy and credibility are fundamental to success in foresight, it is clear that a 'third party', international body like the APEC Center for Technology Foresight cannot hope to achieve them in a multi-country study at the same level and in the same way as a foresight exercise conducted at a national level. On one hand, the Center is not part of the 'water community' which implements water policies. On the other hand, to get the recommendations to the 'APEC power structure', the Center and its project will have to be brought to the attention of many levels of APEC bureaucracy.
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> Nevertheless, that the Center has the mandate of APEC to conduct APEC-wide foresight exercises and that Water Supply and Management was one of the most highly rated topics by representatives of APEC economies, provide some *authority.* Involvement of high-level individuals and relevant institutions in the process would provide more authority, but it is much more difficult to achieve at the multi-country level. Alternatively, the results of the study should be reported at the Industrial Science and Technology Working Group and pass through the APEC bureaucracy to be finally included in the Leaders' statements.[7]

Another substantial issue is grappling with just what an 'APEC perspective' is, given the great diversity in the economies, cultures, geography and history. Clearly a 'one size fits all' approach is quite inadequate. This project has sought to address this issue through an exploration of what are the common, as well as the different features, and to emphasise the extent to which many water supply and management issues have a multi-country dimension. One consequence, and in sharp contrast to the foresight exercises conducted by the leading industrialised nations, was an emphasis on when particular technologies, or management practices would be adopted within various APEC member economies, as opposed to when they would first be produced.

The Delphi questionnaire raised particular concern about the ability of national experts to adopt an APEC regional context. However less than 5% of respondents made any comment on the issue.

4.2 The Scientific and Technological Base for Addressing the Future of Water Supply and Management

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[6] Ben R Martin and John Irvine: Research Foresight: Priority Setting in Science, Edward Elgar, 1989.

[7] T. Jewell and C Sripaipan, 'Multi-Country Foresight – Issues and Challenges', presented to IATAFI 98: Third International Conference on Challenges for Technology Assessment and Technology Forecasting: Equity, Energy and Environment, New Delhi, 1998.

A substantial range of S&T issues were raised as playing an important role in addressing the future of water supply and management. The technologies which were identified by the experts at the scenario workshop as being most significant were:

- Information technology
- Membrane filtration
- Lining materials for storage, distribution and irrigation
- Groundwater recharge techniques
- Trenchless technologies
- Ultrasonics for leak detection
- Water barges, to supply sites near rivers (being developed in China)
- Mini-management systems eg to recycle water in one apartment block.

In some contrast, the most important technological needs that were identified by the Delphi survey were:

- Flood forecasting
- Leak detection
- Rain and precipitation forecast
- GPS (Global Positioning System) and GIS (Geographic Information System) to assist water resource management
- Effective animal waste treatment
- Water-use reducing technologies
- Remote water quality monitoring stations
- Technology to determine the structural strength and surface conditions of pipelines in situ

This could suggest there would be considerable value in an APEC-based process that provides an actively managed database of research and technology development relevant to the very wide range of issues emerging to challenge water supply and management. Moreover, a series of fora between experts in various aspects of water systems could assess the most appropriate technological approaches to addressing some of the needs identified in this study.

In addition to pursuing particular technological solutions, the complexity and multi-disciplinarity of water supply and management problems suggests a strong need for each APEC member economy to seek to develop a capability in the relevant areas of expertise. (See Box)[8]

Examples of S&T expertise required for water issues in the 21st century

Meteorology/Climatology - Changing rainfall patterns, climate change, El Nino effects, artificial rain-making and better long term forecasts.

Hydrology/Land Management - Predicting run-off from catchments, catchment management strategies, most probable flood estimation, ground water interactions, transport of contaminants in surface and ground waters.

Ecology - How to maintain and restore functioning aquatic ecosystems, processes within rivers, wetlands and lakes by which nutrients and contaminants are processed, the assessment of river health management of reservoirs, impacts of waste discharges.

Chemistry - Monitoring traditional water quality indicators as well as the new organic substances being introduced to the environment by industry.

Engineering - Construction and management of dams, treatment plants for drinking water and sewage treatment, construction of pipeline systems, replacement/maintenance strategies, design of drainage and flood plain structures. Risk identification and management.

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8 ASTEC, op cit, ref 5, p.9.

Information Technology - Capturing and processing data about performance of all parts of the system, ranging from remote collection of data on rainfall, run-off and water quality to in-home monitoring of water use and billing.

Planning - Designing the form and density of new urban communities to take into account the costs of water infrastructure, water usage and the volumes of stormwater that must be managed.

Materials Science - Monitoring microbial populations in water supplies, pipelines, waste treatment plants and discharge zones. Including new concerns about contamination with virus materials. Microbial ecology has an important contribution to make in nutrient cycling in the environment and the processing of organic materials.

Epidemiology/Medicine - What are the disease/health risks of operating to different water quality standards? What are the best indicators of water quality from a health perspective? What are the likely health effects of breakdowns in various parts of the system?

Soil Science - Ability to predict infiltration and the movement of water and contaminants through the soil column.

4.3 A New Paradigm in Water Supply and Management

This, and many other reports, point to the need for a new paradigm in water supply and management. The approaches developed largely in the nineteenth century in Europe and the US, and significantly refined during the twentieth century, do not appear adequate to address the huge challenges that have been identified. While there is substantial room, and need for, continuing incremental improvements, they alone will not be sufficient. Rather, approaches based on the recognition of water as a precious and valuable resource, which needs to be used economically and socially to maximum advantage, and hence requiring the adoption and acceptance of demand, and integrated water resource management.

Both the scenario analysis and the Delphi survey identify political action, effective policies and regulation, and appropriate management as the key to effective response to the challenges to water supply and management in the twenty-first century. Thus, 85% of Delphi respondents regarded as of medium-to-high importance that water would be an important issue in national elections by 2006. But they did not see water as an international commodity trade in which would be reported daily in the financial papers eg Water Futures.

These views may prove correct, or they may not. What they certainly signal is the need for a much higher level of consideration of possible and preferred futures in water supply and management, and in the value of multi-country studies on such pressing and strategic issues.