SUMMARY REPORT: FINAL

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Pacific Adaptation (Costs and Benefits) Scenarios

Water Security in Tuvalu: Summary for Policy Makers

Australian Aid

Australian Government
Department of the Environment

TUVALU MO TE ATUA

PACCSAP

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) programme is building the capacity of Pacific Island Countries to manage future climate risks. While there is widespread concern about climate change across Pacific Island Countries, there are still significant gaps in understanding the likely timing, nature and extent of impacts and the types of effective adaptation actions available. Economic analysis of climate change impacts and adaptation options is particularly limited. Such an analysis would assist central agencies and decision makers to make more informed development decisions given competing priorities and constrained resources.

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TABLE OF CONTENTS

1. Introduction

1.1 Study purpose

The Australian Government Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) programme aims to develop the capacity of Pacific Island Countries (PICs) to manage climate risks. The Pacific Adaptation (Costs and Benefits) Scenarios study is a component of PACCSAP. It aims to increase the capacity of decision makers in PICs to assess the costs and benefits of adaptation strategies. To that end, a 'water security' cost-benefit case study was undertaken in Tuvalu with the goals of:

- improving understanding of options for achieving short and longer term water security in Tuvalu;
- developing and testing a framework for assessing the costs and benefits of water security options in the context of climate change; and
- increasing the capacity of decision makers in Tuvalu to assess the economics of strategies and investments, with a focus on water security planning.

This report documents outcomes of the study as applied to the first two goals. The third goal – increasing capacity of decision makers in Tuvalu – is outlined in Appendix A of the technical report.

Water security was selected as a cost-benefit case study recognising that a number of PICS are already facing threats to their water security, including from population growth and climate change and variability. Tuvalu was identified for the water security case study due to the Government of Tuvalu signalling interest in drawing on economic analysis to help inform decisions in the water sector.

1.2 Why Cost-Benefit Analysis?

This case study examines the use of cost benefit analysis (CBA) to assess the best course of action for achieving water security in Tuvalu considering the impacts of climate change. CBA is a valuable tool for comparing alternative options at the project, strategy or policy level. Its advantages over other assessment techniques, such as multi-criteria analysis, are:

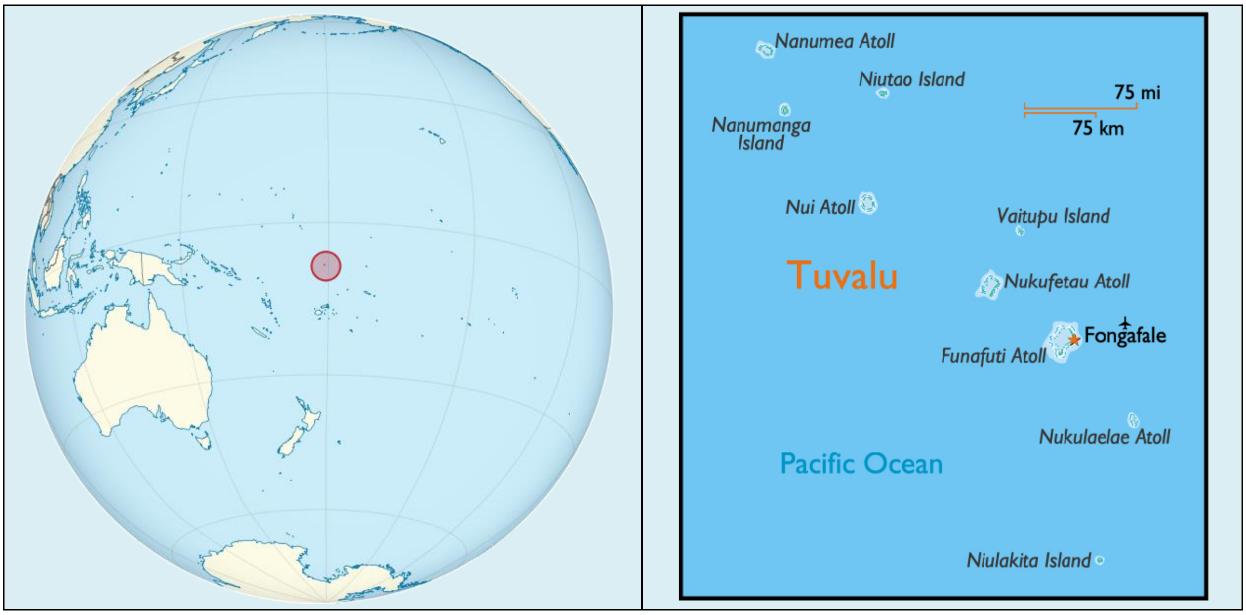
- it uses a common unit of measure (dollars) to assess options that have a wide range of costs and benefits; and
- it can also be used to assess options with different scales and over different timeframes.

It can therefore provide an understanding of the course of action that will provide the greatest net benefit to society over time.

1.3 Background and approach

After discussion with stakeholders in Tuvalu, two areas were selected as sites for water security cost benefit studies. Funafuti is the most populous atoll in Tuvalu (estimated 5,200) and the country's capital. Vaitupu has the largest area of the country's nine atolls and a significant population (estimated 1,600) including the country's largest school (see Figure 1).

Figure 1: Location of Tuvalu, showing Funafuti, Vaitupu and other atolls and islands



Factors influencing site selection include:

- together the two atolls contain almost 61% of Tuvalu's total population;
- both islands face regular water shortages, notably during the severe 2010-2011 drought; and
- the water supplies of both atolls are characterised by being highly rainfall dependent, but there are contrasts between the islands in terms of stresses and potential additional water supplies[1].

Recognising their contrasting circumstances, separate CBAs were undertaken for the two islands, within a broader decision making framework. Workshops were used to take officials from Tuvalu government ministries and regional development organisations through the framework applied to the analysis and to validate data used in the analysis. A smaller CBA mentoring group was also set up to review the process outputs in more detail.

1.4 This report

This 'Summary for Policy Makers' report presents a summary of the framework and process applied to the analysis. Summary results of the analysis, as it relates to this case study, are presented in boxes. Key findings and recommendations are also presented. A separate technical report provides more detailed analysis of the Tuvalu case study including results.

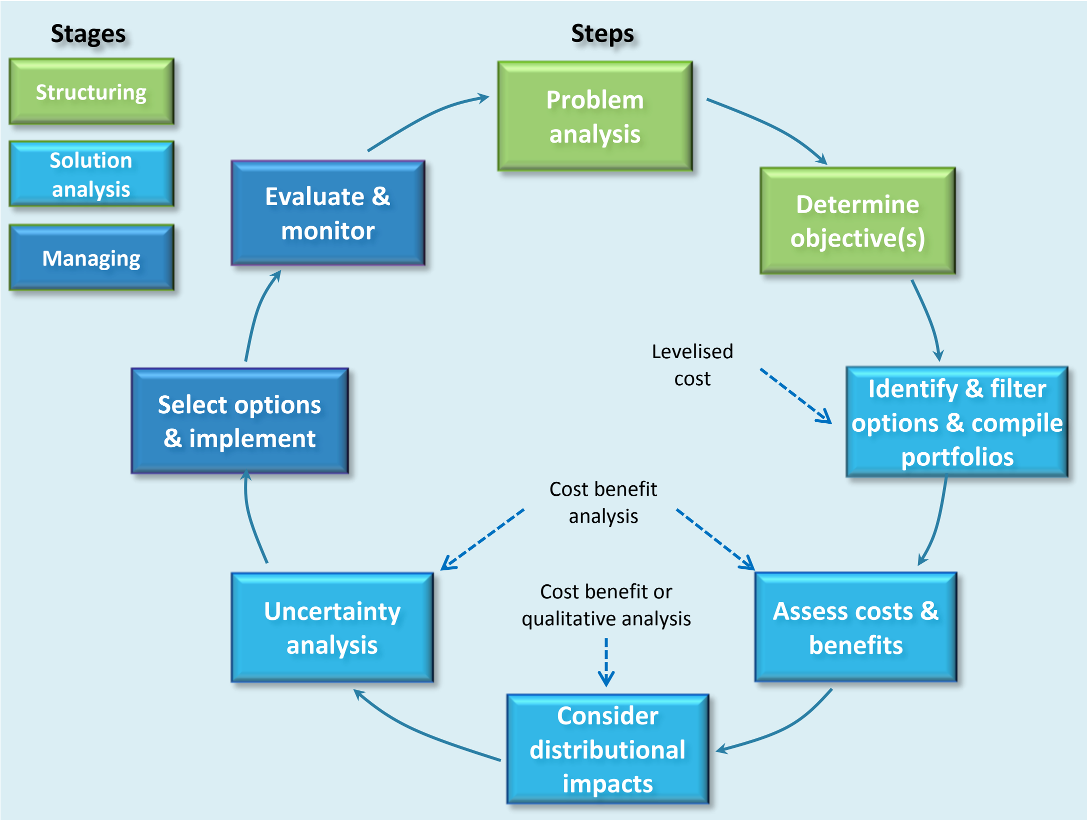
1 For example, whereas Funafuti's groundwater is severely contaminated, effectively ruling it out as a viable water source, available evidence indicates that Vaitupu's groundwater has the potential to be an additional water source provided it is carefully managed.

2. Framework applied to the analysis

2.1 Framework overview

The framework applied to the analysis closely follows the process set out in the guide *Cost-Benefit Analysis for Natural Resource Management in the Pacific*[2] – an important reference guide for decision-makers in PICs. However, the framework applied to this study contains elements that go further than the guide. This is because the multi-faceted nature of the water security challenges faced by Tuvalu and other PICs, including climate change, means that a strategic assessment is preferred to a project by project assessment. In practice this means the CBA is part of an integrated decision making process - useful for developing a (water security) strategy or plan that is intended to cover short and longer term actions. The integrated process comprises three main stages – 'structuring of the issue or problem', 'solution analysis' and 'managing the problem' – each of which entail a number of steps in turn (see Figure 2). Economic analysis is applied at different steps in the solution analysis stage of the process, with cost-benefit analysis being used in the detailed assessment of costs and benefits of options, as well as being used to capture key uncertainties such as climate change.

Figure 2: Stages and steps of water strategy development, indicating where economic analysis used



The process stages and steps are discussed in the following sections, providing specific learnings from application of the framework to the water security case study in Tuvalu.

2 Buncle, A., Daigneault, A., Holland, P., Fink, A., Hook, S., and Manley, M., 2013. *Cost-Benefit Analysis for Natural Resource Management in the Pacific: A Guide*, SPREP and SPC, Suva.

2.2 Problem analysis

Problem analysis is a crucial early step in the decision making process. It establishes the nature of the water security issues or problems to be addressed and is important for informing development of water security objectives (section 2.3) and options for dealing with the problem (section 2.4). Key questions that should be answered at this point include:

- Which regions, communities and individuals are being impacted by problems with water shortage or water quality, when are they being impacted and how severe are the impacts?
- What are the main causes or drivers of the problems – climate and non-climate?
- How do existing water supplies address or fail to address current and projected water security needs?

Risk assessment

Risk assessment provides a means of structuring responses to these questions. Risk is defined as *the likelihood and consequence of a hazard*. Thus risk assessment in the context of water security involves quantifying or otherwise validating the likelihood of the climate and non-climate factors driving water shortages or poor water quality and the consequences of water shortages or poor water quality for communities. The risk assessment is best formalised through an established risk assessment process, notably ISO 31000:2009, which goes through structured process of identifying the full range of risks to water security considering key climate and non-climate drivers (e.g. population growth) and then rating each risk based on its likelihood and expected consequences. However, a formal risk assessment process is not necessarily essential, to identify the nature and severity of water security problems. Instead, the nature and severity of water security problems can often be identified by drawing on experiential knowledge (see Box 1).

Climate change risks

It is important that climate change and associated risks are fully identified at the problem analysis step. Generally speaking, climate change has the potential to add to established water security risks to rainfall dependent systems by increasing rainfall variability (increasing drought incidence) and/or reducing average rainfall for a given period (increasing drought severity). Countries such as Tuvalu, which already experience high inter annual and year on year rainfall variability, will have a fairly good understanding of the potential consequences of increasing drought frequency or severity. Much less certain is the likelihood of these changes. Current rainfall projections for Tuvalu indicate it is possible there could be either an increase or decrease in average rainfall in the future. There is even greater uncertainty about the potential for an increase in the frequency or severity of drought.

More intense storm surges, driven by increased intensity of tropical cyclones and sea level rise, could also lead to greater salt water intrusion into groundwater, salinising freshwater lenses. Understanding the likelihood and consequence of this risk requires oceanographic and groundwater modelling.

Given uncertainties of this nature, and in the absence of more detailed modelling, scenario analysis is often the most appropriate way to build climate change risks and response into the analysis. This is the approach used for the Tuvalu case study (see section 2.5).

Box 1. Key risks to water security in Funafuti and Vaitupu

Drawing on their professional and personal experience, stakeholders were readily able to identify key risks to water security in Funafuti and Vaitupu, at a Workshop held in Tuvalu in March 2014. Risks were subsequently formalised and validated outside of the workshop. Key risks include:

1. Insufficient water storage to meet demand during dry spells and droughts necessitates frequent water rationing from community and government supplies (Funafuti and Vaitupu).
2. Lack of responsibility for the maintenance of water tanks and gutters leads to reduced reliability of household and (to a lesser extent) community water supplies (Funafuti and Vaitupu).
3. Population growth, combined with changing household practices and limited water demand management, leads to growth in water demand (Funafuti and, to a lesser extent Vaitupu).
4. Contamination of groundwater limits access to alternative, non-rainfall dependent water supplies (Funafuti).
5. Inadequate training and resources limit the reliability of desalination as an alternative water supply during dry spells (Funafuti).
6. Poor water and land management practices threaten viability of groundwater as an alternative, non-rainfall dependent water supply (Vaitupu).
7. Changed rainfall patterns due to global climate change leads to an increase in the frequency and/or severity of dry spells and droughts further threatening the reliability of rainfall dependent water supplies (Funafuti and Vaitupu).
8. More intense storm surges, driven by increased intensity and frequency of tropical cyclones and sea level rise, could also lead to greater salt water intrusion into groundwater, salinising freshwater lenses (Vaitupu).

It should be noted that risks 1-4 are already being experienced, implying that their future likelihood is essentially certain. These risks considered together point to the desirability of taking a strategic approach to water security planning in Funafuti and Vaitupu. This approach will combine increased water supply capacity with improved management of resources, both at the household and community levels. Risk 5 (reliability of desalination) is less certain but still very likely. It points to the need to move away from dependence on desalination, at least for emergency water supplies, unless the necessary training and resources can be found to ensure its total reliability. Similarly, threats to groundwater in Vaitupu, although not certain are at least possible, suggesting that any move to increase reliance on groundwater needs to be very carefully managed.

Water supply-demand analysis

In the context of water security planning, supply-demand modelling is an important aspect of the problem analysis, providing a means of validating risks by quantifying the balance between existing water supplies and demand, including in times of drought. The supply-demand modelling can then be used to help set achievable water security objectives (section 2.3) and identify portfolios for meeting those objectives (section 2.4). Supply demand modelling can be (and is generally) undertaken as an Excel spreadsheet based model that captures key variables such as:

- storage capacity (e.g. water tanks and cisterns);
- water yield given rainfall and run-off (which in the case of household tanks and community cisterns is primarily determined by roof collection area and gutter condition); and
- household/ community water demand.

In the case of Funafuti and Vaitupi, supply-demand modelling confirmed the frequency and severity of constraints in water availability given historic rainfall patterns (see Box 2). The modelling also provided parameters for water supply objectives and targets, and informed development of options to meet those targets.

Box 2. Water supply-demand balance in Funafuti – the base case

Water supply-demand modelling was undertaken in Funafuti to determine potential shortfalls in water supply assuming a ‘standard’ drought scenario. The standard drought scenario is based on the lowest 12 months of rainfall in the historic record (2010-2011). Other assumptions include:

- The water storage capacity of existing household tanks and community and government cisterns (including two currently under construction) remains unchanged.
- Desalination plants are not available to provide an ongoing, reliable supply of water.
- 70% of households live in houses with a small roof area, with each household having an average of 1.8 rainwater (10kL) tanks and an average daily consumption of 350 litres/ household/day when there is no rationing. It is estimated that about 300 litres/ household/day is required to meet essential needs.
- 30% of households live in somewhat larger dwellings, with each household have an average of 3.85 rainwater tanks and a daily water consumption of 550 litres/household/ day.
- There is a gradual decline in the condition of gutters and roofs on houses and public buildings that are used to collect water.
- Funafuti’s population continues to grow at a rate similar to the growth rate experienced over the past decade.

Under the base case, small households run out of water from household tanks on 162 days of the year, struggling to meet their water needs for five to six months. This is consistent with reports from workshop participants and others as to the situation in Funafuti in low rainfall years.

In a drought scenario similar to 2010-2011 and in the absence of desalination water supplies, once tanks have run out, community and government cisterns are able to supply water across Funafuti for the remainder of the year, provided water is rationed at an emergency level of (average) 45 litres/ household/ day (a rationing regime that was in place at the height of the 2011 drought). However, storage levels of cisterns fall well below 20% of total capacity and due to population growth, even the emergency target could not be met if a drought similar to 2010-2011 were to eventuate in 2022 or later (2019 or later if a worst case drought scenario were to eventuate – see Box 6).

Furthermore, 45 litres/ household/day is probably insufficient to meet an average household’s critical water needs (drinking, cooking and personal hygiene), estimated to be approximately 90 litres/ household/ day. In the absence of desalination water, the current stock of rainwater tanks and cisterns are not able to meet these needs in a drought year.

Having established the potential supply shortfall under the base case, the next step for water supply-demand modelling was to establish additional supplies required to meet short and longer term water security objectives (see Box 3).

Water security strategy

As noted in Box 1, the range of issues confronting Funafuti and Vaitupu point to the need for a strategic approach to water security planning for those islands (and other islands in Tuvalu). Addressing water security from a strategic perspective can be contrasted with a more piecemeal approach that considers problems/ risks in isolation and individual options for addressing each of those problems. By contrast, a well-considered water strategy has the benefits of:

- providing a structured plan for governments of PICs (in this case the Tuvalu Government) and donor partners - this structured plan will be based around establishing well-defined objectives (2.3) and developing, assessing and implementing portfolios for achieving those objectives (sections 2.4-2.6);
- addressing short term, critical problems as well as improving and sustaining water security in the longer term across the country;
- making informed choice so as to provide the greatest community return ('bang for buck') for investments.

We note that strategy development is already underway in Tuvalu[3]. When further developing this strategy it will be useful for the government to ensure that the strategy addresses the identified problems and risks in a structured manner, using a portfolio approach to identify and assess suites of options against well-defined objectives.

2.3 Determine objective(s)

A well-defined objective or objectives will provide the foundation for a water security strategy. Objectives will be critical to understanding where water planning should be heading and for assisting with the process of identifying and assessing water security options.

Noting the earlier discussion of the benefits of a strategic approach to water security planning, it may be useful to have multiple objectives, with a short term objective linked to critical problems followed by longer term, more aspirational objectives. This approach is consistent with objectives that emerged from a workshop with stakeholders in Tuvalu (see Box 3). Valuable attributes of objectives include:

- that they are measureable; and
- (where there is more than one objective) they do not contain inconsistencies, although they may be subject to constraints or conditions.

Noting the first attribute, supply demand modelling can help to refine objectives based on what is practically achievable.

[3] Draft Tuvalu Integrated Water Resource Management Plan.

Box 3. Possible water security objectives for Tuvalu (Funafuti and Vaitupu)

Water objectives for Tuvalu as defined in the Draft Tuvalu Integrated Water Resources Plan are to:

1. Provide sufficient good quality freshwater for all Tuvaluans to enjoy; and
2. Protect all water resources to enhance the health of our environment and our people.

These provide a sound basis for Tuvalu's water security objectives. To expand these into measurable objectives, workshop groups were asked to develop more specific water security objectives for Funafuti and Vaitupu. What emerged from their discussions and subsequent iterations is a water security vision supported by a series of immediate and longer term targets.

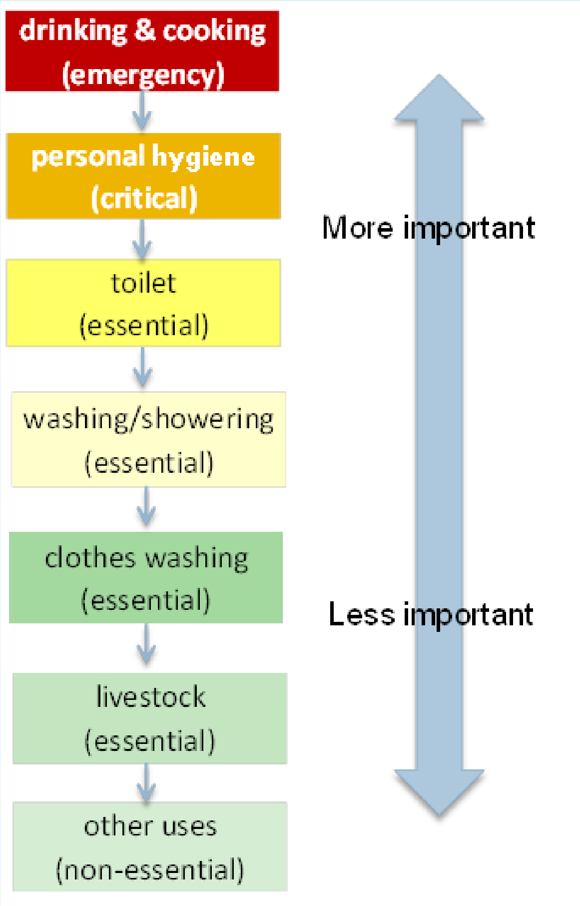
Water security vision

Ensure all households have adequate clean, accessible and affordable water to meet essential uses at all times.

Drought targets

- Emergency target: Sufficient clean and reliable water supplies to meet all households' emergency water needs indefinitely, including in the event of a worst case drought.
- Critical target: Sufficient clean and reliable water supplies to meet all households' critical water needs in the event of a worst case drought.
- Longer term target: Sufficient clean and reliable water supplies to provide all households with essential water needs in the event of a worst case drought.

These targets are informed by a hierarchy of water use needs for households in Tuvalu. Moving from emergency to critical to essential water needs, this hierarchy would look similar to the following.



Emergency needs: At the height of the 2010-2011 drought water for emergency uses was rationed to as little as 31 and 45 litres/ household/day in Vaitupu and Funafuti respectively (~6-7 litres/ person/day assuming an average household size of 5-7 people).

Critical needs: These are defined as water for drinking, cooking and personal hygiene - estimated to be about 62 and 90 litres/ household/day in Vaitupu and Funafuti respectively (~12-15 litres/person/day assuming an average household size of 5-7 people).

Essential needs: These are defined as water for all internal household uses including critical uses (as defined above), as well as water for washing, clothes washing, toilet flushing and animals (potable or non-potable quality). Essential needs are estimated to be approximately 205 and 300 litres/household/day in Vaitupu and Funafuti respectively (60 litres/person/day).

2.4 Identify and assess options, portfolios and pathways

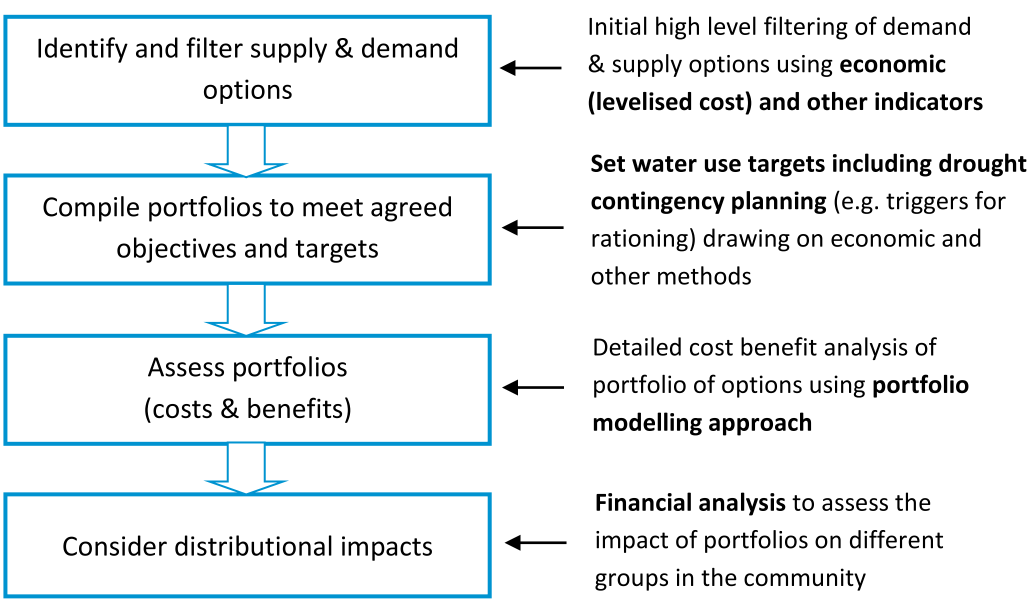
Overview

Different types and levels of economic analysis can be applied at different steps in the process of water strategy development. However, the nature and depth of analysis is likely to differ between the steps (see Figure 3). In summary, the different types of economic analysis and different steps at which they could be applied are:

- economic indicators, which can be used for high level filtering of demand and supply options;
- economic methods that can assist with target setting and drought contingency planning;
- cost benefit analysis used for the evaluation of portfolios of options; and
- financial analysis, which can be used to assess impacts of options and portfolios on different stakeholder groups (distributional impacts).

These components are discussed further below.

Figure 3: Potential application of economic and other analysis in water security planning



Identify and filter options

During the initial phase of identifying demand and supply options, basic economic and other indicators are used to filter options into a short-list of manageable and feasible options. The number of indicators used should be kept to a manageable level. Possible indicators include:

- Cost-effectiveness, the main economic indicator. To compare different options, cost-effectiveness assessment is typically calculated as a 'cost per kilolitre' – also referred to as 'levelised cost'. Levelised cost allows options of different sizes (for example rainwater tanks and desalination plants) to be compared on a like-for-like basis and is calculated as the present value cost of the water source divided by the present value of water that will be supplied by that water source.[4] Levelised cost indicates whether an option is within an acceptable cost range given resource constraints. By providing an understanding of the relative magnitude of cost of each option, it can also be used to inform the sequencing of options within a portfolio.
- Non-economic indicators. These can be assessed quantitatively or qualitatively. Examples include:
  - Effectiveness. Will the option help to achieve the objective?
  - Feasibility. Is the option technically and administratively feasible?
  - Environmental impacts. Is the option likely to have unacceptable environmental impacts, even if it is well-managed?
  - Health and other social impacts. Is the option likely to have unacceptable social impacts, even if it is well-managed?

Box 4. Filtering of water security options for Funafuti and Vaitupu

A wide range of options were considered for the Tuvalu case studies. Through the filtering process, a number of these options were excluded from further analysis because they failed to meet one or more of the indicators. Examples include:

- options for groundwater development in Funafuti, which were excluded on grounds that they are likely to have unacceptable health impacts due to groundwater contamination;
- stormwater harvesting from the airport runway, which was rejected on the grounds of likely very high levelised cost and questions over its feasibility in the Tuvalu context; and
- a centralised sewerage treatment system for Funafuti, which was excluded on grounds that the water security benefits would be minimal and concerns over long term maintenance feasibility.

4 For more information on the theory and practice of calculating present values, see Buncle et al. 2013, *op cit*. For an explanation of why water volumes are discounted, see Fane, S. and White, S. (2003) *Levelised cost, a general formula for calculations of unit cost in resource planning.*

Compile portfolios and pathways

Once a shortlist of options has been identified the next step is to compile a feasible set of portfolios. Portfolios can be described as a 'suite of complementary supply and demand options necessary to meet the water security objective or target'. By compiling different portfolios to meet different objective levels or targets, a pathway or pathways to achieving water security over time can be developed. This 'portfolio approach' to identifying and then assessing options (see below) can be contrasted with a site- or project-based approach that is more piecemeal in nature and therefore not well suited to strategy development. The portfolio approach was used for Funafuti and Vaitupu (see Box 5).

The process of compiling portfolios is not fixed but there are some simple rules that are useful to follow:

- One or more portfolios can be compiled for each objective or target, with the purpose of estimating the different net cost/benefit associated with each portfolio configuration.
- Each portfolio will contain one or more complementary options that meet, but do not significantly exceed, the relevant objective. Some portfolios may contain two or more of the same options.
- A 'base case' (business-as-usual) portfolio should always be compiled. The base case represents the current suite of actions (water supplies, demand management initiatives and associated policies) through which water is currently supplied. Base case portfolios for Funafuti and Vaitupu are outlined in Box 2.

Economic analysis can play a role in the compilation and configuration of portfolios in two ways:

- First, levelised cost (discussed earlier) can be used to rank options (from lowest to highest) and thus the order in which options are included in a portfolio to meet a given objective or target. This approach was used implicitly to assist with the configuration of alternative portfolios for Funafuti and Vaitupu and is likely to be useful to assist with portfolio development in other parts of Tuvalu and other PICs (see Box 5).
- Second, economics can be used to assist with optimising a portfolio considering the costs of options within a portfolio, the level of service (i.e. accessible water supplies) provided by the portfolio and the amenity value and other benefits of the water. In countries with adequate research budgets, the amenity value of water can be understood through community surveys that establish their willingness to pay (WTP) to avoid water rationing. As discussed in Box 7, the high cost and practical difficulty of gathering WTP data in Tuvalu (and other PICs) indicates that a threshold analysis technique (see Table 1) is likely to be more appropriate in most cases.

Box 5. Water Security Portfolios for Funafuti and Vaitupu

Portfolio development for Funafuti and Vaitupu was centred on achieving the long term objective (vision) and associated emergency, critical and longer term targets as set out in Box 3. A number of iterations of portfolios, in conjunction with the water demand and supply modelling, were necessary to provide confidence that the different portfolios could achieve their respective targets.

Funafuti

Portfolio 1a (to meet emergency target)
- **gutter maintenance and cleaning program (houses and community centres)**
- water act and associated measures

Portfolio 1b (to meet emergency target)
- **additional cisterns (2250 kL)**
- water act and associated measures

Portfolio 1c (to meet emergency target)
- **composting toilets (80% of households)**
- water act and associated measures

Portfolio 2a (to meet critical target)
- Portfolio 1a
  Plus
- **additional cisterns (2250 kL)**

Portfolio 2b (to meet critical target)
- Portfolio 1a
  Plus
- **Rainwater tanks (RWTs) (2.6 kL/ house added to small houses)**

Portfolio 3a (to meet longer term target)
- Portfolio 2a
  Plus
- **additional cisterns (3750 kL)**
- **RWTs (10 kL/ house added to small houses)**
- **composting toilets (40% of households)**

Portfolio 3b (to meet longer term target)
- Portfolio 2a
  Plus
- **fully functioning desalination plant (130 kL/ day with ongoing maintenance and repair support)**

Vaitupu

Portfolio 1a (to meet emergency target)
- **gutter maintenance and cleaning program (houses and community centres)**
- **additional cisterns (750 kL)**
- water act and associated measures

Portfolio 1b (to meet emergency target)
- **gutter maintenance and cleaning program**
- **additional cisterns (750 kL)**
- **RWTs (4.5 kL/ house added to small houses)**
- water act and associated measures

Portfolio 1c (to meet emergency target)
- **additional cisterns (1250 kL)**
- water act and associated measures

Portfolio 2a (to meet critical target)
- Portfolio 1a
  Plus
- **additional cisterns (2000 kL)**

Portfolio 2b (to meet critical target)
- Portfolio 1a
  Plus
- **additional cisterns (1250 kL)**
- **RWTs (1.5 kL/ house added to small houses)**
- **composting toilets (50% of households)**

Portfolio 3a (to meet longer term target)
- Portfolio 2a
  Plus
- **additional cisterns (1250 kL)**
- **RWTs (10 kL/ house added to small houses)**
- **composting toilets (24% of households)**

Portfolio 3b (to meet longer term target)
- Portfolio 2a
  Plus
- **groundwater piped to villages and school**

A cistern under construction in Lofeagai, Funafuti

A desalination plant at the Public Works Department

Assess portfolios (costs and benefits)

Once a set of feasible portfolios has been identified, more detailed cost benefit analysis is required using the portfolio modelling approach. This entails modelling the costs and benefits and performance of each portfolio relative to the base case. The steps applied to assessing costs and benefits essentially follows the 'with and without' steps detailed in *Cost-Benefit Analysis for Natural Resource Management in the Pacific: A Guide*:

- Identify the costs and benefits (Step 2);
- Value the costs and benefits (Step 3); and
- Aggregate the costs and benefits (Step 4).

These steps are not further discussed here.

There are two aspects particular to the portfolio modelling approach in the context of water strategy development that should be noted:

- First, the portfolio must be modelled in its entirety not just its individual components. This means taking account of economic and hydrological interactions between options within the portfolio. For example, all portfolios assessed for Funafuti and Vaitupu assume implementation of a 'gutter maintenance, repair and awareness program' and full implementation of the 'Water Act'. These are necessary complements to new and existing water infrastructure (i.e. household tanks and community cisterns) to maximise their long term effectiveness. See Box 5.
- Second, as with standard cost benefit analysis, the portfolio approach can incorporate sources of uncertainty. Key sources of uncertainty and the ways in which uncertainty can be managed within the development of a water strategy are discussed in section 2.5. This uncertainty analysis is important to overall results of the cost benefit analysis. For example, results of the analysis in Tuvalu indicate that the different climate scenarios lead to different conclusions about the level of action required to meet targets and overall costs of actions.

Consider distributional impacts

Before decisions are made on appropriate adaptation portfolios and pathways, attention should be given to identifying groups in the community who will benefit or benefit most from the decision and groups in the community who may be adversely impacted by the decision – usually referred to as 'distributional impacts'.

Consideration of distributional impacts is important for several reasons, including:

- First, the costs of options or portfolios on particular groups may affect their suitability. For example, 'full (variable) cost pricing of desalination water' was one option considered for a portfolio to meet the interim target in Funafuti; likely high impacts of this option on low income groups was an important consideration in leaving the option out of the relevant portfolio[5].
- Second, decision-makers may want to achieve, or contribute to, certain equity objectives through an option or portfolio. For example, the use of borrow pits for the construction of water cisterns in Funafuti would appear to offer substantial equity benefits in that many of the communities who

[5] Another factor influencing the decision to put this option aside was high uncertainty about whether the option would actually contribute to meeting the target. Nevertheless, further water strategy development in Tuvalu or other PICs should consider this option more closely.

are most poorly serviced by existing supplies are ‘new’ communities living close to the borrow pits.

- Third, understanding of distributional impacts can be important for informing how best to share the costs of financing the portfolio or add to the case for financing the portfolio from potential funding sources (e.g. partner countries).

The process of assessing distributional impacts generally involves two main steps:

- mapping out the distribution of costs and benefits between stakeholders; and
- weighting the costs and benefits according to social priorities.

This process is detailed in the guide *Cost-Benefit Analysis for Natural Resource Management in the Pacific* (Step 6) and is not further discussed here other than noting that assessment of the distributional impacts of a portfolio should be considered based on its entirety and not just its individual options.

2.5 Uncertainty analysis

Risk is defined as the likelihood and consequence of a hazard or unfavourable event. Uncertainty can be defined as a poor knowledge of the likelihood (or probability) that the event will occur and/or poor knowledge of the consequence of the event should it occur. Sources of uncertainty include:

- data problems such as data errors, missing data, out-of-date data (e.g. the number of people experiencing gastro-intestinal illness in Funafuti due to poor water quality);
- problems with model outputs (physical and/or economic) such as structure, parameter values, or dynamic and poorly understood systems (e.g. projections of changes to average rainfall in the Pacific); and
- human behaviour (e.g. current and future water demand in Tuvalu).

There are numerous uncertainties with variables used in the analysis of water security costs and benefits in Tuvalu. Principal amongst these are:

- projections of average rainfall, and rainfall variability (including frequency and severity of droughts);
- the value that accrues to water delivered through options and portfolios;
- the potential for outages or failure of plant (in particular desalination plants);
- demand projections, including population growth and the household characteristics that affect either demand or supply (such as the number of people in the house and the condition of tanks and gutters); and
- estimates associated with other benefits such as health and environmental benefits of some options.

Different techniques are available for dealing with these uncertainties. Selection of the technique will primarily be driven by the nature of the variable and associated uncertainty. If ranges of uncertainty can reasonably be estimated for a particular uncertain variable or suite of variables then sensitivity analysis should be used. This is the approach applied to some key uncertain variables in the Tuvalu case study such as the capital costs and health benefits of some options.

If a range of values for the uncertain variable cannot be estimated with any confidence then scenario analysis should be used. This is the approach applied to climate change projections in the case study (see Box 6).

More sophisticated techniques such as Monte Carlo simulation and real options analysis should only be used if the probability distribution for values of the uncertain variable can be reliably estimated. This was not the case for key uncertain variables in the Tuvalu case study and we suggest that application of the advanced modelling and statistics required of these techniques is unlikely to be justified for water security cost benefit analysis in many PICs.

As discussed in Box 7, we suggest that threshold analysis is an appropriate technique for addressing uncertainty about the value of water in Tuvalu and potentially for the majority of PICs.

Table 1: Overview of techniques for addressing uncertainty in cost benefit analysis

Method	Situations where technique is suitable	Example
Scenario analysis	A range of values for the uncertain variable cannot be estimated with confidence but a set of *plausible* outcomes can be constructed.	A *plausible* picture can be painted of the 'best case' and 'worst case' change to the severity of an extreme dry year under climate change.
Sensitivity analysis	A range of outcomes for the uncertain variables can be estimated with confidence.	A reliable range of changes to the severity of an extreme dry year under climate change can be estimated.
Sensitivity analysis with 'correlations'	Same circumstances where a standard sensitivity analysis would be used but also the interaction between the different uncertain variables can be estimated.	A numerical link can be established between projected rainfall changes and sea level rise on the volume of the freshwater lens in groundwater.
Threshold analysis	It is useful to understand at what value for an uncertain variable a particular objective can be achieved or at what value the best course of action changes.	The minimum value that a community would need to attach to rationed water to justify pursuing the minimum water security target. To see how threshold analysis has been applied to the Tuvalu water security CBA, refer Box 7.
Monte Carlo simulation*	Same circumstances where a standard sensitivity analysis would be used but also the *probability distribution* for values of the uncertain variable can be estimated.	The probability distribution of the range of changes to the severity of an extreme dry year can be estimated given climate change projections.
Real Options*	When the value in having flexibility to respond to uncertain variables as and when they become more certain is useful to quantify.	It would useful to quantify the value of deferring a decision on water security investments until the direction of likely changes to rainfall under climate change becomes clearer

*As discussed in the text, it is unlikely that Monte Carlo simulation or Real Options would be applied to a water security cost benefit analysis in PICs.

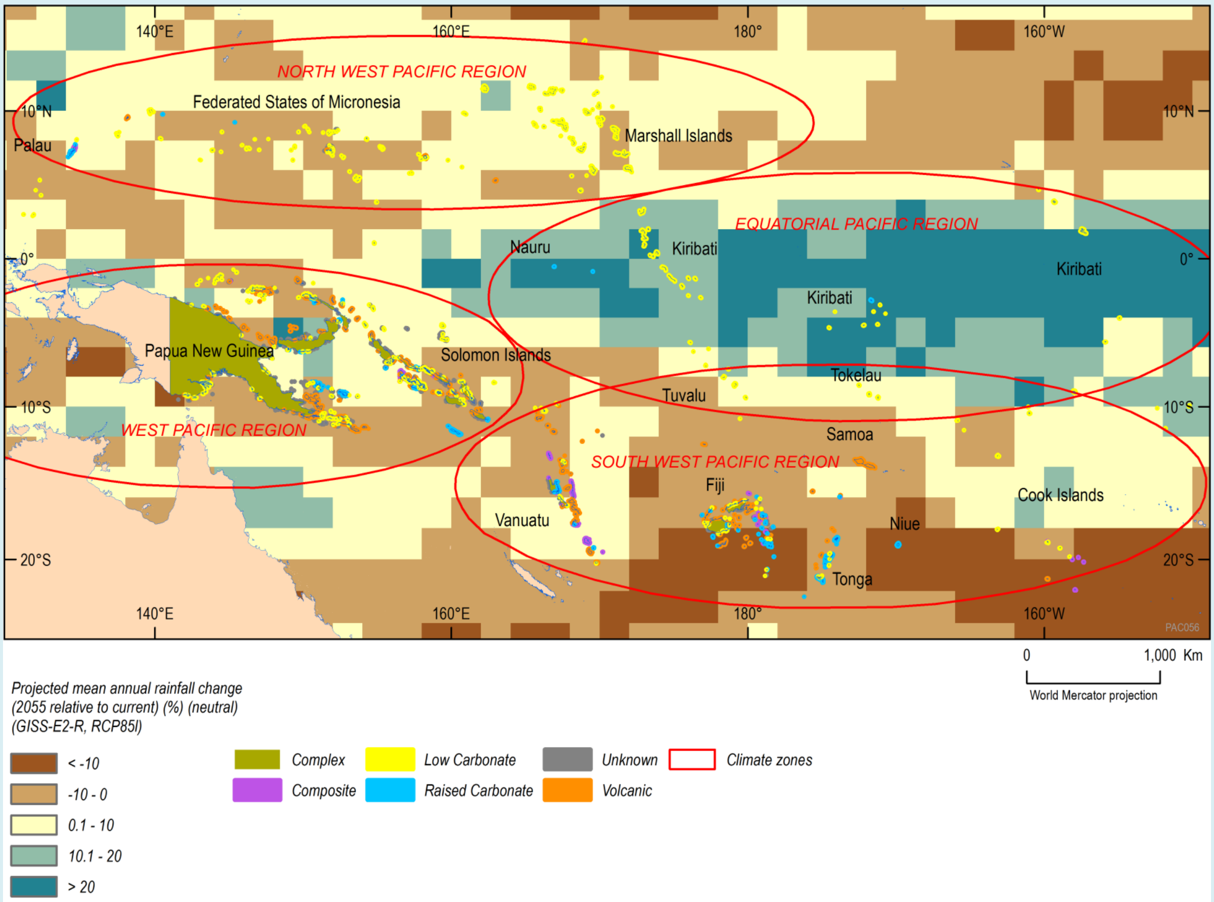
Box 6. Climate change scenarios for Tuvalu

Islands in Tuvalu typically experience high rainfall, with the mean annual rainfall in the southern islands (including Funafuti and Vaitupu) being about 3,500mm/year. Nevertheless, there is considerable week-to-week and month-to-month variability in rainfall and substantial year-to-year variability, driven primarily by the El Nino-Southern Oscillation (ENSO) cycle. This variability is the primary driver of insecurity for water supplies in most parts of Tuvalu. The latest available rainfall projections for Tuvalu are uncertain. The projected percentage change in mean annual rainfall for 2055 (assuming high emissions scenario RCP 8.5 and a neutral ENSO state) varies between the southern and northern islands from about -10 to + 10% (Figure 4), but with average rainfall in Funafuti and Vaitupu possibly remaining unchanged. This reflects the fact that Tuvalu sits in the confluence of the Equatorial Pacific region, where average rainfall is projected to increase, and the South West Pacific region, where average rainfall is projected to decrease. Further unknowns include the changes (if any) to variability and the ENSO cycle.

Given these uncertainties, especially with respect to rainfall variability and drought frequency, a decision was made to use scenario analysis in the case study for the purpose of incorporating climate change and variability into the water supply-demand modelling. Three scenarios were used for modelling water security:

1. The standard drought scenario was modelled on the lowest 12 month rainfall in the historic record, 2010-11 in Funafuti and 1970-71 in Vaitupu.
2. A worst case drought scenario was modelled at -10% of the historic low annual rainfall and assumes two consecutive years of this rainfall.
3. A best case drought scenario was modelled at +10% of the historic low annual rainfall.

Figure 4: Projected percentage change in mean annual rainfall for 2055 in PICs relative to current based on the GISS-E2-R model (RCP 8.5) for the neutral ENSO state



Source: Grose and Bedin 2013

Box 7. What is the value of a secure water supply in Tuvalu?

What value should be attached to the extra security of water delivered through portfolios? This extra security is the primary benefit of the portfolios being assessed, so the answer to the question is critical to results of the analysis.

In some earlier cost benefit studies of water options the assumed value of water was the production and delivery cost of desalination water. This value (or more correctly the variable component of the production and delivery cost) would be appropriate if the cost benefit analysis were considering only of a single option (e.g. a water cistern) rather than a portfolio, and the water provided by that option resulted in a proportionate reduction in demand for desalination water. However, when the portfolio *includes* a desalination plant, this approach is inappropriate.

Even when examining a single option, note that valuing water with reference to reduced desalination costs will only be appropriate *if and when demand for desalinated water reduces*. During times of drought, demand for desalination water would be unlikely to fall but would be reallocated to other families or shifted to alternative uses. In addition, should desalination water become unavailable during a drought and severe water rationing is required, the amenity value of water will increase significantly because essential uses will be affected.

In Australia, uncertainty over the value that should be attached to a secure water supply is often addressed through surveys of households and other water consumers to establish their willingness to pay (WTP) to achieve different levels of water security and to avoid water rationing/ restrictions. WTP values are commonly used in cost benefit analysis as a way of quantifying the value of an outcome that is not traded in a market (i.e. a non-market value), such as the value of taking a shower or washing clothes at home.

The difficulty with this approach for PICs is that WTP studies can be very time and resource intensive exercises. Also, the results of the survey can still be subject to considerable uncertainty and are often open to interpretation. For this reason, a WTP survey was not considered for this study and we consider it unlikely to be appropriate for water strategy studies in Tuvalu or other PICs within the foreseeable future.

Rather than establishing the value of water through WTP studies, it is recommended that PICs utilise a threshold approach (see Table 1 above). In the context of water security, the threshold value for each portfolio would be the cost per household of implementing that portfolio. Unless there are overriding qualitative considerations (such as environmental impacts), the preferred portfolio will generally be the portfolio that results in the lowest cost per household for each of the water security 'targets' (i.e. the minimum target, the interim target and the longer term target).

Decision makers can then assess whether meeting each progressively higher target would be worth the additional cost per household. Without survey information, this 'threshold' decision will necessarily be subjective, but the magnitude of the increments (whether very large or very small) can often be enough to make the decision self-evident.

2.6 Implement, monitor and review

The implementation, monitoring and review aspects of the water security decision making process are outside of the scope of this study. They are nevertheless critical aspects of the process and should receive due attention.

Effective linkages/coordination in water management within the Tuvalu government and between Tuvalu and partner countries will be an important aspect of the implementation stage of a water strategy.

The monitoring and review stage will focus on monitoring to ensure that the portfolio(s) implemented do actually achieve the intended objectives/targets and reviewing, and if necessary adjusting, portfolios in light of the outcomes of the monitoring.

3. Key findings and next steps

3.1 Key findings

3.1.1 Cost benefit analysis

The Funafuti and Vaitupu case studies indicate that a CBA of water security in Tuvalu is best undertaken in the context of developing an overall water/ drought management strategy for each island. This study sets out a framework through which those strategies can be developed, using CBA as part of an integrated decision-making process for achieving and sustaining water security under different climatic conditions.

Outputs of the application of the framework to Funafuti and Vaitupu are preliminary and more work will be needed to achieve fully fledged strategies for those islands. Nevertheless, the framework presented here is robust, having been well tested in Australian contexts in the past, as well as different contexts in Funafuti and Vaitupu. The framework is likely therefore to be suitable for application to other islands in Tuvalu and potentially other PICs seeking to develop water security strategies.

It is important that the framework is applied in a way that reflects the specific circumstances of the location. In particular, island/region/country wide problem analysis is critical at an early stage in the process. The problem analysis stage should include analysis of water supply and demand under existing conditions and assessment of climate and non-climate water security risks. Application of the problem analysis to Funafuti and Vaitupu indicates that differences between the islands in terms of water supply and demand and water security risks can significantly influence the design of option portfolios for meeting water security and hence the costs and benefits of options.

However, many aspects of framework application will be similar regardless of the context in which it is applied. For example:

- Application of the CBA should be consistent with the ‘standard’ cost benefit analysis approach as set out in *Cost-Benefit Analysis for Natural Resource Management in the Pacific: A Guide*[6].
- The CBA should generally be preceded by:
  - island wide context setting, including problem analysis and assessment of climate and non-climate risks;
  - developing measurable water security objectives and targets; and
  - a holistic portfolio approach to options development.
- Cost effectiveness assessment (framed as ‘levelised costing’ ($ per kL) when applied to the assessment of water supply and demand options) can be useful for filtering and ranking options within a portfolio.
- Different techniques will be applied in the CBA to address different levels and types of data uncertainty. Examples include ‘scenario analysis’ (for climate change), ‘sensitivity analysis’ (for key costs and benefits) and ‘threshold analysis’ (for the value of water).

6 Buncle, et al., op cit

- A well-developed (Excel based) water supply-demand model is an essential tool to inform the design and assessment of option portfolios and to understand the potential impacts of climate change on water security. The model needs to be structured so that different portfolios of options can be assessed, allowing for alternative combinations of options (e.g. water tanks, water cisterns, desalination, demand management etc.) and different sequences of options over time.

The framework also has potential application to developing strategies for a range of other issues including wastewater/ sanitation, solid waste management, coastal management and energy security.

3.1.2 Water security in Tuvalu

Assessment of portfolios through the CBA and associated water supply-demand modelling suggests that there is ample scope to improve water security in Funafuti and Vaitupu in ways that will bring net benefits to the community overall (see Box 8). However, which of the targets the government chooses to meet (emergency, critical or essential) will require not only a judgement about the value of each target compared with the cost, but will also need to take into account broader considerations such as funding availability and the country's other expenditure priorities.

3.2 Next steps

3.2.1 Integrating CBA into government decision making

1. The Tuvalu Government, through the Office of the Prime Minister and the Department of Planning and Budget, should seek to integrate cost benefit analysis (CBA) into its decision making on all major investments, policies and programs. This will help to increase confidence within government, the community and partner countries that investment decisions are being made in the best, long term interests of the community.

2. Where possible, CBAs should be undertaken at the strategy/planning level. This will help to ensure that investment decision making is strategically focussed considering short, medium and longer term outcomes. It will also help to ensure that CBAs are integrated into the strategy development process and not undertaken merely as an afterthought.

3. Strategy/planning CBAs will be complemented by project level CBAs where needed or where strategic level analysis is not possible.

4. The broad framework applied to this water security case is likely to be suitable for strategy development for a range of other issues, including potentially wastewater/ sanitation, solid waste management, coastal management, and energy security. However, specific application of the framework will differ according to the particular issue to which it is applied.

5. Nevertheless, the way in which the framework is structured and applied to assessing costs and benefits of investments is likely to have common elements regardless of the issue to which it is applied. Those common elements include:

    - Application of the CBA should be consistent with the 'standard' cost benefit analysis framework as set out in *Cost-Benefit Analysis for Natural Resource Management in the Pacific: A Guide*[7].

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7 Buncle, et al., op cit

- It is desirable (and should be feasible) to develop a new cost benefit model for each new application rather than attempt to use a standard template.
- The CBA should generally be preceded by:
  - problem analysis including assessment of climate and non-climate risks;
  - development of measurable objectives and targets; and
  - a holistic portfolio approach to options development.
- Different techniques will need to be applied in the CBA to addressing different levels and types of data uncertainty.
- It is important to ground truth assumptions (preferably from multiple sources), when there is a lack of documented evidence for key water supply and demand assumptions or cost and benefit assumptions.
- A monitoring and review stage will need to be developed and implemented to ensure that:
  - the portfolio(s) implemented actually achieve their intended objectives/ targets; and
  - portfolios are adjusted in light of monitoring outcomes or in response to new information (e.g. on climate change or the costs and benefits of options).

3.2.2 Water security in Tuvalu

6. A key recommendation of the Rapid Drought Assessment, completed for Tuvalu in 2012 is that a ‘drought management plan/strategy should be developed at the island scale’[8]. A *Sustainable and Integrated Water and Sanitation Policy 2012-2021* has now been developed for Tuvalu[9]. However, there is scope for enhancing implementation of the water security aspects of the policy through developing an implementation plan for each island[10]. The plans would include:
   - Quantified water supply shortfalls under different population and climate scenarios, considering capacity and condition of existing water supplies.
   - Measurable water security objectives and targets.
   - Identified options and portfolios for meeting the targets and assessment of those options.
   - A schedule for implementing preferred options over time, considering objectives and current and potential future shortfalls in water availability.
   - Suitable financing/ funding mechanisms for implementing the preferred options, including funding to ensure that long term operating costs (where relevant) are met.
   - Allocation of responsibility within the Government and between the Government, Kaupule, communities, NGOs and householders for implementation of the options.

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8 Sinclair, P., Atumurirava, F. and Samuela, J., 2012. *Rapid Drought Assessment Tuvalu: 13 October – 8 November 2011*, SOPAC Technical report (PR38), Government of Tuvalu and Secretariat of the Pacific Community, Suva, p.38.

9 Government of Tuvalu, 2013. *Sustainable and Integrated Water and Sanitation Policy 2012-2021*, SOPAC, Vaiaku, Funafuti.

10 Note, the sanitation aspects of the policy have not been examined in depth but would probably also benefit from an implementation plan.

- A monitoring and review schedule.

7. Linkages between all Government departments and agencies, non-government organisations and communities involved in the management of water in Tuvalu should be strengthened so as to achieve more effective co-ordination of water management. Improved co-ordination will require:
   - setting agreed priorities for water infrastructure, programs and services;
   - clearly defining the roles and responsibilities of departments, agencies, Kaupule, communities and households in delivering on priorities and in managing water more generally;
   - avoiding/removing duplication in management roles;
   - co-ordination of funding and program provision by donor countries to ensure that it is targeted at priority infrastructure, programs and services and at priority locations;
   - improved management of water resources at the community level.
8. Further survey-based research on the levels and patterns of household, government and business water consumption in each of the islands in Tuvalu would be a valuable input to water security strategy development, complementing the water infrastructure stocktake that has already been completed by the SPC. This is because better understanding of water consumption can ensure investments are targeted and resources not wasted where they are not required.
9. Significant work has been undertaken through this study to provide a basis for water security strategies in Funafuti and Vaitupu. However, additional work is needed to ensure a fully-fledged strategy is completed for those islands, including:
   - Further assessment of the potential health, environmental and food security benefits of composting toilets, noting that the benefits of avoided contamination of lagoon waters and fish stocks were not assessed for this study.
   - Further analysis of the viability of groundwater as a long term water resource in Vaitupu.
   - Detailed specification of a desalination training and maintenance program to ensure that desalination can be a reliable source of water for meeting the longer term target.
   - The implementation stage of the strategy – covering the last four dot points of recommendation 6.
10. Notwithstanding the need for further water security strategy development in Funafuti and Vaitupu, assessment for this study suggests that some options and portfolios are likely to warrant implementation as soon as is practically feasible. In particular:
    - ***Gutter maintenance and cleaning program***. Given the low net cost of a gutter maintenance program and the significant water security benefits that it could deliver, it should be a foundation of any portfolio, regardless of the target. Thus this option should be pursued as a priority in Funafuti and Vaitupu and probably other islands as well.
    - ***Water Act and associated measures.*** Options aimed at improving water security will be more effective if they are underpinned by complete implementation of the Water Act and associated measures, such as improved management of community water resources. Effective management arrangements for community water resources will entail ongoing

monitoring of community water supplies (generally cisterns) by relevant local communities and effective day to day management of the resources especially during dry periods.

11. Cisterns are likely to be important components of portfolios for delivering the critical and longer term targets in Funafuti. Preliminary analysis suggests that filling in Funafuti's borrow pits has the potential to provide a relatively low cost means of providing the land required for the cisterns, as well as producing other community benefits (e.g. health benefits). Further research into the extent of the benefits created by the borrow pits may be useful. The significant potential distributional impacts of this option will also need to be addressed.

Box 8. Results of the Funafuti and Vaitupu case studies: an overview

Water supply and demand options for Funafuti and Vaitupu were modelled in a water supply-demand model designed specifically to reflect circumstances in Tuvalu. Historic rainfall data provided by the Tuvalu Meteorology Office for Funafuti was an important input to the model, as was a preliminary assessment of groundwater resources in Vaitupu. Iterative modelling of these options, combined with a preliminary cost effectiveness assessment (levelised costing) enabled the options to be developed into a series of alternative portfolios for meeting the 'emergency' , 'critical' and 'longer term' targets in Funafuti and Vaitupu respectively. These portfolios were then subject to a CBA.

Results

Under the standard drought scenario, neither Funafuti nor Vaitupu have adequate water supplies to meet their essential or critical targets, even now. The emergency target can be met in Funafuti but only until 2022. The worst case drought scenario brings forward the timeframe of this constraint to 2019, while the best case drought scenario delays it until 2024. The emergency target cannot be met in Vaitupu under the standard or worst case drought scenarios. It can be met under the best case scenario but only in 2014.

Assessment of portfolios suggests that there is ample scope to improve water security in Funafuti and Vaitupu in ways that will bring net benefits to the community overall. In particular it is likely that the emergency target can be achieved with a net benefit overall to the community in Funafuti ($44/household/year threshold value) given evidence that the community there values water at much greater than $44/household/year in drought situations. For example, household and government outlays for the production of desalination water in Funafuti are estimated to be about $420/household/year in a drought year. Achieving the emergency target in Vaitupu is likely to be more costly than in Funafuti ($96/household/year threshold value) but is still likely to produce a net benefit to the community given the high value the community places on the value of water in drought situations.

The critical target could also be achieved with net benefit overall in Funafuti ($101-142/household/year threshold value depending on whether borrow pits are used for cisterns) given the benefits that it will deliver, although the target will be significantly more costly in Vaitupu ($284/household/year threshold value). Again, given household and government outlays for the production of desalination water in a drought year in Funafuti, achieving the critical targets could be a reasonable objective in the short to medium term, since it is likely to produce net community benefits in both Funafuti and Vaitupu.

Achieving the longer term target will be more costly, in both Funafuti and Vaitupu ($307/household/year and $514/household/year threshold values respectively).