DECEMBER 2011

Planning for Resilient Water Systems

Summary

A Water Supply and Demand Investment Options Assessment Framework

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Smart Water Fund
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Contents

Executive summary of assessment framework

The Managing Directors of the four Melbourne water businesses have set out a clear vision for the future role of water in shaping a sustainable, liveable, prosperous and healthy city. The Melbourne Water Supply Demand Strategy (WSDS) is a 50 year strategy to balance the supply of water to meet Melbourne's consumptive, environmental, industrial and agricultural water needs.

The strategy examines long term future supply augmentations for the city. The last Melbourne WSDS was completed in 2006. The next Melbourne WSDS is due for completion in March 2012, and is one of the key mechanisms through which the Managing Directors' vision can be achieved.

The Institute for Sustainable Futures was contracted by the Smart Water Fund to develop an options assessment framework for the preparation of water supply demand investment strategies, including the forthcoming WSDS, that will meet the MDs' broad vision.

This options assessment framework brief indicates there is now widespread recognition across the Melbourne water businesses that a generational shift is required away from conventional deterministic planning towards more flexible and adaptive planning and management. This shift is being driven by the need to maintain water security in the face of increasing uncertainty in key determinants of water businesses, as well as by increasing determination to broaden the objectives that a water system should meet. For example, the recent dry period highlighted that the role of water in a city is wider than that of a commodity. In addition, feedback from key city stakeholders indicates that there is an opportunity for the water sector to play a larger role in actively shaping the future of our city.

In response, this assessment framework, 'Planning for Resilient Water Systems', provides a process and methodology that specifically:

- Incorporates the vision of the utilities and the multiple values of water into the decision making process by setting clear objectives to ensure that the investment strategies contribute to a sustainable, liveable, prosperous and healthy city;
- Prioritises portfolios of measures that are least cost to the community in the broadest sense by providing methods to assess measures against social, environmental and economic criteria;
- Prioritises portfolios of measures through the use of investment strategies that are resilient to future uncertainty by assessing their flexibility and robustness against a range of scenario paths;
- Provides a clear and transparent process that clearly communicates the outcomes and basis of the assessment to key decision makers; and
- Involves stakeholders in the process of setting the objectives, identifying viable measures and in developing viable investment strategies.

This kind of assessment framework is new, and is pushing the frontiers of best practice. Whilst there are various theoretical methods for decision-making under uncertainty, some of which have been applied in other sectors (e.g., finance), they generally have not been applied to the water sector and have not been brought together in an integrated, practically-grounded process such as that proposed here to guide strategic planning and project level decisions. As such, this framework is a significant conceptual step forward that will mature over time, in the same way that, for example, demand management has matured over the past decade.

Executive summary of assessment framework (cont)

In broad terms, this framework comprises three significant innovations in thinking:

FIRST INNOVATION

The first innovation is to characterise the uncertainties as trends or shocks in order to distinguish and better respond to the impacts of these uncertainties. That is, we need to characterise uncertainty in order to respond effectively to it. In this framework, we use the term 'influence' to mean the changing pressures and drivers that impact on the context in which water businesses operate, and therefore on the performance of supply and demand options. Influences can manifest as either trends (such as reduced run-off or demand growth) or shocks (such as unexpected step changes in the trends). The way that influences occur is significant (i.e., as trends or shocks), because it determines the nature and scale of the impact on system performance. The framework distinguishes trends and shocks, and analyses their impacts separately. Adaptive management through flexible responses deals well with changing trends. Together with flexible responses, robust responses deal well with shocks. Therefore, responses that are both flexible and robust deliver resilience.

SECOND INNOVATION

The second innovation is the idea of 'scenario paths'. A scenario path brings together a specific combination of trends (or drivers), and considers the impact of that combination on the supply-demand balance i.e. whether or not a shortfall exists. The scenario path approach draws on the richness of scenario analysis methods and integrates it into water planning. It is a practical middle way between the potential for lack of subtlety in conventional scenario analysis and for profusion of detail in probabilistic approaches. That is, scenario analysis typically aggregates trends into drivers, and focuses on just two drivers at a time, and explores the upper and lower bounds of those drivers in four scenarios. In contrast, the water sector has to contend with multiple trends in various combinations. Increasing the number and combinations of potential trends has an exponential effect on the number of scenarios and analyses required, which generally leads to numerical optimisation, such as probabilistic approaches. The quality of the outcomes of these approaches is determined by the quality of the inputs and calibre of the models. These methods are not well established in practice, so both of these are questionable for the water sector at this time. 'Scenario paths' is a reasonable and practical way forward at this stage.

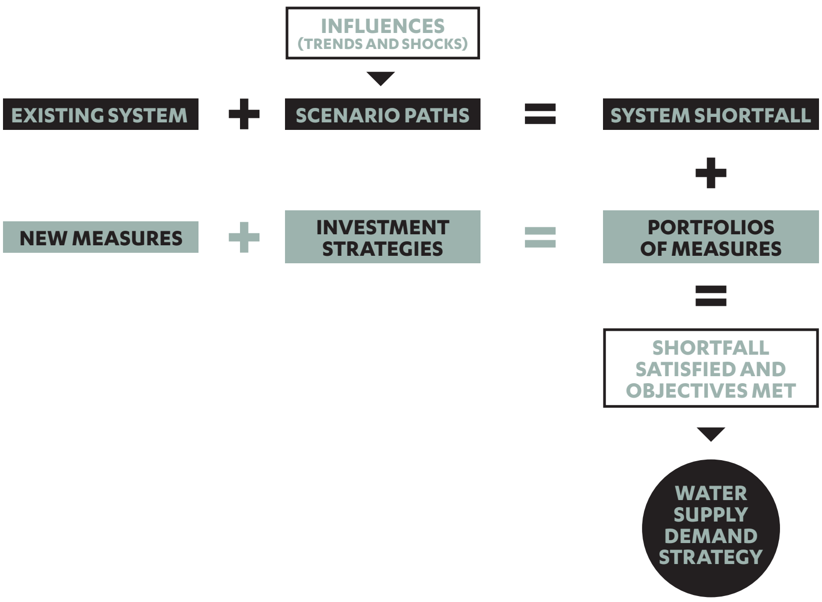
THIRD INNOVATION

The third innovation is the framework's focus on *'investment strategies'*. Investment strategies set the hierarchy for sequencing of types of measures. Investment strategies should be drawn from current policies. In order to set the sequence in which the types of measures are chosen, an investment strategy (such as invest first in small scale recycling) nominates thresholds and triggers for new measures (e.g., invest in local recycling where it helps to avoid construction of additional potable transfer capacity); predecessors and constraints where necessary (e.g., local recycling works best in new growth areas); and lead times before the benefit of a measure can be realised (e.g., time for construction and uptake of new residential development).

Executive summary of assessment framework (cont)

Briefly, in this assessment framework for planning for resilient water systems, objectives, boundaries, and key performance criteria are set, consistent with both statutory obligations and visions. Influences are identified, assessed for significance, and characterised as potential trends or shocks. Scenario paths are constructed from combinations of influences to assess shortfalls in the existing system. Measures (i.e. new demand management or supply side options) that respond to the shortfalls are identified and assessed in economic, social, and environmental terms. Investment strategies are developed that direct the packaging up of portfolios of measures to meet the shortfalls. These portfolios are then finally assessed against shocks, and preferred portfolios emerge, which are assessed systemically on a triple bottom line basis, consistent with the vision of shaping a sustainable, liveable, prosperous and healthy city.

FIGURE 1
Assessment framework in simple terms



This assessment framework has four components:

1) An **assessment framework summary** (this document): an integrated overview of the rationale for the framework and each of the steps and activities that it comprises.
2) A **process map**: a clear and concise visual representation of the seven steps and more than thirty activities that make up the process of applying the assessment framework
3) A **process manual**: a detailed guide to the why, what, how, and so what of each activity within the process.
4) A set of analytical method **guide sheets**: nine documents that each explore and explain a key methodology for the analysis necessary for both strategy and operational decisions that flow from the framework.

Executive summary of assessment framework (cont)

This **summary document**, together with the **process map** and **process manual**, provide a step by step guide on how to undertake this assessment process at a strategic planning level.

The **guide sheets** provide detailed methodological advice for water resource planning to underpin both the strategic planning process and operational decision-making at a project level. The guide sheets fall into three logical groupings:

- Methods for *assessing the performance* of measures and/or portfolios of measures in achieving the key performance criteria. These methods can be used to evaluate options at both a strategic level as well as at an operational or project level. The guide sheets here are for Cost Effectiveness Analysis, Cost Benefit Analysis, Monetisation, Resource Intensity, and Multiple Criteria Decision Making.
- Methods for *testing the assumptions* used in the strategic analysis or the project level analysis. The sensitivity of the outcome to changes in the assumption can be assessed. The guide sheet here is Sensitivity Analysis.
- Methods for *assessing strategies* that ensure flexible and robust portfolios of measures in response to uncertain influences. These methods operate at a strategic level only. The guide sheets here are Scenario Analysis, Probability Analysis, and Decision Analysis & Real Options.

1. Introduction

1.1 PURPOSE OF THE ASSESSMENT FRAMEWORK

The purpose of this assessment framework is to guide the strategic planning process, and to support operational decisions, such that portfolios of investments are identified that are both flexible and robust, delivering a resilient water system over the long term.

This shift is being driven by the need to maintain water security in the face of increasing uncertainty in key determinants of water businesses, as well as by an increasing appetite to broaden the objectives that a water system should meet.

The challenge of ensuring current and future water security under growing demands has become increasingly significant with recent droughts providing a compelling reminder of the variability of the Australian climate and its vulnerability to climate change impacts. Historically, reserve supplies and water restrictions have been the default strategy. In the last few years, many Australian utilities and governments made significant investments in large scale desalination. More recently, water service providers are seeking 'diversified portfolios' and 'flexible strategies' as a means of moving towards providing improved security and resilience at reduced costs.

The emergence of this new way of thinking represents a challenge to existing conceptual and analytical models underlying resource planning decisions. Water planning and management have in the past relied on the assumption that the future will be based on linear extrapolations of the historical trends, which include seasonal and annual variability to some extent. Dams for example have been sized using available information on historical river flows and rainfall figures. However, as has been experienced over the past decade, historical trends are insufficient in and of themselves – the unpredictability of key drivers is a reality.

A shift away from a deterministic approach is therefore required, to one that builds in flexibility through an adaptive planning and management approach based on the information at hand and one that delivers much needed information on phasing and sequencing under different circumstances. A number of advanced methods from finance and decision theory have been suggested in the literature, but these methods are often too complex for practical implementation. A different approach is required that translates and situates these methods in the context of water resource planning.

The strategic intent of the Melbourne metropolitan utilities is to meet its vision: 'Water for a sustainable, liveable, prosperous and healthy city'. To achieve this, the Melbourne water industry faces a number of key changes and challenges to the way water is sourced and used. These include:

- valuing and using water in a way that fully supports the continued development of Melbourne's liveability and productivity objectives,
- a growing population,
- the changing urban form needed to accommodate more and more people,
- increased climate risk and variability, including rainfall patterns and bushfires,
- energy price rises, and
- growing community concern about the rising costs of water.

The challenge presented by these issues for urban water planning is the uncertainty in the shifts in the magnitude (nature and scale) of the associated variations.

1. Introduction (cont)

Water planners in Australia are used to some types of variability – their understanding of historical variability in rainfall is one reason why Australia has one of the highest per capita water storage volumes in the world. However, the uncertainty associated with the frequency and magnitude of the variations, coupled with broader performance expectations, means that a new approach is required that delivers both flexibility and robustness. Key to achieving this flexibility and robustness is the ability to assess suites of options, in terms of assessing potential synergies and the potential benefits to system resilience of diverse supplies, as well as accounting for antagonism between options, i.e. when options are mutually exclusive, or when one option impedes the performance of another.

That is, an adaptive planning approach is needed for the Melbourne metropolitan utilities' water supply demand investment strategies to incorporate changing values of water, future uncertainty, and suites of options.

In response, the Institute for Sustainable Futures was contracted by the Smart Water Fund to develop an options assessment framework for the preparation of water supply demand investment strategies, including the forthcoming WSDS, that will meet the Managing Director's broad vision. The brief required that the assessment framework:

- Incorporate multiple values of water into decision making, such as the way in which water contributes to a sustainable, liveable, prosperous and healthy city;
- Assess portfolios of measures – assessing potential synergies and/or duplication between measures and the potential benefits to system resilience of diverse supplies;
- Manage future uncertainty through delivering flexible, diverse and adaptable outcomes which are capable of effectively responding to future uncertainties such as climate change, population growth, economic activity and black swan events;
- Clearly communicate outcomes of the assessment to key decision makers; and
- Involve stakeholders in decision making.

1.2 STRUCTURE OF THE ASSESSMENT FRAMEWORK

This assessment framework has four complementary components:

1) An **assessment framework summary** (this document): an integrated overview of the rationale for the framework and each of the steps and activities that it comprises.
2) A **process map**: a clear and concise visual representation of the seven steps and more than thirty activities that make up the process of applying the assessment framework
3) A **process manual**: a detailed guide to the why, what, how, and so what of each activity within the process.
4) A set of analytical method **guide sheets**: nine documents that each explore and explain a key methodology to undertake the necessary analysis for both strategy and operational decisions that flow from the framework.

This **summary document**, together with the **process map** and **process manual**, provide a step by step guide on how to undertake this assessment process at a strategic planning level.

1. Introduction (cont)

The **guide sheets** provide detailed methodological advice for water resource planning to underpin both the strategic planning process and operational decision-making at a project level. The guide sheets fall into three logical groupings:

- Methods for *assessing the performance* of measures and/or portfolios of measures in achieving the key performance criteria. These methods can be used to evaluate options at both a strategic level as well as at an operational or project level. The guide sheets here are for Cost Effectiveness Analysis, Cost Benefit Analysis, Monetisation, Resource Intensity, and Multiple Criteria Decision Making.
- Methods for *testing the assumptions* used in the strategic analysis or the project level analysis. The sensitivity of the outcome to changes in the assumption can be assessed. The guide sheet here is Sensitivity Analysis.
- Methods for *assessing strategies* that ensure flexible and robust portfolios of measures in response to uncertain influences. These methods operate at a strategic level only. The guide sheets here are Scenario Analysis, Probability Analysis, and Decision Analysis & Real Options.

1.3 PURPOSE AND STRUCTURE OF THIS DOCUMENT

The assessment framework process comprises seven steps, which together comprise more than thirty activities, so the purpose of this document, the assessment framework summary, is to provide an integrated, high level view of the process as a whole. This includes the overarching rationale for the framework (Section 1), an overview of the framework and an explanation of the framework's language (Section 2), summaries of the purpose, activities, and outcomes for each of the steps (Section 3), and summaries of where and how to use the analytical methods that support both the strategic planning and operational decision making steps that flow from the framework (Section 4).

2. Overview of the assessment framework

2.1 LANGUAGE USED IN THE FRAMEWORK

This assessment framework uses a variety of terms and concepts, like resilience, scenario paths, portfolios, and others, that are relatively new to the water sector. Although these terms are being used more and more frequently, they are at this stage likely to mean different things to different people and within different organisations. The key terms and concepts that make up this assessment framework have specific meanings, so the purpose of this section is to introduce those key terms and what they mean (see footnotes here and the appendix at the back of this document) within this assessment framework. Terms that have a role in the process are also italicised.

An adaptive approach is required to develop a water supply demand investment strategy (such as the Water Supply Demand Strategy (WSDS)) at a metropolitan and utility level in a climate of increasing uncertainty and increasingly broad objectives. This contrasts with conventional deterministic approaches. This assessment framework provides primary guidance for strategy level decision making, and provides secondary guidance for project level decision making. The framework provides a structured process for planners when thinking through the impact that uncertainty[1] in *influences*[2] has on both the *context*[3] and *measures*[4], and therefore on the strategy's capacity to meet the defined objectives whilst avoiding a shortfall (termed in this framework as an '*objective* shortfall'[5]).

These *influences* can manifest in one of three ways: as trends that change over the longer term, as shocks that lead to new norms, or as extreme variability in the short term. The latter is not of interest here because it is addressed through other planning and management mechanisms (such as the Water Outlook processes). Separating and characterising how the influences occur is important because different supply and demand *measures* will respond differently to trends and shocks. At the end of the day, the strategy should provide resilience[6], through *investment strategies*[7] that combine flexibility[8] and robustness[9] in the portfolio of measures they recommend.

2.2 INNOVATIONS IN THE FRAMEWORK

This kind of assessment framework is new, and is pushing the frontiers of best practice. Whilst there are various theoretical methods for decision-making under uncertainty, some of which have been applied in other sectors (e.g., finance), they generally have not been applied to the water sector and have not been brought together in an integrated, practically-grounded process such as that proposed here to guide strategic planning and project level decisions. As such, this framework is a significant conceptual step forward that will mature over time, in the same way that, for example, demand management has matured over the past decade.

In broad terms, this framework comprises three significant innovations in thinking and planning:

1) **The first innovation** is to characterise the uncertainties as trends or shocks in order to distinguish and better respond to the impacts of these uncertainties. That is, we need to characterise uncertainty in order to respond effectively to it. In this framework, we use the term *'influence'* to mean the changing pressures and drivers that impact on the context in which water businesses operate, and therefore on the performance of supply and demand

1 Uncertainty *is the possible range within which an influence will manifest itself. An envelope of this range should be considered when analysing the impact of the influence on the proposed portfolio of measures.*

2 Influences *are the pressures and drivers that have an impact on the context and the likely outcome of a measure.*

3 Context *refers to the system and global environment within which the analysis is undertaken.*

4 Measures *refers to the options identified in response to influences in the context.*

5 Objective shortfall *refers to deficiencies in the measures to meet the requirements of the objectives e.g. volumetric shortfall in supply requirements, shortfall in meeting minimum GHG or nitrogen targets.*

6 Resilience *is a characteristic of a portfolio of measures that displays both flexibility and robustness.*

7 Investment Strategy *is a set of policy rules and instructions as to the sequence in which the types of measures are chosen, the thresholds and triggers for new measures, predecessors for some measures and the constraints of the system.*

8 Flexibility *is a characteristic of a portfolio of measures that can be altered to suit changing trend conditions at minimal additional community cost, e.g. avoiding large centralised supply systems with long lead times.*

9 Robustness *is a characteristic of a portfolio of diverse measures that are not all dependent on the same influences and hence the impact of the variability in the influences is mitigated i.e. to not have all one's eggs in one basket, e.g. conjunctive supply sources.*

10 Portfolio of measures *are a group of measures that satisfies an investment strategy.*

2. Overview of the assessment frameworks (cont)

options. *Influences* can manifest as either trends (such as reduced run-off or demand growth) or shocks (such as unexpected step changes in the trends). The way that *influences* occur is significant (i.e., as trends or shocks), because it determines the nature and scale of the impact on system performance. The framework distinguishes trends and shocks, and analyses their impacts separately. Adaptive management through flexible responses deals well with changing trends. Together with flexible responses, robust responses deal well with shocks. Therefore, responses that are both flexible and robust deliver resilience.

2) **The second innovation** is the idea of *'scenario paths'*. A *scenario path* brings together a specific combination of trends (or drivers), and considers the impact of that combination on the supply-demand balance i.e. whether or not a shortfall exists. The *scenario path* approach draws on the richness of scenario analysis methods and integrates it into water planning. It is a practical middle way between the potential for lack of subtlety in conventional scenario analysis and for profusion of detail in probabilistic approaches. That is, scenario analysis aggregates trends into drivers, and focuses on just two drivers at a time, and explores the upper and lower bounds of those drivers in four scenarios. In contrast, the water sector has to contend with multiple trends in various combinations. Increasing the number and combinations of potential trends has an exponential effect on the number of scenarios and analyses required, which generally leads to numerical optimisation, such as probabilistic approaches. The quality of the outcomes of these approaches is determined by the quality of the inputs and calibre of the models. These methods are not well established in practice, so both of these are questionable for the water sector at this time. *'Scenario paths'* is a reasonable and practical way forward at this stage.

3) **The third innovation** is the framework's focus on *'investment strategies'*. *Investment strategies* set the hierarchy for sequencing of types of *measures*. Investment strategies should be drawn from current policies. In order to set the sequence in which the types of measures are chosen, an *investment strategy* (such as invest first in small scale recycling) nominates thresholds and triggers for new *measures* (e.g., invest in local recycling where it helps to avoid construction of additional potable transfer capacity); predecessors and constraints where necessary (e.g., local recycling works best in new growth areas); and lead times before the benefit of a *measure* can be realised (e.g., time for construction and uptake of new residential development).

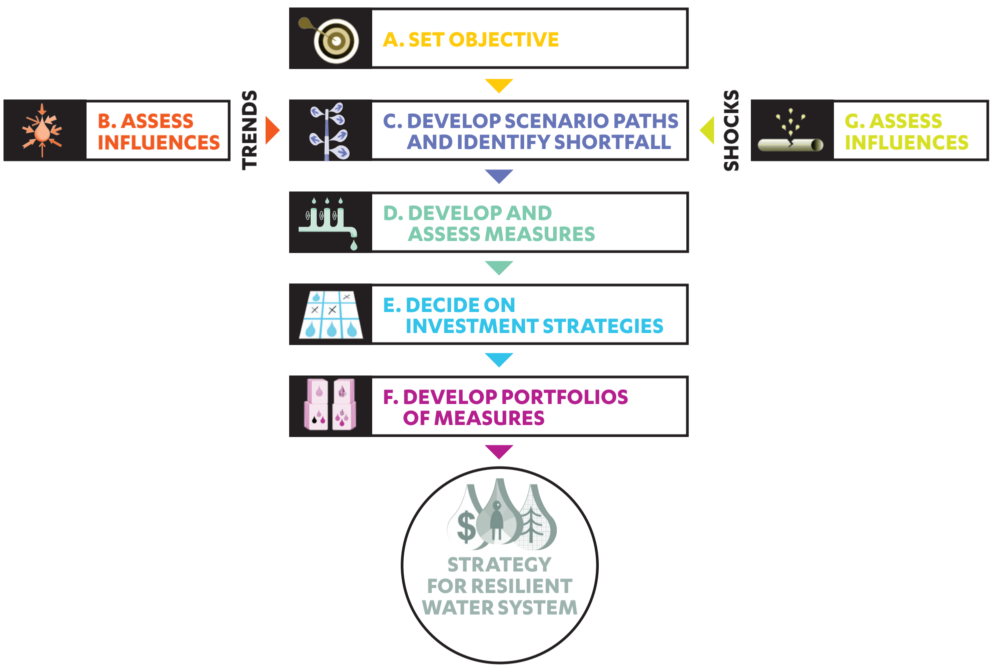
2. Overview of the assessment frameworks (cont)

2.3 A SYNOPSIS OF THE ASSESSMENT FRAMEWORK

The water industry is now recognising that the future is increasingly uncertain. What is needed is a shift in focus from long term deterministic planning to a more flexible adaptive planning and management approach. This will enable the water sector to choose and invest in *portfolios of measures* that respond to future uncertainties in a cost effective and socially and environmentally responsible way.

Refer to Process Map and Manual

FIGURE 2
The assessment framework



The framework consists of seven steps. Each step has multiple activities. In this section, a synopsis of the steps is provided. In Section 3, each step is explained in more detail (purpose, activities, and outcomes) and a synopsis of the activities is provided for each step. In the Process Manual (a separate document), each activity is explained in detail.

Step A: Objectives
This framework for planning for resilient water systems begins by setting objectives, boundaries, and key performance criteria, consistent with both statutory obligations and industry and stakeholder visions. In this document and the associated examples, the assumption is that the objectives are focused on balancing supply and demand. However, the assessment framework is a generic process that could equally be applied to other objectives within the water sector, such as managing nitrogen or greenhouse gas emissions.

2. Overview of the assessment frameworks (cont)

Step B: Trend influences
In order to plan and manage a resilient water system it is necessary to identify what factors may change in the future. In this document these factors are referred to as *influences*. *Influences* include factors which impact on the *context* in which a water business operates (for example changes in population) and also factors which impact on specific *measures* (for example a shift in energy price).

Specifically this step proposes a method for identifying, characterising, assessing and prioritising *influences*. The method is only interested in *influences* that have a material impact on ensuring water security – that is, those that have high levels of uncertainty and high significance to ensuring that the objectives are achieved. *Influences* can manifest as trends or shocks that impact the long term, or extreme variability that impacts the short term as shown in Table 1. Longer term trends and shocks shift operations into a different realm – a new norm or a different baseline – so they are the focus of this framework. Extreme variability, on the other hand, impacts in the short term, after which things return to existing operational norms. Extreme variability is dealt with through short term planning processes (such as the Water Outlook), which are separate from this framework.

TABLE 1
Changes in the planning assumptions

TYPES	DESCRIPTION	RESPONSES
Trends	Gradual changes (but we don't know how gradual or in which direction, e.g. run-off, water demand)	Flexibility through, for example, staging of implementation.
Shocks	Step changes in the *influences* (but we don't know how big or when it will occur, e.g. bush fires, energy pricing spikes)	Flexibility and robustness through, for example, diversity of measures.
Extreme variability	Extremes in existing trends well beyond normal variations associated with seasonal or annual fluctuations, e.g. drought, floods.	Diversity and to a lesser degree redundancy[11] (although this can be an expensive option)

11 Redundancy *refers to the spare capacity required to ensure adequate system capacity is available if a portion of the system fails due to either malfunction or an external impact, such as pump failure or a natural disaster disrupting part of the system.*

Characterising these longer term *influences* as either trends or shocks provides two key benefits. Firstly, the different impacts of the *influences* can be distinguished, and therefore more clearly assessed. For example, a *measure* may be able to cope with gradual change, but may not be able to respond quickly enough to a shock. Secondly, more appropriate response *measures* can be identified to manage the different impacts (see Table 1). Together, flexibility and robustness deliver resilient adaptive capacity to future uncertainties.

Trends and shocks need to be separated for analysis, and there are various ways to do that. In this framework, trends are analysed first, responses are developed to ameliorate the impacts of those trends, then those responses are tested against shocks and the responses modified accordingly. There are more complex ways of analysing trends and shocks in combination, potentially involving probabilities. However, those more complex approaches are 'black-

2. Overview of the assessment frameworks (cont)

box' in nature. The approach advocated here is preferable because it provides transparency in the analysis, which is key for helping decision-makers and stakeholders to follow and understand the logic of the process.

Step C: Scenario paths
Scenario paths are created by combining the significant trend *influences* and assessing the current system's capacity to respond to compound effects of these trends. Each of these *scenario paths* is equally possible because probabilities have not been assigned to them. As explained in Section 2.2, this approach of *scenario paths* is intended to address the shortcomings of scenario approaches (limited to just two sets of trends at a time) and probabilistic approaches (i.e. portfolio analyses[12], which are limited by the quality of available models and inputs). This step identifies gaps between the objectives and what is achievable under different combinations of significant trend influences. Where the objectives relate to supply demand balances, this gap is potential shortfalls in water supply.

Refer to Section 2.2

12 *See the Probability Analysis Guide Sheet and the Decision Analysis Guide Sheet*

Step D: Measures
In this step, individual *measures* are identified that respond to the objectives and help meet the shortfall. These *measures* are first assessed against the objectives using the economic, social, and environmental performance assessment methods set out in the Guide Sheets for Cost Effectiveness Analysis, Cost Benefit Analysis, Valuation, Resource Intensity and Multi-Criteria Decision Analysis. The *measures* are then assessed for their vulnerability to impacts from the significant trend *influences*.

Step E: Investment strategies
Within this framework, *investment strategies* provide the logic for packaging up sets of *measures* into portfolios, to respond to the shortfalls identified under various *scenario paths* above. *Investment strategies* set the hierarchy for sequencing of types of *measures*, and therefore should be drawn from current policies.

Step F: Portfolios of measures
Portfolios of measures are packaged up according to particular *investment strategies*, to meet the identified shortfalls in the objective. The performance of these portfolios is then assessed against the objective of least community cost in the broadest sense i.e. the aim here is to identify the economically, socially, and environmentally preferred portfolios.

Step G: Shock influences
Shock *influences* identified and assessed earlier in the process are now finally brought into consideration. The performance of the top few *investment strategies* (preferred portfolios) is assessed against significant shock *influences*, following a process similar to that for the trend influences: shortfalls are again estimated, and portfolios are modified where necessary, and re-assessed against the broad performance criteria.

2. Overview of the assessment frameworks (cont)

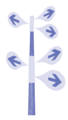
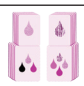
Outcome

The outcome of this series of steps is a resilient strategy that has addressed uncertainties in both trend and shock *influences*, and identified *portfolios of measures* that can meet the shortfall whilst performing sufficiently well against the key performance criteria.

Table 2 provides a summary of the Steps. In Section 3, each step is discussed in more detail including a synopsis of the activities.

TABLE 2

Key steps towards a Water Supply and Demand Investment Strategy

		STEP	PURPOSE
A		**Objectives**	To define what the strategy plan intends to achieve, what the limits to the plan are and how performance against objectives will be measured.
B		**Trend influences**	To identify and assess influences that matter over the scope of the strategy; To characterise the influences as trends, shocks, or extreme short term variability; To identify which are the significant trend influences i.e. those with high uncertainty and large potential impact; To characterise how the significant trends impact on the existing system.
C		**Scenario paths**	To construct possible futures based on the range of significant trend influences that the water system will operate under and be affected by; To determine the objective shortfalls for both the existing and future portfolios of measures under these trends.
D		**Measures**	To identify measures that align with the vision and contribute to reducing the objective shortfall under future scenario paths; To assess their performance against broader objectives and characterise their responses to significant trend influences.
E		**Investment strategies**	To design a number of policies and rules to determine the sequencing of and triggers for each type of measure and under what conditions they should be considered.
F		**Portfolios of measures**	To determine the preferred investment strategies under future trend scenario paths by building portfolios of measures aligned to particular investment strategies to address the objective shortfalls.
G		**Shock Influences**	To identify which are the significant shock influences, and their relationship to existing and proposed measures; To describe possible futures based on the range of significant shock influences, together with the trend scenario paths; To determine the objective shortfalls for both existing and future portfolios of measures.
Outcome		**Water Supply & Demand Investment Strategy**	To determine the preferred investment strategy (portfolios of measures) that responds to future trends and shocks whilst satisfying the objectives and key performance criteria.

2. Overview of the assessment frameworks (cont)

2.4 LIMITATIONS OF THE ASSESSMENT FRAMEWORK

Methods for dealing with uncertainty can be characterised along a spectrum of analytical complexity. There are different pros and cons associated with points on the spectrum – simpler methods can only handle simplified representations of the system under study. More complex methods can handle richer representations of the system, and are more data intensive.

The team (ISF's researchers and the Smart Water Fund's project team) developing this framework made the decision to employ methods at the more simple end of the spectrum that build on Scenario and Contingency Analysis, and stopped short of more complex methods, such as Probability and Decision Analysis[13], that rely on assigning probabilities to the uncertainty of influences.

This decision reflects the current state of data, knowledge and tools available to water planners in the Melbourne water sector. That is, Scenario and Contingency Analyses are valuable tools for situations where quantifying probabilities and/or utility functions is infeasible or inappropriate because of inadequate information. The limitation is that both methods must operate on simplified characterisations of the decision problem through for instance, only assessing a limited set of scenarios, options and/or decision junctures.

This framework currently excludes the use of two key classes of more complex analytical methods relevant to addressing uncertainty, and that are reviewed in the accompanying guide sheets: probabilistic and real options approaches. These methods quantitatively consider the range of possible futures and their probabilities, which represents a potentially more complete picture, but it introduces significant additional analytical complexity (and ultimately cost) to the process, and requires specification of unknowns for which data does not yet exist i.e. specification in the absence of information.

13 *These methods are described and discussed further in the Probability Analysis and Decision Analysis & Real Options guide sheets.*

3. Steps and activities

This section provides a summary of the purpose, outcomes and a number of specific Activities for each of the Steps. The Steps and Activities are described in detail in the Process Manual and illustrated in the Process Map. Each Activity answers a specific question and describes the approach, information flows, tools and the outputs.

3.1 STEP A: OBJECTIVES

Purpose: To define what the strategy plan intends to achieve, what the limits to the plan are and how performance against objectives will be measured.

Outcomes: A well articulated set of objectives, a clearly defined set of measurable key performance criteria and well described constraints and boundary conditions within which to undertake the investment strategy planning.

Activity **A1:** What are the objectives for the planning period?

Based on the consideration of the regulatory requirements of Government, the vision of the utilities and stakeholder expectations, a values and objectives statement to drive the investment strategy development can be prepared. Examples of water supply objectives are provided in Table 3.

TABLE 3

Examples of objectives for water provision and their implications of demand

OBJECTIVES	WATER FOR:
A liveable and healthy city	• Drinking and washing • Sports fields • Public and private parks and gardens • Recreation • Reducing the urban heat island effect
A sustainable city	• Healthy water ways • Groundwater dependent ecosystems • A healthy environment
A prosperous city	• Industry • Agriculture

3. Steps and activities (cont)

The scope of the study should be clearly defined by the boundary conditions and service constraints to avoid undertaking a study of endless proportions and also double counting. In the case of water supply and demand, these should include:

- The types/range of services to be provided, e.g., potable water, recycled water, sewage management, or indirect potable reuse.
- The minimum level of service objectives acceptable to the customers.
- During drought conditions, the maximum frequency, duration and level of water restrictions.
- The geographic area for service provision, current and projected.
- Security of supply and bulk water arrangements.
- Environmental flow obligations.
- Department of Health requirements (now and projected)
- EPA requirements (now and projected)

In order to measure whether the investment strategies meet the objectives and constraints, key performance criteria must be drawn up. These would include, amongst others:

- Minimum levels of service
- Affordability (impact on water prices)
- Waterway health criteria
- Maximum levels of GHG emissions
- Cost to society
- Externalities

WSDS Example: Setting the objectives

Metro Melbourne Managing Directors (MDs) Visioning process
MDs' Vision: 'Water for a sustainable, liveable, prosperous and healthy city'.
Consultation methods:

- Deliberative forums and online surveys to test the MDs Vision
- Website: Let's Talk Water Melbourne
- Industry 'Ideas forums'
- Targeted consultation with Direct Report Group, GMs, Industry

3. Steps and activities (cont)

3.2 STEP B: TREND INFLUENCES

Purpose: To identify and assess influences that matter over the scope of the strategy. To characterise the significant influences as trends, shocks, or extreme short term variability.

Outcomes: A set of significant trend influences and an understanding of the relationship between these influences and the existing system measures.

Activities:
B1: What are the possible contextual influences for the planning period?
B2: What are the characteristics of the current system?
B3: Which are the significant trend influences?
B4: What is the relationship between the trend influences and the existing measures?

The key *influences* of change that determine whether the preferred *investment strategy* achieves the objectives need to be specifically identified and clearly understood. The wide range of *influences* can be determined by undertaking an environmental scan of the *contextual* environment in terms of three dimensions, viz. the social, technological, economic, environmental, and political sectors (STEEP), whether they are supply or demand driven, and if they are trends or shocks (see Table 4, next page). The *measures* and *portfolios of measures* will need to respond to two types of future uncertainty, viz.:

1) **Gradual changes** (climate change, population growth, technological advances) which require an acclimation-type adaptive capacity aimed at reducing system sensitivity to gradual changes in average conditions (or **trends**) through **flexibility** by making incremental interventions over time,
2) **System shocks** (energy price spikes, natural disasters, climate variability and extremes) that require resistant-type adaptive capacity aimed at increasing system **robustness** through diversity in the responses to the shocks.

Using the guide in Table 4 (next page) ensures that a wide range of possible *influences* are identified and categorised. This helps in understanding the types and nature of the *influences* on the system and provides an understanding later in the process of which *portfolios of measures* provide flexible adaptive capacity to changing trends and those that are robust to sudden shocks to the system. This approach ensures the *portfolios of measures* are tested against both types of uncertainty since their responses to the two types of *influences* will most likely be different.

A further distinction should be made between trend and shock *influences* and extreme variability. Whilst extreme variability falls outside of this strategic planning approach, it is identified in this Step to avoid including it with the trend and shock *influences* and should be earmarked for analysis during the short term water security planning process.[14]

14 *The performance of the water supply system and trends in demand under extreme variability will be analysed in a short term (e.g. 3 year) water security plan. The short term planning and management process will consider the potential for sustained low streamflows over the short term period. It will determine whether the existing system can deliver water security without the need for temporary water restrictions, and/or the need to introduce known and costed supply and demand measures that can be implemented within the short term planning period.*

3. Steps and activities (cont)

TABLE 4

Examples of influences

	SUPPLY		DEMAND	
	TRENDS	SHOCKS	TRENDS	SHOCKS
Social			• Willingness to pay for higher levels of service • Increased population growth/influx	
Technical			• Advances in water efficiency	
Economic	• Energy pricing increases	• Energy pricing spikes		Sharp economic decline
Environmental	• Lower average rainfall / run-off • Increased seasonal rainfall variability	• Droughts • Floods	• Changes in average demand profile i.e. more peak demand days	• More peak demand days due to extreme temperatures
Political	• Competition policy		• More diverse supply products (not one size fits all) • No restrictions (bounce back)	

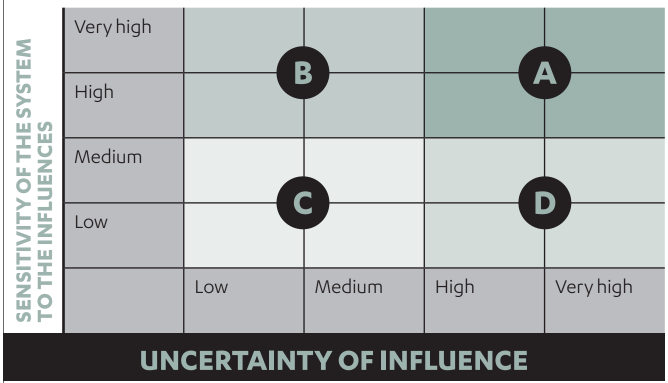
At this point, we set aside the shock *influences* for consideration in Step G. Since it is not practical to assess the impact of all the possible i*nfluences* in combination, the most significant trend *influences* are to be identified by ranking them against the dimensions of uncertainty of the *influence* and the sensitivity of the existing system[15] to that *influence*. This is similar to a risk assessment matrix of probability and consequence, so a useful tool is the matrix illustrated in Table 5. (See next page)

15 *In order to undertake this analysis, the existing system (including any committed measures) needs to be clearly described and the characteristics understood. It is against the knowledge of the existing system that the trend influences are assessed.*

3. Steps and activities (cont)

TABLE 5

Significant influence matrix



Trend *influences* that fall into the top right-hand (A) quadrant are be considered to be significant because they have high uncertainty and the system is very sensitive to changes in the *influences*. The number of significant *influences* should be limited to a few if possible to avoid complicating the analysis later on in the process. *Influences* that fall into the top left-hand (B) quadrant should be included in all *scenario paths* since they have relatively low uncertainty, but the system is relatively sensitive to changes in the. A Sensitivity Analysis[16] can be conducted on these *influences* at the business planning stage to assess the impact of variations in the assumptions. *Influences* that fall into the lower rows (C and D), indicating low sensitivity, are considered less significant, and so are not taken further in this process.

Once the significant trend influences have been identified, the relationship between the variables of the *measures* of the existing system and each of the significant influences is established to allow the changes over time to be accommodated in the analytical model.

These relationships are incorporated in the analytical models to reflect the changes in the variables (e.g. yield and cost) for each significant trend influence over the analytical period. Care should be exercised to avoid double counting, and to ensure consistent boundaries in cost analyses (over time, and with respect to whose costs are included and if the assessment includes whole of society costs).

16 *Sensitivity Analysis – A guide sheet has been developed for this analysis method.*

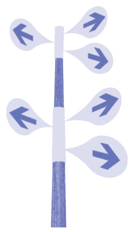
WSDS Example: Identifying significant trend influences

From the list of possible influences that were generated by the WSDS reference group and the influences suggested by the WSDS Guidelines, the following significant influences were identified:

Four Trend Influences:
- Climate change
- Demand
- The urban form
- Energy prices

Four Shock Influences:
- Natural disaster affecting supplies
- Economic collapse
- Sudden energy price spikes
- Community expectations

3. Steps and activities (cont)



3.3 STEP C: SCENARIO PATHS

Purpose: To construct possible futures based on the range of significant trend influences that the water system will operate under and be affected by, and to determine the objective shortfalls for both the existing and future portfolios of measures under these trends.

Outcomes: A suite of trend scenario paths and the objective shortfall for the existing system portfolio of measures.

Activities: **C1:** What are the future trend scenario paths for the planning period?
C2: What is the objective shortfall for the existing system under these trend scenario paths?

Classical scenario analysis usually considers only a two-by-two matrix to develop plausible future scenarios. However this strategic planning process considers more than two significant trend *influences* having a compound effect on the system. Therefore, describing a number of *scenario paths*[17] consisting of various combinations of the trend influences is best to outline the possible future context. These *scenario paths* are all equally possible because probability has not been assigned to them.

To avoid a large number of *scenario path* options to analyse, it is advisable to reduce the number of possible *influence* outcomes. One way to do this is to consider the plausible high and low possibilities of the *influences* when constructing *scenario paths* of *influences* in combination (see Table 6 for an example).

It is necessary to consider the measure-specific trend *influences* identified previously for the existing *measures* as part of the *scenario paths*. Some *measures* are vulnerable to specific *influences* that may not have a bearing on any other *measures* and may not be obvious when looking at the whole system, such as the impact on technology advances in washing machines. It is important to identify these to avoid missing key *influences* that could have an impact on the existing and future system.

Having described the *scenario paths*, the next part of this Step is to determine the impact of each *scenario path* for the existing system in achieving the objectives – this has been termed the objective shortfall. This effectively defines the extent of the problem that the strategy is seeking to solve under each *scenario path*.

Using modelling tools (such as REALM, Excel, End-use Demand Model, WEAP etc), determine the objective shortfall under each *scenario path*. The relationship between the existing *measures* and the trend *influences* is to be incorporated in the analytical models to reflect the changes in the variables.

It is possible that the existing system has sufficient capacity to meet the objectives under the projected trend *scenario paths* and hence there will be no shortfall in the objective and therefore does not require any augmentation. However, the existing system still needs to be checked for its robustness against potential shocks in Step G.

17 *Scenario path – a particular combination of trend influences describing the context at a number of time intervals into the future.*

3. Steps and activities (cont)

WSDS Example: Building trend scenario paths

By drawing on the possible influence trajectories from the WSDS Guidelines, ABS data and utility demand modelling, a number of potential scenario paths can be built.

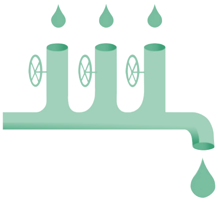
Under each of these scenarios there will be a different objective shortfall for the existing system. Therefore based on the four significant trend influences determined in step B and high and low values for each trend, 16 scenario paths can be described, and hence 16 different objective shortfalls can be calculated for the existing system.

TABLE 6

16 scenarios with combinations of high and low influences

INFLUENCES	SCENARIO PATHS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Climate change	H	L	L	H	H	H	L	H	H	L	L	H	L	H	L	L
Demand	H	L	H	L	H	H	L	L	H	H	H	L	L	L	L	H
Urban form	H	L	H	H	L	H	H	L	L	H	L	H	L	L	H	L
Energy pricing	H	L	H	H	H	L	H	H	L	L	H	L	H	L	L	L

3. Steps and activities (cont)



3.4 STEP D: MEASURES

Purpose: To identify measures that align with the vision and contribute to reducing the objective shortfall under future scenario paths

Outcomes: A shortlist of viable measures that satisfy the key performance criteria.

Activities:
D1: What are the possible measures to meet the objectives?
D2: Which are the effective measures that meet the key performance criteria?
D3: How are the individual measures affected by the contextual influences?
D4: Are there any additional influences that are unique to a measure?
D5: What is the relationship between each proposed measure and each significant influence?

To respond to the projected shortfalls under the various *scenario paths*, viable *measures* (as well as 'fairy godmother'[18] technologies) will be identified. This can be achieved through consultative processes, best practice reviews, previous proposals and expert advice and consultancies, to produce a list of potential measures to achieve the objective function.

Where the list of potential *measures* is very long it is helpful to filter them into a more manageable list of effective measures before considering them in this process. These effective *measures* can be filtered out, using a systematic multi-dimensional approach that reflects the vision underpinning the strategy and comprises the STEEP categories, viz. Social, Technical, Economic, Environmental and Political. Methods such as Cost Effectiveness Analysis, Monetisation, Cost Benefit Analysis, Resource Intensity and Multi-Criteria Decision Analysis[19], are useful in this regard and are discussed later in this document. Care should be exercised to avoid double counting of costs and benefits. The *measures* that effectively meet the key performance criteria at least community cost in broad terms (i.e. social, environmental and economic) should be considered further as effective *measures* to meet the objectives.

Influences impact on both the underlying problem and potential measures to address the problem – for this reason it is important to understand the relationship between the measures and the *influences*, so that the impact on the measures can be properly modelled and assessed. The matrix in Table 7 (see next page), is designed to determine the impact (positive or negative) of each *influence* on each proposed individual measure for regular time intervals. Since the likelihood of the *influences* has already been assessed earlier, the analysis here focuses on the magnitude of their impact on the measure's effectiveness. The assessment is done qualitatively, unless quantitative data is available.

There may be some additional *influences* which specifically impact on the new measures. It is important to identify these to avoid missing key *influences* that may have an impact on the future system. Assess these measure specific *influences* according to their uncertainty, and the sensitivity of the measure to the *influence*. These measure-specific *influences* can either be included in the trend *scenario paths* or as a shock *influence* later on in the process, depending on their nature.

18 *Fairy godmother technologies are those of the future which could have significance for both supply and demand measures e.g. waterless washing, in-home recycling units etc.*

19 *Guide sheets for each of these analytical methods have been developed and are included in this suite of documents.*

3. Steps and activities (cont)

TABLE 7

Examples of the impact of the influences on the yield related measures

INFLUENCES	LOW RAINFALL			ENERGY PRICE SHOCK			INCREASE IN PEAK DEMAND DAYS			INCREASE EVAPORATION		
MEASURES	YIELD	OPEX	CAPEX	YIELD	OPEX	CAPEX	YIELD	OPEX	CAPEX	YIELD	OPEX	CAPEX
Large dam	-2	0	0	0	-1	0	0	0	-1	-1	0	0
Large desal	0	0	0	0	-2	0	0	0	-1	0	0	0
Decentralised sewer recycling	0	0	0	0	-1	0	1	0	0	0	0	0
Stormwater recycling	-1	0	0	0	-1	0	0	0	0	-1	0	0
Toilet retrofit	0	0	0	0	0	0	0	0	0	0	0	0
Permanent water saving measures	0	0	0	0	0	0	1	0	0	1	0	0
Rain tanks	-1	0	0	0	0	0	0	0	0	0	0	0

KEY -2 = Large negative impact / -1 = Small negative impact / 0 = No impact / 1 = Small positive impact / 2 = Large positive impact

Having determined which significant *influences* relate to which future *measure*, define the relationship between them in terms of their capacity to achieve the objectives. The relationship is to be incorporated in the analytical models to reflect the changes in the variables (this is similar to the process undertaken previously for the existing system *measures*).

WSDS Example: Identifying potential measures

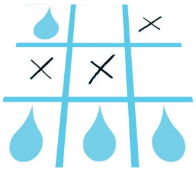
For the WSDS, potential measures have been identified through a number of projects:

- Large Scale Potable Water Supply Options,
- City Scale Alternative Water Options,
- The Alternative Water Atlas,
- Water Efficiency.

The measures will be assessed using the Triple Bottom Line approach and ranked using Multi-criteria Analysis.

The criteria for assessing the measures are based on the objectives for the WSDS and include Community Costs, yield, impact on air water and land, impact on customer price and resilience.

3. Steps and activities (cont)



3.5 STEP E: INVESTMENT STRATEGIES

Purpose: To design a number of policies and rules to determine the sequencing of each type of measure and under what conditions they should be considered.

Outcomes: A number of *investment strategies* to package up portfolios of measures in response to an objective shortfall.

Activities: **E1:** What investment strategies can be used to select and schedule measures?

Investment strategies are set of policy rules and instructions that have been identified as a way to objectively select a number of *measures* to make up a portfolio in response to an objective shortfall. *Investment strategies* include, at a minimum, instructions for the sequence in which the types of measures are chosen; thresholds and triggers for new *measures;* predecessors for some *measures*; constraints of the system for some of the types of *measures*; and lead times before the benefit of a *measure* can be realised.

This approach ensures that specific *measures* (or projects) do not get prioritised at this strategic level, but rather types of *measures* are considered, for example demand side management or stormwater harvesting. The focus is on the strategic approach to addressing the objective shortfall, through the design of sequences of different combinations of types of *measures*, for example to give preference to demand side management measures over infrastructural options. The most preferred *investment strategies* that address the objective shortfall and meet the key performance criteria will be considered for the final strategic outcome.

Using expert judgment and knowledge of existing and foreseeable policies, define the various *investment strategies* that could meet the objectives.

WSDS Example: Designing investment strategies

The following initial investment strategies have been proposed by the WSDS team:

1) Next TBL (least community cost) preferred centralised large scale potable supply measure
2) Decentralised non-potable supply (as city grows), then centralised large scale potable
3) Additional demand side management (DSMplus) now, then centralised large scale potable
4) Decentralised non-potable supply, then DSM, then centralised large scale potable
5) Large recycled water distribution mains pipe, then Investment Strategy 4.

3. Steps and activities (cont)

3.6 STEP F: PORTFOLIOS OF MEASURES

Purpose: To determine the preferred investment strategies under future trend scenario paths by building portfolios of measures to address the objective shortfall.

Outcomes: The preferred investment strategies to consider under shock scenario paths.

Activities: **F1:** What portfolios of measures satisfy each investment strategy under the trend scenarios paths?
F2: Which are the best investment strategies?

Based on the *investment strategies* it is possible to construct *portfolios of measures* to resolve the objective shortfall for each trend *scenario path*. This will enable the identification of the financial cost and cost to society of different *investment strategies* and which strategies are more capable of delivering preferred outcomes under multiple scenarios (i.e. which are more resilient).

For each of the previously described future trend *scenario paths*, construct *portfolios of measures* that correspond to the *investment strategies* in response to the objective shortfalls. An Excel spreadsheet/or model can be used to 'build' the portfolios of measures.

The final part of this Step is to check the systemic effects of the *portfolios of measures*, by using Multiple Criteria Decision Analysis to bring together a qualitative assessment of the social environmental and economic performance of the portfolios. This analysis should be informed by earlier quantitative analysis using for example, Cost Effectiveness Analysis, Cost Benefit Analysis and Resource Intensity. Care should be taken in bringing together assessments of individual *measures* into portfolios where performance may be complementary or negatively compounding. The goal here is not to aggregate qualitatively different forms of performance, but rather to qualify those differences in social, economic, and environmental performance so that they can be highlighted for consideration in decision making processes, leading to transparency in the outcomes.

Since a large number of *investment strategies* may have been considered, the number should be prioritised for further consideration under the shock *influences*. Select the 'top few' preferred *investment strategies* (and therefore the associated portfolio of measures) based on meeting the objectives and criteria as set previously.

3. Steps and activities (cont)

3.7 STEP G: SHOCK INFLUENCES

Purpose:
- To identify significant shock influences from the list of potential shock influences, that will significantly affect the effectiveness of the portfolio of measures, and that have a high level of uncertainty.
- To describe possible futures based on the range of significant shock influences, together with the trend scenario paths, that the water system will operate under and be affected by, and to determine the objective shortfalls for both the existing and future portfolios of measures.
- To determine the preferred investment strategies under future shock and trend scenario paths

Outcomes:
- A number of significant shock influences and an understanding of the relationship between these influences and the existing system.
- A suite of shock and trend scenario paths and the objective shortfall for the existing system portfolio of measures.
- The preferred investment strategies to consider under these scenario paths

Activities:
G1: What are the significant shock influences to the system?
G2: What is the relationship between the shock influences and the existing measures?
G3: What are the future shock scenario paths for the planning period?
G4: What is the existing system shortfall under these shock scenario paths?
G5: What is the relationship between each proposed measure and each shock influence?
G6: What portfolios of measures satisfy the investment strategies under the shock scenario paths?
G7: What new investment strategy could help satisfy the shortfall requirement and the objectives?

Shock *influences* are sudden events which happen unexpectedly and alter the course of a trend, such as sudden economic slumps or bushfires that affect catchments which take a long time to recover, if ever. Shock *influences* move the system to a new 'steady' state and a different operational zone.

The process of this Step is similar to Steps B, C and F, but instead considers the impact of shock *influences* on the system and determines the associated shortfall for that shock *scenario path*.

Firstly, consider the list of shock *influences* (identified in Step B) to determine their significance in terms of their level of uncertainty and the sensitivity of the existing system to them. Then determine the impact of the shock *influences* on the individual *measures* currently in place or committed, and characterise the relationship. If a shock *influence* has the potential to affect overall cost, such as energy pricing, then this relationship should also be built into the model.

Unlike trends, shocks can occur at any time. This means that there is a very high number of potential scenarios that could be derived at this step. Too many scenarios are computationally difficult to manage and can confuse decision

3. Steps and activities (cont)

makers. In order to limit the number of *scenario paths* to analyse, the number of significant shock *influences* should be limited to a handful if possible and they should be considered to happen at only two time steps in the future e.g., early and late in the planning period.

Describe shock *scenarios paths* where the shock *influences* are applied to the high shortfall trend *scenario path* and the low shortfall trend *scenario path* i.e. the envelope of the trend shortfalls for the existing system (so for 4 shock *influences*, 8 shock scenarios will be described). In the same way the total shortfalls were calculated in Step C, consider the shock *scenarios paths* impact on the existing system in terms of the shortfall.

In the same way as Step D, establish the relationship between the shock *influences* and the proposed *measures*. The relationship must be included in the analytical model used previously. Based on each of the 'top few' *investment strategies*, build a *portfolio of measures* to meet the shortfall for each shock *scenario path* for the planning period.

Determine which are the most preferred *investment strategies* (portfolio of measures) under these *scenario paths* by using a similar qualitative Multi-Criteria Decision Analysis to that described in Step F, again building on earlier quantitative analysis using Cost Effectiveness Analysis, Cost Benefit Analysis and Resource Intensity. decision making processes, leading to transparency in the outcomes.

3.8 WATER SUPPLY AND DEMAND INVESTMENT STRATEGY

Based on the analysis in Steps F and G, the *investment strategy* that 'selects' a *portfolio of measures* to satisfy the shortfall requirements under the trend and shock *scenarios paths,* at the least economic, environmental and social cost to the community, is recommended for inclusion in the Water Supply and Demand Investment Strategy.

3.9 INFORMATION FLOWS BETWEEN ACTIVITIES

For the process to be successful, it is important to understand where information is used in the process and what information is required for each Step. The Process Map and the Process Manual indicate the flows of information amongst the many points of connection within and between Steps, and between Activities. Whilst the Steps are broadly linear, there is necessarily some iterating between Steps.

4. Methods for decision making

4.1 OVERVIEW OF THE PROBLEM AND THE POTENTIAL METHODS

The combination of the shift in vision and the need for action in the face of uncertainty means that the industry is increasingly pushing against the frontiers of best practice water resource planning processes and their underlying conceptual and analytical models. While the number of conceptual and analytical models has grown over time, it has become less clear which of these models or frameworks will enable decision making for the water industry that addresses the spectrum of current issues and reflects the vision of the Managing Directors.

The analyses and processes of water resource planning are typically complex, affect various stakeholders, and involve value trade-offs that are challenging or inappropriate to reconcile using expert judgement alone.

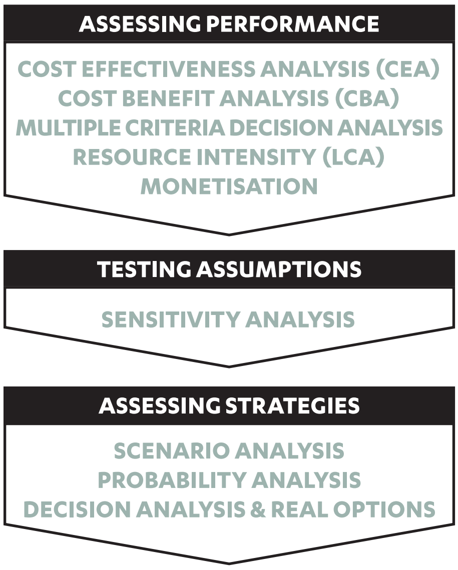
The analyses and processes of water resource planning are typically complex, affect various stakeholders, and involve value trade-offs that are challenging or inappropriate to reconcile using expert judgement alone. Water service providers have therefore sought to involve stakeholders in the decision-making process by applying a series of engagement methods. Although such methods are now embedded in assessment processes, several significant challenges remain: increasingly complex analyses, assessments and decisions must be effectively communicated to a lay audience, diverse values, interests, and local knowledge needs to be represented, and judgements on appropriate levels of service and risk need to be deliberated. The dominant multi-criteria approaches for reconciling multiple objectives suffer from some common pitfalls such as failing to avoid double counting, and conflating qualitatively nuanced tensions within quantitative scores, such that the results do not reflect the assessments and values.

In order to complement the thinking behind the assessment process described in the previous section, a suite of **guide sheets** has been prepared. Each guide sheet focuses on a key method that supports planning for resilient water systems. The nine methods in the guide sheets were identified in collaboration with the WSDS team. They are summarised in the following sections. The methods have been grouped into three types for ease of understanding, viz:

- Methods for *assessing the performance of measures* and/or portfolios of measures in achieving the key performance criteria, and include Cost Effectiveness Analysis, Cost Benefit Analysis, Multiple Criteria Decision Analysis (MCDA), Resource Intensity (Life Cycle Analysis) and Monetisation. These methods can be used to evaluate *measures* at both a strategic level as well as at an operational or project level. The level and type of data required will depend on the stage of the planning cycle.
- Methods for *testing the assumptions* used in the strategic analysis or the project level analysis. The sensitivity of the outcome to changes in the assumptions can be assessed.
- Methods for *assessing strategies* that ensure flexible and robust *portfolios of measures* in response to uncertain influences. The focus is not on specific *measures* and their location, but rather types of *measures* and their responses under various future conditions. These methods (Scenario Analysis, Probability Analysis, and Decision Analysis & Real Options) operate at a strategic level only.

4. Methods for decision making (cont)

FIGURE 3
Water supply and demand investment options assessment methods



In assessing the methods, the following questions were addressed:

- What is the main purpose of the method?
- What relevance does it have for water supply and demand planning?
- What are the key strengths and limitations of the method?
- In what context should the method be used?
- How should the method be implemented?
- What tools are available to undertake the method?

In order that the methods are applied in a consistent manner, a number of overarching principles have been developed:

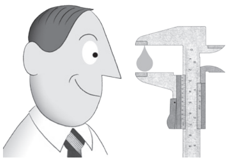
1) Use appropriate assessment perspectives: Assessment perspectives should be considered and specified. Multiple perspectives may be considered. The 'whole-of-society' perspective is critical for promoting sustainable outcomes.
2) Be careful and consistent with defining and applying the boundaries of analysis to different measures
3) Avoid double counting
4) Acknowledge and manage precision and uncertainty: Uncertainty, risk and lack of precision are inevitable and should be acknowledged and managed.
5) Report transparently: The analysis and results are reported in coherent and transparent form.

4. Methods for decision making (cont)

4.2 METHODS FOR ASSESSING PERFORMANCE

Cost Effectiveness Analysis

Cost-Effectiveness Analysis (CEA) is a useful method for comparing a broad suite of measures including both supply- and demand-side options. It enables the comparison of alternative ways of achieving the same objective(s), by determining the least cost means of achieving the specified objective(s) or target(s) such as filling a supply-demand gap or achieving a 25% reduction in per capita potable demand by a specified year. In the context of the urban water sector, CEA may also be useful to compare water supply options in terms of their greenhouse gases environmental impacts translated to a dollar value per megalitre of water supplied



When deciding between various options, CEA can be used to rank the options according to least cost to achieve the same outcome. CEA uses a unitised metric (i.e. $/kL) for comparisons and decisions. It is calculated in various ways. In Australia, the most common approach is levelised cost, based on the present value of both the net cost and the net volume of water saved or supplied., that is, it takes into consideration both the costs and benefits for each option using a full economic assessment and consistent boundary of analysis. CEA seeks to consistently include the capital, operating and avoided costs that accrue to the various key stakeholder perspectives (e.g. government, utility, customer). It may be applied from either an economic (i.e. whole of society) or financial (e.g. utility or developer) perspective. It may be extended further to include greenhouse gas emissions and other externalities. Unlike Cost Benefit Analysis (CBA), in CEA the value of water itself is represented in physical units (kilolitres saved or supplied) rather than in $ units

CEA is well suited to contrast suites or portfolios of options in urban water planning where the underlying objective of providing water services to a community is an accepted public good. It aligns with the existing Integrated Resource Planning (IRP) framework advocated by the Water Services Association of Australia (WSAA) and the National Water Commission (NWC) and avoids the difficulties involved in measuring urban water supply servicing values in dollar terms. However, water service providers are now moving towards integrating an ever broader range of sustainability impacts that are not conventionally captured through CEA. In order to address this, alternative quantitative and qualitative approaches can be used to complement CEA (these are discussed in the following sections).

Cost Benefit Analysis

Cost-Benefit analysis (CBA) is an economic decision-making framework that is widely used to inform public investment choices. Its primary focus is determining whether and to what extent the benefits of a policy, project or action outweigh the costs. By using CBA, different options can be compared using a common dollar metric. CBA involves identifying the dollar values for all costs and benefits associated with an action, project or policy. The decision metric is the net benefit or net cost, or the ratio of total benefits to total costs. Costs and benefits are expressed in present value (discounted) terms, to take into account the time value of money.

As discussed above, CEA determines the viability of one option with reference to a range of alternative options using the metric of dollars per objective unit. CBA

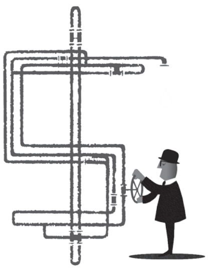
4. Methods for decision making (cont)

in contrast, looks at whether an individual option or action is viable in its own right. That is, CBA tries to answer the question of whether the societal benefits of a particular action or investment or policy outweigh the societal costs. A positive result from a CBA however, fails to reveal the existence or otherwise of more cost effective alternatives.

Using CBA involves quantifying in monetary terms the direct and indirect impacts on all potentially affected stakeholders – including the utility, government and community. In principle, decisions based on CBA seek to achieve the greatest total benefit to society, in contrast to narrower financial analyses, which might seek to maximise the return to an individual business.

The key decision metric of CBA is the net benefit or net cost, or the ratio of total benefits to total costs. Costs and benefits are expressed in present value (discounted) terms, to take into account the time value of money. When deciding whether to implement a specific project, CBA can be used to determine whether the project's total benefits outweigh its total costs – that is, whether its benefit-cost ratio is greater than 1.0. When deciding between a range of options, CBA can be used to rank options in order of benefit-cost ratio or net present value.

CBA is widely recognised as a key economic approach to decision-making. In Australia, CBA is widely endorsed and required by State and Commonwealth Treasuries as a crucial element of deciding whether to implement a new regulation, and for policy and project appraisal. The Office of Best Practice Regulation within the Federal Department of Finance and Deregulation promotes CBA as a best-practice approach to regulation decision-making. Its acceptance as a decision-making approach extends beyond regulatory analysis to other decisions about investing public funds or to meet social or environmental objectives.



Monetisation
Monetisation, or measuring impacts in dollar terms, is one key approach to reflecting a wide range of economic, social and environmental considerations in a urban water strategic planning and decision processes. By estimating dollar values for social and environmental impacts (externalities), they can be evaluated alongside financial costs and benefits in order to facilitate a full economic assessment of a planned urban water project, program or policy. Externalities are defined as the costs and benefits of a transaction not reflected in the market price and borne by a third party. These impacts span a wide range of economic, environmental and social dimensions such as ecosystem functioning, water quality, flood risk reduction, recreational uses, and social and cultural values.

The Melbourne water industry is committed to contributing a wide range of environmental and social sustainability outcomes. The strategic vision and principles for the water resources planning management encompass a wide spectrum of outcomes and stakeholders including protecting and enhancing public and environmental health, social equity, security of supply, and efficient planning and managing of assets. Measuring outcomes in dollar terms is one potentially powerful way to inform decisions which have multiple objectives, including by comparing them with conventionally recognised financial, capital and operating costs.

4. Methods for decision making (cont)

Several key policy documents, including the Central Region Sustainable Water Strategy (CRSWS) and the Melbourne Triple Bottom Line reporting guidelines, are driving the Victorian water industry's focus on extended economic assessment of water supply and demand options. Although there is currently no regulatory requirement to take externalities into account when setting prices for water, monetising these impacts can provide a starting point for engagement with stakeholders from other sectors, such as local government and the Department of Health. Likewise by quantifying benefits and identifying third party beneficiaries, the water service provider may be able to solicit contributions to water scheme investments (e.g. from developers who will be able to increase property prices).

Its limitation is in the process of assigning an appropriate dollar value. That is, the reliability and broad acceptance of dollar values as an adequate representation of worth diminishes rapidly with distance from the market. The need to value benefits is particularly acute for urban water projects because the provision of water services to urban populations is seen as a necessity, a government responsibility and a right for people within our community. Problem structuring approaches (such as Multiple Criteria Decision Analysis) provide an effective alternative approach to monetisation when there is a need to consider broader socio-economic and environmental impacts.

Resource intensity

Taking a life cycle view of a material's use and its impacts is essential in planning for sustainable futures. Life Cycle Assessment (LCA) facilitates this life cycle view because it is the systematic analysis of what materials are required to deliver a service or product, and what potential environmental and human health impacts are created along the way. There are two primary drivers for taking a life cycle view: firstly because high impacts can occur at any stage of a material's life, and secondly, because impacts are not related solely to mass, i.e. small quantity materials can have high environmental or human health impacts which would go unnoticed in the absence of LCA.

The concept of 'life cycle' in LCA terms extends beyond its common usage in the water sector. It is a 'cradle-to-grave' view – it is interested in all the inputs and outputs associated with raw material extraction, manufacturing and production (i.e., translation of those raw materials into products), use, and end-of-life (i.e., reuse, disposal, etc.). In contrast, analyses of performance in the water sector that use the term 'life cycle', e.g., life cycle costing, are usually focused on only the 'use' phase of an asset i.e. planning, construction, operation, and decommissioning.

However, impacts can occur at any point within the broader life cycle. That is, all materials have an impact history before they enter the use phase. Similarly, all materials create an impact when they leave a site or are taken out of use. For this reason, LCA starts with a focus on the potential environmental impacts for the use phase of an option or infrastructure project, but extends 'backwards' to include the impacts along the supply chain, such as mining, smelting and refining of the steel used in construction, or polymers used in membrane filters, and 'forwards' to include the impacts beyond use, such as in discarding membrane filters.

LCA is a valuable tool that can help to identify the optimal mix of measures, including both demand and supply strategies, and considering alternative

4. Methods for decision making (cont)

supplies at various scales. Several water utilities in Australia have already undertaken LCA studies to understand the environmental sustainability of water service provision. The process of undertaking LCA within a water utility can enhance information exchange and encourage stronger relationships between planning and operational staff. External opportunities also exist: LCA results can be used for engaging stakeholders, to promote policy reforms, and to support marketing materials to promote behaviour change.

Multiple Criteria Decision Analysis
The purpose of Multiple Criteria Decision Analysis (MCDA) is to function as an aid to decision making. In any form of systems planning, MCDA provides a structured means for integrating quantitative and qualitative goals and weighing up the performance of a set of options against these goals. MCDA is especially useful in the public sector because of the need to be responsive to broader goals. If used well, the structure provided by MCDA has the potential to provide confidence for decision makers, and improved transparency in an audit trail.

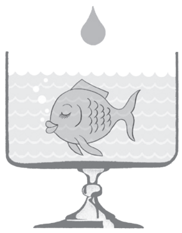
The terminology around MCDA can be a little confusing. Some use the term Multi Criteria Assessment or Analysis (MCA), while others use the term MCDA. In these resources, we prefer the term MCDA for two reasons. Firstly, because it makes explicit the focus on decision making, and secondly, because it provides a distinction between what is proposed here, and the less structured and often problematic applications of MCA in the water sector historically.

MCDA is both an approach and a set of techniques or methods. Methods of MCDA (there are many different methods under the MCDA umbrella) respond particularly to the challenges of seeking accommodations (consensus rarely exists, but accommodations can generally be found) between differing and perhaps conflicting objectives, and between different stakeholder groups. MCDA should form the framework within which stakeholder values and goals are elicited and compared.

The fundamental process of MCDA is (a) to structure the problem in terms of the criteria of evaluation and the alternatives (policies, options, etc.) to be evaluated; and then (b) to assess each alternative in terms of each criterion by value judgments informed by the available impact data. The subsequent aggregation of preferences across criteria typically makes use of quite simple mathematical tools. Within and between these steps, there is typically much iteration to arrive at agreeable outcomes.

The outcomes that are guiding water planning (both medium term (5 year) investment plans and long term (50 year) strategies) are changing, and are increasingly extending well beyond traditional water supply and demand planning goals of safety, security, and efficiency to encompass sustainability and live-ability goals. Making these objectives explicit and transparent within the water planning process requires a new approach informed by effective MCDA that goes beyond existing requirements and much of the existing experience in the water sector. That is, whilst MCA has been applied extensively in the water sector in recent years, it has often been inadvertently misused, in that the focus has been on the numbers for weighting and scoring of criteria, as opposed to stakeholder involvement in deciding on the criteria and the discussion and conversation to reach accommodations. For this reason, effective MCDA offers much to water supply demand planning processes at various levels of detail.

4. Methods for decision making (cont)



4.3 METHODS FOR TESTING ASSUMPTIONS

Sensitivity analysis

Sensitivity Analysis measures the material impact on the outcome of changing one or more key input parameters about which there is uncertainty. It can also be applied to provide a preliminary indication of the robustness of the assessment findings subject to variance in the assumptions associated with for example, climate variability, climate change and customer demand.
A Sensitivity Analysis is therefore a crucial part of the options assessment process informing the water supply and demand strategy.

Definitions of Sensitivity Analysis and Probability Analysis overlap and vary. Here, we have taken a simple view of Sensitivity Analysis and confine it to non-probabilistic approaches to assessing the impacts of uncertainty i.e., gaps in the accuracy or precision of our specification of contextual influences. That is, Sensitivity Analysis can be used to assess uncertainty for a single measure, for portfolios or suites of measures, or for different scenarios, but only in fairly simple ways because of the non-probabilistic constraint. Probability Analysis handles more complex forms of uncertainty in meaningful and elegant ways because it assigns probabilities to the influences.

Since options analysis usually involves complex modelling exercises, varying the underlying assumptions of the model within plausible ranges enables the identification of those assumptions that have the greatest influence on the outcome. The range of outcome results will give an indication of the confidence that can be attributed to the result. In addition, Sensitivity Analysis is essential for assessing which gaps in knowledge matter most. This method is useful in addressing the uncertainty in the key parameters and assumptions (e.g., cost estimates, water balances, discount rate, timing etc) to determine the relative robustness of measures and preferred solutions.

One of the key limitations of Sensitivity Analysis is its inability to assess the robustness of strategies subject to uncertainties in combination. Even for mathematical models Sensitivity Analysis is often only performed in a univariate way (i.e. identification of the change of the outcome of a model as a function of change of one parameter of the model). Since most useful models depend on more than one parameter (multivariate models) and the parameters are interdependent to certain degree, to undertake a multivariate Sensitivity Analysis is very complex, laborious and costly. For such situations either Scenario Analysis or Probability Analysis is necessary.

4.4 METHODS FOR ASSESSING STRATEGIES

Scenario Analysis

Scenario Analysis is the process of analysing possible future events through the consideration of alternative, plausible, though not equally likely, states of the world (scenarios). They are typically used in the context of either planning over long time horizons or making short-term decisions that have long-term consequences.

Scenario Analysis provides an explicit basis for analysing and improving the diversity and robustness of portfolios subject to a range of possible futures. In so doing, tensions between planning for a broad range of possible futures and minimising cost can be managed. By avoiding the quantitative expression of probabilities, the key strength of Scenario Analysis is in allowing the analysts to

4. Methods for decision making (cont)

creatively explore a suite of possible futures. This quality is advantageous for analysing uncertainties characterised by a lack of knowledge or a significant normative dimension, or for analysing the consequences of discontinuities or surprises.

Scenarios are not forecasts or predictions. Nor are they intended to be probabilistic or representative of the most likely future, but are rather meant to portray a set of alternative futures that could occur, no matter how improbable the outcome. Scenario Analysis should be distinguished from Probability Analysis and Sensitivity Analysis. Scenarios are well suited to challenging conventional thinking and accepted assumptions when creating possible futures, whereas Probability Analysis takes a quantitative probabilistic approach to analysing the uncertainties that could arise under different circumstances, both in the present and the future. Sensitivity Analysis assesses how variations in specific factors (e.g., rainfall) can affect an output (e.g., stream-flow, system cost).

In the design of the scenarios, Scenario Analysis incorporates a wide spectrum of perspectives (e.g. of various stakeholders), through scenario workshops. Buy-in to the process and the outcome is facilitated through this process. It also ensures that no essential aspects regarding the system under consideration are missed.

Classical scenario analysis usually considers only a two-by-two matrix to develop plausible future scenarios. However, the strategic planning process presented in this document considers more than two significant *trend influences* having a compound effect on the system. Therefore, describing a number of *scenario paths* consisting of various combinations of the trend *influences* is best to outline the possible future context. These *scenario paths* are all equally possible because probability has not been assigned to them.

Probability Analysis
Urban water systems exist in a dynamic environment characterised by significant levels of uncertainty. Though some uncertainties can be managed through Sensitivity Analysis to identify necessary redundancies, such approaches are not always feasible or effective, necessitating a more diversified portfolio approach. Probability Analysis (or Uncertainty Analysis) provides an explicit basis for analysing and managing the diversity and robustness of portfolios of measures subject to uncertainty by assigning probabilities to those uncertainties. In so doing, plans for a broad range of possible futures with minimised cost can be achieved. Diverse portfolios of measures increase the robustness of the water supply system to sudden shocks and unanticipated changes in the contextual parameters. By assigning probabilities to the uncertainties, the analysis can systematically and simultaneously consider a large number of uncertainties.

Probability Analysis can be applied at various levels – for the performance of an individual measure, for portfolios or suites of measures, and for different scenarios with suites of measures. As the number and complexity of measures and scenarios increases, so too does the complexity of analysis. The quality of the outcomes of probability approaches is determined by the quality of the inputs and calibre of the models. At the simple end of this spectrum lie well-established techniques like Monte Carlo Analysis. At the more complex end of

4. Methods for decision making (cont)

the spectrum (multiple scenarios and portfolios) these methods are not well established in practice for the water sector at this time, so the inputs and models need careful consideration to avoid being questionable.

The key strength of Probability Analysis with respect to more 'deterministic' assessment methods is that uncertainty is explicitly analysed and managed. This analysis typically reveals the benefits of diversified portfolios that are more resistant to variability and fluctuations, resulting in lower costs for similar risk profiles. The key strength of probability analysis with respect to its key alternative, scenario analysis, is that probabilities are quantified explicitly, enabling the decision-making team to simultaneously and systematically analyse a large number of uncertainties in combination on balanced terms.

Probability Analysis methods are associated with a significant additional analytical complexity (and ultimately cost) that can not be justified for many situations. Rigorously eliciting and modelling probabilities for each significant uncertainty can be laborious and expensive, often necessitating shortcuts in probability elicitation, analysis and reporting. Furthermore, it is often impractical or unsuitable to assign quantitative probabilities to uncertainties characterised by a significant normative dimension (e.g. land use policy) or high levels of ignorance, ambiguity, or novelty (e.g. climate change). It is therefore useful to scrutinise uncertainties associated with key underlying drivers using Scenario Analysis methods.

Decision Analysis and Real Options

Though some uncertainties can be managed using Scenario and/or Probability Analysis to form diversified portfolios, developing a sufficiently robust portfolio isn't always feasible or effective, necessitating a more flexible or adaptive strategy. Decision Analysis and Real Options provide this explicit basis for analysing and managing the flexibility and resilience of strategies subject to uncertainty and surprise by assigning probabilities to the uncertainty and introducing decision rules which are dependent on the state of the system, e.g. dam levels. Decision Analysis methods are therefore effectively an extension of Probability Analysis methods to account for managerial flexibility

Decision Analysis and Real Options methods incorporate a learning model, where more informed strategic decisions are made as some levels of uncertainty are resolved over time. The outcomes should be continually refined as new information becomes available over time. Cost Effectiveness Analysis in contrast considers a static investment decision, and assumes that strategic decisions are initially made with no opportunity to choose other options in future. The former implies a dynamic decision-making process, whereas the latter implies a one-time decision-making process.

The key strength of Decision Analysis with respect to more 'passive' assessment methods, is that proactive managerial flexibility or adaptive capacity are less exposed to shocks and surprise, resulting in lower costs for similar risk profiles. Probabilities and optimisation rules are quantified explicitly, enabling the decision-making team to simultaneously and systematically analyse a larger number of uncertainties and options in combination on balanced terms.

Decision Analysis methods are associated with a significant additional analytical complexity (and ultimately cost) that won't be justified for many situations and

4. Methods for decision making (cont)

may obscure perverse decisions and unacceptable outcomes. Owing to this computational complexity, decision analysis methods can only analyse a limited number of uncertainties, options, and time steps. Although this limitation may be reduced using Sensitivity Analysis methods and option screening, this limitation will preclude its application to broad assessment studies.

Contingency Analysis
The key alternative or complementary method to Decision Analysis and Real Options is Contingency Analysis. Where the first two methods apply an optimisation procedure to explore all possible contingency paths, Contingency Analysis explores each contingency individually and assesses the most appropriate course of action qualitatively. Contingency Analysis methods may be applied for initially assessing flexibility subject to drought and other critical shocks without the analytical complexity and cost of a comprehensive Decision Analysis. Contingency methods may also be applied in combination with Decision Analysis methods as a means for identifying critical contingencies for more detailed quantitative assessment. Contingency Analysis has not been included in this suite of guide sheet, but is an appropriate method when preparing periodic drought response plans such as the Water Outlook prepared by the Melbourne water utilities.

TABLE 8
Examples of the impact of the influences on the yield related measures

	INCORPORATES PROBABILITY	INCORPORATES DECISION RULES	MEASURES ROBUSTNESS (DIVERSITY)	MEASURES FLEXIBILITY	UNCERTAINTY MANAGEMENT	SIMPLE / COMPLEX ANALYSIS
Sensitivity Analysis	No	No	Somewhat	No	Iterative testing of changes in parameters	Simple
Scenario Analysis	No	No	Yes (if done properly)	No	Development of scenarios and the identification of common or no-regrets strategies for future point in time	Moderate (though only suitable for simplified problems, limited number of options)
Probability / Uncertainty Analysis	Yes	No	Yes (if done properly)	No	Assigning probabilities	Complex (particularly if done properly)
Decision Analysis / Real Options	Yes	Yes	Yes (it typically includes an Probability Analysis)	Yes	Assigning probabilities and defining decision rules	Complex
Contingency Analysis	No	Yes	Yes (usually used in combination with scenario analysis)	Yes	Assigning and defining decision rules	Moderate (though only suitable for simplified problems with a limited number of options

Appendix: Key definitions and terminology

Context refers to the system and global environment within which the analysis is undertaken

Extreme variability – Extremes in the trends of normal variation (e.g. seasonal or annual fluctuation)

Fairy godmother technologies are those of the future which could have significance for both supply and demand measures e.g. waterless washing, in-home recycling units etc.

Flexibility characterises a portfolio of measures that can be altered to suit changing trend conditions at minimal additional community cost, e.g. avoiding large centralised supply systems with long lead times.

Influences are the pressures and drivers that have an impact on the context and the likely outcome of a measure.

Investment Strategy is a set of policy rules and instructions as to the sequence in which the types of measures are chosen, the thresholds and triggers for new measures, predecessors for some measures and the constraints of the system.

Key performance criteria are a set of indicators used to measure the effectiveness of a measure or portfolio of measure in meeting the set objectives

Measures refers to the options identified in response to influences in the context.

Objective shortfalls refers to deficiencies in the existing measures to meet the requirements of the objectives e.g. volumetric shortfall in supply requirements, shortfall in meeting minimum GHG or nitrogen targets

Portfolio of Measures are a group of measures that satisfy an investment strategy

Redundancy refers to the spare capacity required to ensure adequate system capacity is available if a portion of the system fails due to malfunction or an external impact, such as pump failure or a natural disaster disrupting part of the system.

Robustness characterises a portfolio of diverse measures that are not all dependent on the same influences and hence the impact of the variability in the influences is mitigated i.e. not have all ones eggs in one basket, e.g. conjunctive supply sources.

Scenario Path – a particular combination of trend influences describing the context at a number of time intervals into the future.

Shock Influences – Step changes in the trends (we don't know how big or when it will occur)

Trend Influences – Gradual changes (but we don't know how gradual or in which direction)

Uncertainty is the possible range within which an influence will manifest itself. An envelope of this range should be considered when analysing the impact of the influence on the proposed portfolio of measures.