Water troubles in a Pacific atoll town

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Abstract

South Tarawa is a town on an isolated Pacific atoll of approximately 46,000 people, with absolute water scarcity, poor water safety and consequently water related problems. It relies on shallow groundwater, with contributions from rainwater tanks and desalination. Due to a combination of factors such as small scale, limited human resources, system complexity, isolation and lack of financial resources, water management capacity is inadequate. Sustainability of groundwater resources is also uncertain and there are indications that groundwater has been extracted above the sustainable pumping rates. Social complexity is highlighted by the resistance from traditional landowners against the attempts to deal with the supply side deficit through establishment of new infiltration galleries. In this paper, issues relating to water management in South Tarawa are reviewed. This follows on to an exploration of possible strategies to improve the existing situation. This research forms an empirical building block in the foundation of a larger study, aiming at developing a framework for strategic and adaptive small town water management. In particular, the larger study explores the options and viability of co-management of water and land resources in small scale urban areas as an alternative to traditional urban management approaches.

Keywords: Water management; Co-management; Adaptive capacity; Small town issues
Introduction

This paper forms part of the foundation of a larger study that focuses on small town water management, and in particular opportunities for co-management and decentralised institutions as an alternative to traditional urban management approaches. This is in recognition of, in particular, the capacity issues faced by small towns as well as small island developing states. Tarawa is also interesting because, as will later be described, it involves a wide range of complexities and difficulties and may serve as an extreme case where water issues pose possibly the greatest challenge of this settlement. In fact, it may be described as a modern parallel to the collapsed historical societies described in Jared Diamond’s recent book Collapse (Diamond 2005), where three of Diamond’s critical factors of climate change, environmental degradation and poor capacity for coordinated response all contribute to the vulnerability of the society. In terms of Diamond’s framework, lack of enemies and a considerable influx of goods and services from overseas are factors that support the settlement in its current form.

Tarawa is an atoll island chain, i.e. a string of closely connected sandy islands on a base of coral, with a lagoon in the centre (see Figure 1 for geographical references). This atoll lies in the country of Kiribati, which is located in the Pacific region of Micronesia. It has a population around 46,000 and contains about 50% of the population of the country (Kiribati National Statistics Office 2006). While the islands of North Tarawa are essentially rural, the islands of South Tarawa, the capital, are urbanised and because of their small total land area of approximately 15 square kilometers the island group has a population density of at least 2,600 people per square kilometer. This is on par with population densities in cities in the developed world, and above population densities in most Australian cities. In Betio, the most densely populated island of South Tarawa, the population density is at least 8,500 people per square kilometer. These population densities put considerable pressures on natural resources such as land and water with consequent environmental damage. To further intensify the problem, more than 35% of the population is below the age of 15 and Kiribati has a high population growth rate of about 2% per annum (Kiribati National Statistics Office 2006).
Water management in Tarawa is characterized by scarcity of water resources, small scale leading to limited financial and human resources, as well as a high degree of uncertainty and complexity of operation. This has led to poor water safety, poor community access to water supply and sanitation, and considerable vulnerability of supply. The impacts are severe, especially in terms of health, with some of the highest infant mortality rates in the world. Socio-economic impacts are present through inadequate water supply for business, industry and agriculture; and in terms of environmental impacts, the atoll and its groundwater is increasingly being polluted and/or over-used. Social acceptance of the current strategies is low, and efforts to increase supply volumes through the establishment of new water reserves have been met with resistance, and have as a consequence not been completed. Efforts to increase supply volumes via desalination have collapsed due to inadequate maintenance, rapid degradation of infrastructure and inability to source spare parts. Attempts at holistic water management through a water board collapsed due to interpersonal conflicts and lack of motivation; and participatory management opportunities are largely unexplored. Furthermore, the impact of climate change is uncertain, posing threats through rising sea levels and an anticipated increased frequency of droughts.

**Structure of review**

The review of the water management in Tarawa is done in two key steps: an initial situation review and a subsequent strategy review. The situation review is done in four sub-steps: reviews of the water resources, capacity, performance, and of impacts. It is assumed that there is a causal link between capacity, performance, and impacts. These areas were chosen in acknowledgement that (IIED, 2000):

1. There is a wide range of inter-related factors that influence water management
2. There is a widespread failure to appreciate social and organizational issues
3. It is extremely difficult to achieve a reliable, measurable and subjective assessment

Consequently the situation review focuses on both directly measurable aspects, such as sustainable pumping rates, rainfall data, and health statistics, as well as less quantifiable aspects, such as those relating to decision making processes, social acceptance, civil and political rights, and worker dedication.
The situation review in this paper is based on observations and discussions with stakeholders during a handful of trips to Tarawa, some basic analysis as well as on literature and data sources. Naturally, there is potentially an issue of subjectivity, in particular in relation to the more qualitative assessments.

The strategy review is also based on discussions with stakeholders to identify main pathways, in combination with applying a more general categorization of strategies available for small town water management. In this section, it is assumed that the three key sources of water will remain groundwater, rainwater and desalinated seawater. It is also acknowledged that due to the focus of the larger study, the strategy review is skewed towards finding alternatives to traditional management strategies.

**Review of water resources**

Tarawa relies primarily on groundwater for water supply. Unfortunately access to good quality groundwater is restricted by over-population and shortage of land and for that reason, alternative water sources are used, but only to a limited extent for practical reasons. There are three sources of freshwater in South Tarawa: groundwater, rainwater and desalinated water, and Table 1 shows an optimistic scenario of total supply volumes:

1. **Groundwater catchment reservoirs on the islands of Buota and Bonriki.** The sustainable yield from these reservoirs is 2,530 m$^3$ per day, using all available options. This is produced at a cost of A$2.40/m$^3$ (Falkland, 2003). With currently used options, the sustainable yield is 1,700 m$^3$ per day. Groundwater from domestic wells is available to households as a complementary source.

2. **Rainwater collection, with an average rainfall of 1,943 mm per year.** There is no inventory of rainwater tanks, so the total amount of water available from this source is unknown. With an optimistic scenario of 5,000 tanks with an average collection area of 50 m$^2$ and a coefficient run-off percentage of 90%, this amounts to an average of 1,197 m$^3$ per day or 473,175 m$^3$ per year. However, there are roughly 6,300 households in Tarawa and it has been reported that only 28% of households with an iron roof are equipped with a rainwater tank, and only about two thirds of these are functional (ADB, 2000). This amounts to an estimated current supply volume of 283 m$^3$ per day.
3. **Desalination plants**: 1 plant with potential to deliver 100 m$^3$ per day, and 2 plants with a capacity of 50 m$^3$ per day. Total capacity = 200 m$^3$ per day. Unfortunately, maintenance has been lacking and none of the plants is currently operational. In 2003, the unit electricity cost of running the desalination plants was about $2.80 / m$^3$ (Metutera, 2003).

**Groundwater**

In South Tarawa there are two methods for the community to access groundwater: via domestic wells, or via the reticulation system. The groundwater that is fed into the reticulation system is pumped from a number of infiltration galleries that are protected by water reserves (Metutera 2003). When the water reserves were established, the traditional landowners were displaced by the government, and this has caused social problems and tensions (Crennan, 1998, White, *et al.*, 1999, Dray *et al.*, 2006). The groundwater occurs as a thin lens of freshwater floating over seawater in coral sand and limestone aquifers (White *et al.*, 2005a). Currently, the infiltration galleries are covered by vegetation, reducing the sustainable yield. The groundwater is also pumped a long distance, with consequent leakage losses. The freshwater in the groundwater is recharged through rain, and lost through a combination of:

- Coconut trees that tap into the freshwater lens
- Domestic wells and infiltration gallery pumping schemes
- Discharge to the ocean at the lens and island margins
- Tidal mixing which leads to the development of thick brackish transition zones between freshwater and seawater in the lens.

The critical factors determining the size of the freshwater lens and the sustainable pumping rates are the width of the island, the ease of transmission of freshwater through aquifers and the amount of rainfall (White *et al.*, 2005a). This means that some islands are better suited for pumping groundwater than others, with the wider islands, Bonriki and Buota, being the primary sources of water. Establishing sustainable yields for different islands is of critical importance, and considerable efforts have been invested over the years, each time adjusting conservative estimates upwards. For instance, the estimate for Bonriki, the island with highest sustainable yield, was estimated in 1982 as 750 m$^3$/day, and subsequent investigations by Falkland, based on improved information, in 1992 adjusted the estimate.
upwards to 1,000 m$^3$/day, and in the most recent investigations in 2002, under the Asian Development Bank funded SAPHE project, an estimate was given for Bonriki at 1,350 m$^3$/day (Falkland, 2003). The sustainable yield estimates by Tony Falkland from the islands in North Tarawa in 1992 was 3,850 m$^3$/day, but based on improved information and analysis this was adjusted upwardly in 2002 to 4,620 m$^3$/day (Falkland, 2003).

**Rainwater**

There are about 6,300 households in Tarawa, but only 28% of households with an iron roof are equipped with a rainwater tank (see Figure 2), and only about two thirds of these tanks are functional (ADB, 2000). The Government of Kiribati has regulated that houses with iron roofs are to be fitted with gutters and tanks for the collection and storage of rainwater (Government of Kiribati, 2000). On inspection in 2006, most houses still either lack rainwater tanks or have installed insufficiently sized rainwater tanks. Even some public buildings and new houses lack rainwater tanks. Rainwater collection from roofs is considered merely a supplementary source of water, because, as a consequence of the limited size of tanks, in times of prolonged drought there would be insufficient water volumes. In fact, the potential for rainwater collection appears to be considerable because even with the extremely optimistic scenario above, it would contribute about 25% of the supply. It appears to be an important complement to groundwater; especially as a potable water source.

**Domestic wells**

In addition to extracting groundwater via infiltration galleries and the reticulation system, many of the South Tarawa households rely on extracting groundwater from domestic wells (see Figure 3). In fact, most households have a domestic well, and 6% of households in Tarawa use domestic shallow wells for extracting water for drinking and cooking, while 18% of households use water from domestic shallow wells for other uses (ADB, 2000). The households that rely solely on domestic wells are primarily in rural Tarawa, Bikenibeu and in the squatter areas of Betio.
Review of capacity

The capacity for water management defines what is a feasible and practical strategy, and hence limits the options for water management, which in turn affects performance. For instance, Tarawa has to deal with extreme isolation, small scale, high levels of uncertainty and a severe scarcity of freshwater sources, leading to poor capacity for water management. Local capacity to manage water resources is described below in terms of socioeconomic setting (or circumstances), decision making, and stakeholder motivation.

Circumstances of scale, isolation and uncertainty

Most Pacific Island states including Kiribati, Nauru, Tonga, Tuvalu, Solomon Islands and Vanuatu, are referred to by the United Nations as Small Island Developing States. These states are characterized by:

- Small population
- Lack of resources
- Remoteness
- Susceptibility to natural disaster
- Excessive dependence on international trade
- Vulnerability to global developments
- Lack of economies of scale
- High transportation and communication costs
- Costly public administration and infrastructure

Tarawa is also a small town as per the Town Water Supply and Sanitation (TWSS) e-conference, which was funded by the World Bank, and the Water Supply and Sanitation Report (Pilgrim et al., 2004) and which focused on common challenges such as:

- Small population to support public infrastructure
- Growth in individual towns is unpredictable

• High levels of uncertainty
• Lack of resources
• Lack of economies of scale
• Poor access to skills

Consequently it has been recognized that small towns require an approach which is different from the engineering driven approach that is traditionally applied in urban centers, but also from the fully participatory approaches that are appropriate at the rural scale. The small scale generally means that the stability of settlements is lower (Pilgrim et al., 2004). In Tarawa however, while it can be considered a town, settlements are also characterised by a high population increase, high population density, relatively limited mobility due to geographical constraints, and spatially expanding urban areas, with a large number of squatter settlements. The temporary nature of squatter settlements and the rapidly expanding urban boundary means that the demand side of water services is to some extent uncertain. Due to climate change and naturally occurring droughts there is also uncertainty on the supply side.

**Decision making**

There are many guidelines for decision making in water management, but a recent World Water Development Report by the United Nations, encapsulates the guidelines in a number of succinct categories (United Nations, 2006). These guidelines are used for assessing the decision making capability of the South Tarawa water management, as per Table 2:

1. Managing risk and coping with uncertainty: dealing with natural hazards, global change and slow variable changes in circumstances.
2. Evidence based reasoning: authorities and resource managers need sound scientific data on which to base their projections and decision-making.
3. Managing holistically and in a participatory manner: allowing every sector of society to participate in the decision-making process and taking the interests of all stakeholders into account. This has its basis in the Dublin statement’s “Principle No. 2 - Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels”.
4. Valuing water: appropriately acknowledging the values and costs of water extraction. This has its basis in the Dublin statement’s “Principle No. 4 - Water has an economic value in all its competing uses and should be recognized as an economic good”.

It should be noted that the water utility and the relevant ministries are faced with an extremely complex task, and they are under-resourced, and lack sufficient numbers of educated professionals. In a situation of high unemployment and few qualified positions requiring high level qualifications, there appears to be an issue of counter productive organizational politics, possibly fuelled by a fear of losing the job. Discussions with experts and stakeholders indicate succession planning is poor as there appears to be no obvious succession options for key roles. There also appears to be a need for clearly defined roles, human resource management, and clear policies to reward good management behaviour. These kinds of problems are often observed in situations of small scale and isolation.

Motivation

The motivation of individuals and stakeholder groups drive the evolution of the water management system. For instance, when motivations are driven purely by financial needs, there is a tendency to under-value the true benefits of water. Similarly, when employees at public utilities are driven by politics, personal conflicts, and nepotism, the success rates and overall performance of management is likely to drop. Therefore a number of social circumstances have an impact on the potential for better water management in Tarawa.

Stakeholder motivations

Several participants are involved in the dynamic water management system, such as the
- Public Utility Board (PUB)
- Ministry of Public Works and Utilities (MPWU)
- Ministry of Health (MoH)
- Ministry of Environment (MoE)
- Non-Government Organisations (NGOs)
- United Nations, WHO, etc
- Donor agencies, and their representative governments (such as NZAID and AusAID)
- Development banks (such as Asian Development Bank)
- Traditional land-owners
- Community: households, industries, and business

Successful developments are possible when there is cooperation between the stakeholders, and therefore, it is critical to find solutions where expectations are clear, and where various interests are satisfied to an acceptable level. Formally this can be done by mapping values and interests for each stakeholder, and finding compromise solutions that are acceptable to all. In fact this is not realistic, and negotiation is required to find acceptable solutions. Therefore it is important to allow stakeholders the opportunity to negotiate as part of the early-design process of any developments. Failure to recognize the full range of motivations, or perceptions, in strategy designs usually leads to situations of conflicting interests, and counter-productive behaviour. In addition perceived motivations impact on the level of trust in interactions. For instance, as described in a UNICEF report on Tarawa water management (Crennan, 2006), “staff from any government organisation are often perceived by the wider community as an assembly of individuals whose primary motivation is the promotion and support of their family’s interests.” Participatory and transparent decision making would serve to alleviate such concerns, and given local sensitivities, care is essential when choosing a facilitator for any such process.

**Dedication**

Organisations and communities are made up of individuals with their own motivations for participation, such as monetary rewards, non-monetary rewards, job security, and professional pride. In Tarawa, salaries are low and there are few career opportunities. Sitting fees are generally used to get individuals to attend meetings and workshops. While there may be cultural reasons for the use of sitting fees due to the translation of Western corporate culture into the I-Kiribati culture, it may also indicate variable worker dedication. Worker dedication is critical because, according to Tendler (1997), it has a critical influence on performance in public services. Hence to improve performance, strategies are needed to

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2 I-Kiribati is the word for the native language and people of Kiribati.
motivate public servants. Based on a number of case studies in northern Brazil, Tendler noted that self-interest is not the main driver for improved worker dedication to the job, and advocated worker autonomy and discretion, but she noted that if possible, there should be a focus on local success stories, rather than reliance on inferences from case studies in different cultures and contexts.

**Local participation**

There is a concept in the I-Kiribati language, which is i-matang that refers to Westerners (white people, or literally people from the land of the dead). This term is also used to describe ideas that come from a Western perspective, and without consideration of “how it works in Kiribati”. For example as stated by Crennan (1998): “the notion of private land boundaries being determined by a public institution is a colonial imposition that is still not entirely acceptable by local residents”. Consequently zoning plans are ignored by both central and local Government as they are not enforced and not understood by the wider community (Jones 2003). Crennan (1998) also points out that the process of community consultation is another introduced notion, and that local government staff are often reluctant to undertake it, in order to avoid getting involved in long standing complexities. Decision making in Kiribati is by discussion and consensus (White *et al.*, 1999), and there is a traditional process based on the respect of elders for developing consensus within the village structure (Crennan, 1998). In summary a project that is considered i-matang will have a reduced chance of success, and consequently, collaboration with I-Kiribati people in developments should be seen as critical as it will allow the I-Kiribati to take ownership and influence during the design and implementation stages.

To enable local participation, language is key aspect, as is the knowledge and understanding of local culture and sensitivities, as well as the use of facilitator or practitioners that are perceived as impartial. For these reasons, the availability of strong non-government organizations (NGOs) is a critical factor for successful implementation. In Tarawa, there are a number of NGOs, such as the FSP Kiribati, KANGO (a national NGO umbrella organization) and the Kiribati Women Federation (AMAK), but due to lack of qualified staff and resources, it is questionable whether these NGOs have the capacity to take on
considerable responsibility. There are also concerns in regards what role NGOs can play in a culture where family and church affiliations dominate social interactions.

**Review of performance**

The performance of water management is described in terms of:

1. **Safety**: relating to water quality and how water is being used
2. **Access**: relating to the extent of the distribution network and the opportunities for the community to access water
3. **Scarcity**: relating to the sufficiency of water volumes for a range of uses
4. **Vulnerability**: relating to the risk of over-extraction or damage to water resources

**Safety**

In Tarawa, there are water safety issues relating to all the main water sources, i.e. the reticulated water system, domestic shallow wells, rain tanks, and water storage.

**Reticulated water**

The groundwater that is pumped through the reticulation system is chlorinated at two points before reaching household connections. Chlorination counteracts most pathogens, and at times when by mistake the chlorination has been disconnected, there have been incidents of diarrhoeal disease, including fatalities. This is not surprising because on inspection of the infiltration galleries, there are numerous activities that may cause problems through contamination:

- there are settlements and even burial grounds (see Figure 5)
- there are sand mining activities (see Figure 4)
- there is coconut farming and other agricultural activity, including pig husbandry
- there are open unprotected wells just next to, and on, the infiltration gallery
- there is a septic tank on top of one of the infiltration galleries

Because of this, chlorination is insufficient on its own and has to be complemented with boiling of water before usage (in particular to remove potential Protozoa such as Cryptosporidium). It should be noted here however that 96% of the community claim to boil the water before consumption (ADB, 2000).
Lack of 24-hour pressure in water pipes leads to infiltration of polluted groundwater by backflow into the pipes and consequently a very high level of chlorination is required.

**Domestic shallow wells**

A key source of water for many households is the domestic well, and these wells are located in highly populated areas where the shallow groundwater is commonly polluted. Investigations have indicated a high frequency of e-coli, and while no tests have been done, it is likely that there is a larger variety of pollutants, such as nitrates, faecal coliforms, phosphates, protozoa, and viruses.

**Rainwater tanks**

Rainwater tanks are a key source of water for many households. While they are generally safe, it has been reported that tanks are rarely cleaned, roofs are un-protected from potential contamination (i.e. over-hanging trees), they are sometimes not covered, and there is poor consideration of the impact of storm events on water quality. For the functional tanks, about 20% are reported to have poor water quality (ADB, 2000), and several cases have been reported where drinking water from a rainwater tank has caused water-borne disease.

**Water storage**

Most households store water in containers such as buckets (54%), small metal containers (14%), oil drums (11%) and concrete/plastic tanks (3%), while only 8% of the population do not store water (ADB, 2000). Storing water is a consequence of either not being connected to the reticulation system or not having continuous 24-hour supply. Water storage is a considerable risk factor in terms of water contamination.

**Access of supply**

In an international comparison (see Table 3), only 49% of households in urban Kiribati (i.e. South Tarawa) are connected to water supply, and only 77% of households have access to improved water supply (WHO, 2006). This is lagging behind the global average, the Oceania average, and the average in
developing countries. In fact, in terms of these numbers, South Tarawa is one of the least developed urban water and sanitation systems in the world.

**Scarcity**

With a population in South Tarawa according to the latest census of 46,000 people (Kiribati National Statistics Office, 2006) and an optimistic estimate on sustainable yields of 4,027 m$^3$ per day, there is approximately 80-90 litres available per person per day, which is equivalent to approximately 29 m$^3$ per person per year. With leakage losses, and other losses, this number is possibly even lower. Water availability in Tarawa of less than 29 m$^3$ per person per year falls well below the limit for absolute scarcity, at 500 m$^3$ per year, according to the Falkenmark indicator or “water stress index” (Falkenmark, Lundquist & Widstrand, 1989). This index is usually applied on a country basis, and takes into account the need for water for agriculture and industry, but is simplistic in that it does not consider availability of infrastructure, a society’s adaptive capacity, or variations in demand between countries (Rijsberman 2006). Other indicators are more complete, such as the Water Poverty Index (Lawrence, Meigh, & Sullivan, 2002, Sullivan, Meigh & Giacomello, 2003) that is based on a more holistic approach and can be applied on a household or community level, but is much more intricate to evaluate in comparison to the simple and intuitive Falkenmark indicator. It is possible that the application of a different index would give another result in Tarawa because of the predominant subsistence culture and poor opportunities for agriculture. While increased water supply may reduce reliance on food imports, and may increase its industrial output, it is also acknowledged that Tarawa will not be able to achieve sufficient water volumes for any substantial agricultural or industrial activity. At current population levels, water will always be a seriously limiting factor in Tarawa in terms of agriculture and industry, and without food imports, the islands’ population is likely to collapse. Adequate domestic supply and reduced pollution might allow for other business opportunities such as relating to tourism.

**Vulnerability**

Vulnerability of water supply is related to the sustainability of the resources that are being used. This in turn relates to environmental factors, and/or fresh water usage above sustainable yield levels. The types of natural hazards threatening the South Tarawa water supply are droughts and rising sea levels.
According to the Kiribati Water Assessment Report however (Falkland, 2003): “the impact of current sea level rise scenarios on freshwater resources is likely to be relatively minor, compared with other influences (e.g. present climate variability, human impacts). The main potential impact would be inundation on the edges of the islands.” Droughts in Kiribati are linked to the El Nino Southern Oscillation (Scott, Overmars, Falkland, & Carpenter, 2003), and therefore occur with relatively regular frequency. Droughts affect both quantity and quality of groundwater in atolls (White et al., 2005a) and at times, South Tarawa has had droughts as long as 30 months (White et al., 2005b). This length of drought, in combination with over-extraction of freshwater threatens the groundwater lenses (see Figure 6).

This figure shows the changes in shallow groundwater salinity (EC) in a pumping station near the centre of the Bonriki freshwater lens. There was a drought between 1998 and 2002 and its impact on salinity can be seen clearly. There was also a peak in 1997 which potentially is also linked to over-extraction. In light of this, strong reliance on groundwater, and alternatively rainwater, for water supply makes South Tarawa extremely vulnerable to climate change, with potential catastrophic consequences.

**Review of impacts**

In Tarawa the impacts of poor water supply are considerable and it is not surprising that in a survey from 2000 (ADB, 2000), insufficient clean water was raised as the most critical problem facing households in South Tarawa, ahead of: over-population, health-system access, unemployment and transport. It can be argued however that over-population has triggered the water related problems. The consequences of poor water supply are categorized into health impacts, economic impacts, social impacts, and environmental impacts.

**Health impacts**

Poor access to water services impacts negatively on public health. In particular there is a strong negative link between improved water services and infant mortality and diarrhoeal diseases (Table 4). Accurate assessment of water related health impacts is difficult because of lack of health data, and a way to facilitate a reduction in health impacts is to improve the information system.


**Economic impacts**

Economic development in Kiribati is difficult because of the isolation and multitude of islands, the poor capacity for agriculture, and a prevailing subsistence culture. Hence only about 20% of the population in Tarawa are in cash employment (Kiribati National Statistics Office, 2006), and about two thirds of these employment opportunities are within the government. The key sources of income for the Kiribati government are (Kiribati National Statistics Office, 2006):

1) Payments for licenses from international fishing vessels operating in Kiribati waters,

2) Interest earned from a reserve fund investment, financed by phosphate earnings (from the period of phosphate mining on the island of Banaba),

3) Foreign assistance and taxes.

In the Pacific, towns and cities are key areas contributing to national growth (Jones, 2005), and South Tarawa can be considered the only urban area in Kiribati, generating approximately 60% of the GDP of Kiribati (Jones, 2005). A number of drivers, such as access to education and lifestyle choices, have fuelled considerable urbanisation in most parts of the Pacific region (Jones, 2003), and South Tarawa is a typical example. In South Tarawa where subsistence living is not a realistic option, the lack of employment opportunities is a serious dilemma and there are areas of squatter settlements with social vulnerability, relatively low but increasing crime rates, and the potential for political instability. Hence, creating employment opportunities in South Tarawa is of critical importance but absolute scarcity of water adds a serious difficulty in industrial and agricultural developments. Additionally a clean atoll represents a major potential asset from which employment opportunities could be created, through tourism, fishing and aquaculture. Improved sanitation and waste practices would allow this atoll to once again become clean.

**Social impacts**

The social impacts relate primarily to two broad areas:

1) Impacts on the lifestyle and comfort of individuals.
2) Social resource scarcity, often arising over water related conflicts in society, and the distribution of available water (Ohlsson, 2000).

The impacts on lifestyle and comfort of individuals relates to the efforts required to take care of basic needs, such as cooking and washing. This is important because, time spent on collecting and using water is often taken from other activities, such as education. In Tarawa, the effort to collect water typically involves either extracting it from a private, public or shared tap, or extracting from a domestic well. The water is often stored first, and then boiled before drinking or cooking. In other words, the efforts involved with collection of water are limited and ought not to be an overly onerous demand in terms of time. However, there is a greater effort involved for squatter settlements in areas with unsuitable groundwater, which rely on tanker water that is relatively expensive. This water is often excessively chlorinated, and is stored before consumption (sometimes in unsuitable containers). Due to limited availability of water, there is also reduced availability of water for lifestyle needs. In Kiribati, lifestyle needs that require water are particularly in relation to keeping pigs and pets, as well as for some limited amount of gardening. According to a survey in 2000 (ADB, 2000), 83% of households in Tarawa have pigs, with an average of 2.62 pigs per household. The exact impact on the water supply of keeping pigs is largely unknown, but relates both to pollution and to increased water demand.

The water available per capita in Tarawa is insufficient even for an average Australian domestic customer, let alone for industrial or agricultural activity. This puts pressure on individuals and households, and the conclusion has been that increasing the supply is of critical importance. The situation of insufficient water supply to South Tarawa stirred South Tarawa into a process which Ohlsson (2000) states starts with a first-order water scarcity, that often leads to supply side focussed engineering developments. These developments trigger second-order scarcity where conflicts may arise between displaced groups of people and the state. This kind of situation has been realised in Tarawa, through the establishment of water reserves in Buota and Bonriki (Crennan, 1998, White et al., 1999) and through the plans for additional water reserves in North Tarawa (Dray et al., 2006). These conflicts tend to develop into a phase of demand management where there is a conscious effort to redirect water
to urban areas and industries, where the economic returns are higher. This leads to lower food-security and loss of livelihoods in rural, or water-extraction areas, leading to urban migration and hence increasing population pressure in urban areas.

**Environmental impacts**

The primary water related environmental impacts in Tarawa are: pollution of the atoll lagoon and sea water, over extraction of water from freshwater lenses, and pollution of the groundwater. The lagoon and sea water are polluted by stormwater run-off, sewerage and rubbish dumped on the reef and in the lagoon. Because of the current condition of the lagoon, swimming is discouraged, and eating fish from the lagoon can lead to serious illness, and potential death. Additionally, the groundwater is polluted as a consequence of high density settlements, war remains (from the Battle of Tarawa of World War 2), poor sanitation, leaky sewer pipes, and inadequate rubbish removal. Lenses are very vulnerable because the depth from the surface to the groundwater table is commonly less than 2 metres in atolls (White *et al.*, 2005a) and high levels of e-coli and faecal coliforms have been measured in many of the lenses. Occasionally water from freshwater lenses is over extracted, causing rising salt levels in the groundwater; in particular at times of drought (see Figure 6), when sustainable pumping rates drop. Additional uncertainty relates to rising sea levels, and an increased frequency of storm events due to climate change.

**Strategy review**

There are many strategies that could be used to improve the availability of water supply and improve water management performance in Tarawa. An exploration of strategies to improve performance and to cope with difficult circumstances are detailed in Table 5.

It is noted that some of the strategies are not consistent with requirements and goals, such as:

1. Infiltration galleries have social impacts; especially when they literally trespass on the rights of traditional land owners.

2. As currently stated, no strategy adequately addresses the access to supply without further consideration of location and detailed strategy design
3. Some strategies require considerable funding, and/or have considerable maintenance requirements, and/or they require sophisticated skills. This impact on the feasibility of such strategies.

All these strategies require distribution of responsibilities to the community, and this requires clear roles and an adequate strategic and adaptive management structure and organisational efficiency, and consequently the decision making capability needs to be strengthened. Additionally to allow for any strategy to be implemented, a thorough understanding of motivations of participants and stakeholders is required. There are strategies for capacity building:

1. Create economy of scale
2. Improve ability for coping with uncertainty and complexity
3. Increase utilisation of local capability

**Increased utilisation of rainwater tanks**

While there is a regulation in place regarding rainwater tanks, in reality it is up to the discretion of each household whether to invest, operate and maintain a rainwater tank. In a survey in South Tarawa done in 2000, the following was noted: “ Asked for the reason why so many households did not have a rainwater collection system, while they should have one, is that they were not in a position to afford such a system” (ADB, 2000). Some of the reasons for why operation and maintenance is not carried out efficiently may be (SOPAC, 2004):

1. “Lack of motivation. People may decide they have other more important priorities and uses for their time and money.
2. Lack of funds. People may not have enough money to pay for materials or spare parts, especially when large scale repairs are needed.
3. Lack of skills. Time and guidance may be required to practice the skills they have learned.
4. Lack of self-confidence. Some individuals may be too embarrassed to ask for help or advice.
5. Fear of change. Some may not want to learn or try something new. Traditional or cultural roles may also stop women or men from making decisions or undertaking particular maintenance or repair activities.

6. Poor communication. Household members may have never discussed the specific areas of responsibility with regards to maintenance and repair.”

To increase rainwater tank utilisation, potential strategies are detailed in Table 6.

**Protection and extension of water reserves**

To increase the supply and improve the water quality from freshwater lenses, a number of strategies are available (Table 7). The need for social acceptance around land-acquisitions was pointed out by Crennan (1998) and government relies only on land leases to achieve this (Dray et al., 2006). In a survey by Dray et al (2006), about 50% of the population on the affected islands of Bonriki and Buota were unhappy with the current arrangement; and the legal mechanism is not without problem (Crennan, 1998, White et al., 1999, Dray et al., 2006). In response, a report by the ADB (2004) called for a participatory approach for groundwater protection that focuses on community needs rather than financial solutions, in particular to increase social acceptance.

Within social acceptance constraints there are two options: 1) co-management of water reserves, and 2) utilisation of freshwater lenses in South Tarawa. Freshwater lenses in South Tarawa are however contaminated, perhaps with the exception of the lenses in Bonriki and Buota (White et al., 1999). For public health, funding and political reasons, water treatment to appropriate water quality standards may be particularly costly if there is chemical pollution such as high levels of total dissolved nitrogen, nitrates or nitrites, but there is limited data about pollutants, and information needs to be collected. Co-management of water reserves would require local participation, and distribution of roles and responsibilities, and may be linked to additional costs, such as additional financial support to traditional land-owners.
Increased utilisation of desalination: water syndicate

Previous attempts at managing desalination plants in South Tarawa have failed, but it is possible that community driven initiatives may overcome feasibility constraints. Utilisation of desalination plants is a high-technology solution so it does not fulfil the simplicity requirement, but this may be acceptable if the particular customer or groups of customers that are utilising the plants take responsibility for its management. For instance a commercial customer group may be established, that operates and maintains a desalination plant, separately from the water utility. This would increase ownership, allow flexibility to use local resources, and provide industry an option to add water supply without reliance on water utilities. It may for instance be possible to run a desalination plant on coconut oil that can be produced locally (Etherington, Zegelin & White, 1998).

Creating economy of scale

A strategy for dealing with small scale is to create economies of scale by reducing the per capita cost of production and operation, or to improve the human resource situation. Essentially there are three methods for creating economy of scale: external economy of scale, growth, and internal economy of scale. Examples are shown in Table 8 of how economy of scale can be created.

Coping with uncertainty and complexity

Pahl-Wostl (2002) claims that to evaluate the desired properties of a sustainable resource management regime, it is insufficient to focus only on economic and ecological performance criteria, but essential to explore a system’s adaptability and flexibility. This relates to the fact that both underlying social circumstances and freshwater systems are complex and adaptive and are each subject to change in the form of sudden shifts (Moberg & Galaz, 2005). This means that to acknowledge the intricacies of manoeuvring the water systems there is a need for monitoring, and understanding interactions with and between complex sub-systems so that responsiveness and adaptive capacity can be supported. Strategies for dealing with uncertainty and complexity are detailed in Table 9. Information collection and modelling will improve adaptive capacity by providing capacity for predictive analysis and scenario analysis. Examples of this are climate and rainfall monitoring, systems
modelling and water quality assessments. The focus of information collection and modelling needs to be on supporting decision making, and it is important to realise the practical limitations of modelling, due to limited resources, and insufficient information. To support decision making, transparency and discussion about assumptions and representations is critical.

Attempts to increase water supply by utilising new water resources has an implicit advantage of increasing supply reliability. This relates to using additional infiltration galleries, rain water tanks, or desalination. Infrastructure flexibility can be increased by relying on modular and small scale technology. There are many excellent examples of modular and small scale technology, such as relating to ecological sanitation, small scale treatment or rain water tanks.

**Utilising local capacity**

Many of the feasible strategies rely on utilising local capability and distribution of responsibilities. This is aligned with the recommendations given in the Town Water Supply and Sanitation (TWSS) forum on small town issues, where it was concluded that a strategy is required for small towns that has a mixture of the centralised and engineering focused water management usually applied in large urban areas, and the participatory approaches typically used for rural areas. As pointed out by Durley and Loe (2005), local participation needs to be supported by coordination of clear roles and responsibilities. Additionally motivations and trust as well as pre-existing relationships, including power relationships, need to be acknowledged for local participation to be truly efficient (Crennan, 1998, Eversole, 2003), and consequently the availability of adequate local negotiators or facilitators is a limiting factor. The change to a more decentralised management style requires a change in management philosophy, and to support the transition, lessons can be learnt from the studies on decentralised responsibilities in natural resource management by Ostrom (1990, 2004) or the work on community-driven initiatives by Satterthwaite, McGranahan and Mitlin (2005). It should also be noted that in order to manage both holistically, and in a participatory manner, there is a need for both horizontal (between stakeholder groups) and vertical (between governance levels) information flows (Australian Water Research Facility, 2005). Given the
current poor performance of the current solutions this is desirable. It is however acknowledged that this in some ways requires a redistribution of power that may be unrealistic given political/cultural realities.

**Community of Practice on water safety and adaptive capacity**

A Community of Practice (CoP) could be an invaluable resource for small town water management, if it is designed so that when:

- motivation and dedication is low, it collects and channels motivated individuals to coordinate efforts
- information is limited and dispersed, it improves knowledge management, and directs information flows
- leadership is weak, it generates natural leaders
- skill levels are low, it provides opportunities for learning
- interests are varied, it provides a venue for discussion and conflict resolution
- issues are complex, it allows for discussion about assumptions and representations used for decision making
- trust in government and outsiders is low, it provides a venue for fair and transparent decision making

Rules need to be in place to ensure stable and efficient participation and contribution, and in the long term, the role of a CoP could be formalized via political process so that it would work closely with relevant stakeholders. In Table 10, design requirements of a CoP, in terms of purpose and tasks, are provided for two applications: water safety and adaptive capacity. To build adaptive capacity in a resource constrained environment, it is critical to utilize local capacity for decision making and monitoring of the changing situation, as concluded from a case study by Gwebu (2002) in Bulawayo, Zimbabwe. A CoP can build adaptive capacity, which should be seen as an adaptive co-management approach as described by Moberg and Galaz (2005), where resource management is viewed as a continuous learning-by-doing process that recognizes public participation and collaborative learning. For adaptive capacity a CoP provides the community and stakeholders a venue for identifying strategies
to cope with diminishing resources, understand the local and system wide changes occurring, and provides an opportunity for natural leaders to appear. Another example of an application for a CoP is to increase water safety. For water safety, community cooperation is important from the start of the chain in terms of protecting water sources, to intermediate steps of maintaining infrastructure such as rain tanks, and all the way to the end of the chain of water storage and water utilization (AusAID, 2005).

While extensive laboratory testing is deemed impractical, considerable information can be collected by simple observation of conditions surrounding water sources, such as infiltration galleries, domestic wells, or rain tanks, or by keeping health records (AusAID, 2005).

**Summary of key opportunities**

While directions should be set by local stakeholders, several opportunities to considerable improve the situation have been identified by:

- Introducing co-management of water reserves in order to increase social acceptance, protect water sources, and potentially allow for additional water reserves
- Capacity building: strengthen the human resources of departments and utilities to develop clear work roles, provide succession planning, and ensure adequate knowledge management
- Monitoring water safety and health based on basic observations, and mapping of occurrences of water-borne disease
- Establishing a process, or arena for exploring and negotiating requirements and considering stakeholder motivations within the early design of any development
- Increasing utilisation of rainwater tanks, for which several strategies are available (Table 6)
- Increasing utilisation of local capacity, such as through a Community of Practice (CoP)

**Conclusions**

The water situation in South Tarawa, a small Pacific atoll town is at crisis level because the water related impacts are severe, and several attempts to improve the situation have failed. It appears that urban services are still lagging behind the rapid urbanisation that has occurred in Tarawa, and the pressure on local departments is immense. Sadly infant mortality rates are among the highest in the
world, and this is primarily driven by water borne disease. Perhaps the most limiting factor is the lack of cheap and readily available water resources, leaving many households to rely on water trucks, shallow domestic wells, rainwater tanks and storage of water in unsuitable containers. There is however also significant potential for community members to improve their situation by observing and responding to conditions and health occurrences, but the community relies on the local departments for water management, and these departments are acutely under-resourced, and lack adequate funds and staff. To improve the situation there is an urgent need to strengthen the local capability, so that lasting results can be achieved. Currently, failed developments are frequent, wasting scarce resources and leaving few lasting results.

It is identified that there are a number of hurdles towards improving the supply, such as institutional weakness, lack of social acceptance of additional infiltration galleries, polluted water resources, poor uptake and utilisation of rainwater tanks and inadequate decision making processes. To overcome such hurdles, a number of strategies are identified, that can be classified into the following broad categories:

1. Creating economy of scale, but opportunities are limited
2. Coping with uncertainty, but this requires improved decision making
3. Utilising local capabilities, but this requires a shift in management philosophy

There are opportunities for increasing water supply, but to achieve any real increases in supply volumes, new infiltration galleries are required, but social acceptance of existing galleries is low, and the social acceptance of additional galleries is even lower. Strategies are needed to increase the social acceptance of new infiltration galleries, and two options are identified:

1. Co-management of existing water reserves together with traditional land-owners. This would potentially allow for utilisation of freshwater lenses in North Tarawa
2. Utilisation of freshwater lenses in South Tarawa, but this requires stringent water treatment, which may be impractical
What becomes apparent throughout the exploration of available strategies is that there is a considerable overlap of ingredients, and that a common theme is the utilisation of decentralised management with distribution of responsibilities and community driven initiatives. This requires a new management philosophy; and it is a challenging task to implement, which would require involvement of community members, NGOs, government representatives, ministries, and any other key stakeholders. Therefore to initiate a transition towards a more decentralised management culture it is recommended to create a Community of Practice around the issues of groundwater protection, water safety or building adaptive capacity. The design and details of a CoP need to be carefully chosen in order to fulfill a wide range of design criteria, and to ensure feasibility despite the lack of adequate NGOs, and for this purpose, further research is required.

Acknowledgements

The authors would like to give acknowledgement to Marc Overmars at SOPAC for support. They would also like to acknowledge the input through discussions with Ian White, ANU CRES, Eita Metai of the Ministry of Public Works and Utilities in Kiribati, Teboia Metutera of the Public Utility Board of Tarawa, Tony Falkland of Ecwise, Paul Jones of the Virtual Consulting group, Marjorie Sullivan of AusAID and Anne Dray of the ANU Research School for Pacific and Asian Studies.

References


Figure captions

Figure 1: Map of Tarawa Atoll, with inset map of the area around the Central Pacific Ocean

Figure 2: Household with rainwater tank
Figure 3: Domestic unprotected well

Figure 4: Sand mining on water reserve

Figure 5: Burial grounds on the water reserve
Figure 6: Changes in shallow Electrical Conductivity (EC), in an infiltration gallery (White et al 2005b).

### Tables

Table 1: Currently available and optimistic scenario of water sources in Tarawa

<table>
<thead>
<tr>
<th>Water source</th>
<th>Volume available</th>
<th>Optimistic scenario</th>
<th>Currently available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater – from Buota and Bonriki</td>
<td>2,530 m³ per day</td>
<td>1,700 m³ per day</td>
<td></td>
</tr>
<tr>
<td>Rainwater collection</td>
<td>1,197 m³ per day</td>
<td>283 m³ per day</td>
<td></td>
</tr>
<tr>
<td>Desalination</td>
<td>200 m³ per day</td>
<td>0 m³ per day</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3,927 m³ per day</td>
<td>1,983 m³ per day</td>
<td></td>
</tr>
<tr>
<td>Total per capita</td>
<td>85 liters per day</td>
<td>43 liters per day</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Decision making capability

<table>
<thead>
<tr>
<th>Review category</th>
<th>Description of current ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing risk and coping with uncertainty</td>
<td>Managing risk and coping with uncertainty has previously been done on an ad-hoc basis but there is currently work to improve decision making within the Kiribati Adaptation Project, which is sponsored by AusAID and NZAID (Office of Te Beretitenti 2005).</td>
</tr>
<tr>
<td>Evidence based</td>
<td>Sustainable yields have been established (Falkland 2003), and some rainfall</td>
</tr>
</tbody>
</table>
reasoning

data has been collected (Falkland 2003). The collection of rainfall data and monitoring of water quality is however still lacking.

There were attempts at more holistic management approach to water by the use of an inter-ministerial water board, but this collapsed due to interpersonal conflicts and poor motivation of participants. The potential for reviving a multi-stakeholder water board is being explored under the banner of the EU’s Pacific Water Governance Project (White 2006).

Managing holistically

Participatory management is almost non-existent except for efforts within an ACIAR sponsored study (Dray et al., 2006) and a study by UNICEF (Crennan 1998), around the development of new water reserves. Household surveys (ADB 2000) have been undertaken as part of a project to establish the behaviour and preferences of participants.

Managing in a participatory manner

Water is valued primarily based on the cost of extraction and operating infrastructure, with little consideration of wider impacts or the value for Tarawa of an increased/improved supply.

Valuing water

### Table 3: International comparison of the Kiribati water supply. Only urban areas included. (WHO 2006)

<table>
<thead>
<tr>
<th>Country / Region</th>
<th>Percentage of households connected to water supply</th>
<th>Percentage access to improved water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiribati</td>
<td>49%</td>
<td>77%</td>
</tr>
<tr>
<td>Global average – urban</td>
<td>79%</td>
<td>95%</td>
</tr>
<tr>
<td>Oceania average</td>
<td>67%</td>
<td>91%</td>
</tr>
<tr>
<td>Developing countries</td>
<td>71%</td>
<td>92%</td>
</tr>
<tr>
<td>Least developed countries</td>
<td>31%</td>
<td>79%</td>
</tr>
</tbody>
</table>

### Table 4: Infant mortality rates and other relevant indicators (WHO 2006)

<table>
<thead>
<tr>
<th>Country</th>
<th>Infant mortality</th>
<th>Access improved</th>
<th>Access improved</th>
<th>Percentage of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Rate</td>
<td>Water Supply</td>
<td>Sanitation</td>
<td>Child Deaths</td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td>--------------</td>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Kiribati</td>
<td>49</td>
<td>77</td>
<td>59</td>
<td>21.9</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>67</td>
<td>88</td>
<td>67</td>
<td>15.3</td>
</tr>
<tr>
<td>Marshall islands</td>
<td>52</td>
<td>80</td>
<td>93</td>
<td>14.1</td>
</tr>
<tr>
<td>Fiji</td>
<td>16</td>
<td>?</td>
<td>98</td>
<td>10.6</td>
</tr>
<tr>
<td>Tonga</td>
<td>21</td>
<td>100</td>
<td>98</td>
<td>10</td>
</tr>
<tr>
<td>Samoa</td>
<td>25</td>
<td>91</td>
<td>100</td>
<td>9.7</td>
</tr>
<tr>
<td>Solomon islands</td>
<td>34</td>
<td>94</td>
<td>95</td>
<td>8.8</td>
</tr>
<tr>
<td>Micronesia</td>
<td>19</td>
<td>95</td>
<td>61</td>
<td>8</td>
</tr>
<tr>
<td>Malaysia</td>
<td>10</td>
<td>96</td>
<td>?</td>
<td>5.4</td>
</tr>
<tr>
<td>United States</td>
<td>6</td>
<td>100</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>Australia</td>
<td>3</td>
<td>100</td>
<td>100</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 5: Expected impact of strategies on performance

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Supply</th>
<th>Vulnerability</th>
<th>Safety</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased utilisation of rainwater tanks</td>
<td>Improved</td>
<td>Reduced</td>
<td>Uncertain</td>
<td>Potential for improvement</td>
</tr>
<tr>
<td>Protection of water reserves</td>
<td>Improved</td>
<td>Reduced</td>
<td>Improved</td>
<td>Potential for improvement</td>
</tr>
<tr>
<td>New infiltration galleries</td>
<td>Significantly improved</td>
<td>Significantly reduced</td>
<td>Uncertain</td>
<td>Potential for improvement</td>
</tr>
<tr>
<td>Water syndicates using desalination</td>
<td>Improved</td>
<td>Reduced</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 6: Strategies to increase rain water tank utilisation

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Focus</th>
<th>Description, issues and impacts</th>
</tr>
</thead>
</table>

34
If all public buildings, built by overseas agencies, and in particular government buildings, are fitted with tanks of appropriate size, enforcing the regulation through policing, penalties and/or rewards does not appear to be the culture of operation in Kiribati and may cause secondary issues.

Making sure that the receiver is motivated and has a real need for a tank. Appropriate training needs to be provided and clear roles and responsibilities developed and distributed. Participatory workshops can be used to achieve this (SOPAC 2004).

It may be worthwhile for the relevant utility or Ministries to provide training, public outreach, or services to support the community in this process.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Focus</th>
<th>Descriptions, issues and impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection of water reserves</td>
<td>Reliance on legal mechanisms</td>
<td>Displacement of traditional land owners from reserves Poor social acceptance</td>
</tr>
<tr>
<td>Additional water reserves</td>
<td>Co-management of water reserves</td>
<td>Improved water protection Increased social acceptance</td>
</tr>
<tr>
<td>North Tarawa water reserves</td>
<td>Sustainable yields in North Tarawa is 4,630 m$^3$/day (Falkland, 2003). Significant volumes would be lost in leakage as water is pumped to South Tarawa</td>
<td></td>
</tr>
</tbody>
</table>
Issues with social acceptance
Reduced ability for agricultural production.

South Tarawa
Freshwater lenses are contaminated meaning extra cost of water treatment.
Less social disturbance
Some reduction in availability of land

Table 8: Opportunities for economy of scale in Tarawa

<table>
<thead>
<tr>
<th>Type</th>
<th>Method</th>
<th>Limitations and issues in Tarawa</th>
</tr>
</thead>
<tbody>
<tr>
<td>External economy</td>
<td>Regional, national or international cooperation</td>
<td>Limited by geographical separation, and potential inefficiencies relating of centralized services (i.e. not really applicable in Tarawa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regional cooperation can be used to source funding and skills. Currently, this is done through the regional research organisation SOPAC.</td>
</tr>
<tr>
<td>Growth</td>
<td>Increase population</td>
<td>Ability for growth is limited by external factors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is not an option in Tarawa where land is extremely scarce</td>
</tr>
<tr>
<td>Internal economy</td>
<td>Local cooperation</td>
<td>Sharing resources on a small scale, such as by having communal rainwater tanks, and public services such as public toilets and shower blocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited by social acceptance, and is applicable in areas where social capital is high, as can be expected in some of the peri-urban areas, and in Eita village</td>
</tr>
</tbody>
</table>

Table 9: Coping strategies for dealing with complexity and uncertainty

<table>
<thead>
<tr>
<th>Coping strategy</th>
<th>Options in Tarawa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing reliability</td>
<td>Reliance on multiple water sources, for water resource reliability</td>
</tr>
</tbody>
</table>
Succession planning, training and knowledge management for skills and knowledge reliability

Building adaptive capacity

Holistic and participatory decision making

Flexible information collection, improved predictive capacity and adaptive decision making

Increasing infrastructure flexibility

Small scale water treatment

Ecological sanitation

Rainwater tanks

Table 10: Community of Practice design requirements

<table>
<thead>
<tr>
<th>Focus</th>
<th>Purpose</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water safety</td>
<td>Collection of information</td>
<td>Observation of conditions surrounding water sources, such as infiltration galleries, domestic wells, or rain tanks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Health monitoring</td>
</tr>
<tr>
<td></td>
<td>Coordination of efforts</td>
<td>Provide leadership and influence political decision making</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Understanding causes of water related health problems</td>
</tr>
<tr>
<td></td>
<td>Increase awareness</td>
<td>Provide a venue for concerned and motivated community members to improve the situation</td>
</tr>
<tr>
<td>Adaptive capacity</td>
<td>Adaptive decision making</td>
<td>Monitor and respond to changes in conditions</td>
</tr>
<tr>
<td></td>
<td>Coordination of efforts</td>
<td>Provide predictive capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide opportunities for learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consider a holistic perspective of changing conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide opportunities for conflict resolution around diminishing resources</td>
</tr>
</tbody>
</table>