WATER GLOBAL PRACTICE

Building Urban Water Resilience in Small Island Countries

THE CASE OF SOUTH TARAWA, KIRIBATI

WORLD BANK GROUP

OCTOBER 2019

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Foreword

Small island developing states are on the front lines of the climate crisis. They face enormous climate adaptation challenges stemming from rising sea levels coupled with more frequent and intense storms and droughts. Many island states are already water constrained due to small watersheds and limited opportunities for groundwater and surface water storage. Their water quality is all too frequently degraded because of generally high population densities, low levels of sanitation, and salt water intrusion. Advanced water technologies, such as desalinization or wastewater reuse, can potentially help address these challenges but are financially and institutionally difficult to sustain in many countries and in the event of breakdowns may even—perversely—increase water security risks.

Kiribati faces all of these challenges and more, and this report aims to shed light on improved water management approaches to boost resilience and increase water security. We believe the proposed resilience measures—many of which are low cost and nature based—are applicable to other small islands across the Pacific and beyond. The study also draws special attention to the role of social resilience during water-supply crises, a dimension often overlooked by water sector policymakers and yet critical in most contexts.

Water challenges in a city such as South Tarawa, Kiribati's capital, matter not only because the lives and prosperity of its own inhabitants are at stake, but also because issues such as climate variability, anthropogenic pressure on water resources, and systemic infrastructure weaknesses foretell the human, physical, and economic challenges many other cities are likely to face later this century. In this way, places like Kiribati are the canary in the coal mine when it comes to the perils of climate change. Because South Tarawa's climate risks are more imminent and more threatening, and because its capacity to address these risks is more constrained than elsewhere, water management models that prove resilient and sustainable in such a context today could help unlock solutions to future urban water security challenges globally. We believe this report makes a valuable contribution to sharing these lessons.

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Executive Summary

What Is Water Supply Resilience in a Context of Water Scarcity?

Resilience is the capacity of a system to absorb the shocks or stresses imposed by climate change and other factors. Water supply services around the world are increasingly being affected by shocks or stresses such as droughts, flooding, or human-induced disasters. Building water supply resilience requires long-term planning that takes into account the uncertainties faced by decision makers.

Why Does Water Supply Resilience Matter for South Tarawa?

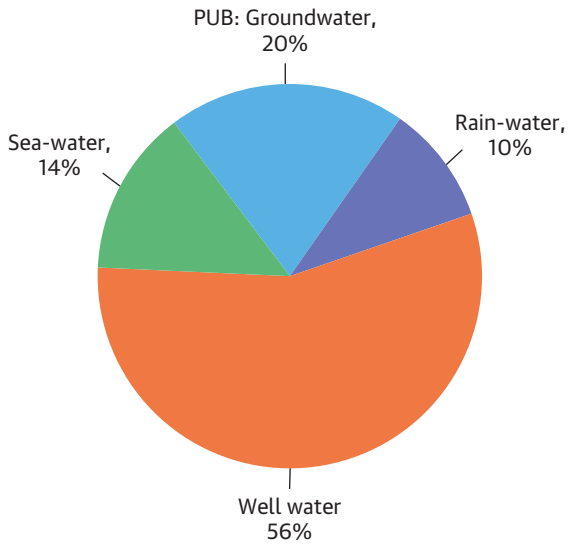
South Tarawa presents striking features of geographic, physical, and socioeconomic fragility. Kiribati is one of the smallest, most remote, and most geographically dispersed countries in the world. Its capital, South Tarawa, has uniquely fragile water resources due to its small size, lack of natural capacity for water storage, and competing land use.

Water supply insecurity is chronic across South Tarawa. Despite the presence of a centralized water supply system operated by the public utilities board (PUB), and fed primarily by groundwater from the water reserves located in Bonriki and Buota, access to safely managed, piped water supply services remains very limited in South Tarawa: Only two thirds of the population has PUB house connections that supply 10 liters per capita per day, on average. As shown in figure ES.1, rainwater harvesting (RWH) has emerged as an important coping strategy, but its quantitative contribution to water use remains marginal. Urban groundwater is generally brackish and contaminated bacteriologically, but is still widely used for nonconsumptive purposes through a network of private, shared, and communal shallow wells. A piped supply of seawater for toilet flushing is available in several areas that are served by sewerage networks.

In this context, the population of South Tarawa has developed sophisticated strategies for coping with inadequate water supply. Households follow several advanced water scarcity management principles, such as diversification of water resources, fit-for-purpose water use, thrifty water consumption, and adaptive strategies of water use, depending on the local level of water stress. Collectivism and water sharing also play a critical role in reducing affordability challenges, water-related conflicts, and vulnerability to drought.

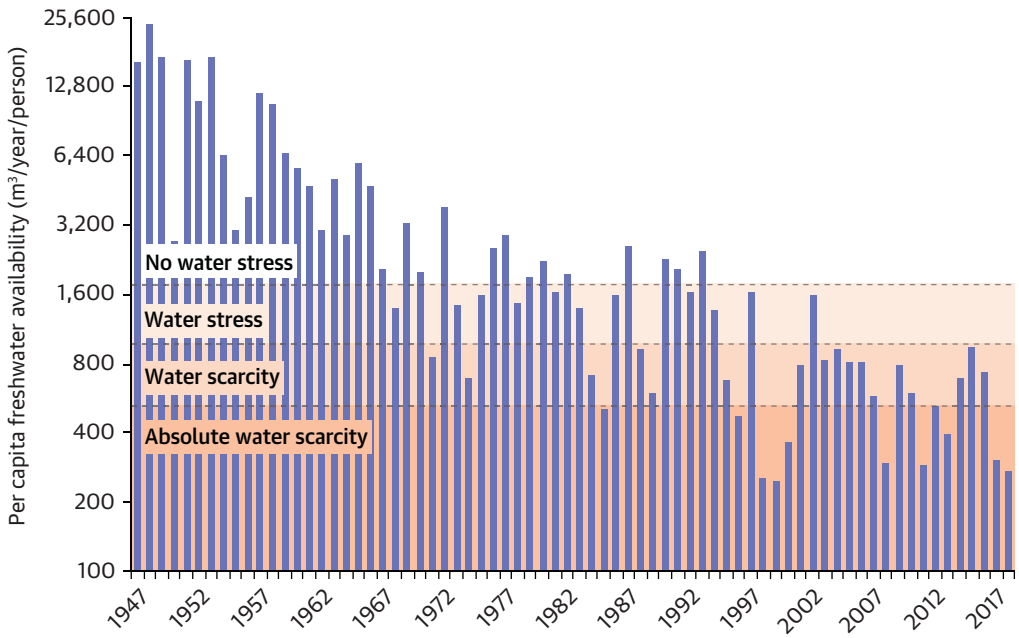
Water scarcity challenges, and the effects of climate change are increasing, and they underline the need for additional water resources. Inherent limitations in freshwater resources, climate variability, sea level rise, and continuous population growth are exposing South Tarawa to increasingly severe water supply

FIGURE ES.1. Contribution of Water Resources to Water Supply, 2019



Source: World Bank data.
Note: PUB = public utilities board.

FIGURE ES.2. Per Capita Freshwater Availability in South Tarawa, 1947–2017

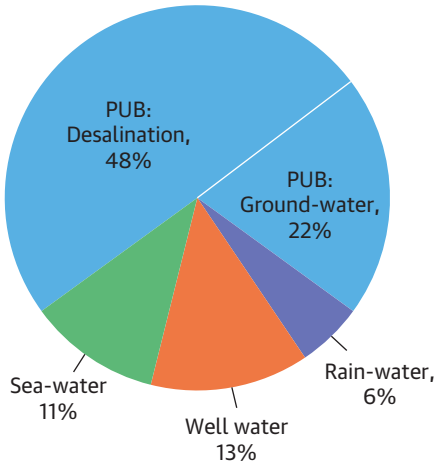


Sources: Rainfall data: Kiribati Meteorological Services; Historic population: Hoy et al. 2014.

deficits. Per capita freshwater availability in South Tarawa has dramatically declined in recent decades, as shown in figure ES.2, primarily due to a six-fold population increase over the last 50 years. Since the end of the 1990s, freshwater availability has hovered around the absolute water scarcity threshold.

In recognition of this deepening challenge, the South Tarawa Water Supply Project (STWSP) is planning a 4,000 cubic meter (m3) per day seawater desalination system to address water supply deficits in the long term. The centralized water supply system will rely on a combination of desalinated seawater and groundwater abstracted from the Bonriki and Buota freshwater lenses, as shown on figure ES.3.[1] In addition to the improved PUB water services, South Tarawa's population is expected to continue to rely to some extent on shallow wells and RWH for a variety of reasons, including affordability, taste preferences, and attachment to cultural practices.

FIGURE ES.3. Contribution of Water Resources to Water Supply (2030, after STWSP)



Source: World Bank data.
Note: PUB = public utilities board; STWSP = South Tarawa Water Supply Project.

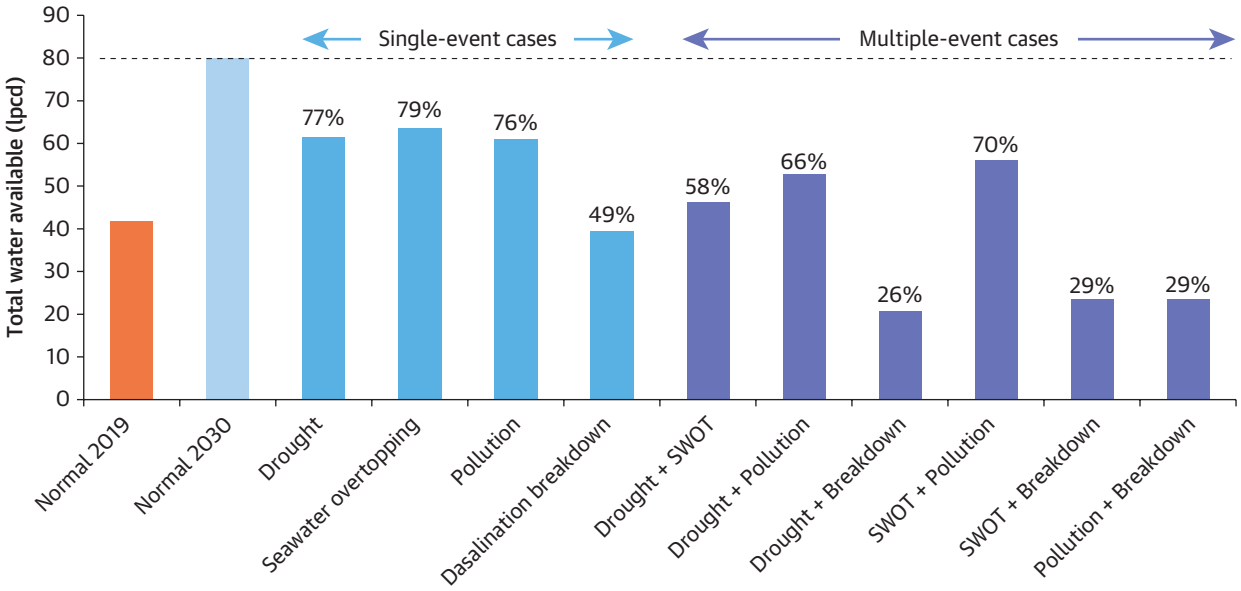
Despite the PUB water system upgrade and the additional production of desalinated water, the water sector will continue to present key vulnerabilities, both

natural and artificial. Severe droughts, such as those experienced in the past, could lead to a significant decrease in yields at water reserves, drive well-water salinity above acceptable levels—even for nonpotable water use—and dry up most of the RWH systems. Sea level rise will aggravate the likelihood and impact of seawater overtopping the water reserves, threatening salinization of the lenses. In the long term, the contamination of the water reserves whether by settlers, or by airport-related activities, could affect water quality to a degree that requires very costly treatment solutions, particularly if encroachment by settlers continues unmitigated.

The modernization of the PUB water system may also introduce new risks for South Tarawa. Water supply will be vulnerable to the systemic risk of a temporary breakdown of seawater desalination due to technical issues. To mitigate such risks, STWSP will help strengthen PUB's operational capacity with private sector support. However, once people become accustomed to an improved reliability of water supply and to higher levels of water consumption, traditional water scarcity management strategies may fall in disuse, undermining resilience to water scarcity crises.

Once the PUB water system is upgraded, three water crisis scenarios stand out as having potentially the greatest impact on water availability. For this study, each event (and combination thereof), and the effect it would have on the production capacity of each water resource has been estimated, and this is illustrated in figure ES.4. For example, a breakdown of the desalination plant would reduce freshwater availability by more than 50 percent, or even more if combined with a major drought or pollution event. In all of the crisis scenarios, the availability of potable water would, however, remain above 10 liters per capita per day (lpcd), which can be considered a

FIGURE ES.4. Freshwater Availability 2030, in Normal and Various Crisis Scenarios



Source: World Bank data.
Note: The percentage figures show the ratio of water volumes available during an event vs. during the normal situation. Percentages shown are the ones remaining in case of crisis events vs. the "normal" level. SWOT = seawater overtopping.

minimum acceptable level for human consumption (that is, for drinking and cooking) in an emergency. Efforts to build water supply resilience in South Tarawa should therefore seek to improve availability during these types of events, in order to reduce the gap between availability and the water consumption levels South Tarawa will have grown used to.

How Can South Tarawa Improve its Water Resilience?

A first measure, critical to the resilience of South Tarawa's water sector, is strengthening the utility's overall capacity and sustainability. PUB's ability to plan for and react to any water crisis will greatly depend on its operational performance and its financial stability. Furthermore, the efficient management of its distribution network will be essential in order to minimize leaks and water shortages during a crisis.

The Kiribati inhabitants' tradition of thrifty water use is a major asset that the authorities should seek to encourage and sustain. The delivery of safe and plentiful PUB water will require careful management of changes in people's water-use habits by building enhanced awareness of water conservation principles, and applying appropriate water tariffs.

Opportunities to improve water availability during crises, through RWH, are related more to improving water resource management than to expanding infrastructure. The current stock of hard-roofed structures could allow significant expansion of RWH, but low cost-effectiveness remains a barrier. When yields from the water reserves decline due to drought or a pollution crisis, advising the public that they should keep their rainwater tanks full, if necessary by progressively filling them with PUB water, will provide a critical safety cushion of a several-week supply if the desalination plant happens to fail in that same period.

There is significant scope for better managing, recharging, and using urban groundwater. The recharging of urban lenses with treated greywater and/or with rainwater overflow from tanks could improve the availability and quality of well water, making this resource a more relevant backup solution for non-consumptive use when other sources fail. Increased PUB water supply delivery will boost greywater generation and enhance the recharging of lenses, especially during droughts. Pilot programs will be required to test the design of simple treatment and infiltration systems that can maximize the water quality of nearby wells. This will also improve South Tarawa's environment by reducing the unmanaged discharge of greywater in backyards. Policy measures could also contribute to the management and protection of urban groundwater quality. These could include the establishment of quality guidelines for and monitoring of well water; prohibiting the use of soaps and detergents that are harmful to the environment; and an amendment of the Kiribati Building Code to prescribe the direction of overflow of RWH systems for recharging wells.

There is also significant scope for managing PUB's infrastructure in a way that is more resilient to short-term breakups of the desalination system or the water reserve production system. Protection of the Bonriki water reserve, stands as a priority measure for helping to weather brief breakdowns of the desalination plant, or other parts of the system, but the adoption of planned management procedures for bulk PUB water storage facilities, and prudent asset management strategies that are designed to gradually respond to such events, are also important.

Direct reuse of nonpotable water, already practiced informally in South Tarawa, could reduce water demand and thereby minimize the impact of decreased water availability. In low density areas without a seawater network for toilet flushing, direct reuse of greywater at the household level could help reduce the reliance on PUB water and/or minimize the burden of fetching well water. Similarly, direct reuse of nonpotable water could be considered in lieu of seawater

flushing in high density areas where sewerage system expansion is envisaged. Across South Tarawa, we estimate that up to 40 percent of households could benefit from the implementation of a direct nonpotable water reuse scheme.

Various measures could help reduce pollution risks in the water reserves. Diffuse pollution from people living on the reserves could be mitigated through a variety of low-cost watershed management approaches. Similarly, potential pollution linked to fuel spillage from the airport could be contained, facilitating remediation, through continuous groundwater monitoring.

Another option for improving resilience could be the construction of a backup seawater desalination system, independent from the existing ones. There is no technical limit to the production capacity of such a backup system, and in theory it could address the supply gaps in all of the crisis scenarios. However, keeping a seawater desalination plant in standby mode to cope with emergencies requires regular and careful maintenance, at a nonnegligible cost.

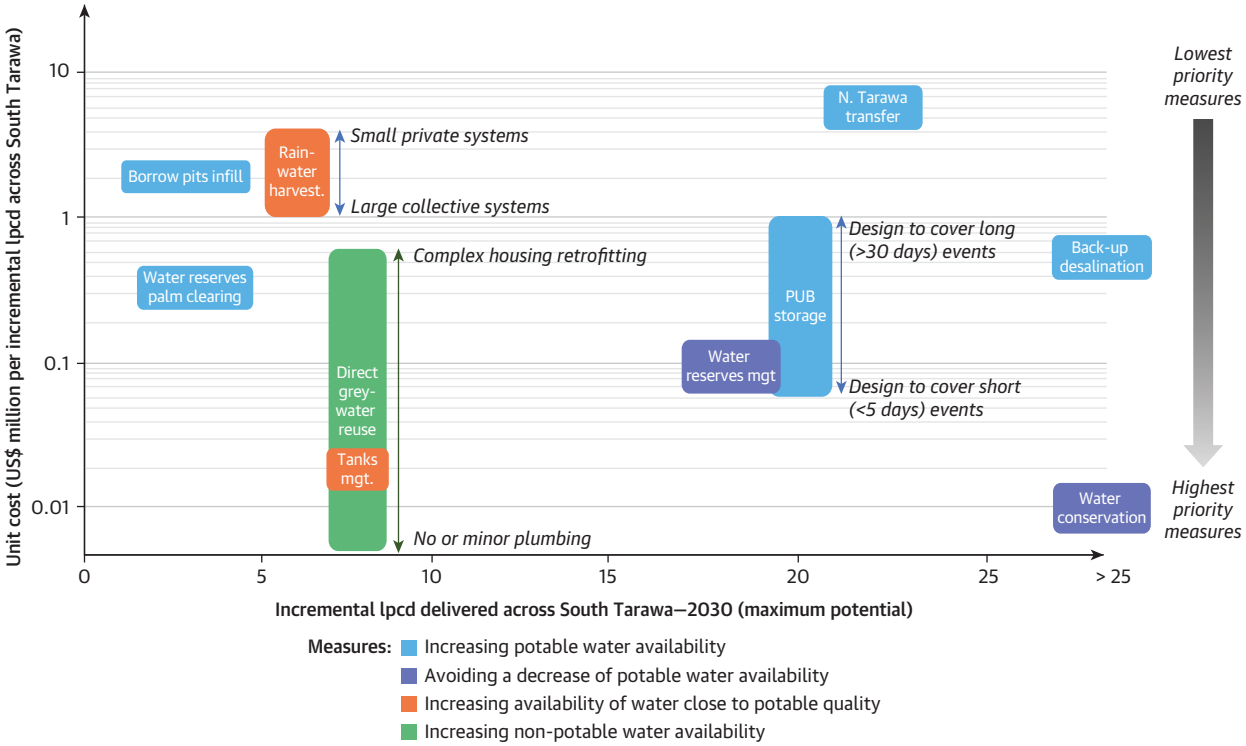
A clear prioritization of measures emerges from a comparison of their cost-effectiveness.[2]

- As shown in figure ES.5, water conservation measures, tank crisis management, direct greywater reuse, deep-rooted palm tree clearing, and pollution mitigation can all significantly augment (or prevent the loss of) water supplies at a very limited cost, and can be considered as no-regret measures.
- The managed recharge of urban water lenses is also expected to require very limited investment, but the benefits in terms of incremental water availability at acceptable nonpotable water quality levels are not known at this stage, and will require piloting and monitoring to ascertain. Any meaningful increase of well-water availability at an acceptable level of quality would make this measure more cost-effective than the following ones.
- If the above measures are implemented to their fullest potential, two options could be considered, to bridge the remaining water deficit: the implementation of bulk PUB water storage in Bonriki; or the construction of a back-up desalination unit. If desalination system breakdowns are expected to last less than 2 weeks, then bulk water storage would be technically feasible and sufficient to weather the crisis, and would be the more cost-effective of the two options. If desalination system breakdowns for more than 2 weeks are considered credible, however, then the back-up desalination plant would become more cost-effective, and could help address water shortage crises over time.
- Finally, the infill of borrow pits[3] in Bonriki, along with RWH and groundwater transfer from North Tarawa appear to be the costliest measures being considered by far. There could still be justification for RWH, however, if it is determined that households will be willing to pay a large premium for private ownership of this quality water resource, which is anchored in Kiribati tradition and appreciated for its taste.

What Can Water-Scarce Cities on Small Islands and Elsewhere Learn from this Study?

The sophistication of urban water scarcity management in South Tarawa, shaped by long exposure to water hardship, illustrates the value that small island countries can bring to global discussions on urban water resilience. The convergence of droughts, anthropic pressure on water resources, and systemic infrastructure failures represents a clear societal threat, even more immediate than the potential effects of sea level rise. An important finding of this study is that, after the planned modernization of PUB's water system, water supply security can be significantly boosted by local, low-tech, low-cost measures that make the most of existing resources.

FIGURE ES.5. Overview of Resilience Enhancement Measures



Source: World Bank data.
Note: Greywater and rainwater recharge to urban water lenses is not illustrated, due to uncertainties about the unit costs and benefits.

Finally, the preservation of traditional water management practices, which are both frugal and collectivist, and are shaped by a long history of water scarcity, will also be critical in maximizing the resilience of communities to future water-supply shocks. Sustaining social resilience should remain a priority when investing in the water resilience of urban infrastructures.

Notes

1. A freshwater lens is a convex-shaped layer of fresh groundwater that floats above the denser saltwater, usually found on small coral or limestone islands and atolls.
2. Due to insufficient data availability, full cost-benefit analyses were not carried out.
3. Pits resulting from the excavation of material used for the construction of the Bonriki airport airstrip.

Abbreviations

ADB	Asian Development Bank
$A	Australian dollar
CAPEX	capital expenditure
CSO	community services obligation
DBO	design build operate
DFAT	Department of Foreign Affairs and Trade
EC	electrical conductivity
ENSO	El Niño Southern Oscillation
EU	European Union
GDP	gross domestic product
GEF	Global Environmental Facility
GoK	Government of Kiribati
HCI	Human Capital Index
HDI	Human Development Index
HIES	Household Income and Expenditure Survey
IPCC	Intergovernmental Panel on Climate Change
KAP	Kiribati Adaptation Program
KIRIWATSAN	Water and Sanitation in Kiribati outer islands
LMD	Land Management Department
lpcd	liters per capita per day
M&E	monitoring and evaluation
MELAD	Ministry of Environment, Land and Agriculture Development
MFAT	Ministry of Foreign Affairs and Trade
MHMS	Ministry of Health and Medical Services
MICTTD	Ministry of Information, Communication, Transport and Tourism Development
MISE	Ministry of Infrastructure and Sustainable Energy
NOAA	National Oceanic and Atmospheric Administration
O&M	operation and maintenance
OPEX	operational expenditure

PUB	public utilities board
PV	photovoltaic
RCP	Representative Concentration Pathway
RWH	rainwater harvesting
SAPHE	Sanitation Public Health and Environment
SMP	Sustainable Management Plan
SODIS	solar water disinfection
SPC	Secretariat of the Pacific Community
STWSP	South Tarawa Water Supply Project
SWOT	seawater overtopping
TA	technical assistance
TBD	to be determined
UNDP	United Nations Development Program
WASH	water supply, sanitation, and hygiene
WHO	World Health Organization
WSS	water supply and sanitation

Chapter 1
Introduction

The water sector in South Tarawa, the capital city of Kiribati, is entering a time of extensive transition. On the one hand, climate change and the pressures placed on fragile water resources by overpopulation are converging to create unprecedented risks for water-supply security. On the other hand, an unparalleled effort by the government of Kiribati and donors to support modernization of the city's reticulated water supply system will drastically improve water supply services, although it may also introduce some new systemic water security risks.

In a small island context, risks can materialize more quickly than elsewhere, and can have disproportionate consequences. Strengthening water sector resilience is therefore critical both to people's welfare and to the economy. Traditional perceptions of risk, and the resilience mechanisms adopted by households and communities based on centuries of experience with water hardship, may no longer apply in these changing times.

This report was conducted in parallel with the preparation of the South Tarawa Water Supply Project (STWSP), to provide a diagnostic of the vulnerabilities that South Tarawa's water supply sector may still face after the completion of the project. Its main objective is to inform decisions by the government of Kiribati about how to address these vulnerabilities. Chapter 2 sets the stage with a brief presentation of the concept of water supply resilience in a context of water scarcity. Chapter 3 provides a summary of water supply conditions in South Tarawa, and analyzes the impacts of various stresses and shocks on freshwater availability. Chapter 4 discusses potential measures to reduce water supply deficits during major crises. Finally, chapter 5 offers an overview of these measures in the form of an action plan, and proposes several lessons that can be applied to water-scarce cities on other small islands, and elsewhere.

Chapter 2
What is Water Supply Resilience in a Context of Water Scarcity?

1. Water supply and sanitation (WSS) services around the world are increasingly being affected by external shocks, including climate-related shocks. Rapid urbanization is compounding the effects of a lack of urban planning with substantial impacts on water availability and quality both within and beyond city boundaries. These include the overexploitation of water resources; decreased water security; increased vulnerability to floods and other natural disasters; and various water-related health issues. Climate change is exacerbating these impacts and worsening water scarcity. The consequences of climate change will continue to be felt through more frequent, and/or more severe, extreme weather events, changing rainfall patterns and temperatures, seasonal shifts, and sea level rise.

2. In the case of the Pacific islands, population growth in urban centers and increasing vulnerability to storm surges, seawater overtopping (SWOT), and variability in rainfall patterns could pose serious threats to habitability, and to the availability of water resources. The built environment is not always equipped to weather these shocks, which leads to vulnerability in the WSS infrastructure, and in the urban structures that affect service provision. At the same time, tensions between municipal and other water users are growing over access to water resources. Because climate change amplifies existing uncertainties and threats it should not be evaluated as a stand-alone impact. In order to promote water security, it is critically important to give proper consideration to both climate risks and opportunities when planning for WSS services and water resources.

3. Resilience is the capacity of a system to absorb the shocks or stresses imposed by climate change and other factors, and in the process to develop greater robustness. Projects planned with resilience as a goal are designed, built, and operated to better handle not only the range of potential climate change and climate-induced natural disasters, but also to promote contingencies that will lead to efficient, rapid adaptation to a less vulnerable future state (Bonzanigo et al. 2018).

4. In light of increasing water scarcity, building water-supply resilience will require long-term planning that takes into account the uncertainties faced by decision makers. To establish what resilience really means for a water system, stakeholders must first agree on the performance objectives that the system must meet when confronted with strains and shocks. The resilience of each element of the system can then be assessed against these objectives in possible future scenarios, which can be constructed by considering the various risks faced by the system. The system's ability to meet the performance objectives under various types of stress will determine its current resilience, and help identify measures to strengthen it in the future. This requires analyzing various scenarios and the associated responses to them, and developing a publicly communicated plan of how to handle both the triggers and the responses.

Chapter 3
Why Does Water Supply Resilience Matter for South Tarawa?

3.1. Geographic, Physical, and Socioeconomic Fragility

5. The Republic of Kiribati is one of the smallest, most remote, and most geographically dispersed countries in the world. The country consists of one raised coral island and 32 low-lying coral islands distributed in three groups: the Line Islands, the Phoenix Islands, and the Gilbert Islands. The capital city, South Tarawa, which is in the Gilbert Islands, is located about 4,000 kilometers from the major trade markets of Australia and New Zealand, as illustrated in map 3.1. South Tarawa presents features of striking geographic, physical, and socioeconomic fragility.

MAP 3.1. Location of Tarawa and Kiribati in the Pacific Ocean

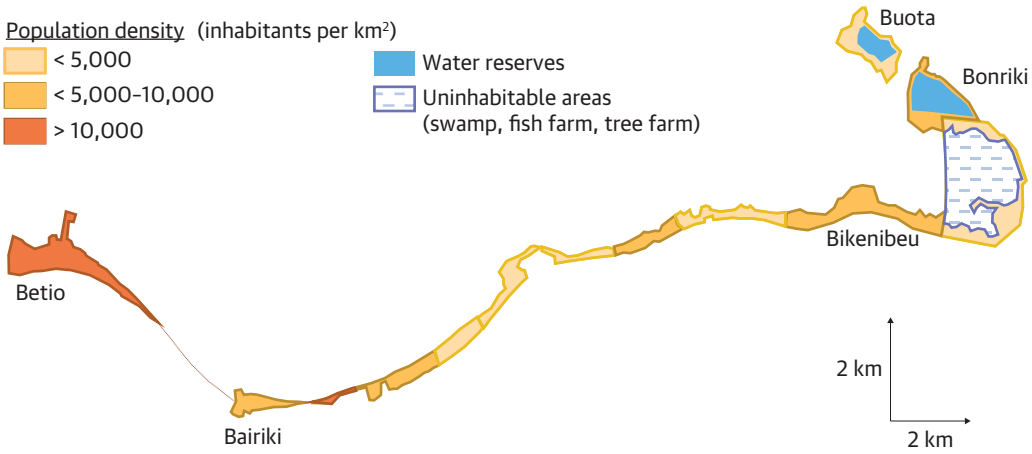
IBRD 44312 | MARCH 2019

Source: IBRD 44312 | March 2019

6. South Tarawa has uniquely fragile water resources due to its small size, lack of natural capacity for water storage, and competing land use. South Tarawa is the country's main urban center: it is located on the atoll of Tarawa, and spans a string of coral islets connected by several causeways. Its population is expected to grow from 58,000 in 2016 to 96,000 in 2040. No more than two meters above mean sea level, South Tarawa stretches for more than 30 kilometers and is on average less than 250 meters wide. Only three of the islets are wide enough to hold meaningful groundwater storage volumes: the urban center of Betio, and the islets of Bonriki and Buota. As shown in map 3.2, the population density exceeds 7,500 inhabitants per square kilometer in many of the islets (a remarkably high number considering the absence of multistory residential buildings). This exerts constant pressure on the integrity of the water reserves.

7. These geographic features create significant challenges for human development and economic growth. According to the last available Household Income and Expenditure Survey (HIES), conducted in 2006, 24 percent of the population of South Tarawa lived under the poverty line (Kiribati National Statistics Office 2006). Opportunities for cash employment and consumption, and access to higher education and specialized social services that are not available elsewhere in Kiribati, have made South Tarawa a magnet for internal migration from the Outer Islands. This further increases the challenges of population density and urban development. In 2012 it was estimated that half of South Tarawa's population was living in informal areas. Only around 20 percent of the country's population is formally employed in the cash

MAP 3.2. South Tarawa: Population Density and Main Physical Features[a]



Source: World Bank data.
Note: Heteromorphic map to aid visualization.
a. The islet of Buota is administratively located in North Tarawa, but due to its integration into South Tarawa's economy and water system, it is broadly understood in this report to be included in "South Tarawa."

economy, with 70 percent of the jobs provided by the public sector (World Bank 2018). Despite improvements in revenues in recent years, Kiribati's Human Development Index (HDI) ranking is 137, and its Human Capital Index (HCI) ranking is 113; both are among the lowest in the Pacific region.

3.2. Chronic Water Supply Insecurity

3.2.1. Historical Reliance on Three Sources of Water

8. Despite the presence of a centralized water supply system, access to safely managed water supply services remains very limited in South Tarawa. About 90 percent of the urban population in Kiribati (which largely overlaps with the South Tarawa population) has access to a basic water supply service.[1] South Tarawa's reticulated water supply system provides service to about two thirds of its population through house connections (as shown in photo 3.1), and is operated by the Public Utilities Board (PUB). Water is abstracted primarily from two freshwater lenses, located in the Bonriki and Buota water reserves. Services are provided for up to 2 hours every 48 hours, and at very low pressure. Connected households consume an average of 10 liters per capita per day (lpcd), while nonresidential customers consume about 3 lpcd. Water is chlorinated at various points in the system (and on demand, through water tanker delivery), but negative pressure in the distribution pipelines is leading to groundwater infiltration and recurrent bacteriological contamination. Water at the tap fails to comply with microbial water quality standards two thirds of the time.[2] Water is currently supplied for free to most customers, except in three pilot areas (Nanikaai, Tebikenikora, and Tanaea), where network upgrades under the Kiribati Adaptation Program (KAP)-III now allow the delivery of a continuous water supply.[3] The purchase of fuel, such as wood and kerosene, presents an additional expense for the majority of households (58 percent), which currently boil water before consuming it (ADB 2018). Many households rely on multiple water sources, including rainwater collected from roofs, and local groundwater from household wells. Both reticulated water and groundwater show high levels

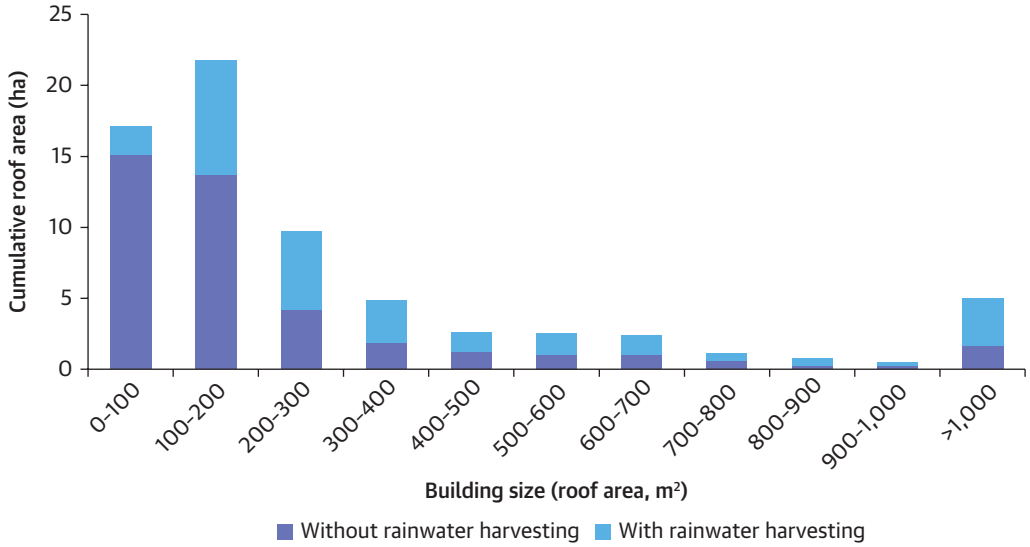
PHOTO 3.1. PUB Water Connection

Source: © Stephane Dahan/World Bank.

of bacterial contamination. A baseline survey carried out by the World Bank in 2018 found that two thirds of households spend more than half an hour a day on water collection tasks.[4] This situation is expected to improve significantly with the donor-funded project that is due to be approved in 2019, as explained in section 3.3.

9. Although rainwater harvesting (RWH) has emerged as an important coping strategy, much of its potential is unrealized. The use of RWH, historically practiced in Kiribati, was significantly boosted by the development of modern roofing that allows rainwater capture. More recently it was expanded by the Sanitation Public Health and Environment (SAPHE) project, which set up a revolving fund in 2001 to provide loans for public servants to purchase rainwater collection and individual storage devices. This scheme led to the installation of more than 1,000 water storage tanks (which typically hold 6 cubic meters each) across South Tarawa. An analysis of drone imagery and field surveys conducted for this study suggests that more than 2,000 buildings (that is, about 20 percent of residential buildings, and 38 percent of nonresidential buildings) are now equipped with RWH systems across South Tarawa, as shown in figure 3.1. The uptake of residential RWH systems remains limited due to installation costs, and to the prevalence of traditional housing (with its thatched roofs), which

FIGURE 3.1. Prevalence of Rainwater Harvesting across Buildings in Betio, Bairiki, and Bikenibeu



Source: World Bank data.

represented two thirds of all residential buildings in 2013 (ADB 2013). Nevertheless, around 60 percent of households report using rainwater on a regular basis, with our survey revealing that: (1) one third owning RWH systems; (2) one third using rainwater that is shared with neighbors (on average two households per system); and (3) the rest purchasing rainwater from nonresidential buildings (for example, from community halls or churches).

10. Rainwater is perceived locally as the most precious water resource, and it is used primarily for drinking water, despite its substandard bacteriological quality. The total RWH catchment area is estimated at 30 hectares. However, only a limited fraction of the water collected, generally less than 50 percent in collective buildings and about 10 percent in individual houses, is eventually consumed.[5] The rest overflows during rain events. Indeed, stored rainwater is perceived as a lifeline option in case of significant disruptions in PUB services, and it is used sparingly, even when tank water levels are high. As rainwater is generally perceived by the people as the highest quality water resource, its use for nonconsumptive purposes is not viewed positively by the people. Overall, our survey suggests that rainwater consumption represents 5 lpcd, about half of which is for residential water use, as shown in table 3.1. Household rainwater is largely used for human consumption despite the almost complete absence of disinfection systems. Unfortunately, even when the system is well maintained and clear of leaves, the presence of birds, rats, and other animals/vectors can be a source of contamination (and potential corrosion of the roof can add heavy metals to the mix). Weekly random water quality testing by the Ministry of Health and Medical Services (MHMS) across South Tarawa in 2017 showed the presence of *E. coli* more than 90 percent of the time.[6]

11. The current stock of RWH systems illustrates the high value the South Tarawa population assigns to water quality and security. The estimated value (at installation) of the RWH assets exceeded US$10

TABLE 3.1. Water Use by Source (lpcd): Current Situation (2019)

	Residential				Other	
	Consumptive	Non consumptive			All uses	Total
		Laundry/ washing	Toilet flushing	Animals, gardening		
Total	**5**	**18**	**6**	**7**	**6**	**42**
PUB	4	4	<1	<1	2	10
Rain	2	<1	0	0	3	5
Urban well	<1	14	6	7	1	28
Seawater			7			

Source: World Bank data.
Note: Color scale: the darkness of the blue is proportional to the amount of lpcd.

million (on average, about US$200 per South Tarawa inhabitant). In a large majority of cases, these systems were financed by the building owners, sometimes with the support of microcredit schemes (such as the SAPHE revolving fund). As discussed in section 3.1.1., the associated average cost over the 20-year life of the equipment has exceeded US$6 per cubic meter. People lacking access to rainwater from their own, or a neighbor's, household system can purchase rainwater from nonresidential buildings that sell water to the public. The most common market price is US$18 per cubic meter (or $A 0.50 per bucket). This very high level of willingness-to-pay demonstrates the high value placed by the population on this resource. In the presence of other free water resources, it illustrates the high premium people put on the organoleptic quality—that is, the taste—of rainwater (compared to the often brackish taste of well water, or even PUB water), and on the security represented by full rainwater tanks (compared to the erratic PUB water supply).

12. Urban groundwater is abundantly tapped into for nonconsumptive uses through a network of private, shared, and communal shallow wells, such as the one illustrated in photo 3.2. Outside of the few islets that are wide enough to hold a small freshwater lens in their middle, groundwater is generally brackish. It is also almost systematically contaminated bacteriologically, and is used primarily for laundry, bathing, gardening, and so on. It is widely recognized in South Tarawa that urban groundwater is not suitable for human consumption, although its salinity is a stronger deterrent to consumption than any information about microbial or other types of contamination. There has been a gradual shift away from using well water for drinking or cooking purposes over the past two decades. This has been prompted by the increased salinization of the local lenses, (which is probably due to increasing water abstraction and urban density); as well as by the availability of alternative sources of water (PUB water and RWH). However, our survey shows that 8 percent of households still report using well water for drinking or cooking in the absence of accessible or affordable alternatives.[7] Abstraction is usually done manually, although more than 20 percent of households were found to use electric pumps in a 2011 household survey (ADB 2011). The last major urban groundwater quality assessment campaign was carried out in 2011 in Betio, Bairiki, and Bikenibeu. Results of the analysis showed significant microbiological contamination; a high nitrate content (up to 800 milligrams per liter) in the most densely

PHOTO 3.2. Shallow Well Next to a Private Toilet and Pig Enclosure

Source: © Stephane Dahan/World Bank.

populated areas; and petroleum-related industrial pollution in several areas (ADB 2011).

13. Inadequate sanitation is a major issue in South Tarawa. Only 49 percent of the population has access to at least basic sanitation services.[8] The other 51 percent uses shared sanitation facilities; unimproved onsite sanitation systems such as pit latrines without a slab or platform; or practices open defecation in the sea (near-shore), with 60 percent of the population resorting to this at least occasionally (ADB 2013). Fecal contamination of the environment due to the human waste stream is aggravated by the unsafe disposal of pig manure. There were as many as 16,075 pigs in South Tarawa in 2015,[9] and they generated almost as much organic pollution as the human population.[10] Kiribati's infant mortality rate is among the highest in the Pacific, at 44 per 1,000 live births, and is partly attributable to infantile diarrhea (UNICEF 2013). In 2012, one in every two persons was treated for a waterborne disease in a hospital or clinic in South Tarawa (ADB 2013).

14. Major efforts remain to be undertaken toward the conceptualization and further development of sanitation services. South Tarawa has three sewerage systems, coupled with seawater supply networks for flushing, in the original settlement centers. About 25 percent of the population is connected to

these systems. PUB offers a vacuum truck service that comes to households to empty septic tanks. All sewage (from both sewerage systems and septic tanks) is discharged through submarine outfalls into the deep ocean, beyond the reef, after screening: dilution, dispersion, and die-off are relied upon to avoid pollution of near-shore areas. Except in areas that have sewerage systems, households generally discharge greywater locally, taking advantage of the high infiltration capacity of coral sand. There is currently no consensus among sector stakeholders on the most appropriate sanitation option for South Tarawa as a whole, as a universal sewerage system cover would be unaffordable. A concept study is currently being carried out with financial support from New Zealand to identify appropriate sanitation models, and to prepare for their implementation. While seawater flushing helps minimize freshwater use, it is suspected that leaks from seawater networks are affecting the salinity of urban lenses.

3.2.2. Strategies for Coping with Inadequate Water Supply

15. Water use practices in South Tarawa are largely aligned with techno-scientific definitions of water quality, although choices about water use are rarely connected to health considerations. The practice of boiling water is very common, and children's water consumption is often different from that of adults. However, when people acknowledge that there is a link between water and illness, they typically refer to an external source of information (for example, health professionals) rather than stating it as a personal or deeply ingrained insight. Well water is avoided as much as possible for consumptive uses, but this is mostly due to its salinity, or its organoleptic properties, rather than its bacteriological contamination. In practice, the people's satisfaction with their water is less connected to concerns of water quality than to convenience of access, entrenched habits, and the emotional cost of negotiating access to water with neighbors or relatives. People who have to walk the "last mile" to get better quality water do not always walk it. More than half of households boil water before consuming it. There is also limited use of the solar water disinfection (SODIS) method.[11]

16. Households in South Tarawa follow several key water scarcity management principles. In the context of unreliable sources of water (whether from PUB, or from rainwater) and low-quality sources (groundwater), the survey conducted as part of this study showed that the vast majority of households in South Tarawa use a variety of sources to meet their daily water needs. Our survey found that 50 percent of respondents use three different sources of water on a regular basis; 43 percent use two sources; and only 6 percent use a single source. This almost systematic reliance on multiple sources of water is consistent with findings from other Pacific island countries, such as the Marshall Islands or the Solomon Islands (Elliott et al. 2017). This allows fit-for-purpose water use depending on water quality—as explained in the previous paragraph and illustrated in box 3.1—and adaptive water use, depending on the availability of PUB water and the abundance of rainfall. Local water storage helps buffer variability of supply. More than 75 percent of the population stores water in one of the household storage tanks that were distributed in the 2000s as part of the SAPHE project, while the rest collect water in buckets, small drums, or pots. Monitoring of the water level in rainwater tanks plays an early warning role, drawing attention to fluctuations in the water supply, and increasing at least the stated awareness of residents regarding the need to save water. Finally, many households already practice greywater reuse to some extent for gardening or for their pigs, closing the water cycle. Thus, South Tarawa provides a remarkable illustration of how best practice water management principles in a

BOX 3.1. Ancestral Thrifty Water Use Traditions in Kiribati Households

Ms. N. is a 49-year-old working mother living in the urban village of Bairiki. She lives with her husband and their extended family in a household of 10 persons. Ms. N. is satisfied with her water situation: she has access to all three sources of water available in South Tarawa. The family uses water sparingly, and carefully matches different sources with intended uses. Their well is of particular importance in their daily life, and Ms. N. feels sorry for those who don't own a private well: "A well is a basic need," she says. Although the water is brackish—Ms. N. knows it is, because the soap does not lather when they shower—water is used for multiple purposes: dishwashing, bathing, gardening, laundry, toilet flushing, and feeding the family's five pigs. A significant part of the water used in the household comes from the public water supply network (PUB). PUB water is reserved for cleaning the dishes, cooking, and hand washing. Ms. N tells her children not to shower with PUB water: "We need to conserve it." Like many people in South Tarawa, she does not like the taste of PUB water, but she drinks it anyway, and boils it for tea when necessary. But her favorite source of drinking water is rainwater: "It is easier to drink," she says. The family owns a 3,000-liter rainwater tank. The priority use for that water is drinking, but when it is abundant, rainwater can also be used for other purposes. "Messages are broadcast on the radio to inform the population when it is time to ration water, but we can see it by ourselves." Although Ms. N. does not use kitchen water for gardening, the most nutritious part of it containing leftover food is carefully set aside for the pigs and mixed with their feed.

Source: Face-to-face interview, July 2018.

context of water scarcity can be applied at the household level (World Bank 2017).

17. Collectivism and water sharing play a critical role in reducing affordability challenges, water-related conflicts, and vulnerability to droughts. As in many Pacific cultures, people in Kiribati hold to a collectivist worldview, in which people "identify as being part of a large interdependent group comprising the nuclear family, extended family and lineage members from their village community" (Kolandai-Matchett et al. 2017). The powerful ties that bind society together through water exchange offers important information about the everyday uses of water at the domestic and community level. A significant portion of access to water in South Tarawa is probably attributable to water sharing between households, as illustrated in box 3.2. This is particularly significant in areas that are densely populated. Water sharing helps maintain culturally significant customs in contemporary Tarawa, such as cultural norms of generosity, exchange, and reciprocity. These play a central role in maintaining social cohesion, cultural identity, and urban survival. The prevalence of kin relationships in Kiribati society is reflected in the networks of water sharing in South Tarawa. Kin-based sharing can, however, also exacerbate the vulnerability of individuals, and consuming shared water is almost never the preferred option. Birth position and gender often determine the degree of control over shared water sources, and can affect the location of houses relative to the water infrastructure.

18. While the sharing of water with relatives, friends, or neighbors helps alleviate exposure to water risks, it can also exacerbate individual vulnerability and social tensions. Observations conducted for this report also found that the need to depend on relatives for

BOX 3.2. Water Sharing–A Social Duty Deeply Anchored in Kiribati Culture

Rotia, a 30-year-old woman, lives in the Betio village, in the center of the island, together with her husband and their two children. The family shares a connection to the PUB system with three other households, totaling 21 persons. This means that when the water is distributed to their rationing zone every other day, the family needs to be present, and negotiate with their neighbors to make sure they can store enough water to last until the next distribution time. Rotia also has access to rainwater for free from a neighbor's tank, but in limited quantities (four 12-liter buckets for 3 days). Even when these sources of water are not sufficient, Rotia says that they don't resort to drinking water from their personal well, which they share with more than 30 persons in the community. Instead, she occasionally buys bottled water, or asks for water from a relative living nearby who has "a good well."

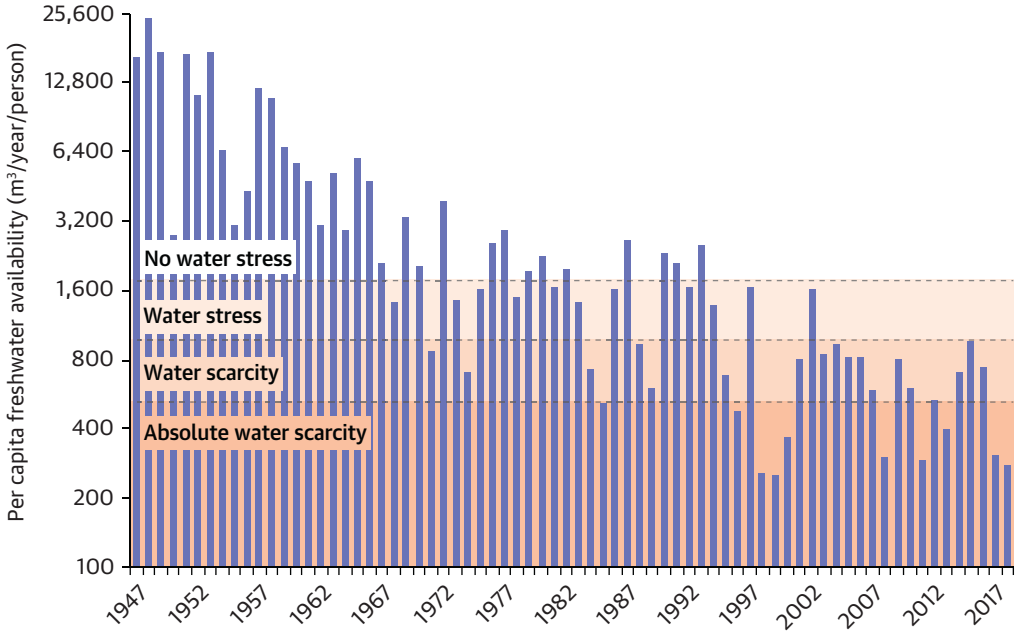
Source: Face-to-face interview, July 2018.

drinking water can significantly increase the distances that have to be covered to fetch water. Furthermore, within family water-sharing arrangements, sisters and younger siblings may have less control over the water than their older brothers. Such dependence can become a stigmatizing and stressful experience. We noticed that social and cultural obligations to share water are increasingly being questioned. As a result, several owners and users of rainwater tanks mentioned tensions caused by the quantity of water that is being shared. Cultural factors can also increase hardship in the case of collective RWH systems. In some cases, people choose to spend more time fetching water in order to ensure that it is from their own parish. Population growth, the geographic fragmentation of kin groups, environmental changes, and the rise of individualist values are contributing to dismantling the cooperative living system that used to be intrinsic in society, and increasing the perceived price of conforming to water-sharing norms. The improvement of PUB services will probably further undermine the role of traditional kin-based water sharing.

3.3. Increasing Water Scarcity and the Need for New Resources

19. Inherent limitations in freshwater resources and continuous population growth are exposing South Tarawa to a growing water supply deficit. Freshwater availability[12] across South Tarawa has dramatically declined in recent decades, as shown in figure 3.2, primarily due to a six-fold population increase over the last 50 years. Freshwater availability now hovers around the absolute water scarcity threshold,[13] and it reached an all-time low of 277 lpcd in 2018. Bonriki and Buota's rainfall-fed groundwater lenses, which are used for producing PUB drinking water, have a combined sustainable yield of approximately 2,000 cubic meters per day. The estimated sustainable freshwater yield of the urban water lens in Betio is marginal, at 25 cubic meters per day (White 2010). Even with a major reduction in water losses (currently at 60 percent), and with consumption limited to basic needs, basic water demand is expected to exceed groundwater production capacity by 2,500 cubic meters per day in 2020, increasing to a range of 3,300–4,800 cubic meters per day in 2040 (ADB 2017a).

FIGURE 3.2. Per Capita Freshwater Availability in South Tarawa, 1947–2018



Sources: Kiribati Meteorological Services (precipitation data); South Tarawa Office of Te Beretitenti and T'Makei Services, 2012 (population data).
Note: A logarithmic scale is used; population data available at: http://www.climate.gov.ki/wp-content/uploads/2013/01/6_South-Tarawa-revised-2012.pdf.

20. This deepening water deficit along with emerging climate-related challenges require the consideration of new resources for South Tarawa's potable water supply. The government of Kiribati adopted the National Water Resources Policy in 2008. Demonstrating the importance of this sector, it also developed the Tarawa Water Master Plan 2010-30 and the Tarawa Water and Sanitation Roadmap 2011-30. Considering all water production options and the potential for reduction in physical losses of water, these plans identified nonconventional water sources, such as desalination, as the only option that will be able to meet South Tarawa's water demand over the long run, along with a diversification of sources, including urban groundwater and RWH, for risk mitigation and increased resilience. These studies encouraged the use of rainwater, but point out that it cannot be relied on during droughts.

21. The South Tarawa Water Supply Project (STWSP), to be initiated in 2019, will finance a seawater desalination system to address water supply deficits in the long term, and build resilience to climate change. The project, which is under preparation with donor support, will implement a 4,000-cubic-meter-per-day seawater desalination plant, and a solar photovoltaic (PV) array to offset the energy requirements of the system. The aim is to guarantee consumption of 59 lpcd (52 lpcd of which is for residential water demand) with a water system that is resilient to climate-related threats such as droughts and seawater overtopping[14] (SWOT). The seawater desalination system will be expandable to 6,000 cubic meters per day should residential water demand further increase in the future. The system will be in Betio, which is the only available land option identified during project preparation. STWSP will also rehabilitate and upgrade South Tarawa's water distribution system to achieve universal coverage, which is expected by 2022, and will drastically reduce physical losses, which are

TABLE 3.2. Water Use by Source (lpcd): Future Situation (2030)

	Residential				Other	
	Consumptive	Non consumptive			All uses	Total
		Laundry/ washing	Toilet flushing	Animals, gardening		
Total	**10**	**39**	**10**	**9**	**12**	**80**
PUB	8	37	8	2	8	63
Rain	2				3	5
Urban well		2	2	7	1	12
Seawater			10			

Source: World Bank data estimates.
Note: Color scale: the darkness of the blue is proportional to the amount of lpcd.

expected to fall below 25 percent after rehabilitation of the system. The centralized water supply system will rely on a combination of desalinated seawater and groundwater abstracted from the Bonriki and Buota freshwater lenses. It will also incorporate two desalination plants, which can produce 500 and 100 cubic meters per day (about 5 lpcd overall), one at the western end of the Betio causeway and the other at the Tungaru Central Hospital. These are currently under completion with financial support from the government of New Zealand. Groundwater resources are expected to contribute 26 percent to PUB's water sources by 2030.

22. In addition to using upgraded PUB water services, South Tarawa's population is expected to continue to rely to some extent on shallow wells and RWH. While no precise quantitative information is available on current consumption from these sources, various surveys[15] provide a general appreciation of their contribution to people's mix of water sources to date (with PUB water services still limited to 2 hours every 48 hours). As indicated earlier, rainwater is, together with PUB water, the preferred source of drinking water, and to a lesser extent it is used for cooking. Its use for other purposes is and will remain marginal. Shallow wells are recognized as the resource of lowest quality, and are used primarily for water for washing, mopping, gardening, and for pigs. Overall, current consumption from RWH and from shallow wells is estimated, respectively, as 2 lpcd and 20 lpcd. Table 3.2 shows the expected shift toward PUB water under the new water supply system, with households still relying to some extent on shallow wells for non-consumptive uses, and on rainwater. The behavior in communities that already have a continuous water supply under the KAP III pilot project confirms that households continue to rely, albeit to a lesser extent, on these local water resources. Actual reliance on the various sources depends on factors such as PUB water tariffs, and the population's level of confidence in the potability of PUB water.

3.4. Water Sector Vulnerabilities

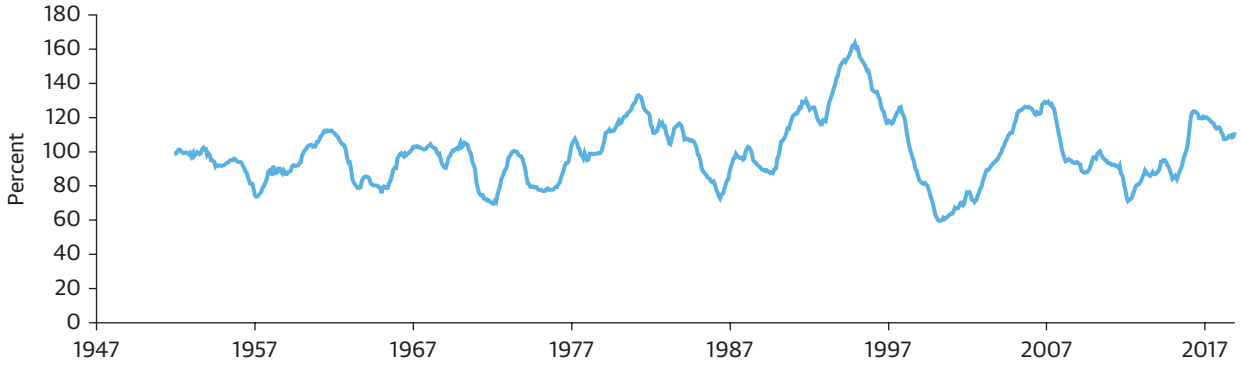
23. Despite the PUB system upgrade, the water sector still presents key vulnerabilities. Water supply vulnerabilities are both natural and anthropic. South Tarawa's water balance is vulnerable to the effects of climate change (droughts and SWOT); to the impact of human activities on freshwater resources (encroachment and pollution in water reserve areas); to possible systemic water infrastructure (desalination plant breakdowns); and to an unforeseen escalation in water demand. From a probabilistic perspective, these hazards are independent of each other. It should be noted that the

critical water infrastructure is being designed under STWSP to withstand SWOT). It should also be noted that due to its proximity to the equator, South Tarawa is never on the path of cyclones. This section provides an overview of the relevant vulnerabilities for South Tarawa, and proposes summary scenarios to assess potential impacts on the current system in each case.

3.4.1. Droughts

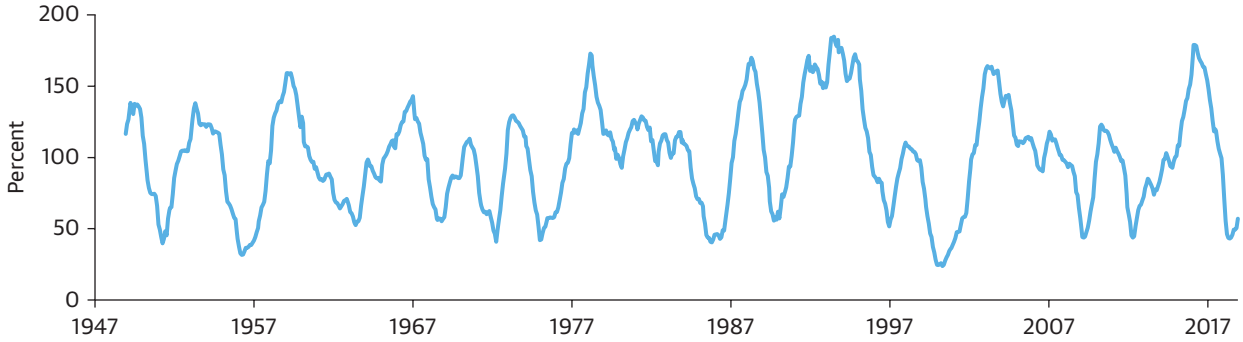
24. There is little understanding of how droughts and climate change are likely to affect South Tarawa in the future. The climate of Kiribati shows high year-to-year variability (particularly for rainfall), driven primarily by the El Niño Southern Oscillation (ENSO), as can be seen in figures 3.3 and 3.4, where the cumulative precipitation has been plotted since the 1950s, for 5- and 2-year periods, respectively. South Tarawa experiences occasional severe droughts, which are often associated with La Niña events. In 1998-2000, during one of these events, the amount of precipitation was a third of the annual average (2,020 millimeters per year). Although climate change scenarios are projecting an increase in annual and seasonal mean rainfall with high confidence (PACCSAP 2015), groundwater recharge is expected to be negatively affected by additional evapotranspiration caused by an increase in the intensity and frequency of days of extreme heat. Long-term droughts (those lasting more than a year) occur on average every 10 years, and are understood

FIGURE 3.3. Five-Year Cumulative Rainfall in South Tarawa, Actual/70-Year Average Ratio



Source: Kiribati Meteorological Services.

FIGURE 3.4. Two-Year Cumulative Rainfall in South Tarawa, Actual/70-Year Average Ratio



Source: Kiribati Meteorological Services.

to be almost fully driven by ENSO. There is no consensus on how climate change will affect ENSO. There is more consensus, however, on the expected sea level rise due to climate change—22-49 centimeters by 2064—but the thickness of the Bonriki groundwater lens is not expected to vary due to sea level rise, at least not until 2050 (Mack 2015).

25. Extreme droughts could lead to a significant decrease in yields from water reserves. Severe droughts, if they increase in frequency and length, could lead to saline intrusion at the perimeter of the lens, and to a significant deterioration of water quality at many of its infiltration galleries if abstractions are not reduced accordingly. The Bonriki water lens is estimated to have a hydraulic residence time of 4-5 years (White, Falkland, and Scott 1999). As shown in figure 3.3, every 10 years on average the cumulative amount of precipitation over the previous 5 years drops by more than 20 percent below the 1947-2017 average (40 percent during the recent 1998-2000 drought). Consistent with this reduction in cumulative precipitation, hydrogeological modeling has suggested a decrease of 40 percent in the sustainable yield of the Bonriki lens in the event of such a severe drought event (Jolliffe 2017). While such a scenario does not currently appear in climate projections, it is consistent with South Tarawa's history of drought. A more extreme scenario, which has not been experienced so far but cannot be excluded as a possibility—that is, one involving two such droughts in a 20-year period—would lead to a reduction of up to 50 percent in the sustainable yield. Given the range of uncertainties surrounding the influence of climate change on ENSO, and the frequency and intensity of future droughts, a 50 percent reduction in the yields from the water reserves will be considered as the worst-case scenario.

26. Urban well water salinity is also affected by major drought events, and can be expected to significantly exceed acceptable standards for nonpotable water during these events. The 1993 World Health Organization (WHO) guidelines suggest a maximum salinity (EC) value for nonpotable purposes of 2,500 micro-Siemens per centimeter.[16] At this value, water can be considered as mildly brackish. In September 2011, when conductivity surveys were carried out in wells across Betio, Bairiki, and Bikenibeu, 51 percent of the samples exceeded this threshold. South Tarawa had, at that time, received cumulative precipitation over the previous 2 years, comparable to the 1947-2017 average, as can be seen in figure 3.4.

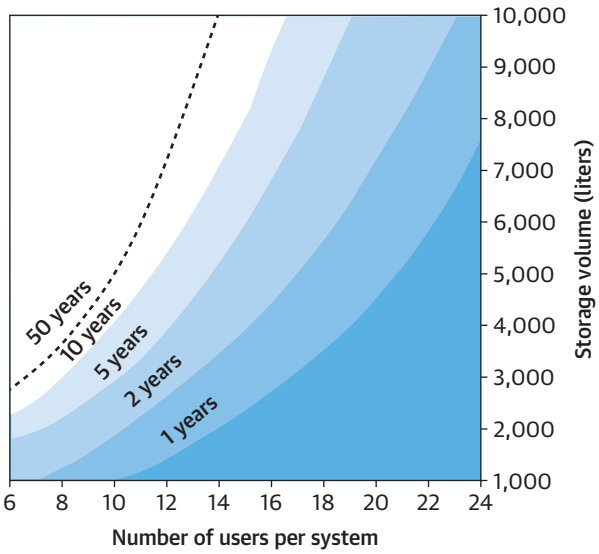
27. Major droughts will continue to cause salination of urban groundwater lenses. The small urban freshwater lenses of South Tarawa from which urban wells are fed (excluding the Bonriki and Buota lenses) are estimated to have hydraulic residence times of between a few months and two and a half years, with the times generally higher the further away they are from the coast (ADB 2011; White et al. 1999). As shown in figure 3.4, every 6 years on average, the cumulative amount of precipitation over the previous 2 years drops by more than 50 percent below the 1947-2017 average (and it dropped by 75 percent during the 1998-2000 drought). That severe drought event resulted in dramatic increases in the salinity of domestic wells and in the death of trees (Jolliffee 2017). In the absence of long-term monitoring data to quantify the impact of droughts on the urban groundwater lenses of South Tarawa, it is difficult to say precisely what the impact of such an event has been on the quality of well water across South Tarawa's islets. However, it can be estimated with a high level of confidence that a 75 percent reduction in cumulative precipitation for a 2-year period would cause salinity in most wells to strongly exceed the WHO guidelines on maximum salinity values for nonpotable purposes.

28. In the absence of alternatives, temporary deterioration of urban groundwater quality does not significantly impact the use of this resource. Although it is common knowledge locally that groundwater is

subject to saline intrusion during droughts (as well as during high tides), awareness of the recent changes in salinity levels is limited, since most people refrain from drinking well water anyway. Variations in salinity levels are more often noticed, for example, by women when their detergents or soaps do not lather as easily as usual. Anecdotal evidence that some households have shifted entirely to PUB water or rainwater due to excessive groundwater salinity has been gathered during this research. However, as shown by the household survey conducted in June 2018, during a significant drought event (with a 57 percent drop in 2-year precipitation compared to the normal situation), 90 percent of the population continued to use well water. This illustrates the lack of water supply options during episodes of severe water scarcity, and it does not represent a desirable level of service.

29. Most RWH systems cannot withstand major drought events, as was seen during the 2017–18 dry spell. A simulation of tank-operating regimes over 50 years of monthly precipitation records suggests that, if used by one household at an average of 5 lpcd, the common residential RWH systems found in South Tarawa[17] could withstand any of the droughts recorded in the past 50 years. This outcome is, however, very sensitive to the number of households that use the system (typically 1-3 households), and to the size of the tank (typically 3-7 cubic meters), as shown in figure 3.5. Across this spectrum of system configurations, about 80 percent of residential systems would not withstand a 10-year return drought without running dry for at least 1 month. This situation should now improve, since the 2017 Kiribati National Building Code defines household storage requirements based on the number of users, and is designed to prevent system failure more often than 1 month in 10 years. Nevertheless the performance of large, nonresidential RWH systems is highly variable, given the multiplicity of building types, water uses, and number of purchasers.

FIGURE 3.5. Return Period of Rainwater Harvesting System Dry-Ups Exceeding 1 Month



Source: World Bank data.

Our detailed assessment of the 40 largest systems supplying 5,600 people suggests that more than 60 percent of them (in terms of number of users) are likely to run dry once every 10 years.

3.4.2. Seawater Overtopping

30. Sea level rise will aggravate both the likelihood and the impacts of SWOT on the water reserves. SWOT could be generated in South Tarawa by a combination of storm surges triggered by low atmospheric pressure; high-level, long-term sea level rise; and severe wave conditions created by distant weather formations, in particular in the North Pacific. Currently the risk of significant inundation of the Bonriki water reserve leading to a significant impact on the lens is negligible, and such an event has never been recorded. However, over time this risk is expected to grow with the projected rising of seawater levels, which is predicted to be 22-49 centimeters by 2064, across a range of climate scenarios studied by the Intergovernmental Panel on Climate Change (IPCC) and the National Oceanic and Atmospheric

Administration (NOAA).[18] Modeling of a 28-centimeter sea level rise (which could be reached before 2050) suggests that SWOT that temporarily (that is, for up to 5 years) were to reduce yields from the Bonriki lens by 54 percent would have a 20-year return period (Mack 2015). Map 3.3.a shows the location of infiltration galleries in Bonriki, while map 3.3.b illustrates the extent of SWOT across the water reserve in that scenario. Following such an event, it would be necessary to significantly limit abstraction for up to 5 years in order to allow the lenses to recharge. Should drought occur at the same time, the limitations would be even more restrictive.

31. The risks of SWOT on the Buota water reserve and in urban areas cannot be quantified precisely at this stage. The conditions—sea level rise, with swelling on the lagoon side generated by storms in the North Pacific—that were simulated in the study of the Bonriki water reserve would also be relevant to the Buota water reserve, and to the freshwater lenses in urban areas from which private wells draw water. In the absence of modeling based on detailed topographic data, it is not possible to infer the risk of significant inundation and what its impact would be on these local groundwater lenses. As a first, and probably conservative approximation, it will be considered that the impact of a major SWOT event on the freshwater yield of Buota and urban water lenses would be similar to those expected to affect the Bonriki water lens.

32. Severe droughts represent a more immediate threat than SWOT. While the yield reduction for overtopping appears comparable in size and probability to that caused by severe droughts, the risks associated with SWOT would only materialize following a significant rise in sea level. Analyses undertaken as part of the STWSP preparation suggest that climate change-induced SWOT and drought could together lead to a drop in the lenses' yield to nearly zero for a significant period of time (ADB 2017b).

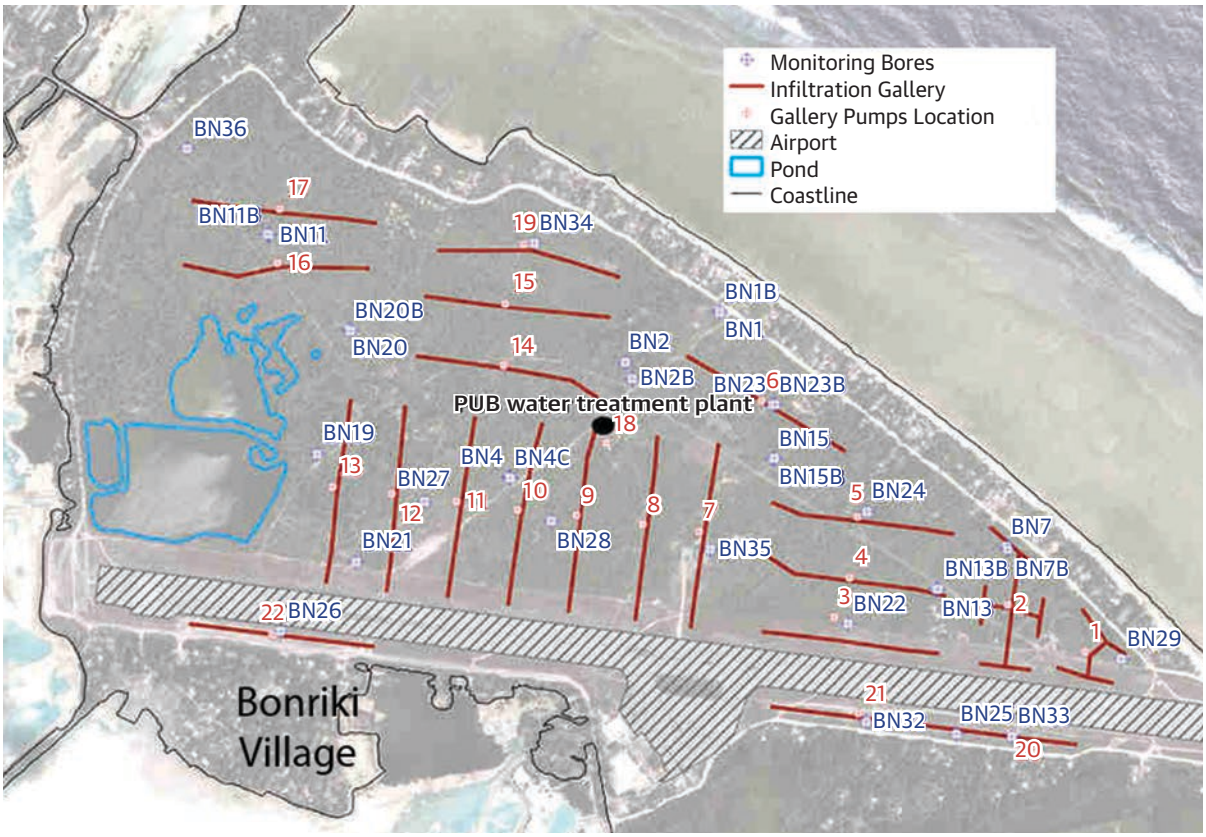
3.4.3. Anthropic Risks

33. The most serious anthropic risk in the long term is contamination of the water reserves to a degree that would require costly treatment, in addition to current means of treatment being used (aeration and chlorination). There are currently close to 80 unauthorized dwellings on the Bonriki water reserve, and 20 on the Buota reserve. Overall, this represents a 300 percent increase compared to the situation in 2005. Encroachment by settlers and squatters is continuously increasing because of South Tarawa's rapidly growing population, the scarcity of land, and the lack of enforcement of existing regulations. Human settlement and activity on these reserves could affect water quality through sand and gravel mining; the digging of wells; the use of graveyards; the raising of pigs; and the growing of crops and taro swamp fields, which use animal manure and fertilizers; as well as direct pollution of the freshwater lenses through poor sanitation practices. As indicated in the Tarawa Water Master Plan (2010), "continued settlement [in the water reserve areas] greatly increases the risk of a severe disease outbreak, such as the 1977 cholera outbreak." It is worth noting that South Tarawa's two other water reserves, in Betio and Teaoraereke, which are much smaller than the one in Bonriki, were abandoned in the past due to similar encroachment issues. The proposed expansion of Bonriki International Airport, with airplane hangars, workshops, and possibly fuel stations within the reserve, would also entail pollution risks that would require careful management. The key environmental risks at airports relate to fuel storage, transport and refueling, electrical substations, and the storage of chemical products (Nunes et al. 2011).

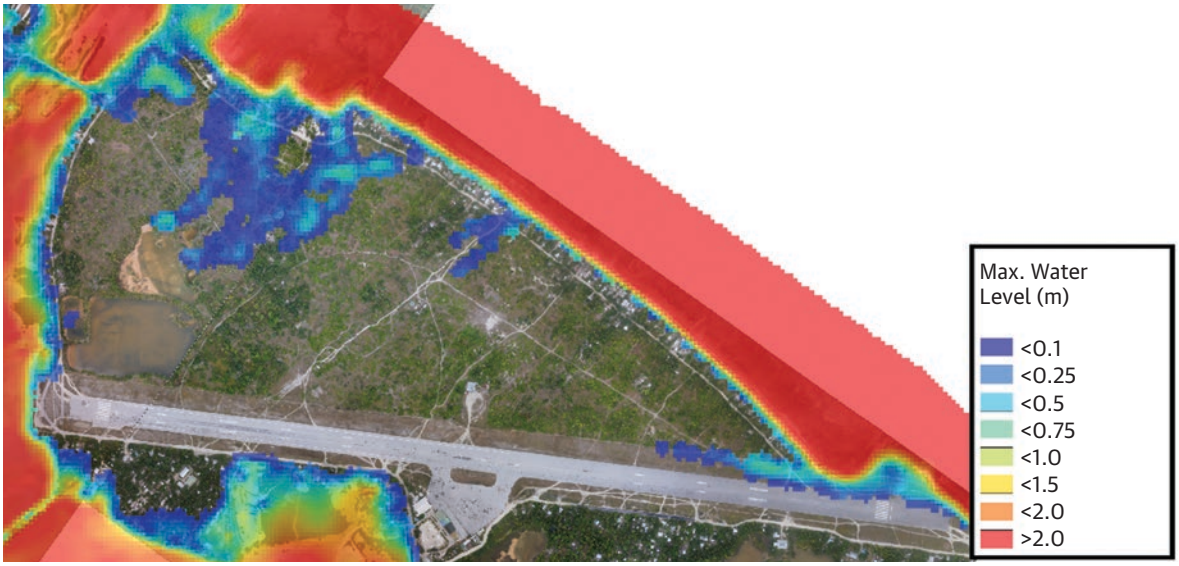
34. Any contamination of the Bonriki water lens would affect water supply, as any treatment process would be very costly and time consuming. While bacteriological contamination could be addressed through

MAP 3.3. Bonriki Water Reserve Infiltration Galleries and Seawater Overtopping

a. Infiltration galleries and monitoring network



b. Inundation



Sources: panel a, Galvis-Rodriguez et al. 2016; b, Fenton and Laplante 2018.

Note: Simulation for Representative Concentration Pathway (RCP) 8.5, 2064 sea level rise, offshore scenario, 20-year return period event.

chlorination, pollution by nitrates (fertilizers, pig manure) or toxic substances (oils, fuel, metals, chemicals) would not be treatable with the methods currently used in Kiribati. Once the water lens is polluted, there is no available or affordable technology to remedy it. This pollution risk would probably materialize gradually if related to human settlements, but in a short timeframe in the context of an industrial or airport contamination incident.[19]

3.4.4. Technological and Operational Risks

35. In the long term, any analysis of potential risks to water supply availability must consider a temporary interruption in seawater desalination due to technical issues. Desalination technology with solar offset requires constant maintenance and the availability of spare parts, including expensive membranes that must be replaced every 5 years. Some of the spare parts are unavailable locally, and their procurement and delivery from overseas, together with the necessary repairs and possibly the need for external technical support in the case of a major breakdown, could leave the capital city without desalinated water for some weeks before the plant would be back to full capacity. While the plant is being designed to take into account the risks of SWOT, other calamities, such as fires, could also leave PUB without the capacity for desalination. This was recently experienced in the capital city of the Maldives, as described in box 3.3. In such an event, which is entirely possible, the centralized water system would need to be supplied entirely from the water reserves on the far eastern side of South Tarawa, as these would be the only remaining sources of PUB water. ***This risk underlines again the need to preserve the water reserves, and also to maintain the capacity of Bonriki's pumping systems to operate under this hydraulic regime.***

36. PUB's current operational and financial underperformance could lead to a significant risk of systemic breakdown and service interruption. The water distribution network is in an advanced state of disrepair. Physical non-revenue water is estimated to exceed 60 percent. Inadequate quality of water services (regarding water pressure, continuous supply, and so on), together with the effect of customers' lack of willingness to pay; their tampering with the networks; and water leaks have been self-reinforcing in a vicious cycle over the past two decades, against the backdrop of an increasing freshwater deficit. Facing widespread discontent by the population, in 2013 PUB's line ministry requested that it stop charging residential customers. In the absence of a residential water tariff, PUB water and sewerage revenues now mostly come from nondomestic customers, and from on-demand services such as delivery by tanker and septic tank emptying. Overall, from 2010 to 2017, PUB's income has been generated from electricity (85 percent); water supply and sewerage (6 percent); water supply subsidies in the form of community service obligation (CSO) (7 percent); and other income (2 percent). The current average operation and maintenance (O&M) costs of water services amounts to US$1.7 per cubic meter ($m^3$) sold, a high level given the system's simple physical features. This is driven notably by (1) high physical losses; (2) high electricity[20] and chlorine supply costs (26 percent of total costs); and (3) high labor costs (47 percent of total costs). Some improvements in operational efficiency have, however, been achieved since 2015 with enhanced donor support.

37. The water network efficiency of PUB is critical to maintaining water availability during a drought event. The new water system implemented under STWSP is designed to cope with physical losses within the network of up to 25 percent, provided that water consumption does not exceed its design level. With an almost entirely renewed water supply network it is anticipated that water losses will be much lower. Such a parameter could have an indirect impact on

BOX 3.3. Water Crisis in Malé

On December 4, 2014, a fire crippled the seawater desalination plant in Malé, the capital of the Maldives. This was the only potable water production system on the island. The city's 120,000 inhabitants were instantly left without access to potable water services, prompting the declaration of a state of emergency. The only remaining water sources were the limited water volumes stored in the city's reservoirs. Malé's lens, which had been depleted and salinized by decades of over-abstraction, could not be used for drinking or washing purposes. After several days without water supply services, the local media started to report that angry residents were attacking shops that had rationed mineral water, while hotels indicated that their supplies were running out. In response to the crisis, countries such as China, India, and Sri Lanka stepped in, shipping or airlifting in bottled water, as well as small emergency desalination units, to help address vital needs and calm public discontent. The crisis lasted more than a week before the plant was put back into operation. As President Abdulla Yameen declared to the media: "We did not have any fallback plan for any disaster of this magnitude."

Sources: Freyberg 2014; "Maldives Faces Water Crisis after Fire at its Sole Desalination Plant," *DownToEarth*, July 4, 2015, https://www.downtoearth.org.in/news/maldives-faces-water-crisis-after-fire-at-its-sole-desalination-plant-47757

the city's resilience to a water crisis: (1) physical losses could further reduce the availability of water for supply, creating hardships for the population during normal times, and even more during an emergency; and (2) such losses would undermine PUB's financial position and its capacity to react, an aspect that is not modeled in this analysis.

38. STWSP will help strengthen PUB's O&M capacity through private sector support under Design-Build-Operate (DBO) contracting arrangements. In addition to ensuring reliability of the desalination plant and the water supply network over the 5-year operation period (2023-27), the DBO contract will play a key role in helping to improve PUB's operational and financial performance, and will help modernize its management systems and build its capacity to undertake preventive, predictive, and breakdown maintenance of the plant and network, and ensure sound asset management. In such a remote location, and with a water system that relies primarily on one desalination plant, keeping a generous supply of quickly available spare parts is advisable. Beyond the O&M phase of the DBO contract, PUB could consider guaranteeing repair or supply contracts with regional suppliers, in order to minimize response times in the event of a crisis.

39. Assessing PUB's future operational cost recovery remains difficult in the absence of a water tariff, but preliminary analyses suggest that the water business branch of the utility could become financially viable as a result of STWSP. A volumetric water tariff is already applied in the three KAP-III pilot areas, illustrating the government's willingness to discontinue the free distribution of water. The Ministry of Infrastructure and Sustainable Energy (MISE) is now commissioning a study to build on this experience, and identify a tariff that would be applicable across South Tarawa after the water system has been upgraded by STWSP. A preliminary cost-recovery analysis shows that, with a tariff that is consistent with local socioeconomic parameters and an expressed willingness to pay, 155 percent of operating expenditure (OPEX) (without depreciation) could be recovered during the O&M phase of the DBO contract, and 117 percent after

the completion of STWSP. This is to be compared to the current cost coverage ratio of 32 percent.

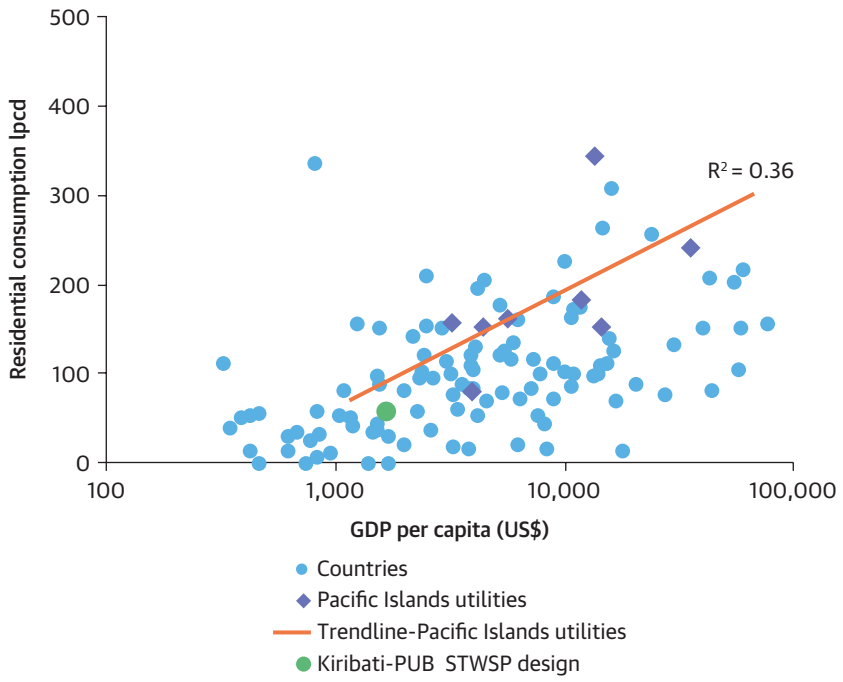
3.5. How Resilient Will the Future Water Supply Be?

40. Water resilience can be defined as the system's ability to meet defined delivery objectives despite shocks. In the case of water supply, these objectives could be simplified to maintaining a minimal, acceptable level of residential water availability for a city in a prolonged emergency—that is, one lasting several weeks or more. The absolute minimum water consumption guidelines, such as those provided by WHO, would not be acceptable in a capital city that needs to sustain its social and economic activities, and where the population has become accustomed to a certain level of service (WHO 2013). During the worst of its 2017 water crisis, the city of Cape Town, South Africa reduced its water demand by 45 percent, putting a significant strain on the population, but avoiding critical socioeconomic disruptions. During its 2008-09 drought, Cyprus lowered household water allowances by up to 30 percent below normal consumption levels, and preferred to ship in freshwater from Turkey at the prohibitive cost of US$8 per cubic meter rather than impose further restrictions.

41. South Tarawa's population is likely to become more reliant on an abundant water supply, and this will shape its vulnerability to water scarcity crises. The extent to which the population will accept a decrease in water consumption during a prolonged crisis will be largely influenced by its level of dependence upon an abundant and reliable water supply once the new system is in place and has been operating for some time. The current level of PUB water service makes it difficult to infer with a high degree of certainty the level of water use that households will adopt once safe water is supplied continuously to homes in a reliable manner. South Tarawa's water use trajectory is multifactorial, and will largely depend on economic growth, the evolution of cultural norms around water use, and the extent to which housing can accommodate modern plumbing and appliances. However, some factors suggest that there is likely to be a progressive loss of thrifty, resilient water practices over time. Water resource diversification at the household level, and the fetching of well water and transporting of rainwater to the point of use, can be laborious and time consuming. Also, traditionally, sharing water has not been so much a matter of decision, as part of a broader set of social and cultural norms expressed in water use habits. As these norms are increasingly questioned in the contemporary urban context, the obligation to share water will likely be questioned as well.

42. In the long run, overall water consumption could reach 100 lpcd, that is, more than two and half times the current level. Considering STWSP design assumptions, and the two new desalination plants that were implemented with financing support from New Zealand, PUB water use is expected to reach 64 lpcd by 2030. This is consistent with the water consumption levels usually found in systems with one tap at each house. It is also estimated that the population will continue to complement the PUB supply with rainwater and urban groundwater by another 10-15 lpcd. It should be noted that the water supply network is being designed with the assumption that consumption from PUB could rise to 100 lpcd in the long term, which corresponds to the level typically supplied through multiple household taps. International benchmarking with other Pacific Island countries in a comparable Gross Domestic Product (GDP) per capita range suggests that residential water consumption from PUB in South Tarawa will approach 100 lpcd in the long term, as shown in figure 3.6. For this analysis, water consumption in 2030 (5 years after STWSP completion) has been considered to reach 80 lpcd (see table 3.2),

FIGURE 3.6. Residential Water Consumption from Water Utilities Compared to Countries' GDPs



Source: IBNet (accessed from www.ib-net.org on April 10, 2019).
Note: GDP = gross domestic product; PUB = Public Utilities Board; STWSP = South Tarawa Water Supply Project.

and the minimum acceptable level of water availability 30 percent lower, at 56 lpcd. To satisfy any water demand increase beyond 80 lpcd, an additional augmentation of PUB's water production capacity would be required after STWSP.

43. Once the PUB water system is modernized, the most severe water crisis scenarios, in terms of decreased water availability, will be those involving a temporary interruption of the desalination plant. As indicated in box 3.3, the worst-case single-event scenario would be a temporary interruption of the desalination system due to technical breakdown, which would leave the South Tarawa population without adequate freshwater availability, and more critically so if combined with pollution of the water reserve, SWOT, or a drought. In such cases, gaps of 38-41 lpcd below acceptable thresholds would occur. It would not be possible to absorb these gaps relying on RWH or well water, given the significant limitations in terms of water quality of the latter resource. Drought or SWOT events that primarily affect traditional water sources (water reserves, urban groundwater, rainwater) would lead to a reduction of less than 30 percent of total water availability, an impact deemed acceptable on a temporary basis. Even two-event combinations involving a drought, pollution, and/or SWOT, as shown in figure 3.7, could almost be weathered due to the contribution of seawater desalination and network improvements resulting from STWSP. The gaps would be limited to about 10 lpcd, which could be closed by using well water.

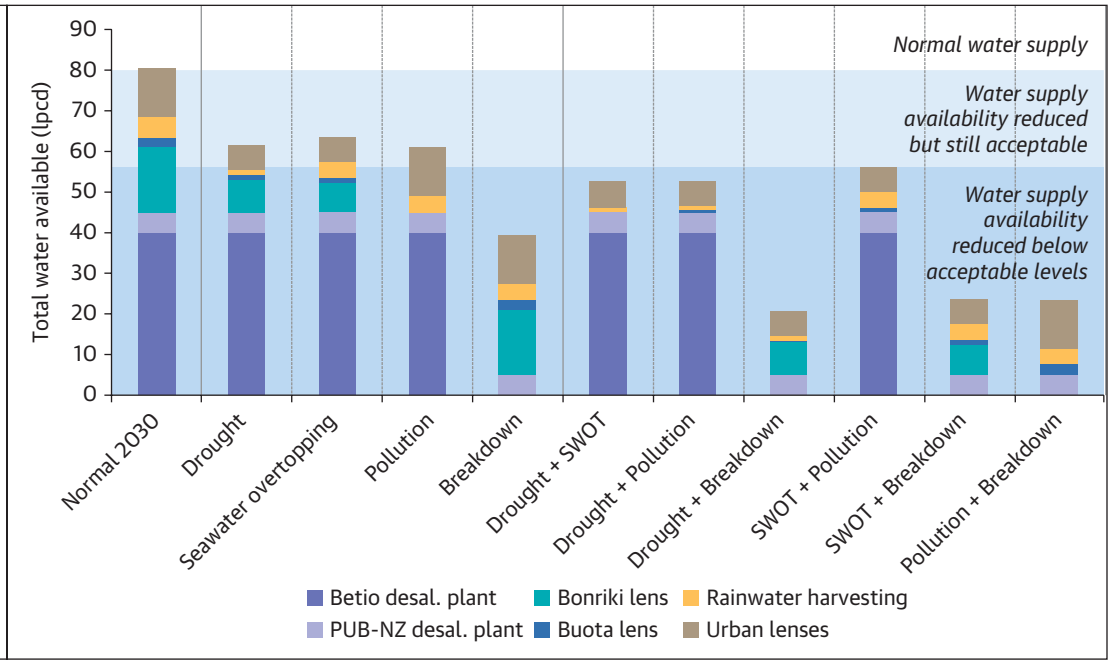
44. In all crisis scenarios, potable water availability would remain above 10 lpcd, which can be considered a minimum acceptable level for human consumption (that is, for drinking and cooking) in an emergency. As illustrated in figure 3.7, in all except one scenario (pollution of the Bonriki water reserve, combined with a breakdown of the Betio desalination plant),

this threshold could be met by PUB water services relying on the two other desalination plants and the Buota water reserve. In this worst-case scenario, PUB would be able to supply 8 lpcd, which could be supplemented by rainwater. Public messages recommending the boiling or chlorination of rainwater would then need to be reinforced, in order to ensure that it would meet potability standards.

FIGURE 3.7. Impact of Water Crisis Scenarios on Production Capacity, by Water Resource (in percent) and Water Availability (in lpcd), 2030

		Single-event scenarios				Combined-events scenarios					
Events	Drought										
	SWOT										
	Pollution										
	Tech. breakdown										
Impacts on production capacity of water resources	Betio desalination				-100			-100		-100	-100
	PUB-NZ desal.										
	Bonriki lens	-50	-54	-100		-100	-100	-50	-100	-54	-100
	Buota lens	-100	-54	-100		-100	-100	-50	-100	-54	-100
	Urban lenses	Quality impact				Quality...				...impact	
	Rainwater	-70				-70	-70	-70			

Total water available (lpcd) in 2030



Source: World Bank data.

Note: The contribution of urban lenses to water availability is provided for illustration purposes, because (1) water is usually brackish and does not comply with bacteriological standards; (2) the impact of events on water quality cannot be quantified; and (3) people's future willingness to rely on water of various salinity levels for nonpotable use is not known. NZ = New Zealand; PUB = public utilities board; SWOT = seawater overtopping.

Notes

1. WHO/UNICEF JMP 2017, https://washdata.org. A household has access to basic water supply service when a water point is available and the collection time is no more than 30 minutes for a round trip, including queuing time.
2. According to random weekly water testing carried out by the Ministry of Health and Medical Services across South Tarawa, 2017.
3. Current residential water tariffs are US$1.4 per cubic meter ($m^3$) per month from 0 to 2.5 m^3; US$4.2 per m^3 per month up to 10 m^3; and US$12.6 per m^3 beyond this. A review of this tariff is planned in the short term, under STWSP.
4. The survey was carried out in June 2018; baseline information was collected from 300 households in South Tarawa.
5. Calculation is based on a review of monthly precipitation from 1947-2008, and a standard runoff coefficient of 0.85 of the reported water consumption data from our survey.
6. Raw water quality data communicated in 2017.
7. However, due to the stigmatization of well water consumption, and fluctuations in access to safe water, the exact extent of the practice is likely to be higher.
8. WHO/UNICEF JMP 2017, https://washdata.org. A basic sanitation facility is defined as one that hygienically separates human excreta from human contact and is not shared between households,
9. 2015 census.
10. Based on a daily production of 130 g of DBO_5 per pig, as proposed by E. P. Taiganides in *Pig Waste Management and Recycling: The Singapore Experience* (1992).
11. Under this method clear PET bottles are filled with the water and set out in the sun for six hours to kill viruses, bacteria, and parasites (giardia and cryptosporidium). Source: www.sodis.ch.
12. Ratio between the internally generated surface water annual runoff and groundwater recharge derived from precipitation falling within South Tarawa's boundaries.
13. Absolute water scarcity relates to areas whose freshwater availability is below 500 lpcd, according to the Water Stress Index (also known as the Falkenmark Indicator).
14. Seawater overtopping occurs when a storm surge combined with high winds, a high tide, large waves and sea level rise project significant volumes of seawater inland.
15. Surveys providing information on water consumption from shallow wells and rainwater harvesting include: Ministry of Finance and Economic Development of the Republic of Kiribati, 2016. Population and Housing Census Report; White and Falkland. 2009. Tarawa Water Master Plan. Kiribati Adaptation Program II; Jacobs, Scope Pacific Ltd. 2017. South Tarawa Desalination Economic and Social Feasibility Study; New Zealand Ministry of Foreign Affairs and Trade; a survey of 292 households conducted as part of this study.
16. Calculated based on chloride guidelines (250 mg/l). Recent editions of WHO guidelines only focus on potable water standards.
17. With a 75 square meter (m^2) roof, a 5 m^3 tank, a 0.85 runoff coefficient, and 5 liters per capita per day.
18. Including IPCC's RCP6, RCP8.5 scenarios and NOAA's Intermediate High scenario.
19. A pollution event in urban groundwater lenses has not been considered in this analysis: its scale would be limited to one of South Tarawa's islets, and it would not have systemic impacts on the city's water supply security.
20. This is driven by high power supply costs (US$0.5/kWh), compounded by old electromechanical equipment.

Chapter 4
How Can South Tarawa Improve Its Water Supply Resilience?

4.1. Potential Measures for Reducing Water Stress during Supply Crises

45. Several approaches can be considered for improving the resilience of the South Tarawa water supply in response to the various potential hazards presented in the previous section. This section provides an overview of these approaches and assesses their potential contribution to improved resilience of the system. A first measure, critical to the resilience of public utilities board (PUB) and South Tarawa's water sector, is the strengthening of the utility's capacity and sustainability.

4.1.1. Encouraging Water Conservation

46. The I-Kiribati tradition of thrifty water use is a major water security asset that the authorities should seek to encourage and sustain. The delivery of safe and abundant freshwater through South Tarawa Water Supply Project (STWSP) will require careful management of changes in people's water use habits. The project will entail significant communication and awareness-building efforts concerning water conservation. In addition, PUB and MISE have demonstrated their willingness to enforce block tariffs that will discourage wasteful water use, and to allow for limited residual pressure at water distribution points to help households better control their water use. Constant monitoring will be of critical importance in order to ensure that PUB water use does not significantly exceed planned allocations (64 lpcd), with corrective tariff measures and/or communication campaigns ready for launching if need be. As indicated in Section 3.5, countries with a similar level of socioeconomic development commonly show water consumption levels of 100 lpcd, sometimes even up to 150 lpcd. Communication efforts should also promote safe water use at times of reduced water availability, considering the greater risk of water-borne disease, with fewer (frequently zero) hand washing sources available; and greater use of lower-quality water sources (Elliott et al. 2017)

47. Demand management awareness campaigns should take into consideration and build on existing practices that are consistent with the logic of water conservation advocacy. It is critically important to encourage water conservation by crafting outreach messages that approach water use from the perspective of local expertise and priorities: that give credence to direct experience rather than the knowledge of experts in assessing potability and quality of water; and that place prime importance on self-reliance and responsibility in water management at the household level. Widespread reuse of kitchen water for gardening and pig rearing could be extended to reusing good quality laundry and shower greywater to irrigate gardens; the rationing of high-value water could also be systematically extended to all three types of water sources, including well water; and attempts could be made to apply the logic of the monitoring of rainwater tanks, which already informs water management efforts in many households to assessing the quality of domestic well water and understanding groundwater supply in relation to rainfall and demand.

48. Harnessing the competitive mindset of communities in Kiribati could also help drive progress in achieving water conservation goals. One possibly effective strategy for involving local communities may be

through the awarding of prizes, gifts, and competitions to stimulate citizens' interest in water conservation, and to make engagement in it attractive-provided these are approved by local authorities. In this spirit, community outreach messages should reflect a collective identity, focusing on family and the household as a functional unit, and on community rather than on individuals.

49. Volumetric water tariffs will remain a highly effective tool to promote water conservation and help sustain thrifty water practices. Increasing the block tariff structure can be particularly useful for communicating the value of water to users. In general, pricing signals such as tiered-rate structures seem to be more efficient than conservation mandates (World Bank 2017). Setting tariff levels drastically higher than people are willing to pay in the higher-tariff blocks can also help to effectively target the desired consumption levels.

4.1.2. Optimizing the Use of Rainwater Harvesting

50. The current stock of hard-roofed structures could, in principle, allow a significant expansion of rainwater harvesting (RWH) as part of South Tarawa's portfolio of water resources. This could be achieved by: (1) rehabilitating out-of-order systems (about 10 percent of the total stock according to field visits), and ensuring that gutters on all of the sides of large buildings are connected (these systems capture on average only 75 percent of roof areas as found in our survey); (2) expanding coverage from the current 20 percent to all houses with suitable roofs, which represent about 70 percent of houses in South Tarawa; and (3) expanding RWH coverage for nonresidential buildings, from the current level of about 50 percent to up to 90 percent of buildings.[1] This would be consistent with the provisions of the 2017 Kiribati National Building Code, which stipulates that rainwater storage and roof drainage should be provided on all permanent buildings with an impermeable roof surface, and that they should collect water from the entire roof area. Production capacity could theoretically increase by almost 300 percent in residential buildings, and by 23 percent in nonresidential buildings, as shown in table 4.1.

51. However, due to the high cost, maximizing RWH production capacity is difficult. The capital cost of a typical residential RWH system[2] is around US$2,000. Over the estimated 20-year lifetime of the equipment, the long-term average supply cost is US$8.1 per cubic meter (75 percent of which corresponds to the purchase of the tank). On large nonresidential buildings opportunities for economies of scale are limited because both the water supply capacity and the optimal storage capacity (which represent the bulk of the capital costs) increase almost linearly with the roof surface area. The savings potential associated with the purchase of a larger water tank remains limited by the current local market, which only offers individual storage capacity up to 10 cubic meters. For a typical 500-square-meter communal hall, the long-term average cost becomes US$6.1 per cubic meter. In comparison, the PUB water tariff is on average US$1.4 per cubic meter for typical household consumption levels.

52. If RWH is to further expand, it will be driven by its perceived benefits in terms of resilience. The existing

TABLE 4.1. Rainwater Harvesting: Current and Potential Increase Capacity

	Current production capacity (lpcd)	Maximum potential production capacity (lpcd)
Residential buildings	1.9	7.4
Nonresidential buildings	2.3	2.8
Total	**4.2**	**10.3**

Source: World Bank data.
Note: Average liters per capita per day across the population of South Tarawa.

PHOTO 4.1. Private Rainwater Tank and Laundry Area

Source: © Helene Le Deunff/World Bank.

rainwater storage infrastructure could contribute to communities' resilience to water crises, for example the combination of a temporary breakdown in the desalination system with a reduction in the yield from water reserves lenses due to drought, seawater overtopping (SWOT), or pollution events. In total, rainwater tanks across South Tarawa currently represent an estimated storage capacity of 15,000 cubic meters, with about 11,000 cubic meters (equivalent to about 200 liters per capita) available for residential water consumption. This could provide an average of 8 lpcd for 1 month. While technical breakdowns cannot be predicted, droughts or pollution incidents usually develop gradually, and can be monitored. In the case of a significant decrease in the yield from the water reserve lenses, the public could be advised to maintain storage tanks close to maximum water levels by filling them frequently with PUB water. However, there are three main challenges in operationalizing such a system: (1) ensuring access for everyone to the tanks in a time of crisis (currently 37 percent of the population never uses RWH, which might in some cases be due to affordability or accessibility (that is, distance) issues); (2) ensuring adequate water quality, since RWH systems rarely comply with bacteriological quality standards, and are almost never chlorinated; and (3) encouraging the filling of water tanks in a staged manner that does not overwhelm PUB water production capacity.

53. Improving the equity of water security requires a denser network of storage facilities, as well as incentives to owners to contribute to the resilience of the system. A full mapping of water tanks across South Tarawa[3] could help identify the areas where inhabitants do not have access to at least 200 liters of storage capacity within a reasonable distance (up to 200 meters). Expansion of storage capacity should prioritize those areas. Along with this, continuous awareness campaigns will be needed in order to ensure that everyone has access to water from tanks installed on private property, particularly during droughts. Currently water sharing is determined by proximity of relationship; close relatives have priority. Because of recent urbanization, people who are not related to each other or who do not even originate from the same island are now living side by side, and may not be inclined to participate in systematic water sharing. The marginal cost of connecting tanks to residential RWH systems is estimated at US$1.3 per cubic meter (less than US$1.0 per cubic meter for large institutional buildings). This additional cost is financially justified in relation to the current PUB water tariff of US$1.4 per cubic meter (in the lower tariff block). To incentivize the filling of storage tanks with PUB water in situations of enhanced water lens vulnerability, temporary rebates on the higher PUB water tariff blocks could be offered to institutional rainwater tank owners.

54. Efforts to enhance public awareness about the safe management of RWH and storage will be required. Two main factors contribute to substandard water quality from RWH systems: (1) the insufficient maintenance and cleaning of roofs and storage tanks; and (2) the lack of first-flush and disinfection systems. Even if tanks are used to store high-quality PUB water, health hazards will remain due to the possible contamination of water tanks. Currently, only 58 percent of households boil water prior to consumption, and chlorination is rare (ADB 2018). To aim for universal treatment of rainwater, it is recommended that the public awareness campaigns on safe water supply and hygiene planned under STWSP will promote the systematic simple disinfection methods of tanks, and the boiling of rainwater before human consumption; incorporate messages about the maintenance and proper use of RWH systems; and suggest cleaning methods that both respect and protect the widely perceived purity and value of rainwater.

55. Economic benefits related to the hedonic value of rainwater, along with the desire to retain cultural identity, may contribute to sustained reliance on this resource. The value that people place on the organoleptic qualities of rainwater is likely to evolve with the improvement of the PUB water supply, which combines water from the Bonriki and Buota lenses with desalinated water. The factors that can influence willingness to change behavior are poorly understood, but ethnographic studies suggest that the I-Kiribati are reluctant to conform to anything that is perceived as not local (Brewis 1991). Thus, integrating the cultural values that local people attach to the water resources they control and use into the efforts to adapt to the stresses on these water resources is of critical importance (Kuruppu 2009). The cultural processes negotiated by people in their daily lives in Kiribati have been shown to reinforce and reproduce water hardships, as illustrated in box 4.1. The sense of vulnerability associated with environmental change and urbanization might also produce an urge to preserve cultural values (Jones 1996). As culture is so fundamental to I-Kiribati behaviors and outlook on life, the perception of PUB water as being "modern" might prevent its full adoption even when it is abundant, accessible, safe, and of good quality: an enduring attachment to rainwater as a culturally valued resource may be maintained. This must be considered if the I-Kiribati are to be

BOX 4.1. When Cultural Norms and Requirements Reinforce Water Hardships

Water sharing has benefits, but it also entails additional burdens. When members of the same kin group live far apart, the distances to collective water distribution points can be a strain. Mr. R., a man in his 50s living in Ambo, has to beg for one bucket of rainwater a day from relatives. To collect it he must also walk for 10 minutes to the other side of the islet. Exchanging water can also come at a high psychological cost. Mr. A., for instance, who is 30 years old, moved from North Tarawa so he could live with his young small family close to the house of relatives in Bikenibeu. He reports that depending on others for water creates emotional distress: "I am so tired of asking for rainwater from the neighbors!" he says.

Source: Face-to-face interview, July 2018.

encouraged to fill their tanks with PUB water as a preventative tactic for crisis management during periods of low rainfall, as they may be reluctant to mix the two sources.

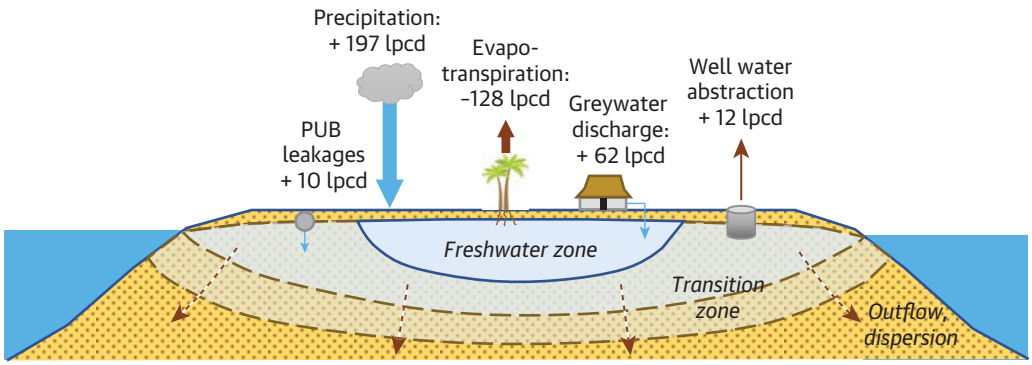
4.1.3. Improving Urban Groundwater Through Managed Recharge

56. Even with improved PUB services, urban groundwater, like rainwater, will remain a last- resort water resource anchored in the I-Kiribati's deep cultural relationship to the land. The improved management of urban groundwater, therefore, has a multilayered impact on water security, at both a material and a symbolic level.

57. Human activities significantly influence the availability and quality of urban groundwater, particularly during droughts. Along with rainwater infiltration, leaks from PUB networks and greywater discharge contribute to the recharge of urban lenses. On the other side of the equation, freshwater is drawn out of lenses through well water abstraction, evapotranspiration, outflow, and dispersion at the bottom and sides of the lenses. The respective contributions of these different factors are illustrated in figure 4.1, assuming conditions of severe drought lead to a 75 percent decrease of the 2-year cumulative rainfall (which is identified in Section 3.4.1 as the worst-case scenario for urban groundwater). This schematic water balance is presented in the absence of detailed knowledge, adequate monitoring, or accurate modeling of the flows of freshwater in the lenses. Given the current tree cover in urban areas, evapotranspiration is considered to be 65 percent of precipitation.[4] Greywater returned to the lens is, in the absence of a dedicated sewerage system,[5] assumed to represent 80 percent of total consumption, and leaks are projected to be a maximum of 25 percent of PUB water production in 2030.

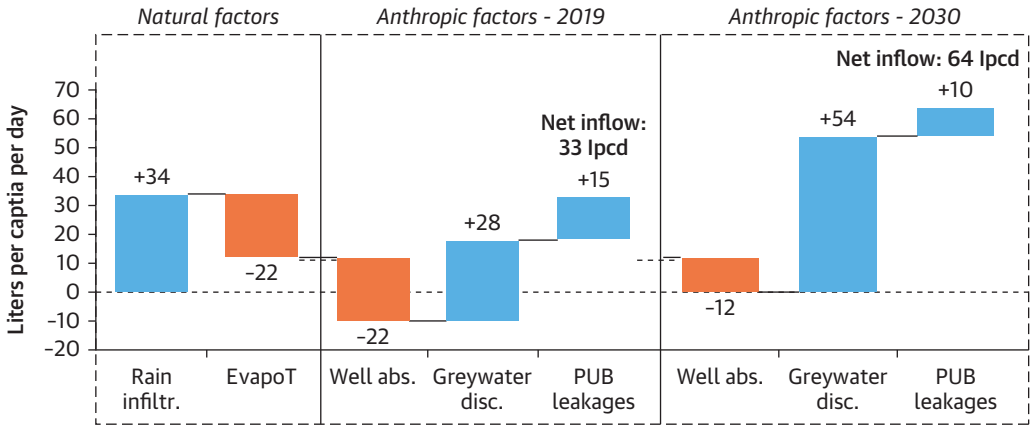
58. Improvements in the availability and efficiency of PUB water supply services may have significant, positive impacts on the recharge of urban lenses. As shown in figure 4.2, which shows the inflows and outflows at the surface of a lens in a dense urban area like Betio during a severe drought, the net inflow due to natural factors (+ 11 lpcd) increased threefold in 2019 (up to + 33 lpcd) thanks to anthropic factors, and would be expected to increase almost six-fold by 2030 (up to 64 lpcd). The increased contribution of greywater discharge is of particular importance to future water balance, and it is made possible by a massive transfer of desalinated seawater without which the net freshwater inflow to the lenses would be almost nil. This analysis highlights the potential benefits of managing greywater discharge in situ, rather than

FIGURE 4.1. Key Contributing Factors to the Water Balance of Urban Lenses



Source: World Bank data.
Note: Average flows across South Tarawa, drought conditions, 2030. PUB = public utilities board.

FIGURE 4.2. Balance of Freshwater Inflow and Outflow by Urban Lens Surface

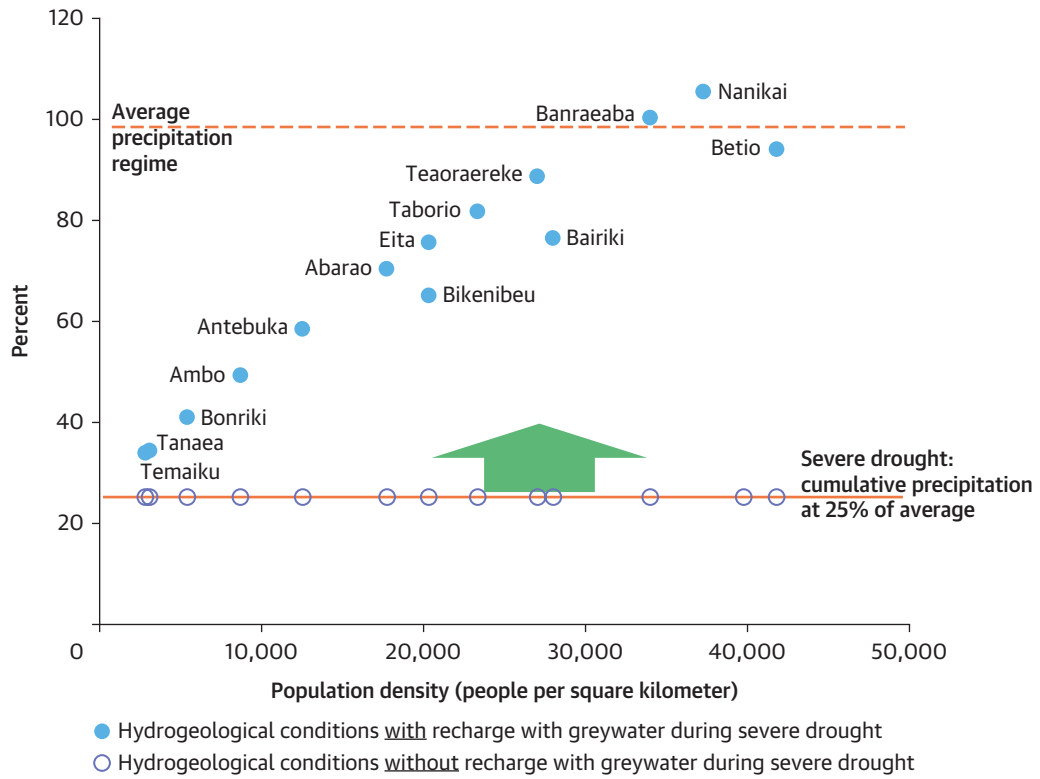


Source: World Bank data.
Note: Drought conditions in Betio, 2019 (left and middle sections) and 2030 (left and right sections). Anthropic factors (related to human activity) include well water abstraction, graywater discharge, and PUB network leaks.

discharging it into the sea (treated or untreated), mixed with toilet flushing and other high-organic content wastewater.

59. The recharging of urban lenses with greywater during severe droughts can maintain hydrogeological conditions comparable to a normal precipitation regime. In communities with a high population density (from about 20,000 people per square meter, which represents about 80 percent of South Tarawa's population), greywater flow is comparable to the natural recharge that occurs when precipitation is close to the average level, as illustrated in figure 4.3. While freshwater yields would remain very limited (up to 2 lpcd in Betio, 5 lpcd in Bairiki, 2 lpcd in Bikenibeu, and probably similar, or even less, elsewhere), and would only be available toward the centers of the islets, the overall quality of groundwater across the top of the lens would be significantly improved (White 2010). For most South Tarawa inhabitants, the

FIGURE 4.3. **Potential Relative Contribution of Greywater**



Source: World Bank data.
Note: Potential relative contribution to total lenses of freshwater inflows, depending on population density—in case of a severe drought in 2030.

recharge of lenses with increased graywater volumes could therefore translate into reduced salinity in otherwise brackish groundwater.

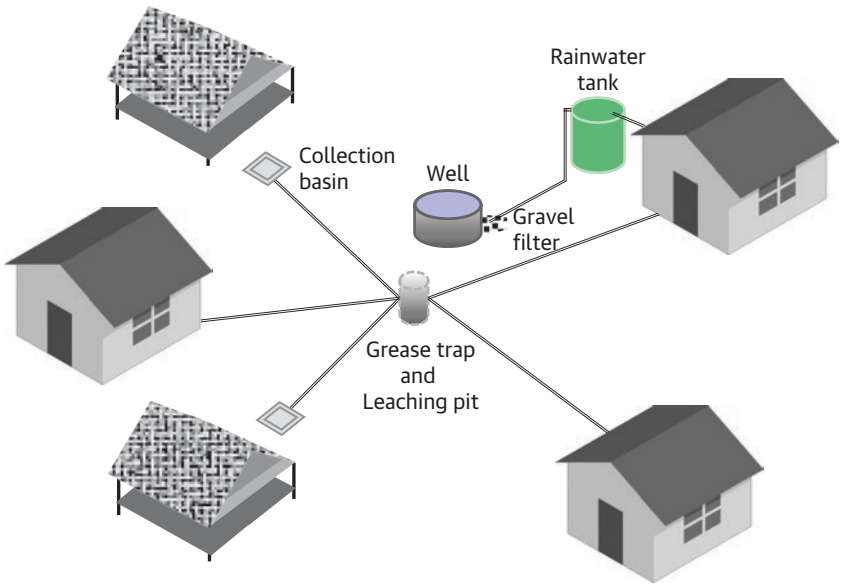
60. As currently managed, greywater could pose increasing challenges to the quality of the environment, and possibly of the groundwater, in the long term. Currently greywater is discharged without treatment by households directly into their plots, where it infiltrates quickly due to the high absorption capacity of South Tarawa's sandy ground. Water from the kitchen (used for cooking and dishwashing) is generally shared with pigs when it is free from soap or detergents; otherwise it is used for gardening, or to water plants. Water used for hygiene (shower, toileting), and water from the laundry are left to infiltrate the ground. People sometimes dig holes to bury smelly liquid substances, or bring them to the beach for discharge into the sea. These practices have the potential of becoming aggravating nuisances once supply volumes significantly increase. The contamination of the lenses can also be expected to increase due to the pollutants they will carry when improved water availability triggers new consumption behaviors, leading to an increase in the bacteria, detergents, and nutrients that were already found in excessive quantities in some areas of the lenses in 2010 (White 2010). Their discharge into the ocean through deep submarine outfalls (as is currently being done, together with the rest of household sewage in Betio, Bairiki, and Bikenibeu) would avoid these problems. However, it would miss the

opportunity to use these low-pollution, low-salinity waters for recharging urban lenses, and for increasing the resilience of communities to droughts; and it could also potentially negatively affect coastal ecosystems.

61. Simple, inexpensive solutions could help improve greywater management, and well water salinity and bacteriological quality. Reducing water salinity in shallow wells requires the disposal of greywater in proximity to them. But water recharged from point sources usually stays relatively close to the point of discharge, as has been found from pollution studies at and near point sources in other atolls (Falkland 2001). Current greywater disposal practices, which ignore this insight, would be unlikely to notably improve the quality of the water in shallow household wells. Given the nature of the pollutants contained in greywater, simple facilities such as grease traps and leaching pits could be considered for treating centralized household greywater, and for ensuring its dispersion into the ground, as shown in figure 4.4. Such solutions would be better suited to areas with moderate population density. Where houses are traditional and lack plumbing systems, simple concrete collection basins (such as the one shown in photo 4.1) would be required to receive washing and laundry greywater and transfer it through underground piping to the treatment systems. The design of these systems would also take into consideration the capacity of local coral sands to effectively remove pathogens within a very short distance from the discharge point (Institute of Environmental Science and Research Limited 2016).

62. Several measures are of critical importance in order to better regulate water use from urban lenses, and to reduce the impacts of greywater discharge. The establishment of quality guidelines for well water, and a monitoring system could help clarify the advisable nonpotable water use conditions; define targets for the management of urban lenses; and rationalize recommendations for the population. Salinity limits could build on the 1993 edition of the

FIGURE 4.4. Schematic Lens Recharge System (Greywater Disposal+Rainwater)



Source: World Bank team.

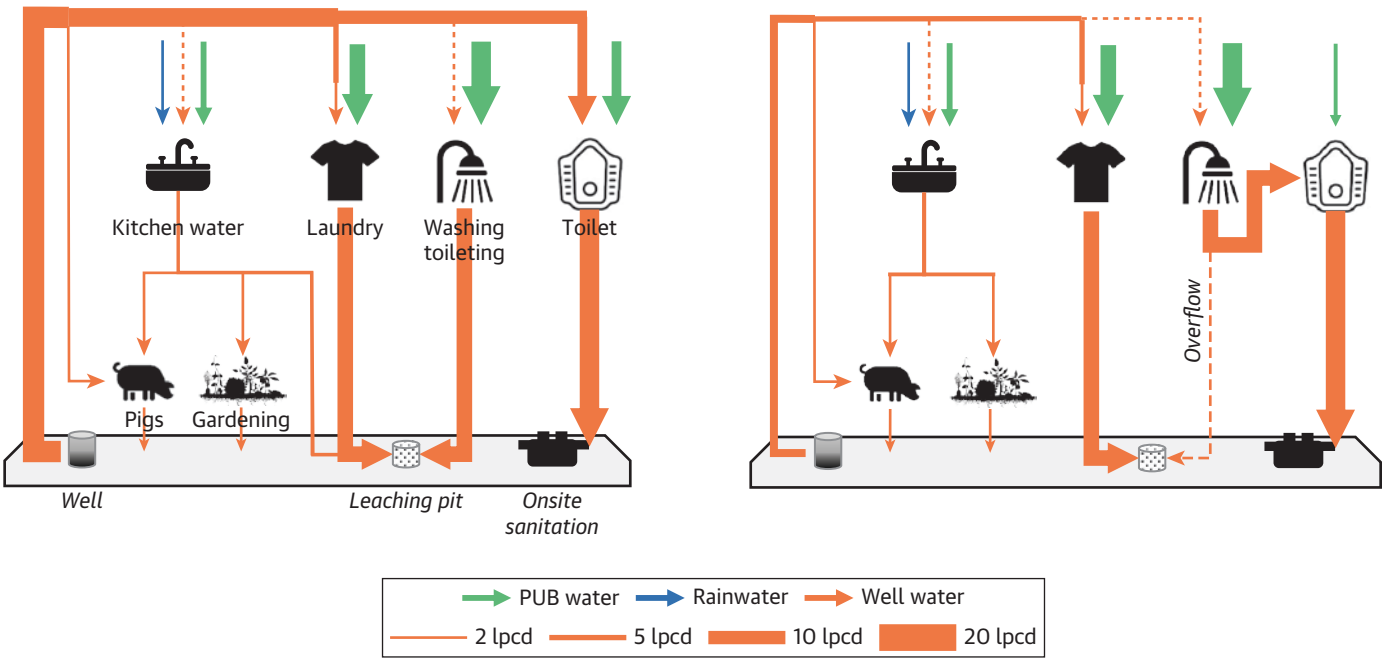
WHO guidelines (2,500 µS/cm), while guidelines for bacteriological quality could be based on the latest WHO guidelines for safe recreational water environments. Limiting the use of soap and detergents to those that are free of inorganic phosphates, and that contain only surfactants that minimize environmental pollution would contribute significantly to the protection of urban groundwater quality. A national regulation restricting or disincentivizing the purchase or importation of detergents that do not comply with such requirements is recommended from a water security perspective. Also, the inclusion in the Kiribati Building Code of requirements to direct RWH system overflows to the wells could be considered, along with the measure presented in the next paragraph. Finally, investigations to identify leaks from the seawater flushing network, and their impact on urban lenses is critical in order to avoid groundwater salinity hotspots.

63. RWH can also help maximize the freshwater recharge of shallow wells, and reduce salinity. As was successfully shown in the outer islands of the Maldives, directing rainwater into or near shallow wells could help improve their salinity (Falkland 2001). Together with greywater recharge near the well, the injection of rainwater would lead to the development of "domes" of groundwater of reduced salinity around the well. Such systems would target overflows from RWH systems, which represent close to 90 percent of rainwater collected in average precipitation years, and more than 70 percent even during severe drought periods. Where no RWH system is installed, this approach can still be used by both households and community buildings at a relatively low cost by installing gutters and piping to nearby wells. In addition to reducing the salinity of well water, this method can improve the bacteriological quality of the water by increasing the water level locally, and slowing the migration of pollutants from nearby latrines or septic tanks. Piping rainwater overflows through a gravel filter adjacent to the well appears advisable in order to ensure that leaves and other debris on roofs and in gutters are not flushed directly into the well (Falkland 2001). Pilot testing in South Tarawa is recommended before rollout. This should include long-term monitoring of the impact on water quality in wells with and without such an installation, to confirm the concepts of both rainwater and greywater recharge, and to quantify their benefits.

4.1.4. Direct Nonpotable Water Reuse

64. In low-density areas without a seawater network for toilet flushing, direct reuse of greywater could help save PUB water and/or minimize the burden of fetching well water. According to the household survey that was conducted as part of this study, 60 percent of households in Bairiki, Betio, and Bikenibeu, and probably a smaller percentage in other areas of South Tarawa, have access to private flush toilets—a number that is likely to increase in the coming decade. Washing areas for showering and bathing are frequently located close to toilets, a configuration that lends itself to the reuse of greywater for toilet flushing, as illustrated in figure 4.5. A small ground tank (less than one cubic meter) could be installed to receive greywater from the washing area and could feed into the toilets through a manual pump. With an expected water use of about 20 lpcd (comparable to average household washing needs), such a system would save almost 5 cubic meters from the monthly PUB water bill (which could amount to US$5-10 per month, considering the post-STWSP PUB water system operating costs), or the lifting of 5 tons of water from wells, which most households carry out manually. This conservation of water would be particularly critical during severe droughts, where any reduction in well water abstraction can weigh significantly on

FIGURE 4.5. Options for Greywater Reuse Management in Low-Density Areas



Source: World Bank data.
Note: Left panel: without direct reuse; Right panel: with direct reuse in a shower-to-toilet configuration.

the lenses' freshwater balance, as was shown in figure 4.2 above.

65. Similarly, direct reuse of nonpotable water could be considered in lieu of seawater flushing in high-density areas where sewerage system expansion is envisaged. (Such expansion is considered a priority in the areas of Betio, Bairiki, and Bikenibeu that are not currently covered by the sewerage network.) In-house direct reuse could enable major savings, considering the cost of seawater flushing systems (up to US$800 per beneficiary) (GHD 2017); operating (pumping); and maintenance costs, not to mention the risks of groundwater salinization due to possible leaks in the seawater network. Depending on the house's configuration, greywater from the kitchen or laundry could be used for that purpose as well; and in more modern houses dedicated plumbing could ensure that greywater is transferred to the reuse area. A rapid review of a typical household layout suggests a difference between the modern type of housing—where the places that water is consumed are close to each other in a single building—and more traditional settings, where water can be accessed and used in different parts of an open compound. While some households have been reusing greywater for gardening, as illustrated in box 4.2, such use should not be encouraged without appropriate prior treatment.

66. Across South Tarawa, up to 40 percent of households could benefit from the implementation of a direct reuse scheme for nonpotable water. Such measures could lead to an overall incremental water use of 8 lpcd from sources normally used for toilet flushing outside of the areas that are already served by a sewerage system. Brochures designed to raise awareness of and describe possible reuse arrangements for a

BOX 4.2. Improvised Graywater Reuse in Kiribati Households

Mr. N. is a 68-year-old microentrepreneur who retired a few years ago from his job in the shipbuilding industry. The house he shares with his wife is conveniently located on the main road. This enables him to run a small kiosk where he sells fresh fruits and vegetables from his garden and a mixed basket of dry products. With his protected well and a connection to the water supply system, Mr. N. has access to two of the three types of water usually accessed in South Tarawa. When it rains, he also collects rainwater in buckets from his metal roof. Mr. N. is very proud of the ingenious plumbing system he has designed to channel greywater from the kitchen sink to the banana pit behind the house. The two young banana trees, mulched with organic material and fed with kitchen water, have already produced fruits that he has sold to his customers. The water he uses to boil fish and to clean rice is also carefully set aside every day to feed his pigs.

Source: Face-to-face interview, July 2018.

variety of household layouts, and possibly a dedicated revolving fund, could help spur the rollout of this solution. Photo 4.2 shows an example of a bathroom setup that is well suited to direct sink-to-toilet reuse. According to our household survey, well water is being used by 90 percent of households for toilet flushing, and PUB water is used in the remaining 10 percent of cases. It is likely that the use of PUB water for toilet flushing will increase after the PUB system is upgraded. Moreover, the actual scope of greywater reuse will largely depend on the solutions implemented to improve sanitation across South Tarawa. As indicated in Section 3.2.1, a concept study is currently being carried out with financial support from New Zealand for the purpose of identifying appropriate sanitation models and preparing for their implementation. Solutions that require minimal freshwater input (for example, dry sanitation, vacuum sewers, and seawater flushing) would need to be compared with opportunities for greywater reuse in toilets. The rollout of this solution could, for example, be financed by a revolving fund, through a scheme similar to the one that was used in the past for the expansion of RWH.

4.1.5. Increasing PUB Emergency Storage Capacity

67. Expanded storage of treated water could help to effectively address short-term emergencies related to technological breakdowns. Available space is the main constraint in the western part of South Tarawa, where the main desalination plant will be located. The implementation of aboveground water tanks could be considered for water reserves that have a minimal impact on aquifer recharge. Any location near the Bonriki headworks would seem particularly appropriate for taking advantage of existing chlorination facilities. Sizing would be limited by investment costs (about US$200-300 per cubic meter), and ensuring acceptable water quality (subject to simple rechlorination) in the tanks could also be a challenge in the case of extended storage duration. Also, the water transmission system in the eastern part of South Tarawa has an insufficient conveyance capacity for pumping well beyond the normal production levels in Bonriki and Buota. An upgrade of the pumping and transmission system from Bonriki may be required in order to allow the simultaneous operation of these systems during emergencies at the Betio desalination plant.

PHOTO 4.2. Favorable Setup for Direct Reuse

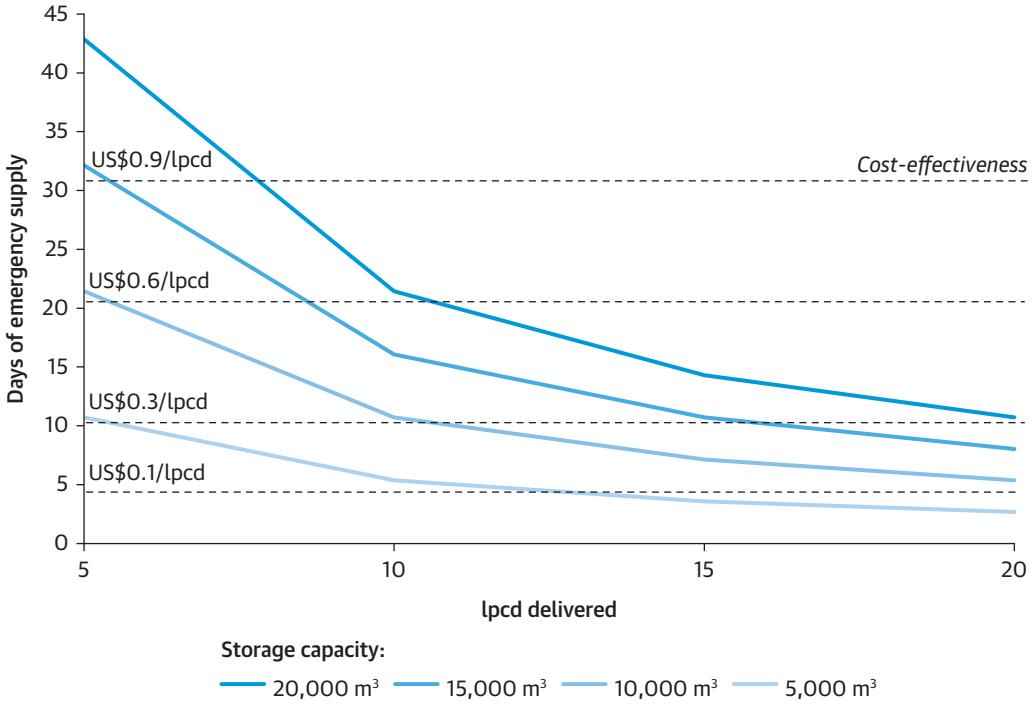
Source: © Helene Le Deunff/World Bank.

68. The economic relevance of this solution, compared to other previously discussed solutions, strongly depends on the type and expected duration of a water crisis. As shown in figure 4.6, the cost-effectiveness of water storage would be more economical for small-storage capacity (5,000 cubic meters or less), and for emergencies that could be addressed within a few days, than low-cost solutions such as pollution mitigation measures, or clearing vegetation or palm trees from the groundwater reserves (US$0.10 and US$0.13 million per additional lpcd respectively). For long-term crises of 2 weeks or more, the solution appears less cost-effective than a backup desalination system would be (US$0.3-0.5 million per incremental lpcd across South Tarawa). Experience operating the desalination plant will help in better appreciating the nature and frequency of potential breakdowns and reaction times, and will facilitate the prioritization of solutions.

4.1.6. Increasing Desalination Capacity

69. Implementing the new seawater desalination system will significantly improve the resilience and operation of PUB water systems. The solar-powered desalination system planned under STWSP is designed to meet a water demand of 59 lpcd until 2030, with a 4,000 cubic meter per day production capacity. The plant will be located in Betio, at the western end of South Tarawa, and its water transmission and brine disposal systems are designed to allow

FIGURE 4.6. Cost-Effectiveness of an Emergency Storage Solution for Various Storage Sizes, Durations, and Intensities (lpcd gap) of Emergencies

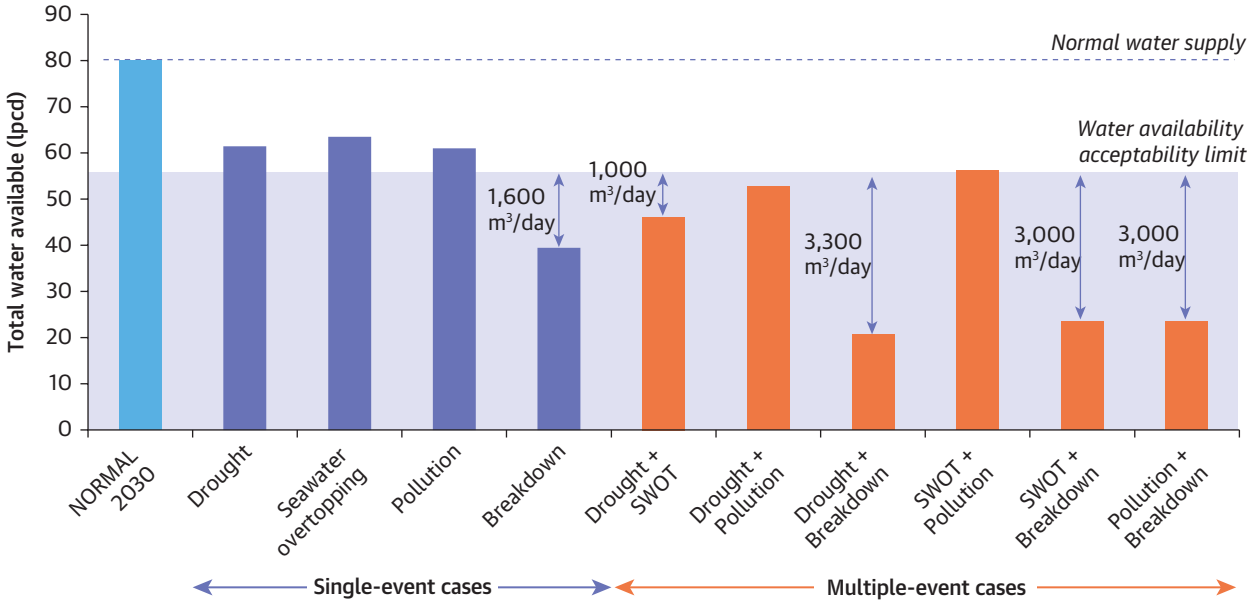


Source: World Bank data.

future expansion of production capacity to 6,000 cubic meters per day. While the marginal cost of increasing desalination capacity on this site would be much less than the construction of a new unit, the introduction of a new desalination system in a different location would help reduce the systemic impacts of a local failure or disaster affecting one plant. Even though in both cases the source of water remains identical (seawater), the use of independent desalination systems represents a diversification of PUB's portfolio mix, and the hedging of water supply risks. A new 3,300 cubic-meter-per-day desalination backup system could, in principle, fully address the freshwater supply gaps described in figure 4.7 for all crisis configurations. The introduction of other, more cost-effective measures could, however, mitigate the need for such a large additional desalination capacity, and should be considered in priority.

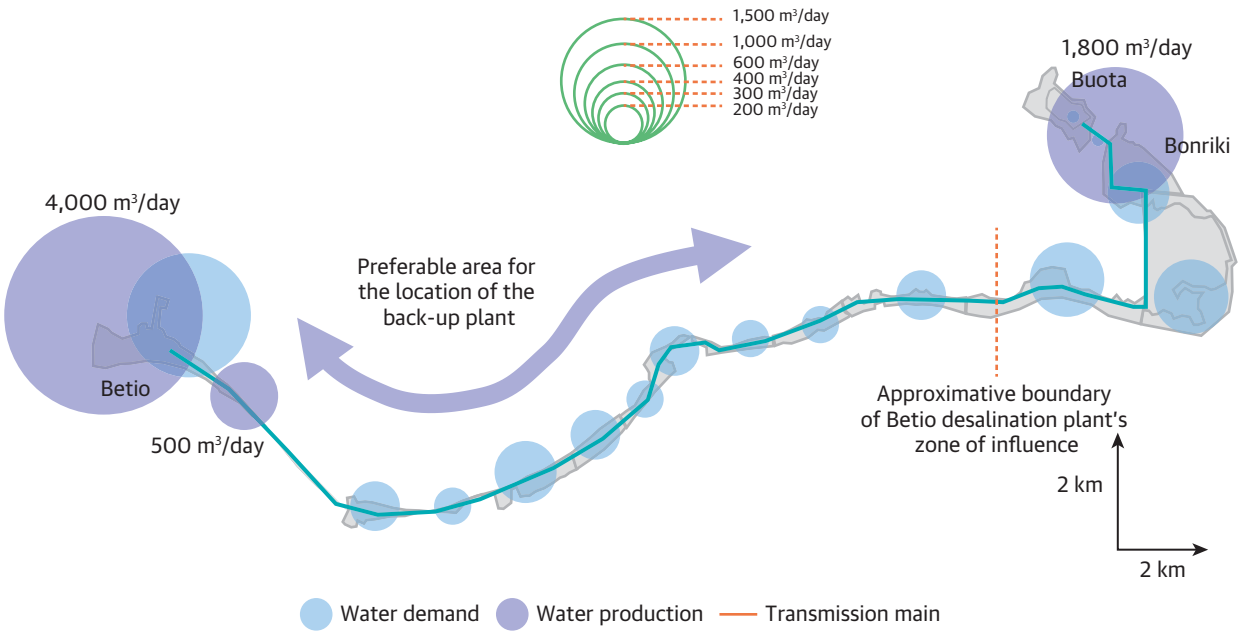
70. Investment costs for the engineering, procurement, and construction of desalination plants of this capacity can be expected to be in the range of US$2,000–3,000 per cubic meter per day of production capacity. These cost ratios are at the higher end of normal prices for reverse osmosis desalination plants (which start at US$500 per cubic meter per day), due to the small scale of the units and the remoteness of Kiribati. The architecture of PUB's distribution system would in principle allow for the installation of an additional desalination unit across South Tarawa's transmission system. However, a review of the Bonriki pumping system would be needed in order to ensure its capacity to operate in this altered hydraulic regime, without the Betio desalination plant and with the backup production system. As shown in figure 4.8, from a hydraulics perspective it would be preferable for such a system to be located in the

FIGURE 4.7. Desalination Backup Capacity Required to Cover Crisis Supply Gap



Source: World Bank data.
Note: Production capacity needed to fill the supply gap in various scenarios (well water is excluded from the portfolio mix). SWOT = seawater overtopping.

FIGURE 4.8. Preferred Areas for a Backup Desalination System



Source: World Bank data.

western part of South Tarawa (subject to land availability), in order to minimize the need for upgrades of the transmission system.

71. Keeping a seawater desalination plant in standby mode to cope with emergencies requires regular and careful maintenance. Even if a large new desalination unit were built within the PUB water system to cope with emergencies, the Bonriki and Buota freshwater lenses would probably continue to be relied upon in the first instance, given their lower associated operating costs.[6] To ensure that the plant was in good working condition and capable of being put into operation immediately, if for example there were a failure of the Betio desalination system, it would need to be operated in "hot standby" mode: this suggests that it should be briefly run on a frequent basis. Such a strategy was adopted during the Millennium Drought by the government of Queensland, Australia, with the use of a standby desalination plant in the Gold Coast to cope with acute drought events or the failure of other water production systems.[7] Together with investment costs, long-term operation and maintenance could represent up to US$0.5 million per additional lpcd of water availability across South Tarawa.

4.1.7. Managing Water Reserves in a Sustainable Manner

72. Diffuse groundwater pollution generated by human settlers in water reserves can be mitigated. Organic and nitrate pollution appears to be the most immediate threat related to the presence of settlers in the water reserves. The best way to preserve the yield from these reserves is to control urbanization over them, and to properly manage the activities that take place in their proximity. However, pollution risks to the water lenses can also be minimized through sustainable water management plans designed to mitigate risks and prevent further encroachment. These plans can include a range of measures, such as: (1) clearly defining permitted activities and land use; (2) clearly defining prohibited activities and land use, and the regulatory measures that will be enforced in cases of infringement; (3) creating public awareness-raising and behavior change campaigns regarding the impact of human activities on groundwater quality, along with warning signs that describe the penalties for noncompliance; (4) establishing an active surveillance and compliance regime, with the equipment and technology needed to regulate and prevent further encroachment on the reserves; (5) filling in the existing pits through which the lenses are most vulnerable to contamination; (6) implementing small-scale infrastructure improvement (sanitation, drainage); (7) creating low-cost perimeter barriers, and erecting educational and signs around the water reserves; and (8) enhancing groundwater monitoring so that it can detect early signs of groundwater pollution. Even if settlers were relocated away from the reserves, some of these actions would remain critical in order to avoid any further inflow of people. Further details are provided in appendix D.

73. Industrial pollution from the airport must be prevented, and remediation measures prepared in case of an accident. In addition to observing normal airport infrastructure design and operation standards, it is critical to adopt prevention measures, including the installation of observation wells around the most exposed areas (where fuel is stored and handled), and monitoring these wells in order to allow for the timely detection of possible leaks of oil products into the lens. If contamination can be identified before it spreads out in the lens, affected soil can be removed and abstraction of polluted groundwater can be carried out from remediation boreholes dug around the contaminated site (Svoma and Houzim 1984). In such a case, only the nearby infiltration gallery(s) would have to be temporarily interrupted,

and the impact on PUB water production would be limited.

74. The costs associated with these various measures are particularly difficult to estimate at this stage. Significant technical assistance will be required for those elements of the sustainable management plan that are associated with mitigating household-borne pollution, or the preparation and management of resettlement processes. The main infrastructure costs are related to the fencing of the reserves, if this is deemed necessary. The cost of a sanitation infrastructure would probably be negligible. The main costs associated with mitigating industrial pollution would be the drilling of bores, and equipment for monitoring them. An overall cost estimate of US$2 million over the next 20 years is assumed for the various measures considered in this analysis.

4.1.8. Other Supply Augmentation Measures

75. Two measures described in previous studies could increase the yield of the Bonriki water lens. The removal of deep-rooted palm trees from the central portion of the water reserve to reduce transpiration losses is described in the Tarawa Water Master Plan as allowing an increase of 250 cubic meters per day of the lens's yield, at a cost of about US$325,000 (White 2010). The infill of borrow pits located on the edge of the reserve that are filled with brackish water could also increase the yield by 250 cubic meters at a cost of around US$3.0 million. Both approaches would, however, require negotiations with landowners, and might also require the payment of compensations to those who are using the trees or the pond for economic activities. From a water security perspective, these measures would be most beneficial during water crisis events that do not affect the water reserves (for example, a temporary breakdown of the desalination system).

76. The transfer to South Tarawa of groundwater abstracted on North Tarawa's main islets could also be considered in order to diversify water resources. The Tarawa Water Master Plan (White 2010) and later the Water and Sanitation Roadmap 2011-30 (ADB 2011) discussed the development of groundwater production systems in several islets of North Tarawa, and cross-lagoon water transfers to South Tarawa. Aside from the complexity and cost of securing abstraction rights from North Tarawa landowners, this solution was found to be very onerous, with a unit cost of about US$11.5 per cubic meter delivered.

77. While this report promotes the consideration of urban aquifer recharge with greywater, future densification and modernization of South Tarawa could in the long term require adjustments to this strategy. Changes of lifestyle, and an increase in pollution loads could at some point overwhelm local greywater treatment capacity. Alternative greywater management strategies would then need to be considered, including centralized treatment, provided that flushing systems do not rely on seawater, which would undermine conventional treatment solutions. A wastewater reclamation system would eliminate the need to discharge the effluent into the ocean, and, together with a nonpotable water supply network, it could, in a circular manner, supply households with the recycled water for flushing and other nonconsumptive uses. In the context of South Tarawa, this approach would, however, face several constraints: (1) the cost of building a second pressurized water network and doubling PUB's O&M and commercial efforts to manage both services (potable and nonpotable); (2) the city's elongated shape, which stretches for 30 kilometers, would complicate the centralization of wastewater at a single reclamation plant; and (3) the introduction of another technological solution, with the associated risks of systemic failure. On the other hand, the energy requirements for wastewater

reclamation are generally lower than for seawater desalination. Should technology improvements in wastewater reclamation make it financially competitive with the alternatives described in this report, an initial pilot in Betio could be considered in the long term, since: (1) population density in this area is likely to make decentralized greywater management more difficult; and (2) a sewerage system is already in place there, centralizing wastewater in a location close to the future Betio desalination plant.

78. The recharge of the Bonriki water lens has been analyzed as part of this study, but the technical and economic feasibility of this remains uncertain. Artificial recharge of the Bonriki water lens could be particularly helpful in speeding up recovery of its sustainable yield after severe droughts or SWOT events. However, such a solution would only be sensible if water production in Bonriki has been fully interrupted: reducing abstraction from the lens would otherwise be preferable, in order to improve its hydrogeological conditions. If the Bonriki water production system is stopped, it is unlikely that water production from other plants would cover all of South Tarawa's needs and leave any surplus that could be used for water recharge.

4.1.9. Assessing the Proposed Resilience Measures

79. The resilience measures presented so far in Section 4.1 cover a broad spectrum of cost-effectiveness and types of benefits. Table 4.3 provide an overview for each of these measures, of the potential incremental water availability; its quality; the situation in which it could be mobilized; and the long-term unit cost per cubic meter. Costs were found to vary between US$0.02 million per incremental lpcd delivered across South Tarawa for improved tank management (which relies primarily on policy decisions and awareness raising), to US$1-3 million per incremental lpcd for decentralized RWH schemes. All the measures listed below can be programed independently and their benefits added up cumulatively. The exception is tank crisis management policy (Measure 2), the specific benefits of which would be increased if the RWH infrastructure were expanded (Measure 3), with a combination of these two measures yielding a greater benefit than the sum of each individual measure. Figure 4.9 shows the combined effect of these measures on water supply availability in the various crises scenarios, confirming that water availability thresholds can be met even in the most dire scenarios.

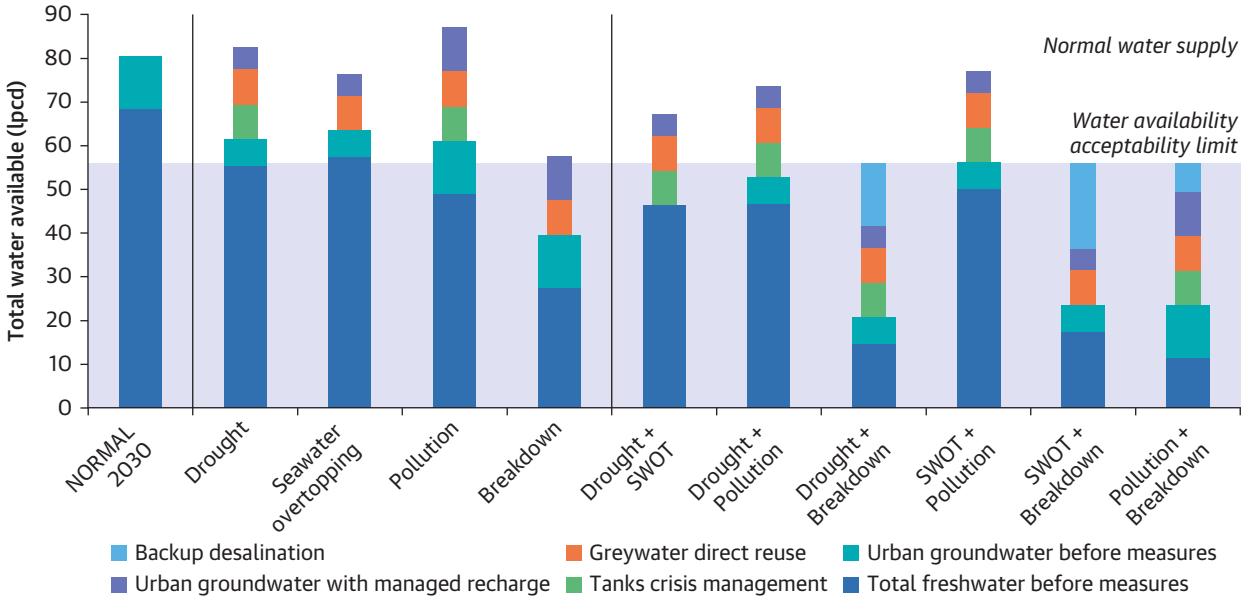
80. During a water shortage crisis, the relevance of certain measures is strongly conditioned by the temporal characteristics of the events at play. Certain events (droughts, pollution) can be monitored as they unfold and can trigger enhanced preparedness, but their outcomes can be impossible to predict. The breakdown of the desalination system cannot be anticipated, but we can assume that its resolution would most likely take place within a few days (or weeks at worse), making water storage solutions relevant. Water conservation efforts that minimize people's reliance on abundant water are particularly useful for helping people cope with prolonged crises. During short emergencies, altered water availability would likely be perceived as exceptional, time-bound, and more or less acceptable regardless of usual water reuse. Table 4.2 summarizes

TABLE 4.2. Temporal Characteristics of Water Crisis Triggers

Event	Onset	Time before the recovery of water resources
Droughts	Slow (months)	Long (months to years)
Seawater overtopping	Sudden	Long (months to years)
Pollution	Slow (years)	Long (months to years)
Desalination breakdown	Sudden	Short (days to weeks)

Note: The onset of pollution events can be sudden with, for example, accidental fuel spillage, but this would be unlikely to affect the entire lens.

FIGURE 4.9. Improvement in Water Supply in Crisis Scenarios due to Proposed Measures



Source: World Bank data.
Note: The contribution of urban groundwater to water availability, and the split between urban groundwater and backup desalination are illustrative only and cannot be ascertained at this stage.

the temporal characteristics of the four main water crisis triggers.

81. A clear prioritization of measures emerges from a comparison of their cost-effectiveness. It follows the following principles:

- Water conservation measures, tank crisis management, direct greywater reuse, clearing of deep-rooted palms in water reserves, and pollution mitigation can significantly augment (or prevent the loss of) water supplies at a very limited cost. These can all be considered as no-regret, or low-regret, measures.
- The managed recharge of urban water lenses is also expected to require very limited investment, but the benefits in terms of incremental water availability at acceptable nonpotable water quality levels are not known at this stage, and piloting and monitoring will be required in order to ascertain them. Any meaningful increase of well water availability at an acceptable level of quality would make this measure more cost effective than the following ones.
- If the above measures are implemented to their fullest potential, two options could be considered to bridge the remaining water deficit: the implementation of bulk PUB water storage in Bonriki; or the construction of a backup desalination unit. If desalination system breakdowns are expected to last less than 2 weeks, then bulk water storage would be technically feasible and sufficient to weather the crisis, and the more cost-effective of the two options. If scenarios of desalination system breakdown for more than 2 weeks are considered credible, then the backup desalination plant becomes more cost-effective and can help address water shortage crises without capacity limitation.
- Finally, the infill of borrow pits in Bonriki, RWH, and groundwater transfer from North Tarawa appear to be the costliest measures by far. There could still be justification for RWH based on the

willingness of households to pay a large premium for private ownership of this quality water resource, which is firmly anchored in Kiribati tradition and appreciated for its taste.

82. South Tarawa can, to a large extent, rely on low-tech solutions to boost its water resilience. All the measures described in this report, except for seawater desalination, consist of optimized management of existing water sources, and improved water use habits. The need for backup seawater desalination is still to be clarified in some of the worst-case scenarios. The management-related measures can be implemented and maintained with materials and equipment that are usually available in local plumbing supply stores. They also favor the use of nature-based solutions to filter and store freshwater locally underground. In the context of remote, developing small island states, these features are essential in building the resilience of communities to water-related shocks.

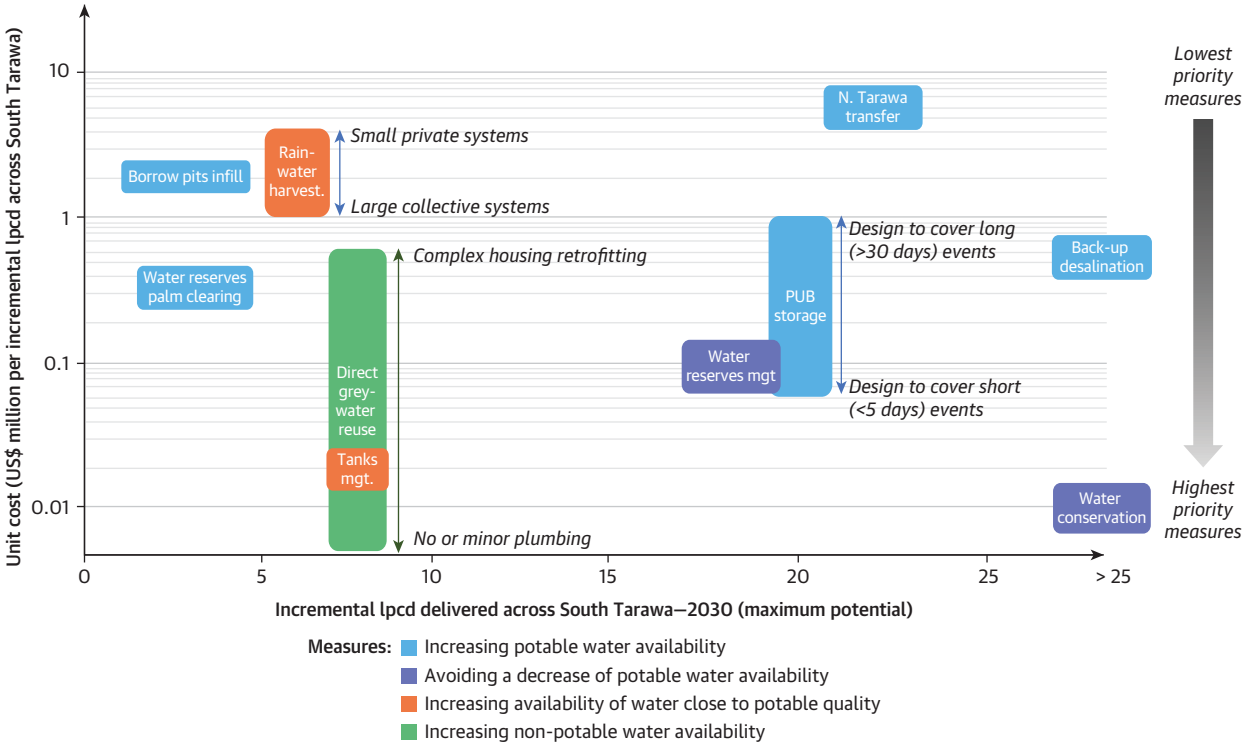
83. A full cost-benefit analysis of all measures could not be conducted at this stage, due to a lack of data. Most measures entail externalities that are not captured in the calculations presented in table 4.3. Positive externalities include, for example, the health and economic impacts of major water supply shortages, and a healthier urban environment (improved greywater management), while negative

TABLE 4.3. Overview of Resilience Enhancement Measures

	Measure	Impacts on water resources across South Tarawa								Unit cost (US$ million per incremental lpcd)	Comment
		Incremental lpcd	Potable quality			Benefits possible/visible during:					
			Yes	Can be	No	Drought	Break-down	Pollution	Normal regime		
1	Water conservation	Up to 50	•	•	•	•	•	•	•	0.01 (awareness campaigns)	Avoids wasteful water use
2	Tanks crisis management	Up to 8		•		•				0.02 (awareness campaigns)	Need for enhanced awareness about disinfection needs and techniques
3	Rainwater harvesting expansion	Up to 6		•			•	•	•	1.0–3.0 (max for private systems)	
4	Managed urban lenses recharge	TBD through pilot			•	•				TBD	Positive health and environmental externalities
5	Direct greywater reuse	Up to 8*			•	•	•	•	•	0–0.15 (based on plumbing needs)	*Depends on how much PUB water is used for flushing
6	PUB water storage	Up to 20*			•	•	•	•	•	0.08–1.0 (< 0.4 for crises under 2 weeks)	*Depends on crisis duration (20 lpcd if <1–2 weeks)
7	Backup desalination system(s)	No limit	•			•	•	•		0.3–0.5 (CAPEX + standby OPEX. Based on size)	Requires strong and continued PUB financial position
8	Water reserve pollution mitigation	Up to 18	•					•		0.07	Avoids reduction in production capacity
9	Water reserve palm clearing	Up to 3	•				•		•	0.13	Rental/compensation to water reserves landowners not included in the costs
10	Infill of borrow pits	Up to 3	•				•		•	1.1	
11	North Tarawa water transfer	Up to 22	•				•	•	•	5.0	

Source: World Bank data.
Note: CAPEX = capital expenditure; OPEX = operational expenditure; TBD = to be determined.

FIGURE 4.10. Overview of Resilience Enhancement Measures



Source: World Bank data.

externalities could be impacts on local ecosystems (infill of burrow pits, palm tree clearing, greywater infrastructure solutions); brine release (in the desalination system); or the social impacts associated with changes in land use or relocation of inhabitants (water reserve management, burrow pit infills, palm clearing, water abstraction in North Tarawa). The valuation of these externalities would require socioeconomic and environmental data that were not available in the context of this study.

84. Figure 4.10 provides an overview for each of these measures, of the potential incremental water availability; its quality; the situation in which it could be mobilized; and the long-term unit cost per cubic meter.

Notes

1. Baseline values are based on the surveys carried out in the present study; future values are proposed as an ambitious but possibly achievable target.
2. With a 5 m^3 water storage capacity and 75 m^2 guttered roof, allowing the supply of 292 m^3 of rainwater for household consumption over 20 years.
3. In this study such analysis focused on Betio, Bairiki, and Bikenibeu. The prevalence of rainwater tanks is likely to be less in other areas, as they have been populated more recently.
4. Estimate is based on Falkland 1992.
5. The sewerage systems in Betio, Bairiki, and Bikenibeu are for the moment collecting blackwater only.
6. The solar PV power generation will feed into PUB's grid and will not be specifically assigned to the desalination plant. Non-electricity-related costs are minimal at the Bonriki and Buota production systems.
7. https://www.seqwater.com.au/water-supply/water-treatment/desalination.

Chapter 5
Recommendations and Lessons Learned

5.1. Priority Measures and Complementary Analyses

85. Table 5.1 summarizes the list of measures identified in the previous sections and the complementary studies that should be carried out to confirm their feasibility. It assigns a tentative timeline that takes into account, in particular, the parallel implementation of South Tarawa Water Supply Project (STWSP) and its key prerequisites. These prerequisites include completion of the new desalination system before Measure 2 (tank crisis management) can be carried out, and the completion of managed recharge pilots before the backup desalination system can be sized, among others. A number of the measures proposed for the first years of the action plan could be conducted under STWSP, under which activities such as water, sanitation, and hygiene awareness or sanitation pilots are being considered.

5.2. Lessons for Water-Scarce Cities in Small Islands and Elsewhere

86. The level of sophistication already reached in the management of Kiribati's urban water scarcity illustrates the value that small island countries can bring to global discussions about urban water resilience. Principles such as diversification of resources, fit-for-purpose water use, water sharing, and adaptive water management, which underpin the water scarcity management strategies of cities around the world, are already at play in South Tarawa. In the absence of a functional centralized water system, these principles, which are usually most relevant to water utilities, are applied here at the household level. The measures proposed to help households optimize the local freshwater cycle—such as integrating greywater management, managed aquifer recharge, use of groundwater for specific purposes, and rainwater harvesting (RWH)—could be very relevant for other island states in the Pacific, and at the urban utility scale for other water-scarce areas of the world as well, if properly adapted to local conditions and cultural norms.

87. Droughts, anthropic pressure on water resources (pollution), and systemic infrastructure failures represent more immediate societal threats than the projected effects of sea level rise. Over the next 20 years South Tarawa appears vulnerable to the degradation and loss of fragile freshwater lenses due to pollution, over-abstraction, drought-induced salination, and seawater overtopping (SWOT). These growing threats increase reliance on seawater desalination, the technological complexity of which creates a new vulnerability of its own. While the solution being implemented through STWSP is necessary in order to address PUB's water supply issues, along with this, efforts should be made to strengthen South Tarawa's resilience in the face of these emerging threats.

88. System efficiency is key for resilience. PUB currently incurs significant losses, with more than 60 percent of the water produced not reaching final consumers. This issue will be addressed, through STWSP, with the modernization of the entire distribution network. However, network mismanagement is a gradual process that can develop unnoticed, leading over time to significant losses that, in this case, would translate into a need for additional desalination capacity at a significant cost. If this were combined with increased physical losses, the various

TABLE 5.1. Indicative Action Plan, 2020–30

Measure	See para.	Cost	Water generated/ saved (lpcd)	Financial cost-effectiveness	0–3 years	3–6 years	6–10 years	Leading agency
A. Water conservation measures								
Awareness campaigns and tariff regulation	50	+	Up to 50	A	•	•	•	PUB
B. Tank crisis management								
Awareness campaign (when to fill with PUB water)	56	+	Up to 8	A		•		MISE
Map rainwater tank gaps, support expansion there	57	++			•	•		MISE
Review incentive needs for institutional tank owners	57	–				•		MISE
C. Rainwater harvesting expansion								
Enhance safe rainwater awareness	58	+	Up to 6	D	•			MISE
Expand private and institutional rainwater harvesting	40	+++			•			Private
D. Managed recharge of urban water lenses								
Restrict usage of non-groundwater-friendly detergents	66	–	To be confirmed based on results of pilots	B To be confirmed based on results of pilots	•			MELAD
Study and pilot for greywater recharge around wells	65	+			•			MISE
Pilot rainwater recharge around shallow wells	67	+			•			MISE
Wells salinity and bacteriological quality monitoring	67	+			•	•	•	MISE
Set-up of guidelines for non-potable water quality	66	–				•		MHMS
Roll-out of rainwater, greywater treatment and recharge systems	67	+++				•		MISE
E. Direct greywater reuse								
Awareness campaign on benefits, set-up options	70	+	Up to 8	B	•			MISE
Setup of revolving fund	70	+				•		MISE
F. Bulk PUB water storage								
Assess needs based on performance of other measures	85	–	Up to 20	C		•		MISE
Design and implement if needed		+++					•	PUB
G. Backup desalination system(s)								
Assess needs to cover deficits after D and F measures	85	–	No limit	C		•		MISE
Design and implement (if needed)		+++					•	PUB
H. Water reserve management								
Implement relocations (if preferred)	76	++	Up to 18	B	•			MELAD
Implement sustainable management plans (if needed)	76	++			•	•	•	MELAD
Monitor wells around airport fuel handling areas	77	++			•			MICTTD
Water reserve palm clearing	79	+	Up to 3	C	•			MELAD
Infill of borrow pits	79	+++	Up to 3	D			•	MELAD

Source: World Bank data.

Note: MELAD = Ministry of Environment, Lands and Agriculture Development; MICTTD = Ministry of Information, Communication, Transport and Tourism Development; MISE = Ministry of Infrastructure and Sustainable Energy; MHMS = Ministry of Health and Medical Services; PUB = Public Utilities Board. Lpcd estimate based on 2030 population. The table was elaborated based on preliminary calculations of long-term costs (including capital and operational expenditures), and information gathered from MISE, PUB, and the Asian Development Bank's Project Preparation Technical Assistance during the preparation of STWSP and of this study.

Cost (US$ million)		Cost-effectiveness (US$ million per incremental lpcd [or avoided loss thereof])	
-	Less than 0.1	A	less than 0.05
+	0.1–0.5	B	0.05–0.1
++	0.5–1	C	0.1–0.5
+++	More than 1	D	more than 0.5

water crisis scenarios described in this report could challenge South Tarawa's resilience sooner and more acutely than is predicted here. This vividly illustrates the role that system efficiency can play in resilience: it is a silent but important contribution that is often overlooked in favor of more visible measures, such as augmentation of supply.

89. Water supply security can be significantly boosted by local, low-tech, and low-cost measures that make the most of existing resources. Many of the priority measures identified rely on changes in water use practices, nature-based solutions, and other local arrangements that can be undertaken at the household level with very limited need for technical capacity or additional investment in technology. This ensures that these solutions can be sustained more easily by the population than complex infrastructure approaches can be; this is a key feature of long-term resilience in a fragile context. The fact that solutions such as RWH and greywater reuse, which are considered "nonconventional" in some contexts, are already commonplace at the household level in Kiribati emphasizes the importance of service providers understanding household water management practices when considering their own broader strategies. It is, however, important to note that addressing PUB's water supply issues through the planned investments under STWSP is a prerequisite for many of these measures.

90. Although conversations about sanitation often focus on blackwater[1] and solids, greywater management should be considered an integral part of sanitation strategies. In the case of Kiribati, those who have access to improved sanitation mostly rely on seawater flushing and sewerage network discharge into the sea. While the idea of blackwater reuse in South Tarawa was discarded early on given the cost, complexity, and land requirements associated with such treatment, greywater management at the household level shows promising potential for increasing local resilience. The differentiation of sources means that effluents are separated at the household level, which provides a good starting point for differentiated treatment and use based on the quality of the effluent. ***The formalization of greywater reuse practices can be a first step in normalizing reuse behaviors as part of a comprehensive sanitation and water resilience strategy.***

91. The still largely informal urban infrastructure in Kiribati offers opportunities to establish improved water management solutions at the household and community levels. Retrofitting plumbing, and water and wastewater management systems to differentiate various types of effluents can be very costly in modern communities and homes, and is even more expensive in multistory buildings. Introducing such approaches in a city that is still transitioning to formality and modernity can help establish good standards and practices before technological lock-in reduces the opportunities to increase resilience. Municipal land use planning, building codes, and associated financing mechanisms can be a powerful tool to stimulate the development of good practices, as well as to strengthen the protection of water resources located within municipal boundaries.

92. The preservation and revitalization of traditionally frugal and collectivist water management practices, shaped by a long history of water scarcity, will be critical in maximizing the resilience of communities to future water supply shocks. In a context of severely constrained water resources, the I-Kiribati have already incorporated into their cultural norms and behaviors key features of resilient water management. The delivery of safe and reliable water at the tap by PUB may weaken this precious legacy, eroding people's perception of water as a scarce resource that requires constant conservation efforts at the individual level, and solidarity at the community level. This would undermine their capacity to cope with the

future temporary but drastic decreases in water availability that can be expected. Awareness campaigns that promote the continuation of traditional water conservation practices, and an adequate tariff policy will play a critical role in retaining and sustaining positive cultural norms around water use.

93. Effective paths toward improved water resilience, therefore, need to recognize not only the technical-economic drivers of water supply security, but also people's broader social and cultural relationship with water. Interventions that build on the lived experiences of water use are more likely to be owned, honored, and sustained by the population. Ethnographic accounts of social and cultural dynamics provide a valuable starting point for reviewing the options for improvement of water resilience. Such an informed approach implies a focus on context and on embedding analysis of local perceptions and uses of multiple water sources in the intervention design.

Note

1. Wastewater from toilets.

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Appendix A
Multiple Water Sources and Their Uses in South Tarawa—Sociocultural Analysis

A. Introduction

This paper reports on multiple household water source usage in South Tarawa.

The study employed a mixed-method approach, triangulating data from 38 semi-direct interviews; a survey of 239 households; a system mapping of access to water; and observations of participants in the study.

The objective of the study was to understand the sociocultural context within which high-risk and high-consumptive multiple uses of water are taking place in South Tarawa in order to assess the relevance of various fit-for-purpose water supply strategies in the local context, and the need for supporting behavior change and awareness campaigns.

The research found that although local practices are in line with contemporary good practices of water management, they are independently formed and maintained. The organization of the way households use multiple water sources in South Tarawa is not only a response to water insecurity: cultural norms also play an important role in the people's choices concerning water use. Cultural and social factors can also create specific dynamics of vulnerability that affect access to water in South Tarawa. The study found that following local tradition, households often manage their water resources quite carefully.

The recommendations include proposals to:

1. Acknowledge people's cultural and material resources for dealing with water stress, including the existence of informal networks working alongside public utilities board (PUB) in providing access to water;
2. Integrate multiple water sources and uses into a water governance framework that goes beyond a mere focus on drinking water;
3. Seek solutions that are embedded in and reflective of social relations and norms, allowing for a robust shared commitment to emerge.

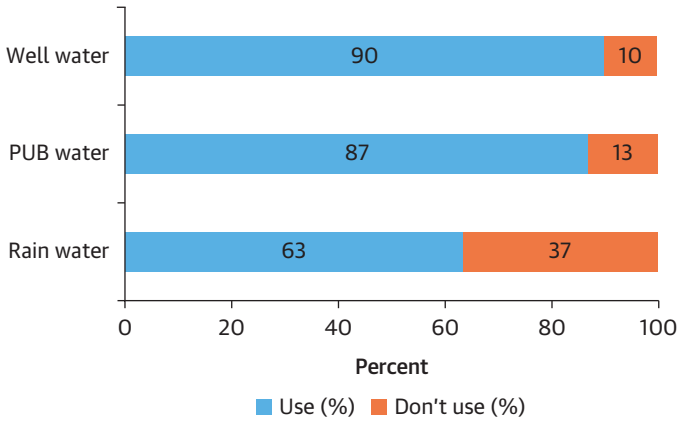
B. Material Conditions of Access to Drinking Water in South Tarawa

Domestic water use in South Tarawa is primarily influenced by **material conditions of access**, that is, the quality, quantity, equity, and ease of access to local sources of water.

Quality: ***Water is accessed through multiple sources of varying quality.*** In South Tarawa, five main sources of water are available for domestic use: raw water from domestic wells; treated water from the public supply system (PUB); rainwater; bottled water; and seawater. Three of these sources are used on a regular basis for both consumptive and nonconsumptive purposes[1]: well water, reticulated water (PUB water), and rainwater (See figure A.1). Our survey found that a vast majority of households in South Tarawa use multiple sources to meet their daily water needs: 50 percent of the respondents use three sources of water; 43 percent use two sources; and only 6 percent use only a single source.[2] The majority of respondents (90 percent) use water from a domestic well; 87 percent use reticulated water, and 63 percent use rainwater.[3]

Quantity: ***Water sources and uses vary over time.*** One recurring word in the data garnered from individual interviews about choices of water sources was "sometimes." In other words, water availability

FIGURE A.1. Answers to the Questions "Do You Ever Use PUB Water? Water from a Well? Rainwater?"



Note: PUB = public utilities board.

varies, and this variability is not captured by studies that are done at a single point in time. As a result, the boundaries between potable and nonpotable water are under constant negotiation, depending on water availability. ***Two types of factors influence changes in access to the sources of water and how it is used: the availability of PUB water, and the abundance of rainfall. Intermittent supplies of treated water often force people to turn to alternative sources, such as rainwater or well water; and variations in rainfall create changes in the type of water that is used for drinking.*** Access to quality drinking water is improved during the wet season. Several of the households that do not have a private rainwater tank reported that they drink rainwater when heavy rainfalls enable them to collect it in buckets. The purposes for which rainwater is used can also vary, with owners of private harvesting tanks prioritizing rainwater for drinking, and to a lesser extent for cooking in the dry season.

Equity of Access: ***Changes in water availability affect households with limited storage facilities.*** The quantitative survey shows that in more than 33 percent of households, water is collected in buckets, small drums, or pots, while 77 percent of the sample store water in one of the storage tanks distributed to single-family dwellings in the 2000s as part of the Asian Development Bank (ADB) Sanitation for Public Health and Environmental Improvement (SAPHE) Project. Observations have confirmed that many of the tanks still play a central role in everyday water use. However, the tanks are getting old and need to be replaced, as noted in the case of Betio.

The differences in storage volume have implications for access to both PUB water and rainwater. It is crucial for households to be able to store water that is distributed only intermittently. Furthermore, in the absence of sufficient storage, households cannot use the services of water trucks for the delivery of additional PUB supply. The lack of sufficient storage also precludes the possibility of water storage over time. Therefore, families without a rainwater tank or adequate storage are more affected than others by variability in rainfall. In periods of drought, sporadic access to piped water can translate into high-risk water uses. In several interviews, drinking raw underground water was described as a last-resort response to conditions of absolute water scarcity "when running out of rainwater."

One respondent in Bairiki, where five households share one PUB connection, "would like to have more

tanks if possible, to keep rainwater," and added that "right now we use buckets and basins to catch rainwater." Similarly, a dweller in Betio (who shares a PUB connection with 35 persons) says she needs a bigger tank so she can store PUB water.

Ease of Access. ***In this urban atoll setting, access points are generally quite close to the residents' homes.*** This was confirmed by the distances reported in the quantitative survey, where the maximum distance to water was said to be 289 meters. However, users may have to collect water several times a day, and carry buckets weighing between 26 and 30 kilograms.

C. Sociocultural Determinants of Water Use

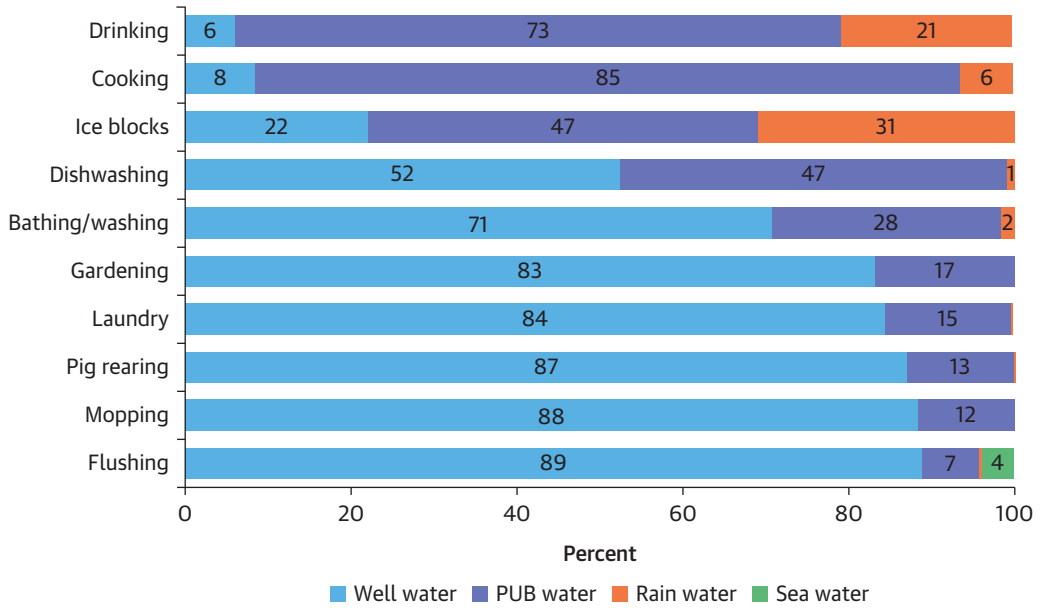
Domestic water use[4] in Tarawa is not only determined by the material conditions of access to water but also by the social and cultural dimensions of water users' lives.

Three intersecting themes emerge from our data as significant aspects of the underlying local context of access to water and its influence on water use: the understanding of what "good water" is; beliefs in collectivism and water sharing; and the importance of self-reliance. Understanding of "good water"

Drinkability is a fundamental criterion in the local definition of water quality. A clear distinction is made between primary and secondary water sources and uses in South Tarawa. The survey data, which recorded four different water sources, and 10 uses for each source, confirms that water for human ingestion needs to be of the best possible quality (see figure A.2).

- Rainwater and PUB water are used for drinking, cooking, and producing drinks for selling in the form of ice-blocks;
- Nonconsumptive uses are overwhelmingly provided by lower-quality water (well water).

FIGURE A.2. Domestic Water Sources Allocated for Various Uses



Source: World Bank data.
Note: PUB = public utilities board.

In addition, several practices are compatible with techno-scientific definitions of water quality:

- **Boiling water is very common.** In most cases, drinking water is boiled in the morning, and sometimes several times a day. Boiled water is kept in the kettle or poured into a bucket covered with a lid, or a thermos that is used as a water dispenser, making water readily available for tea and cold drinks throughout the day. One respondent in Banraeaba said that his family drinks tea with hot water in the morning "until it is finished, then cold drinks for the rest of the day." The consumption of cold or hot drinks influences the choice of water. PUB water is often described as being good enough for tea and coffee (since it needs to be boiled anyway), while rainwater (which is often not boiled) is used for cold drinks.
- **Children's water consumption is often different from that of adults**. For instance, bottled water is often bought for serving to the children. In some cases, Solar water disinfection (SODIS) is reserved for the children; sometimes, on the contrary, it is specifically seen as ***not*** for them. Rainwater is sometimes boiled for the children, but not for adults; or PUB water is boiled only for the children. In some cases, adults and children also use different kinds of water for bathing: adults might shower with well water while children bathe in PUB water.
- **There is a high level of literacy on good water practices.** Interviewees are generally aware that they are not supposed to consume well water; and it can take many follow-up questions to uncover the practice when it exists. Similarly, respondents tend to over-report desirable behaviors: one interviewee in Ambo, for instance, asserted that children in her family consumed exclusively SODIS water, while our observations contradicted this assertion.
- **An unclear understanding of bacteria does not prevent appropriate responses to water contamination.** Some respondents mentioned "germs" or "bacteria" that come through the air; overpopulation; or the proximity of wells to toilets. They responded to pollution by avoiding well water, or by boiling drinking water, even without being able to explain precisely how contamination occurs.

However, locally, the notion of "good water" differs from the scientific or technical definition of potable water. In South Tarawa, ***health concerns are not a significant dimension in the people's definition of "good water."***

- **Health issues are rarely connected to choices about water consumption**. Interviews show that gastric diseases are common in Tarawa, but they are not seen as being linked to water contamination. Our opinion poll revealed that 94 percent of the sample can't name a water-related health issue in their community. Only 2 percent blame water for incidences of diarrhea. The interviews disclose that diarrhea is most often seen as being connected to food poisoning or epidemics. ***The primary water-related concerns are about scarcity rather than the impact of water on health.***
- **The main problem with well water is its salinity, rather than its contamination**. Salinity is the most common reason people give for not drinking water from domestic wells. On the other hand, they acknowledge that they consume underground water, and argue that this water is "not salty." Two of the persons in that situation—including one in Betio—mentioned that they have access to two types of well water: one is acceptable for drinking water, and the other one is for other uses. ***Salinity is the immediate constraint to using well water that is directly experienced by people.*** When asked how they know about the salt content, people say they

have tasted the water, either intentionally or not, when showering. Salinity is also noticed in relation to the fact that detergents or soaps do not produce as much lather with underground water as with PUB water or rainwater. In one instance, an interviewee mentioned that the first bucket of water used for the laundry was filled with PUB water "otherwise there is no lather." Another person said they use rainwater for cleaning the dishes "because the water mixes well with the soap," something that the salty well water does not permit.

- **When a link is made between water and illness, it is usually in reference to an external source of information.** When respondents mention that they don't drink well water because it is contaminated, it is stated as information provided by the Ministry of Health. If further questions are asked, respondents may report the presence of "germs" or "worms," without adding any further details. It is rare to find evidence of direct experience of water contamination other than in terms of its taste. In one case, a woman said that her family does not consume water from their domestic well "because it is dirty. It has a brown color." She also said it is "not salty." In contrast, the water from their neighbor's well is "good." Another case is a resident of Betio who mentioned that well water sometimes smells bad. The special nature of well water is also reported as being experienced through contact with the skin, which feels uncomfortable after a shower. Some people are not sure of the reason why they are not supposed to drink well water.
- In several cases, respondents witnessed well water consumption and reported that it does not have any serious impact on health: "People get sick and they recover. That's part of life." (These firsthand experiences contradict the messages received from health care personnel, and contribute to the perpetuation of high-risk practices.
- **Satisfaction is not often connected to the chemical quality of water.** When asked to explain why they are satisfied with their water conditions, people said that they value for instance:
  - Not having to share water with people from outside their family;
  - Regularity of service (hardship is often identified with irregular PUB flows);
  - The amount of water in relation to household need;
  - That water is readily available;
  - That water is free.

The only health-related aspect that contributes to users' satisfaction with their water is the convenience of not having to boil or treat water before consuming it.

- **In practice, convenience of access, entrenched habits, and the emotional cost of gaining access to water override concerns about water quality.** People in households that are left to walk the "last mile" for water quality tend not to walk it. There is, for instance, a low level of uptake of the SODIS (SOlar water for DISinfection)[5] method. Some people have tested the technique but abandoned it. Only three cases of regular use were reported in the survey. One respondent in Banraeaba said he was informed about the technique by "Environmental Health." Similarly, families who have been recommended to clean their rainwater tanks do not always do so. Shame and embarrassment are important emotional experiences connected with access to water that can prevent users from soliciting water from unrelated kin groups.

Collectivism and Water Sharing

The combination of water scarcity, a growing urban population, and inadequate delivery of water might have been expected to result in the emergence of an informal sector of private water vending through

kiosks or other vendors, as it has in larger developing countries. However, the growth of this sector in South Tarawa has so far been limited to the reselling of rainwater for fundraising purposes by churches and community *maneaba* (the traditional meeting houses).

Water stress is still managed in large part without financial transactions, through the use of domestic wells and water sharing. But while interventions in South Tarawa have typically addressed the problems connected with well water consumption, the central role played by collective social support structures in access to water has been insufficiently acknowledged. As in many Pacific cultures, the inhabitants of Kiribati hold to a collectivist worldview, in which people "identify as being part of a large interdependent group comprising the nuclear family, extended family and lineage members from their village community" (Kolandai-Matchett et al. 2017). The powerful ties that bind society together through the sharing of water offers important information about everyday uses of water at the domestic and community level.[6]

A significant part of access to water in South Tarawa is likely attributable to water sharing across households. Evidence collected through this research indicates that water sharing is widespread in the urban settlements of South Tarawa. In the course of the 38 semi-structured interviews we conducted, there were only 9 cases of households that did not have any form of water sharing relationships with other households.

Water sharing is more common and far reaching in areas that are densely populated such as Betio and Bairiki. In urban settlements, water points are shared with many different households. Urban families also generally share a greater number of water sources, while in semiurban areas, inhabitants tend to share only one source with others.

Water sharing arrangements are primarily a coping mechanism for households that have inadequate water services. Studying the reasons for water sharing reveals the types of hardship being faced by some households. Depending on others for drinking water can be a response to seasonal scarcity; a lack of punctuality of delivery (when PUB water has not been delivered on time); or it can be structural in nature (for example, in cases of failures of local infrastructure).

Benefits and potential harms of water sharing. The practice of water sharing without payment reduces some of the challenges documented in other countries with respect to affordability, water-related conflicts, and resilience to drought. Within a family enclave, the boundaries of cooperation and obligation that include requests for water are extended to include the households of relatives. In a settlement of 38 persons in Betio that is comprised of the houses of three brothers and a cousin, the older brother took on the responsibility for the allocation and management of rainwater. He reported making sure that water is apportioned with increased caution when there is a drought warning. However, the kin-based sharing that lies at the heart of water access in South Tarawa, and the moderate inequity of access, can exacerbate individual vulnerability. Analyses of household-level access in three communities show that ordinal position of birth and gender not only determine the degree of control over shared water sources, but can also affect the spatial disposition of houses in relation to the water infrastructure. One respondent explained that the cost of water gauged by the meters on the household doesn't distinguish the amount of water use by each of several large family units. Having only a single meter for several different family units placed pressure on her, as a single individual, for paying the water bill, in the absence of a breakdown of charges incurred. But as the youngest sister, she felt that she was not in a position to negotiate with her siblings.

The hybrid water provisioning system of Tarawa normalizes water sharing. When the usual source of drinking water is exhausted, households swiftly move on to the next source. If the second type of water is not available within the household, people rely on outside sources. One respondent in Bikenibeu for instance, begs for water from her neighbors' rainwater tank when all the PUB water they have managed to store has been used. On a practical level, fetching water from a relative's rainwater tank is very similar to everyday access from any other water point, using the same devices and without the need for a financial transaction. Every household in Tarawa has a profusion of buckets at its disposal. Buckets are used both for collecting and storing drinking water. The most common type of bucket on the atoll is a white plastic bucket with a lid, initially used as a container for crackers. When filled with water, it contains more than 10 liters. The quantities of water exchanged are counted in numbers of buckets per day, or jugs or teapots per week.

Different sources of water are shared differently. It is quite common to share well water among family and neighbors in Tarawa. Some parts of the country also have a long tradition of sharing other water sources. On islands in the drier southern part of the Gilberts archipelago, inhabitants have long had access to two types of wells, including some shared ones that are situated in the widest part of the island, where the freshwater lens is deepest and where water stays fresh even during droughts. Several cases were identified in South Tarawa of proud owners of "good wells" readily letting their neighbors come and fetch water. The contemporary sharing of water from rainwater tanks may depend on such past experiences with sharing water. However, unlike with wells, it is not unusual for quantities of rainwater to be strictly limited. PUB connections can also be shared among many households, especially in urban villages. Improvement in the water infrastructure seems to affect the likelihood of soliciting or providing rainwater from or to a relative or neighbor. Sharing of well water do not seem to be affected by access to an improved water supply.

Sharing relations can be complex. In some cases, one household may let other families access their well while depending on relatives for their own drinking water.

Water sharing helps to maintain a culturally significant custom in contemporary Tarawa. Water sharing practices are part of broader set of socioeconomic activities based on norms of generosity, exchange, and reciprocity that play a central role in social cohesion and cultural identity in Kiribati. Gifts of water result in the preservation of the highly valued principles of an "egalitarian society." Water sharing may involve households with different social ranks, and with a diversity of assets and livelihoods. For some families, ties to well-off relatives are crucial in managing water shortages.

The prevalence of kin relationships in Kiribati society is reflected in the networks of water sharing in Tarawa. Households are expected to provide for immediate kin in need through the system of *bubuti,* a "social form of reciprocal aid most common between family members and friends" (Jones 1997). This form of reciprocity is prevalent in Kiribati as well as in other parts of the Pacific and the world, and is a way of safeguarding subsistence in a context of chronic insecurity of resources. According to traditional concepts of decency, requests for water can only rarely be refused. In the interviews, customary norms and bonds of kinship were commonly mentioned to justify providing water to others, but the notion of Christian charity was never used as a reason to provide water to fellow citizens. In fact, it is considered shameful to ask for water from someone outside of one's own family network. One result of this is that

water sharing, while it perpetuates and sustains kinship relations, can also extend the distance that must be traveled to access water quite significantly. However, traditional kin-based relationships do continue to provide a model of organization for social exchanges in urban Tarawa that are helpful in coping with water stress (Jones 2016). Water sharing relationships can also be formed across unrelated households within a settlement when families share close ties, and can sometimes be maintained for several generations. These relationships are often described as "family like" (for example, "our grandmothers were like sisters") or "partnerships." In the heterogeneous and densely populated areas of South Tarawa, where many new settlers are not related to their neighbors, networks of water sharing are increasingly being extended to ensembles of sustained sharing and neighborly cooperation, or among members in a group or community of interest, such as a parish.

Independence vs. cooperation: consuming shared water is never the preferred option. Although there is apparent pride over the insular model of communities bound together by social cohesion, and strong cultural norms of sharing, this sometimes comes into conflict with the reluctance to depend on others (including depending on PUB). The emotional cost of sharing was also evident in interviews. One respondent from Bikenibeu, who lives in a household that is totally dependent on others for their water supply, says he is "tired of having to ask for rainwater from the neighbors." It often took some time in the interview and several follow-up questions to uncover situations of dependence. In other instances, sharing arrangements were disclosed by neighbors, not the interviewees themselves. On the other hand, households that are sharing water with others would be more open about it: for example, one family in Bikenibeu shares their PUB connection and private rainwater tank with a neighbor family, and a household in Banraeaba allows their neighbors to take a few teapots of rainwater from their tank each week. Still, sharing appears to be a solution of last resort. The perception of dependence on others is stressful, and can lead to power entanglements, as was summarized by a household in Bikenibeu.

Anecdotal evidence suggests that people's water sharing practices may be changing. Increasing changes in the abundance and quality of water due to population growth and environmental change, as well as the rise of individual values and a growing number of urbanized communities that are comprised of strangers are gradually dismantling the formerly built-in cooperative living system and related water sharing arrangements (Jones 2016), thereby eroding water sharing practices in South Tarawa. However, in an interview conducted for a separate project, one woman reported, for instance, that she could not risk compromising her family's well-being by sharing her rainwater with neighbors. Traditionally, sharing water is not an individual decision, but rather one manifestation of a broader set of social and cultural norms. As these norms are increasingly being questioned in the contemporary urban context, the obligation to share water is being questioned as well.

Self-Sufficiency

The priority given to self-reliance, and belief in one's own effectiveness in responding to water stress, are major determinants of water use in South Tarawa.

The importance of independence explains the use of multiple resources for water. Participants in our study referred to the importance of the diversification of sources in securing access to water. The wealthier households that participated in the study were middle-class urban dwellers with two or more incomes. These families typically make sure they can secure access to at least two, and ideally three, different

sources of water. One middle-aged civil servant said: "I worry about water because we rely on only one source of drinking water. What would happen if the pipes were damaged?" Respondents in Eita and Baraeaba expressed the same concern. Another participant who has access to PUB services 24/7 said: "We would like to have a rainwater tank to drink. We could use it if there were problems with PUB."

The idea of self-reliance is central to the sustained use of well water. Domestic wells have played a long-standing role in demonstrating the link between landownership, kin, and residence in Kiribati. Digging a well is one of the first material and moral claims made on land. Owning a well also helps meet obligations to the family, an important factor for maintaining social recognition and self-esteem in traditional cultures. One respondent in Ambo, an elderly man born on Aurorae, a drought-prone island, explains: "I have tried to dig at least 10 wells since I moved here but they were all salty (...). With a well, you are not dependent on others, you don't have to wait for others to deliver water. (...) If my well yielded potable freshwater (not salty), I would stop using PUB right away." In practice, well water seems to function as a safety net. "I am not worried because I have a well" says a man in Bikenibeu. And a 72-year-old man in Bairiki says: "We need the well in case there is a problem with PUB water." Many of those who disclosed that they consume well water for drinking or cooking purposes, said that they do so "when [they] run out of rainwater and PUB water." One noted "We need to use the well because PUB is unpredictable." The overall importance of well water is palpable in numerous statements: "I feel sorry for those who don't have a well;" "A well is necessary because you always need water;" "In our situation, well water is necessary;" and "It would be a problem without a well." The central role of wells in everyday life is also visible in practice. Water is bailed at all times of the day for a multitude of domestic purposes.

The primacy given to self-reliance drives the inhabitants of South Tarawa to meet their water needs. Water users in South Tarawa are actively engaged in gaining access to water through sharing water; relying on noncentralized water supplies; getting water from illegal connections; and using electric pumps to draw water out of municipal pipes. Kiribati families have traditionally played a central role in securing their own water. Their practices are grounded in communal solutions that are devised to manage scarce resources. They believe that water should be fetched and shared within the household: "Traditionally, individual ownership of goods or services was absent (in the Pacific islands), with high value placed on the kin groups working together and sharing the fruits of their collective efforts" (Jones 2016). In contemporary South Tarawa, this happens within the context of a high fluidity of households marked by frequent departures and returns, and households of a large size largely exceeding the average seven or eight people.

Domestic efforts to be self-reliant are consistent with the absence of well-defined lines of accountability in the provision of drinking water. PUB water is perceived as belonging to entities that are not clearly linked to the general public: the government; PUB; or the local landowners of Bonriki and Buota. The perception of inadequate access to water does not translate into political demands for better services. To solve a problem of water supply in a local community, contacting the MP or a councillor does not seem to be considered an option. Complaints to PUB have arguably increased over the past years[2] but dissatisfied water users that we talked to in Tarawa had either given up after several unsuccessful attempts or did not even try to approach the utilities. Participants in the study expressed a general lack of trust in services provided

by public agents outside of their own personal networks or family: "People work for their family first. It's difficult to work outside families, because there is no reciprocity. It is changing, but this is still very strong in Kiribati." The lack of trust in public services in this society translates into a lack of action to hold service providers accountable for standards of water delivery.

Respondents tend to minimize water-related hardships. This is illustrated by the answer to the question about problems experienced with water supply: 145 of the 237 respondents (61 percent) said they had no problems at all. In longer interviews, participants would almost always start by stating that they are "satisfied" or "happy" with their water situation. But then they described very poor conditions of access. For example, in Bairiki, a household of 9 experienced recurring difficulties in covering the cost of the 20 or 50 cents charged by the nearby church *maneaba* (meeting hall) for a bucket of rainwater. Nonetheless, they often say they are "satisfied" with their water situation. To understand this apparent contradiction, it should be understood that the I-Kiribati don't willingly share information, whether positive or negative, with strangers. Furthermore, as underlined by several local experts, "This is their normal life." In other words, they are used to these conditions and see no urgent need to change them. There is no evidence of an understanding of what acceptable conditions would be. More fundamentally, as one participant said, "People have water and they work hard for it." Securing water for the household is still a responsibility for each family to shoulder. Despite the shift to an economy based on wages, failure to meet one's water needs is still often seen as reason for shame. It is perceived as a sign of laziness and therefore is not readily disclosed, especially to outsiders.

However, in follow-up questions, some people reported that they worried about some aspects of their access to water. Those who reported water hardships tend to be those who share water with a large number of people, drawing on sources that are limited. One respondent shares one PUB connection with 5 other households (or about 32 people); another one, in Ambo, shares two ineffective PUB connections with 20 people: both of these individuals indicated that they would like to have more PUB water. One respondent said they "need a lot more water, more rainwater." Another respondent—a member of one of 4 households, or 21 persons, sharing all three water sources—complained about the poor quantity and irregular services available from PUB. Some people talked about the hard work, the time, and the number of people that need to be mobilized in order to collect and store PUB water: "When water flows, the whole family is called. Everybody needs to interrupt whatever they were doing and mobilize all the containers available."

Local Dynamics of Vulnerability

There are multiple signs of vulnerability to water insecurity associated with the socioeconomic and demographic characteristics of households in South Tarawa. The capacity to deal with water stress is constrained for many families by the absence of access to a PUB connection: 13.2 percent of the sample reported not using any PUB water. In the qualitative study, which was limited to questions about water storage capacity, the lack of money to pay for rainwater punctually, or to buy kerosene to boil the water were also mentioned. Several persons interviewed said they would like to have a rainwater tank but that they can't afford the cost.

In addition to differences in wealth, profession, and education, some factors of unequal access to water are specific to South Tarawa. Local norms, values, attitudes, and aspirations constantly shape and

influence the way residents of South Tarawa access and use water.

- **Situation among siblings.** Analyses of household-level access in three communities (family plots in Ambo, Eita, and Bairiki) show that the communities located along the water supply network are heterogenous and difficult to categorize in socioeconomic terms. Within family land plots, ordinal position of birth and gender determine the degree of control over shared water sources and can affect the spatial disposition of houses in relation to the water infrastructure.
- **Situation of new settlers.** With new settlements increasingly flourishing on state and freehold lands (Jones 2016), the already low water pressure, local cuts in services after the renovation of the main road, the cost of new connections, and rules that make illegal settlers ineligible to apply for water connections preclude many new settlers from accessing the PUB network. Furthermore, new settlers are by definition not equipped with the 500 liter storage tanks that were distributed by the SAPHE project.
- **The intermittent water supply system creates and reinforces inequalities.** The PUB schedule produces differences in the ability of families to access water. Residents who own storage tanks can fill and store enough water to last until the next day. For households without storage, or who share a tap with many other families, the uncertain access to water generates anxiety. They need to negotiate with others and be physically present in order to collect water at the time it is supplied.
- **Multiple forms of spatial differences in water access.** Different households experience different levels of hardship linked to uneven water pressure and the variable quantities of water that are supplied through the network across the atoll. Respondents in Bikenibeu say their geographical proximity to the water reserves explains why they receive better service. At the island level, the water pressure in neighborhoods farthest from the distribution main and service reservoirs is not kept at the threshold required to reach the homes. Communities in this situation are often new settlers, but also households with vulnerable members, such as the elderly, or female-headed households. The quality of underground water in periurban areas is experienced as more acceptable than in the most urbanized areas, which fosters consumptive use of well water.
- **Social obligations.** Obligations to community and kin, and especially financial obligations to the church, are often fulfilled ahead of household expenses that could improve water security. One respondent in Eita said that some families may be contributing up to several hundreds of dollars a week to their church, including at church fundraising events that are organized every payday. These contributions are likely to reduce the capacity of the poorest homes to invest in strategies of diversification to improve their access to water.
- **Urbanization trends.** In the villages of Betio and Bairiki, which are the most densely populated areas in South Tarawa, households sometimes lack sufficient space to install water tanks near their homes. In addition, some people living in government housing are entitled to a rainwater tank but can't get one because their houses have thatched roofs.
- **Intersectional differences in gender-differentiated roles require attention.**
  - **There is no clear gender skewing for the fetching of water.** Men and women share the burden of fetching water for their domestic needs, both for large quantities of drinking water from distant sources and for more frequent and limited

quantities of water from closer sources. This insight gathered from direct observation was confirmed in the answers to direct questions about gender sharing of labor. The outcome is consistent with the observation that men and women seem to have similar levels of knowledge about water resources (knowledge of the PUB delivery schedule, and familiarity with water storage, treatment, and uses). The level of stress and worry linked to the vagaries of access to water, therefore, do not seem to be gender specific.

- **However, gender inequalities are found in the differentiated uses of water, and in practical arrangements that discriminate against women.** Observations confirm that women and girls are primarily responsible for preparing water for domestic use, household sanitation, and hygiene, including caring for sick family members.
- **Mothers, wives, sisters, and daughters depend on the decisions made about water by male relatives.** The convenience of water use is significantly improved for women in households where the male head of the family has invested in even rudimentary plumbing systems and pumps. Male family members are often the ones who make the decisions with regard to PUB connections, or who purchase or build water-related technology for household use.

D. Water Conservation and Reuse

The use of multiple sources for water translates into specific patterns of its domestic management, including practices of water conservation and graywater reuse. The various values of the different water sources have an impact on how much water will be used from each source,[8] and whether it will be conserved or not.

Water Conservation

- **There is a link between the quantities of water that are demanded per source and the number of sources available for domestic use.** When more than one source is accessed, household water management is complex, and the sources are matched with intended uses according to whether they require more or less water. Therefore, the quantities and types of uses are one indicator of the value and accessibility of each source. When it is easily available, rainwater is generally the preferred source. The preference for rainwater is not always verbalized in situations where households have no private rainwater tank. In everyday water use, rainwater is reserved for high-value uses such as drinking and cooking, for which more limited quantities are necessary. Even in the rainy season, rainwater is rarely mentioned for water-intensive, nonconsumptive activities such as bathing, gardening, flushing, or washing clothes. In contrast, well water supports the majority of nonconsumptive uses at any given time and across seasons. The number of different nonconsumptive uses of well water and types of uses explain the fact that, although it is less visible, well water is still very present in everyday life.
- **The equipment in rainwater tanks fosters attentiveness to fluctuations in the water supply and increases residents' stated awareness of the need to save water.** People who own a rainfall tank can track the abundance or scarcity of rainfall by being aware of the volume of water in storage. "There are messages on the radio to warn us about drought. We see it also ourselves." This knowledge informs how people manage their water supplies. There are some reports of rainwater being apportioned ahead of droughts. People who simply harvest rainwater opportunistically do not report planning their consumption to the same extent.

- The use of devices designed for centralized water schemes such as flush toilets, washing machines, or pressure hoses is still not widespread in South Tarawa.
- **There is no notion of responsibility to a common-pool resource.** Water has been traditionally managed at the household or kinship group level in Kiribati. The changes introduced by the networked water system do not seem to have transformed the people's relationship to water sources. The vulnerability of the water reserves of Buota and Bonriki is sometimes presented as a potential threat, but no direct link is made to household water use.
- **Pigs are significant water consumers.** A vast majority of the surveyed sample (70 percent) answered the question about their water practices in relation to pigs. This is loosely consistent with the 2015 census, according to which 80 percent of households in South Tarawa rear pigs. According to the 2015 census, there were 16,075 pigs in South Tarawa. Given the numbers, the amount of water consumed by pigs is significant. In the great majority of households interviewed for this study and for a separate research project, respondents reported giving their pigs liquid feed, generally twice daily. Self-reported measures of the quantities of water fed to pigs show that adult pigs get around 10 liters of water per animal per day.[9] Of the 165 households in the sample that reported ownership of backyard pigs, 87 percent said that the pigs are given well water.
- **Many pigs get extra fluid in addition to their feed**. It is common in South Tarawa to give pigs extra water from a variety of sources "for drinking at lunch time," "sometimes," "when it is too hot," "in the morning," "when the children come back from school," "when we have a bucket full" or "every day." One respondent mentioned that she even gives her pigs a shower. (This statement was validated by the observation that her three pigs were indeed wallowing in a muddy pen.) Additional water is also needed to clean the trough and to clean pens that have concrete flooring. (This type of enclosure is, however, not usual in the city, and the cleaning of these sites is not always regular).
- **Cultural norms of water rationing are multiple and changing**. Historically, the landowners of South Tarawa have had ready access to fresh underground water. Today, the city is home to residents from the outer islands, who have different types of water resources and precipitation patterns, and are still attached to the traditions of the rural societies from which they came. Teachers who participated in the study also tell of a new generation that is less prone to conserving water. As a result, the evidence of behavior patterns remains somewhat mixed. However, the following general remarks can be made:
  - **Practices of water conservation differ according to the source.** Rainwater is conserved to a greater extent than other sources, especially by families who do not have their own rainwater harvesting (RWH) systems. Well water is not discussed in terms of scarcity or saving. For instance, in Ambo, a male respondent in his fifties with seven pigs and very limited PUB water resources said that he showers twice a day: "It's not wasting because it is well water."
  - **The conservation practices for PUB water are more complex.** Evidence of rationing treated water is reported by families whose water pressure is low; by teachers; by families that are entirely dependent on the PUB network; and in households where the "user pays" cost-recovery pilot program is being implemented. A woman in Bairiki recalled the signs "Kawakina

te ran" ("Conserve water") that were put on taps in Betio in the 1980s, when connections were metered and PUB water had to be paid for. In other households, parents say they encourage their children to save water. Several parents mentioned that they scold their children for wasting PUB or rainwater. One respondent forbids her children to bathe using PUB water, and insists that they use well water instead. The children in another respondent's family use PUB water for showering only at the time of distribution, after all containers have been filled.

- However, when no one is home to collect the water at the time of its distribution, the liquid is left to seep into the ground (as seen in Ambo), unless prior arrangement for collecting the water has been made with the neighbors. What could be seen as a sign of indifference to waste can be understood first and foremost as a sign of strong respect for neighbors' integrity in Kiribati: one is king on one's land.

Water Reuse

- **Kitchen water is used as a source of irrigation water.** The most advanced example we saw in Tarawa of a low-tech system that uses gravity to increase the productivity of a backyard fruit-growing business was in Ambo. In this instance, sink water is drained from the kitchen to a single large banana pit. In other cases, good-quality water is infiltrated into the ground by throwing kitchen water together with other valuable waste products (leaves and other organic material) on fruit trees and ornamental plants. The process of dishwashing is described as follows: "There are three basins used for washing the dishes: one in which food residue is scraped from dishes and rinsed a first time with clear water: this is the pig food. Then there is a basin filled with soapy water for washing (combined water and dish detergent); and a third one for rinsing." Several residents reported having abandoned gardening because of a lack of water.
- **Pigs are part of domestic greywater reuse.** The lived realities of water used for pigs that came to the fore through interviews and observations point to the important role played by backyard pigs in domestic water management. Most interviews revealed that, in addition to their wet feed, pigs are fed a variety of liquid kitchen waste: water used to rinse the rice, to wash and prepare vegetables and fruits, to gut and clean fish before its preparation, and fish stock or soup. The fish is cleaned in a small basin and the water used for this purpose, along with fish guts, blood and scales, is then boiled for the pigs. A teacher in Bairiki says this is "an advice from old people, otherwise the mothers will kill their babies." In addition, pigs are also served leftover drinks. As recycled liquids, these different fluids consist in a mix of different types of water that extend beyond well water.
- **Water transformed by backyard pigs plays a role in the contamination of underground water.** Raw pig slurry (which is a mixture of animal feces, urine, and water) is spread onto the soil without any treatment. Pig slurry is well known to be a source of organic matter that has micronutrients, but it also has high levels of copper, zinc, iron, manganese, cobalt, and cadmium (Gunkel-Grillon et al. 2015). The high hydraulic conductivity of the coral sands means that pig waste is rapidly transported through the soil to groundwater (White et al. 2007). The long-term application of raw pig slurry onto coral soils can lead to an increase of the total nitrogen, phosphorus, and other metal content, with a high level of contamination factors (Gunkel-Grillon et al. 2015).

E. Recommendations

This section summarizes key recommendations drawn from the study of water uses in South Tarawa. It aims to provide practical ideas to guide culturally appropriate strategies for increasing and sustaining the health and livelihood benefits of improved access to safe water. The recommendations are referenced at the point where the findings of evidence and analysis were made.

1. Insights from the Review of Material Conditions of Access to Water

The review of the material conditions that determine water usage offers lessons in how development partners can help foster water security.

The expansion and improvement of drinking water supply services in South Tarawa will no doubt reconfigure residents' access to safe water, notably by reducing vulnerability to contamination and seasonal variability. However, the study clearly shows that residents will likely continue to supplement piped water with various noncentralized supplies of water in the foreseeable future.

Key recommendations in this regard are to:

- **Integrate the multiple water sources into data collection efforts** and assist practitioners in collecting and using the data in the monitoring of water quality and water use practices.
- **Involve residents of Tarawa in the management and monitoring of rainwater and the urban lenses** under Betio, Bairiki, and Bikenibeu, and along South Tarawa. Several residents indicated that tests had been performed in their wells, and that they were interested in being informed about the results. One option is to make information about underground water quality regularly available in communities. A simple total coliform test and a participatory approach could also encourage communities to learn more about their water quality problems and take actions to address them.
- Establish more equal conditions of storage, and increase water security by **equipping households with RWH tanks and promoting the storage of PUB water**, including through the distribution of new containers to the most vulnerable households, and replacing the old ones.

2. Insights from the Analysis of Sociocultural Determinants of Demand for Water

The cultural resources already mobilized by the inhabitants of South Tarawa for dealing with water stress show that cultural norms of equality; the prevalence of nonmonetary exchanges of water; and ubiquitous access to domestic well water all provide a safety net that explains the general absence of the commodification of water in Tarawa. As a result, even the poorest citizens have access to water. However, there are concerns about the correlation between these practices and water-related illnesses, as well as about overconsumption.

Key recommendations in this regard are to:

- **Work "with the grain" in community awareness work.** Many interventions have made great efforts to build on traditional forms of governance in order to inform inhabitants about projects, seek their approval, and collect views of members of the communities (White et al. 1999). Most community outreach projects are conducted in the *maneaba*, a convenient platform from which to train and educate people. But these hybrid forms of participation do not always mean that local participants, bureaucrats, and external support agencies understand and acknowledge each other's motivations. In addition, data collected in the interviews shows that many people engaged in income-generating activities do not have time to participate in community outreach meetings; that concepts being

discussed are often misunderstood; and that proposed solutions are not adopted.[10]

- **Use existing forms of community organization** to reach out to local residents about their water use. The water supply, sanitation, and hygiene (WASH) community mobilization program, conducted as part of the South Tarawa Sanitation Improvement Sector Project (STWSP),[11] has successfully strengthened or encouraged the creation of community groups that are modeled on traditional forms of decision-making bodies at the community level. Building on the vibrant participation of individuals in these community activities, and on the competitive mindset of the I-Kiribati, communities are brought together in beach cleanup operations; or they compete with other communities for the financing of projects.[12]
- **Harness the competitive mindset of communities in Kiribati** to help drive progress in reaching development goals. One possible effective strategy for involving local communities is through the awarding of prizes, gifts, and competitions (subject to approval by local authorities) in order to stimulate interest, and make the process of engagement attractive.
- **Create community outreach messages that reflect the importance of a collective identity**, with a focus on family and/or the household as a functional unit, and on community rather than individuals.
- **Make choosing high-quality water attractive**, in line with local motivations. Data collected in South Tarawa has highlighted the fact that communities are already very well aware of public health messages emphasizing better health. Promoting the healthy use of water within the local context of Tarawa may be more effective if more emphasis is placed on the social norms of dignity, self-reliance, and quality of life, and less emphasis on health. This strategy would also benefit from better integration into the work of health and water professionals in water monitoring and communication to the public. Advice concerning water use should flow from multiple sources, including from elder to younger members of the community, and in cooperation with the churches.
- **The water needs of pigs need to be factored in, within a management framework of multiple water sources.** Pigs will remain an integral part of residents' water use and reuse in the near future, and this use is linked to the quality of the underground freshwater lenses. Measures to improve animal health and welfare would improve their survival rate. This, combined with restrictive policies about pig housing in certain areas, could translate into reduced numbers of animals and thereby decreased the volume of water being consumed and transformed by pigs.
- **Enhance the level of trust between users and service providers.** This study shows that in South Tarawa, the formal institutions of water supply are coexisting with dense informal networks made up of strong traditional ties. These tight-knit communities not only demand a great deal from insiders, but they tend to fragment society overall, because trust is confined to a close circle of kinship. In the context of inadequate delivery of water services, this particularized trust fuels distrust for the entities responsible for the allocation and provision of water to the general public. In addition, there could be a perception that the opportunity for dialogue on water supply is being usurped by the international donors' role in assistance to the water sector. External support agencies need to work toward bringing water users to hold PUB accountable for the quality of water services. Key recommendations in this regard are to:
  - **Clarify the accountability framework in water supply** for domestic stakeholders (Jiménez and

Le Deunff 2015). Provide water users with clear, accessible, comprehensible information on water services and users' rights and responsibilities through understandable contracts and detailed water bills.

- Operators can counteract the lack of trust by **improving the functioning of complaint mechanisms**. This can be achieved through providing users with better information about those mechanisms; assuring that there is sufficient transparency of the process; and providing feedback on outcomes within clear and appropriate time limits.
- **Additional channels can be put into place for handling complaints** through existing institutional mechanisms for oversight (such as ombudsmen) that function as watchdogs to ensure accountability.
- **Establish opportunities for dialogue on water services** (public hearings, community water and sanitation mapping, and the like.)

3. Insights from the Descriptions of Local Dynamics of Vulnerability

The study highlights some of the complexities and dynamics of the cultural and social factors that can affect access to water in South Tarawa. This calls for closer attention to local enabling and constraining contextual factors in the monitoring and evaluation of interventions.

Key recommendations in this regard include:

- **System mapping of water access.** The system-based mapping approach was found to provide a good complement to face-to-face interviews in the context of collective water access in South Tarawa. The mapping enabled identification and description of the many social, cultural, and economic interconnections, as well as the multiple sources of water that are integral to water access in the capital. This approach exposed situations of vulnerability that otherwise might have gone unnoticed. It also enabled the triangulation of information received from interdependent individual households.
- **Appropriate selection of data collection strategies to reduce bias**. For example, face-to-face interviews were conducted, to reduce respondent discomfort due to the presence of bystanders or focus group members; also, several different interviewers, who represented different demographic characteristics (age, gender, nationality) were used. The latter may have helped to reduce the overall effect of interviewers' expectations, whether real or inferred.
- **The tendency of residents to minimize water-related hardship argues for the triangulation of various sources of data**—direct observations, and both qualitative and quantitative methods—in order to more carefully examine the tensions between cultural and physical constraints, and the gaps between verbal accounts and actual practices.

4. Insights from the Descriptions of Water Conservation and Reuse Practices

This research has identified a variety of water conservation and reuse practices taking place in the capital of Kiribati, together with the careful use of various qualities of water to satisfy different kinds of water demands. Advocacy work in promoting water conservation should harness and support these local practices.

Key recommendations in this regard are:

- **Water management awareness campaigns should take into consideration and build on existing practices that are consistent with the principles of water conservation being advocated.** For example, widespread kitchen water reuse for gardening and pig rearing could be extended to include the reuse of laundry and shower graywater to irrigate gardens. The rationing of better-quality water could be

systematically extended to all three types of water sources, including underground freshwater. Attempts could be made to apply the logic of water monitoring of rainwater tanks that is already informing water management in many households to measuring the quality of domestic well water and understanding groundwater supply in relation to rainfall and demand.

- **Encourage water conservation by crafting outreach messages that consider water use from the perspective of local expertise and priorities.** Priority should be given to direct experience rather than expert knowledge in assessing the potability and quality of water; and the primacy of self-reliance and responsibility in water management at the household level should be recognized and appreciated.

Notes

1. Drinking and cooking are defined as "consumptive" uses; all other uses are "nonconsumptive."
2. Percentage calculated on a total of 233 responses, i.e. not including those who did not respond, and three persons who declared that they don't use any of the three sources.
3. Percentages calculated on the basis of valid responses, that is, 235 respondents for PUB water, and 237 for well water and rainwater.
4. The aspects of domestic water use that are analyzed here are household choices about water; the allocation of water to various uses; the quantities of water consumed; and water conservation practices.
5. Water disinfected with the SODIS method is made drinkable using the rays of the sun. Clear PET bottles are filled with the water and set out in the sun for 6 hours. The UV-A rays in sunlight kill germs such as viruses, bacteria, and parasites (giardia and cryptosporidia). (Source: www.sodis.ch)
6. The significance of reciprocal bonds for urban survival in South Tarawa will likely increase "as global climate change is expected to intensify chronic ecological risks, including flash-flooding, heat stress, drought, and water insecurity" (Wutich 2011).
7. Personal observation of the author.
8. It is difficult to assign precise quantities of water consumed in South Tarawa. The measure of volume of water used per source was not amenable to the interview technique. Respondents were, however, asked to name and discuss the source of water from which they used the largest quantity. Very few interviewees disclosed quantities expressed in terms of liters. As an illustration, many respondents who have access to a well said they thought that the greatest quantities of water used in the household came from domestic wells; but there were almost as many who thought that piped water represented the largest volume consumed.
9. The research finds that self-reporting on the quantities of water used are very unreliable in South Tarawa, making both the quantitative survey and the interviews poor tools for serious efforts to measure the volume of domestic water demand. In the case of pig feeding, however, the quantities of water are reported in terms of buckets. Given that most buckets are of the same type in Tarawa, the reporting regarding this water use provides a higher level of reliability of the data.
10. For example, tippy-tap, SODIS.
11. South Tarawa Sanitation Improvement Sector Project Additional Financing Project Administration Manual (PDF) Accessed October 22, 2017.
12. Interview with a representative from the WASH NGO "Te Maeu."

Appendix B
Rainwater Harvesting

Data collection and analyses were conducted through consultations with stakeholders, household surveys, and aerial imagery analysis by a team of water specialists of the World Bank, and by Ian Hay Consulting, with the support of Ministry of Infrastructure and Sustainable Energy (MISE).

A. Review of Rainwater Harvesting (RWH) Programs in Kiribati

Scope of past and current programs. According to the 2015 Census, rainwater is the main source of drinking water for 3,901 households, roughly 50 percent of the households in South Tarawa. Dividing South Tarawa into Betio and the rest of South Tarawa, it appears that outside of Betio, the majority of households (53 percent) use rainwater as their main source of drinking water (*not* PUB [public utilities board] water, as most do in Betio). Based on a quick review of past and existing rainwater harvesting (RWH) initiatives in South Tarawa, including interviews with various organizations conducted during this study, there are at least 750 RWH systems installed in South Tarawa. (This estimate covers the main programs implemented over the last 15 years). One system usually consists of 1-10 tanks, ranging from 500 to 10,500 liters each. The most common systems consist of 2-4 tanks of 5,000 liters each. These systems were installed mainly on: (1) communal buildings (most commonly village and church *maneabas*); (2) government buildings, including ministerial offices, hospitals and clinics, and schools (public and private); and a small number were installed on private houses. Most households, therefore, rely on collective RWH schemes. The inventory of RWH programs was further validated by discussions held with the two local suppliers of polytanks in Kiribati. About 70 percent of their business is generated from donor and NGO-supported projects; 20 percent is from government ministries; and roughly 10 percent involve individual household-level engagements.

Program funding, selection, and implementation. The review scoped seven major RWH programs that have been implemented since 2000 in Kiribati. Specific interventions in RWH in South Tarawa were supported by the KAP Programs (about 20 systems); the MFAT Sector Program (about 40); and the Kiribati Housing Corporation, through which at least 710 loans for the construction of RWH systems were provided. The rest of the programs and projects implemented systems in North Tarawa and the Outer Islands of the Gilberts group. Details about these programs are provided in table B.1.

KIRIWATSAN Phase 1 & 2. The European Union (EU)-funded Water and Sanitation in the Outer Islands of the Republic of Kiribati, or KIRIWATSAN, series of projects have supported the construction of several RWH systems, both in North Tarawa (Phase 1) and in the Outer Islands (Phases 1 & 2).[1] KIRIWATSAN-1 primarily financed the full installation of RWH systems in priority villages identified by MISE, which targeted 141 RWH systems in total (17 in North Tarawa, and 124 in 12 of the Outer Islands), including 117 that were completed as of July 2017. About 250 tanks of 5,000 or 6,000 liters each were installed under KIRIWATSAN-1. Under KIRIWATSAN-2, the project adopted a more holistic approach in assessing water resource alternatives, focusing on eight of the Outer Islands. Implementation has also evolved from an

TABLE B.1. Summary of Rainwater Harvesting Programs implemented in Kiribati

Program Name / Funding	Implementing Agency	Description of RWH Projects Funded	Implementation Arrangements (Application, Procurement, Management, O&M)	Project Cost
Kiriwatsan I / EU	MISE-UNICEF	Primarily financed new systems; MISE provided a list of the locations, with a target number of 141 RWH systems in N Tarawa and 12 Outer Islands. 117 were completed as of July 2017.	Full installation of RWH systems (material, shipping, labor, installation) was contracted out to a company; project could afford to buy additional tanks at the end of the implementation period, with the agreement that the beneficiary councils would take over and finish the installation (but they did not).	
Kiriwatsan II / EU	MISE-SPC	Project worked on existing RWH catchments, and took a participatory approach, involving the communities in the construction or rehabilitation of the RWH systems. About 30 systems are to be built in 8 Outer Islands	Trained and assisted by 2 construction supervisors and 1 water technician from MISE, the communities took an active role in the implementation and O&M of the systems.	
KAP II / GEF DFAT, MFAT,	Office of the President and line ministries	Initial target of KAP II for RWH systems was 20. Only 4 were built, on churches/schools, due to an appraisal process that underestimated the costs of the water and coastal works under the project.	The roofs were selected based on an assessment conducted on more than 100 communal building roofs. Criteria for selection unknown.	
KAP III / GEF-LDCF, GFDRR, Japan PHRD, DFAT	Office of the President and line ministries	This project finances RWH systems in both North and South Tarawa, as well as on the Outer Islands. In South Tarawa, the grant provides materials and TA (through technical works supervisors) to the selected applicants, with a maximum of five 5,000-liter tanks, regardless of the potential capacity of the RW catchment—in some instances more than 25,000 liters. In all, 14 systems serving 419 households (around 3,700 people) are being installed in South Tarawa. In North Tarawa, 4 villages were identified to benefit from RWH investments, and systems were installed in 6 different sites.	In South Tarawa, the project has adopted an application process approach. Communities can apply for, and need to comply with, a list of criteria (e.g., existing roof, minimum of 10 households served, available space to install the system, etc.); present an O&M plan; commit to providing free labor; and be responsible for maintenance. Successful grantees are usually church groups, or communities composed of a limited number of neighboring households. Design is provided by MISE. TA is provided by a works supervisor (through the project). While all grantees agreed to charge for water, it was observed during the research that community or church *maneabas* charged for water (50 c/bucket). In North Tarawa, the selection is at the project level, based on a water resource assessment, and one system, providing 25,000 liters of capacity storage, is built for about 60 households (or 200 people). The installation is contracted out to a company (contract available, collected during the research). On the community side, formal arrangements are introduced through the creation of a legally binding village constitution that creates and specifies the roles and responsibilities of various	Average cost for small system in South Tarawa is AUD 7,000 Average cost for larger system in villages in North Tarawa is AUD 25,000.

table continues next page

TABLE B.1. continued

Program Name / Funding	Implementing Agency	Description of RWH Projects Funded	Implementation Arrangements (Application, Procurement, Management, O&M)	Project Cost
			committees (welfare, mangrove plantation, rainwater harvesting, groundwater abstraction, etc.) For instance, the rainwater and groundwater committees are entitled to and responsible for setting the price of water, the O&M rules, etc. They charge a fixed rate of $A1/week for RW and 50 c/week for groundwater.	
Kiribati Housing Corporation		Since 2002, at least 710 loans for household RW tanks (and the associated gutters and downpipes) have been arranged through the Corporation in South Tarawa. The loans (a maximum of $A1,500) initially were provided from a revolving fund, and repayment could be made over a period of 1–2 years depending on household income. Current modalities unknown.	Application for a loan. Nature of applicants unknown: individual households, possibly others. RKL offers a 20-year warranty on their tanks and provided some of the systems; they have confirmed that they have never had to provide maintenance services. Some of the houses and RWH systems are visible from the main road at Bairiki.	Max. of $A1,500/ loan
MFAT		The New Zealand Aid Program financed the installation or rehabilitation of at least 40 RWH systems (estimate of 110 tanks of 6,000 liters on average, so a total storage capacity of 660,000 liters), mostly on community or church *maneabas*, schools, hospitals, and clinics.	The project was implemented in two rounds: the first one was based on an application process, while the second one followed a checklist approach built on the lessons learned from the first round.	
KOIFWAP / IFD	MISE	Total of 277 RWH systems in 4 outer islands; RWH systems were rehabilitated in existing church *maneabas*.	Church members were charged a water fee; members were willing to pay for water.	

Note: RWH = rainwater harvesting; MISE = Ministry of Infrastructure and Sustainable Energy; SPC = Secretariat of the Pacific Community.

external private company contracted to provide material supply, shipping, labor, and installation, to a more participatory approach employing a private/community partnership model, with the latter taking a more active role in village promotions, and the construction, rehabilitation, and operation and maintenance (O&M) of the systems. To date about 30 RWH systems have been built through KIRIWATSAN-2 in eight Outer Islands.

KAP II & III Programs. The World Bank has been supporting the WASH sector with investments through the Kiribati Adaptation Program (KAP) series of operations that began in the early 2000s. KAP II was funded by the Global Environment Facility (GEF), the Australia Department of Finance and Trade (DFAT), and the New Zealand Ministry of Finance and Trade (MFAT), and was implemented by the Office of the President and key line ministries. KAP II had an initial

target of 20 RWH systems to be installed in government or communal buildings, but only four systems were built in South Tarawa due to underestimated costs for the water and coastal works components. KAP-III, through its Resilience Fund facility, has been supporting the creation of small community-based RWH systems in South Tarawa, and larger village-based RWH systems and groundwater-based reticulated systems (where suitable groundwater lenses are available) in North Tarawa and a few of the Outer Islands. The implementation of RWH systems in both North and South Tarawa have adopted two different approaches, as follows:

In North Tarawa, four villages were identified to be covered by the installation of RWH systems and the construction of two village-based groundwater abstraction systems, in Notoue and Tabonibara, providing a total of 16,000 liters per day of potable water. Selection was made at the project level following a water resource assessment. The typical RWH system can benefit as many as 60 households, or about 200 people, through collective distribution, and provide 25,000 liters of storage capacity. Facility installation is contracted to a company with formally agreed-upon community arrangements through the creation of a legally binding village constitution that creates and specifies the roles and responsibilities of various committees (welfare, mangrove plantation, rainwater, groundwater, etc.). For instance, the RWH and groundwater committees are responsible for setting the price of water, general operating rules, assigning O&M committees charged with looking after facility upkeep, and so on.

In North Buota, KAP III also financed the construction of an RWH system with a reticulation to two villages with 19 tap stands (3-5 households per tap stand), providing 800 liters per day of potable water. The system includes roofed structures and RWH tanks within the northwestern boundary of the Buota Water Reserve. It was designed to allow for future connection to a piped supply of PUB water, which will eventually allow for more tap stands.

In South Tarawa, the project has adopted an application process approach, where participating communities are rated based on a set of eligibility criteria (adequacy of existing roofs, number of beneficiary households served (a minimum of 10), availability of space to install the system, etc.); and are required to present an O&M plan, provide free labor, and commit to maintaining the system. The grant provides technical assistance (TA) by making technical works supervisors and materials available, with a maximum of five 5,000-liter tanks, regardless of the potential capacity of the rainwater catchment (which is in some instances more than 25,000 liters). In total, 14 systems have been installed, serving 419 households, or around 3,700 people. The average project cost is $A 7,000, following the standard design provided by MISE. Successful grantees of the Resilience Fund are usually church groups. The rest are small communities composed of a limited number of neighboring households: RWH systems are in this case built on one or more of the host households (still with a maximum of five tanks per community). Water is always distributed through a collective tap, with no reticulation.

Kiribati Outer Island Food and Water Project (UNDP). A total of 277 RWH systems were installed in four of the Outer Islands. The works often consisted of rehabilitation of existing systems attached to church *maneabas*.

MFAT Sector Program. Between 2012 and 2016 around 40 RWH systems were installed in South Tarawa, including at least 110 tanks (most of which were 6,000 liters). The project was implemented in two rounds, the first based on an application process, and the second employing a checklist approach that built on lessons learned from the first round.

MFAT developed a preliminary research concept note to carry out baseline research that will collate available information on RWH in the Pacific. Its scope will cover rainwater collection, storage, and treatment, but will not include the distribution of stored water to consumers. This research will make design recommendations with the objective of contributing to a better infrastructure, and improvement in O&M. The World Bank is closely coordinating with MFAT to avoid potential duplication of activities.

Kiribati Housing Corporation. Since 2002, at least 710 loans for household rainwater tanks (and the associated gutters and downpipes) have been arranged in South Tarawa. These loans (a maximum of $A 1,500 per application) were initially provided from a revolving fund, and repayments could be made over a period of 1-2 years, depending on household income.[2] Some of the houses and RWH systems are visible from the main road in Bairiki, and they seem to be in good condition. RKL, which offers a 20-year warranty on their tanks, and which provided some of the systems, confirmed that they have never had to provide maintenance services.

B. Design, Construction, Governance, Operation, and Maintenance of Rainwater Harvesting Systems

Governance, management structure, and O&M. Most, if not all, of the RWH systems installed though aid programs are collective installations for churches, hospitals, clinics, and schools; or they are for distribution to a defined community of households. In the latter case, the system can be installed on a communal building such as a *maneaba,* and households affiliated with the *maneaba* (as well as others) can come and collect rainwater. In some cases, the system is installed on the private property of one of the community members, with a clear agreement that the member will provide the land and look after the system, and that access will be given to the other members. The Resilience Fund of KAP III took a participatory approach in South Tarawa, involving the communities in the construction, rehabilitation, and O&M of the RWH systems, by running an open application process requiring the provision of free labor for construction and rehabilitation, and requesting a viable O&M plan from the applicant community. MISE provides the necessary TA to beneficiary communities, including training and support of design and construction supervisors, and water technicians who are available for technical advice after the system is built.

Implementation Costs. The average cost for the most common type of water tank (5,000 liters) ranges from $A900-1,000. Full installation, including material supply, shipping, and labor is around $A1,500-2,000 per tank. For the communal systems installed under KAP III, the total cost is about $A7,000-10,000 (with a maximum of five tanks installed). The Resilience Fund has a grant ceiling amount of $A10,000 that supports communities and church groups comprised of at least 10 families. For the bigger systems, which were financed by KAP III in North Tarawa or the Outer Islands, the total cost for one system varied, from $A24,000-27,500 (for a capacity of 25,000 liters). Table B.2 provides the costing details per program.

Current roles and responsibilities of the government concerning the quality of construction, and water quality. MISE is responsible for overseeing and monitoring the technical design and quality of RWH systems built in Kiribati. Some RWH guidelines (for design, construction, and O&M) were developed by MISE under KAP II for application throughout the country. MISE also provides TA for O&M of the systems, especially in the Outer Islands, where there is at least 1 technician trained and available on each island. The Ministry of Health is responsible for regulating drinking water quality, and its Environmental Health unit is responsible for monitoring the quality of the five

TABLE B.2. Storage Capacity and Costs for Rainwater Harvesting Development Programs

Program	Typical storage capacity installed per system	Cost of installation of one system	Cost of water sold by the community
Kiriwatsan I (No system in South Tarawa)	10,000 liters (total of 1,375,000 liters, installed through 117 systems)	No data available	No data available
Kiriwatsan II (No system in South Tarawa)	No data available	No data available	No data available
KAP II System in South Tarawa	From 10,000 to 24,000 liters (total of 68,000 liters, installed through four systems)	No data available	No data available
KAP III in South Tarawa	20,000–25,000 liters (total of 295,000 liters, installed through 14 systems)	$A7,000 tbc	Free of charge when installed on an individual household $A0.5/bucket (of 10–15 liters) when installed on a community or church *maneaba*
KAP III in North Tarawa	25,000 liters	$A25,000	AU $1/week (regulated by Rainwater Committee)
KAP III in North Tarawa, Buota, through reticulated system	No data available	No data available	No data available
Kiribati Housing Corporation	No data available	No data available	No data available
DFAT	Estimated 16,000 liters (estimated total of 660,000 liters, installed through 41 systems)	No data available	No data available

types of water that are available in Kiribati (well water, rainwater, PUB reticulated water, ocean water, and lagoon water). They sample and test these five sources every 8 weeks from fixed sites, and perform physical, chemical, and microbiological tests. However, in practice, because of the limited resources available to conduct this monitoring, it is not clear how often it is actually done, and what actions are taken based on the results.

Technical Issues Identified during the Site Visits:

1. **Height of *maneabas*.** The design for RWH systems associated with *maneabas* takes into account the height of the roof, considering that gutters on *maneabas* are generally quite low (< or > 1.5 meters). This will require additional pumping or excavation so that the rainwater tanks can be installed below ground level. Accordingly, under KIRIWATSAN, two types of "generic" designs were developed.
2. **First flush device.** The RWH guidelines for Kiribati recommend a manual system; however, KAP III in North Tarawa installed a semiautomatic device, based on past experiences. It is worth examining which of the two works better. The semiautomatic device still requires a manual intervention, but it is a simple maneuver.
3. **Optimizing the potential of the catchment area.** During the visit to the Mwegaraoin Nanikaai community, it was noticed that gutters and pipes were installed on only about half of the surfaces of the roofs, missing the opportunity to capture twice the quantity of water. It is not clear whether this was an issue of the limited number of tanks per application (a maximum of five); or of the difficulty of clearing the leaves on one side of the roofs; or whether it was an oversight of the community and/or the project when the application was submitted and reviewed. In any case, from this experience,

KAP III has confirmed that they now do a more detailed onsite inspection for each application, in order to better assess all technical aspects, including the catchment areas.

4. **Concrete tanks and cisterns**: KIRIWATSAN has introduced some concrete tanks (in addition to the water tanks) in the RWH systems to provide more storage; and MISE is in the process of inspecting the first ones. Some leaks were noticed, and are being further assessed.

5. **Need for treatment/filter.** The few tests conducted by the Department of Health, as well as other assessments completed under different projects, have shown that RWH facilities have a high risk of getting contaminated in South Tarawa. Even if the system is well maintained and clear of leaves, the presence of birds, rats, or other animals/vectors can be a source of contamination (and potential corrosion of the roof can add heavy metals to the mix). This is the reason it is recommended that rainwater be boiled, which some residents do, and that chlorine also be used when needed: but this was never heard by the team during the visits. Ideally rainwater should be periodically tested and the results should be used to take necessary action.

6. **Applying the Rain Tank Calculator.** Most of the programs worked on existing catchment areas, which means that the area of roof catchment was a parameter that was more or less set. In principle, RWH systems should be designed at full capacity, optimizing all of the available roof catchment area. It was observed that: (a) some government offices could capture and store more rainwater if they had had more tanks installed, but the system was designed only to serve the people working in the office; (b) KAP III provided grants at a ceiling of US$10,000 and a maximum number of five 5,000-liter tanks per grant; some beneficiary communities expressed the wish they had more tanks because some of the roof catchment areas could effectively hold more tanks. Some members in the communities are now buying additional tanks to add to the system for their own private use (not to be shared with the rest of the community). This demonstrates the capacity for leverage that some publicly-funded initiatives can have.

Charging for rainwater. In South Tarawa, some of the RWH systems financed by KAP III were built on private lots or households, but they serve a larger community, usually composed of a limited number of households living around the system (and predefined during the application process). These beneficiary communities initially planned to charge for each bucket of water, in order to support a maintenance fund; however, in actual practice the caretaker who is a member of the community does not charge anything. Caretakers rely on a common but informal understanding with the neighbor community members that when a repair or a maintenance issue comes up money will be raised, and each household will need to contribute.

On the other hand, in the case of an RWH system installed on a communal building, such as a church *maneaba*, where there seems to already be another fee collection system established, a fixed rate of $A0.50 cents per bucket is collected by an appointed member of the community, and guarded by the chairman of the community who manages all funds collected (for water as well as other things). In Naanikai, church *maneabas* are charging $A0.20 cents per 10 liter-bucket. In KAP III beneficiary villages in North Tarawa, the committees established under the village constitutions supported by the project are the ones setting up prices and collecting the money, at a fixed rate of $A1 per week for RW and $A0.50 cent per week for groundwater (where there is a reticulated

groundwater system). Finally, on the private side it was learned that the Toyota facility in Eita in South Tarawa sells desalinated water for $A2.50 per 10-15-liter bucket. From all the interviews, it appears that nonpayment for water is never an issue in these types of systems.

Sustainability of past programs. In general, the programs financed by donors are recent, and the operation of these systems (for example KAP III) is relatively new; and in most cases there seems to be a follow-up mechanism the donors themselves use to monitor the condition of the systems. For example, MFAT is keeping a list of the RWH investments done by tracking maintenance conditions along with potential actions to be taken. KIRIWATSAN II likewise actively monitors the performance of their systems, building on KIRIWATSAN I experience. Nevertheless, our visits showed that there were some rainwater tanks being left abandoned and with no hardware, and there were some systems that were becoming rundown. In North Tarawa in particular, where KAP III had financed one RWH system, there were three spare water tanks onsite that had been left abandoned (two from Australian Aid (AusAID) and one from KIRIWATSAN I).

C. Lessons Learned from Past RWH Programs and Initiatives

Functionality and sustainability of RWH. Projects should build and turn over complete and operational systems. It was observed in this study that some communities ended up with rainwater tanks but without the supporting hardware (pipes, gutters, taps, etc.) that are necessary to build a complete system. This was due to: (1) failure to comply with or honor an agreement made between the donor and the beneficiary council (for example, the council was supposed to complete the system but never did, while MISE was not aware of or did not feel accountable for or responsible toward the abandoned tanks); or (2) piecemeal shipping of materials, combined with poor inventory and onsite safekeeping resulted in missing spare parts by the time construction started. Implementation must include a clear plan for purchasing and shipping complete sets of materials; and full installation of the system must be completed before phasing out.

Community involvement is critical. Whether the community is involved in the construction or not, (depending on the approach taken by the program), it is of critical importance that they are consulted prior to construction; made fully aware of the project; and organized in assigning either a "caretaker" for the system, or a committee that is charged with looking after O&M of the facility. In cases where communities are involved in the construction work (for example, when there is a free labor requirement in exchange for the grant, or the provision of an RWH system), the likelihood of success depends on strong leadership, and the community's eagerness and demand for rainwater as an alternative source of water. In some cases, despite the expressed commitment on paper during the application process, there were implementation issues and delays because the community failed to provide the labor they had promised. On the issue of charging money for community members there was an interesting finding: that is, that in collective systems, when the system is built on a village, community, or church *maneaba* that already seems to be well-functioning, with a chairman or a committee organizing things, money was able to be effectively collected. On the contrary, when the system is built on private property and designed to serve only a limited number of neighboring households (pre-identified during the project design or grant application process), even though they may have committed to an O&M model where water is to be charged to the users, the caretaker of the system (in this case the owner of the private property) does not charge for water, but relies instead on a common and informal

understanding that the beneficiary households will contribute if repair or maintenance issues arise.

RWH systems need to be visible to the caretakers and communities. Cases of vandalism are most likely to occur in systems that are not under the direct supervision of a caretaker or a host household. Furthermore, the communities usually want to be able to see the system, either so they can keep the children away from the taps, which is a frequent cause of leaks (and for this reason some projects are now considering installing lockable taps); or to be able to monitor who is coming to get water. MISE has a technician in each council (ideally) who is trained and able to provide TA.

Promoting water conservation measures. Beneficiary communities are becoming more and more well educated on the proper use and conservation of water; in particular, they are learning not to use rainwater for washing or anything other than drinking or cooking. However, one issue that repeatedly came up during the interviews in the communities was the improper use of RWH for making *kava* (a beverage traditionally consumed throughout Pacific Ocean countries for medicinal, religious, political, cultural, and social purposes). Communities do forbid rainwater use for drinking *kava*—this is an explicit rule set by the Rainwater Harvesting Committees in North Tarawa, under the village constitution. Under KIRIWATSAN 2, the village councils have imposed a strict penalty of $A20-50 for the use of rainwater for *kava*.

Strengthening an enabling environment. The experience of KAP III in supporting villages in establishing a basic constitution have been helpful in introducing elements of sustainability into their water systems. Establishing a legal framework in the form of community agreements that help determine the O&M responsibilities of RWH, and simple reticulated village water systems helps strengthen local accountability and support mechanisms.

Working models. Various models have proven successful for supplying RWH at the household level: (1) when the works are contracted out, the O&M plan has to be enforceable, for example, through the creation of a legally binding agreement like the one created under KAP III in North Tarawa; (2) when the communities participate in the works, strong works supervision and active participation from the government through the project team is required. In both cases, consultation with the communities, educational and awareness-raising campaigns, and training for the caretakers are essential. The involvement of MISE is likewise critically important, as MISE is the entity responsible for the quality of the designs, and for providing TA to the communities when needed, through the presence of technicians on the ground. The role of the Ministry of Health in ensuring the quality of drinking water is also an important aspect, which has so far been missing in the implementation of past and ongoing programs. Coordination among these key sector agencies could and should be further strengthened.

For rainwater supply at the institutional level, such as in government buildings, ministerial offices, hospitals, schools, sport complexes (whether public or private), and commercial buildings, the construction of RWH systems that are designed to provide sufficient water at least for the building users, are no-regret investments that should be supported and encouraged by the government.

Survey Results

Table B.3 provides a summary of surveys conducted with large RWH system owners, through both infrastructure diagnostic and interview with owners or operators. Figures B.1, B.2, and B.3 describes the location of rainwater tanks in Betio, Bairiki and Bikenibeu respectively, resulting from the review combining aerial imagery and site visits.

FIGURE B.1. Individual and Collective Rainwater Harvesting Systems (dark dots): Identification through Aerial Imagery (Betio)

FIGURE B.2. Individual and Collective Rainwater Harvesting Systems (dark dots): Identification through Aerial Imagery (Bairiki)

FIGURE B.3. Individual and Collective Rainwater Harvesting Systems (dark dots): Identification through Aerial Imagery (Bikenibeu)

TABLE B.3. Collective Rainwater Harvesting Systems Survey—Selected Indicators

Building	area (m^2)	% of sides guttered	Year installed	1st flush system?	Volume (m^3)	Nb users	Type of building	Industrial water use?	Who can use water?	Price of bucket (AUD)	Tank cleaning frequency	Has tank run dry?	Someone checks on water quality?
Saint Joseph Bikenibeu church	1226.694	0.5	Cant say	No	4,000	100	Community	No	Can't say		Can't say	Cant say	Cant say
Diocese of Kiribati.		1	Cant say	No	10,000	100	Community	No	Members of the community	1	Can't say	No	No
Tekaibangaki	300.3338	1	2000–04	No	25,000	100	Community	Yes	Members of the community		Once a year	Every 3 months or +	Yes
Otan Bikenibeu	896.3627	1	< 1995	No	5,000	100	Community	Yes	Everyone		Every 2 years	2-3 times per year	Yes
Tabukintion	259.4451	1	2010–14	No	5,000	11	Community	Yes	Users of the building, e.g. workers		Can't say	Once a year	Yes
Tebonnano Maneaba.	387.6772	1	2015–18	Yes	4,00,000	73	Community	Yes	Only members of the community		Can't say	Once a year	No
Tenarikai Maneaba	32	1	2010–14	No	10,000	cant say	Community	Yes	Everyone		Cant say	No	No
Santo Rabaere	292	1	2015–18	Yes	10	cant say	Community	Yes	Everyone	0.5	Once a year	No	Yes
Arebwa Omeka Maneaba	76	1	2005–09	No	15,000	cant say	Community	Yes	Everyone	0.5	Cant say	Once a year	Yes
Santo Mikaere	33	0.5	2010–14	No	5,000	100	Community	Yes	Everyone		Once a year	2-3 times per year	Yes
Santo Betero	134	1	< 1995	No	10,00,000	cant say	Community	No	Everyone	0.5	Once a year	Has not run dry	Yes
Angaieta maneaba 3	52	1	< 1995	No	40	cant say	Community	Yes	Everyone	0.5	Once a year	Once a year	Yes
Tekaotitaeka church	125	1	< 1995	No	25,000	200	Community	Yes	Everyone		Once a year	No	Yes
Tibereti maneaba	370	0.5	2015–18	No	10	300	Community	Cant say	Everyone	0.2	Cant say	No	Cant say
MYSA building.	2030	0.5	2015–18	No	5,000	80	Community	Yes	Users of the building, e.g. workers		Once a year	No	Yes
Te Tokatarawa mwaneaba.	334	0.5	2005–09	No	5,000	13	Community	Yes	Members of the community		Once a year	Every 3 months or +	Yes
Broadcasting and Publications Auth.	66	0.5	1995–99	No	30,000	40	Community	No	Users of the building, e.g. workers		Every 3+ years	No	Yes

table continues next page

TABLE B.3. continued

Building	area (m^2)	% of sides guttered	Year installed	1st flush system?	Volume (m^3)	Nb users	Type of building	Industrial water use?	Who can use water?	Price of bucket (AUD)	Tank cleaning frequency	Has tank run dry?	Someone checks on water quality?
Betio Nippon.	38	1	2005–09	No	60,000	10	Community	No	Users of the building, e.g. workers	1	Every 3+ years	No	Yes
Sport Complex	3340	1	Cant say	No	1,00,000	100	Community	Yes	Users of the building, e.g. workers	0.5	Once a year	No	Yes
Santa Maria.	44	0.5	2005–09	No	15,000	100	Community	No	Users of the building, e.g. workers	0.5	Eveiy 3+ years	Every 3 months or +	Yes
Marakei Mwaneba.	474	1	Cant say	No	5,000	30	Community	No	Users of the building, e.g. workers		Every 3+ years	Every 3 months or +	Yes
Commerce	13	0.5	2010–14	No	5,000	80	Community	No	Users of the building, e.g. workers		2+ times per year	2-3 times per year	Yes
Save Up	211	0.5	2015–18	Yes	10,000	20	Community	No	Members of the community	0.5	Cant say	2-3 times per year	No
Teiaroo Maneaba.	56	1	2005–09	No	4,000	200	Community	No	Members of the community	0.5	Not cleaned	Every few years	No
Beetereem Mwaneaba.	34	0.25	< 1995	No	2,500	30	Community	No	Members of the community	1	2+ times per year	Every 3 months or +	Yes
Ministry of Education.	407.8516	0.5	2010–14	No	5,000	35	Government	No	Users of the building, e.g. workers		2+ times per year	No	No
Ministry of Education.	544.7964	0.25	2010–14	No	40,000	50	Government	No	Users of the building, e.g. workers		Can't say	No	No
KPF building.	1443	1	2005–09	Yes	1,500	24	Government	No	Users of the building, e.g. workers		Every 3+ years	Cant say	No
Betio Hospital.	26	1	Cant say	Yes	70,000	cant say	Government	Yes	Everyone		Cant say	No	Yes

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TABLE B.3. continued

Building	area (m^2)	% of sides guttered	Year installed	1st flush system?	Volume (m^3)	Nb users	Type of building	Industrial water use?	Who can use water?	Price of bucket (AUD)	Tank cleaning frequency	Has tank run dry?	Someone checks on water quality?
KIT	2257	1	2005–09	No	40,000	120	Government	Yes	Users of the building, e.g. workers		Once a year	No	Yes
Sacred Heart College.	757.6737	0.5	2010–14	No	1,250	478	Institution.	No	Members of the community		Cant say	2-3 times per year	Yes
KGV and EBS	682.1387	1	1995–99	No	10,00,000	300	Institution.	Yes	Users of the building, e.g. workers		Can't say	No	Cant say
St. Maria high school.	901.9878	0.5	2005–09	No	10,000	370	Institution.	No	Users of the building, e.g. workers		Every 3+ years	No	Yes
KGV and EBS	439.1089	1	1995–99	No	10,00,000	300	Institution.	Yes	Users of the building, e.g. workers		Can't say	No	Cant say
KGV&EBS	396.7749	1	1995–99	No	10,00,000	300	Institution.	Yes	Users of the building, e.g. workers		Can't say	No	Cant say
KGV & EBS Classroom.	1011.117	1	1995–99	No	10,00,000	300	Institution.	Yes	Users of the building, e.g. workers		Can't say	No	Cant say
KGV and EBS	400.3573	1	1995–99	No	10,00,000	300	Institution.	Yes	Users of the building, e.g. workers		Can't say	No	Cant say
St John Bosco Primary school.	673	0.25	1995–99	No	5,000	100	Institution.	No	Members of the community	0.5	Not cleaned	No	No
Taaken Bairiki Primary School.	206	1	2015–18	No	20,000	360	Institution.	No	Members of the community		2+ times per year	2-3 times per year	Yes
Rurubao Primary School.	142	1	2015–18	No	20,000	271	Institution.	Yes	Users of the building, e.g. workers	0.5	Not cleaned	Once a year	Yes
FSPK		0.25	2010–14	No	3,000	10	NGO	No	Everyone		Every 3+ years	Cant say	No
Father Iotebwa Building	469.9338	0.5	< 1995	No	1,000	5	Residential	Cant say	Everyone		Every 3+ years	Eery few years	Yes

Notes

1. KIRIWATSAN is an EU-supported WASH program implemented by MISE through EDF-10. Phase 1 was executed with UNICEF, with three subcomponents (RWH, CLTS, and Water Resources Assessment) from 2011-2016; Phase 2 is currently being co-implemented with SPC, exclusively in eight Outer Islands.
2. South Tarawa RWH Assessment, GWP Consultants commissioned under the KAP II Program.

Appendix C
Urban Lenses: Water Balance

TABLE C.1. Current and Future Water Balance across South Tarawa Populated Areas

			TOTAL	Tanaea	Bonriki	Temaiku	Causeway	Bikenibeu	Abarao	Eita	Taborio	Ambo	Banraeaba	Antebuka	Teaoraer.	Nanikai	Bairiki	Betio
Area (km²)			**10.33**	**0.09**	**0.70**	**1.49**	**0.15**	**1.81**	**0.58**	**0.74**	**0.26**	**0.28**	**1.04**	**0.20**	**0.87**	**0.12**	**0.46**	**1.54**
Pop 2020			**54,901**	198	2,829	4,072	1,843	7,575	1,761	3,395	1,443	1,293	2,072	1,615	5,105	1,152	3,218	17,330
Pop 2030			**70,321**	254	3,624	5,216	2,361	9,703	2,256	4,349	1,848	1,656	2,654	2,069	6,539	1,476	4,122	22,197
Density (inh/km²)			**6,807**	2,818	5,177	3,500	15,738	5,361	3,889	5,876	7,109	5,915	2,552	10,343	7,516	12,296	8,961	14,414
Precipitation (m/yr)			**2.1**	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
CURRENT - Normal conditions		Assumpt (coeff)																
Runoff	*lpcd*	*25%*	***206***	*499*	*272*	*402*	*89*	*262*	*361*	*239*	*198*	*238*	*551*	*136*	*187*	*114*	*157*	*98*
Evapotranspiration	*lpcd*	*65%*	***−134***	*−324*	*−176*	*−261*	*−58*	*−170*	*−235*	*−155*	*−129*	*−154*	*−358*	*−88*	*−122*	*74*	*−102*	*−63*
Natural recharge	lpcd		**72**	175	95	141	31	92	126	84	69	83	193	48	65	40	55	34
PUB Leakages	lpcd	*60%*	**15**	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
WW discharge	lpcd	*0.8*	**28**	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Well water abstract.	lpcd		**−22**	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22	−22
Total	**lpcd**		**93**	**196**	**116**	**162**	**52**	**113**	**147**	**105**	**90**	**104**	**214**	**69**	**86**	**61**	**76**	**55**
Natural recharge	m³/day		**5082**	44	344	733	74	890	285	364	128	138	512	98	428	59	226	758
PUB Leakages	m³/day	*60%*	**1055**	4	54	78	35	146	34	65	28	25	40	31	98	22	62	333
WW discharge	m³/day	*0.8*	**1969**	7	101	146	66	272	63	122	52	46	74	58	183	41	115	622
Well water abstract.	m³/day		**−1547**	−6	−80	−115	−52	−213	−50	−96	−41	−36	−58	−46	−144	−32	−91	−488
Total	**m³/day**		**6558**	**50**	**420**	**842**	**123**	**1094**	**333**	**455**	**167**	**173**	**567**	**142**	**565**	**90**	**313**	**1224**
2030 - Normal conditions		Assumpt (coeff)																
Runoff	*lpcd*	*25%*	***206***	*499*	*272*	*402*	*89*	*262*	*361*	*239*	*198*	*238*	*551*	*136*	*187*	*114*	*157*	*98*
Evapotranspiration	*lpcd*	*65%*	***−134***	*−324*	*−176*	*−261*	*−58*	*−170*	*−235*	*−155*	*−129*	*−154*	*−358*	*−88*	*−122*	*−74*	*−102*	*−63*
Natural recharge	lpcd		**72**	175	95	141	31	92	126	84	69	83	193	48	65	40	55	34
PUB Leakages	lpcd	*25%*	**17**	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
WW discharge	lpcd	*0.8*	**62**	66	66	66	66	54	66	66	66	66	66	66	66	66	54	54
Well water abstract.	lpcd		**−12**	−12	−12	−12	−12	−12	−12	−12	−12	−12	−12	−12	v12	−12	−12	−12
Total	**lpcd**		**139**	**245**	**166**	**211**	**102**	**150**	**197**	**155**	**140**	**154**	**264**	**118**	**136**	**111**	**113**	**93**
Natural recharge	m³/day		**5082**	44	344	733	74	890	285	364	128	138	512	98	428	59	226	758
PUB Leakages	m³/day	*60%*	**1160**	4	60	86	39	160	37	72	30	27	44	34	108	24	68	366
WW discharge	m³/day	*0.8*	**4388**	17	241	346	157	523	150	289	123	110	176	137	**434**	98	222	1198
Well water abstract.	m³/day		**−844**	−3	−43	−63	−28	−116	−27	−52	−22	−20	−32	−25	**−78**	−18	−49	−266
Total			**9786**	**62**	**601**	**1103**	**241**	**1457**	**445**	**672**	**259**	**255**	**700**	**245**	**892**	**164**	**467**	**2055**

Note: PUB = public utilities board.

Appendix D
Conservation of Freshwater Lenses on Bonriki and Buota, through Watershed Management

A. Introduction and Background

Introduction

The Buota and Bonriki freshwater reserves are one of the main sources of freshwater for the 58,000 residents of South Tarawa, who comprise more than 50 percent of the population of Kiribati (2016 census). This report has been carried out as a desk exercise, and draws on work carried between June and December 2014 under the Kiribati Adaptation Program (KAP). The 2014 work was contracted by the government of Kiribati as an input to the KAP Phase III, and involved preparation of a roadmap of actions to address the threats facing the integrity of these two water reserves.

Background

The key issues affecting sustainability of the Buota and Bonriki water reserves that were identified in the 2014 baseline report included:

- **Property Rights Relating to the Water Reserves**

The complex legal position regarding property rights of the landowners over whose land the water reserves are established. The Buota and Bonriki water reserves were not "acquired" as state land in terms of the State Acquisition of Lands Act 95B—as was the case for the Betio, Bairiki, and Bikenibeu (township) acquisitions prior to independence in 1979. Although the existing landowners in Buota and Bonriki held ownership property rights over strips of land (lagoon to ocean) they did not, at the time that the water reserves were established—Bonriki in 1969, and Buota in 1974—have all of their land converted to State land, only the designated water reserve area that was created; and they did not enter into the same lease payment arrangements as occurred in the case of acquisitions under Cap 95B. They did receive "one-off" compensation.

Subsequently, the Buota and Bonriki landowners pressed for additional compensation, and access to the water reserves (LMD 2014). This resulted, in the late 1990s, in a decision (raised in Parliament, and approved by the Cabinet) that the landowners would be treated as lessors, and be paid annual "lease" payments in the same way as the lessors that were created under the State Acquisition of Lands Act. This practice continues. In addition, the right to occupy the ocean and lagoon fronts for a depth of up to 50 meters was established; a road was constructed around the perimeter to mark the 50-meter boundary; and survey beacons were erected to mark this boundary as well.

As is the case with "state land" acquisitions in South Tarawa, the Bonriki and Buota landowners regard themselves as holding the absolute title to the land, while the government has acquired temporary, or lessor, rights (legally as a water reserve, in practical terms, as a lessee). This perception results in beliefs that the land can be accessed and the produce thereof (water from wells, coconuts from trees, etc.) gathered, as the "land belongs to them." In these circumstances, it is likely that measures will be required, either as incentives to cooperate (or disincentives to *not* cooperate), in order to secure a sustainable method of managing the reserves. Disincentives have proved very difficult to enforce; by the police in Kiribati generally, and in South Tarawa in particular.

- **Differences Between Settlement Patterns on the Buota and Bonriki Reserves**

The Land Management Department (LMD) of Ministry for the Environment, Lands and Agricultural Development (MELAD), as the government's "custodian of the land," is responsible for making and maintaining an inventory of unauthorized households and dwellings on the two water reserves. In April 2014 there were about 59 such households on the Bonriki reserve, and 20 on the Buota reserve. The household size of settlers on the Buota and Bonriki reserves is an average of around 5 persons, with a small number of households having 10-20 members. There is a significant difference in the average number of years of occupation: Buota settlers have been on the water reserve for almost three times as many years—17.6, compared to 6.7 years in Bonriki.

Analysis of the percentage of households settled on the reserves, by number of years of occupation (figure D.1) shows that while in 2012 63 percent of households on Bonriki had been there 1 year or less, only 10 percent of Buota residents fell into this category. At the other end of the scale, 40 percent of Buota residents had been on the reserve for 26 years or more; 50 percent for more than 16 years; and 35 percent for 6-15 years. It is clear that Buota and Bonriki have very different patterns of settlement, with Bonriki showing a much higher level of short-stay, transitional households, and Buota a more settled pattern of long-term occupation.

The unauthorized residents in Buota are settled wholly along the inside of the 50-meter perimeter, while in Bonriki they are scattered in clumps in the middle of the reserve, as well as just inside the perimeter.

LMD has carried out inventories of the unauthorized settlers on the Bonriki water reserve for the years indicated in table D.1. The overall movement of

FIGURE D.1. Percentage of Unauthorized Households, by Years of Occupation, 2014

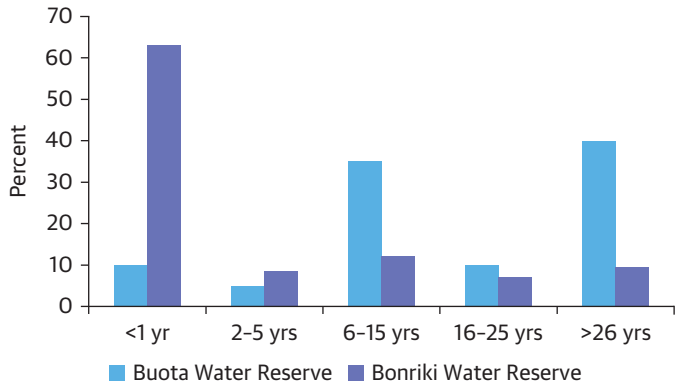

TABLE D.1. Summary of the LMD Census of Illegal Households in Bonriki

Year	Total	Old	New	Move out	Total on site	Net movement	% increase
2005	24	24				–	
2006	34	34			34	+10	29
2007	52	22	18	12	40	+6	15
2008	46	17	29	0	46	+6	13
2009	62	16	37	8	54	+8	15
2011	85	38	22	25	60	+6	10
2012	99	51	13	35	69	+9	13

squatters in and out of the reserve supports the observation that Bonriki has a high turnover of settlers (roughly 30 percent each year).

Although the net increase has dropped from a high of 29 percent in 2005-06, it has held at a fairly consistent rate of 13-15 percent since then. The number of households moving out each year fluctuates, but is quite high; on average around 30 percent.

- **Relationship Between Authorities and South Tarawa Communities**

There is a long history of distrust, and at times open antagonism between the residents of Buota and Bonriki and the government authorities responsible for the land, for lease payments, and for the water. To a significant extent this conflict arises when the demands of a densely populated and urbanizing South Tarawa come into conflict with more traditionally oriented community values. *There is a general distrust of government officials and their intentions, and a lingering grievance around the feeling that local communities have paid a high price ceding control of their land and received too little benefit in return; and, at times, a feeling that their rights to the land and the fruit of the land they own have been unjustly taken from them.*[1] *In the past, this has led to vandalism of water supply equipment in the reserves. This fact must be taken into account in addressing the future sustainable management of the reserves.*

- **Many Stakeholders, with Different Interests in the Water Reserves**

The key stakeholders with an interest in ***management of the reserves*** include:

  - **South Tarawa Communities, including Betio, Bairiki, and Bikenibeu**

While they are almost certainly not representative of all members of the community, discussions with the wider community of South Tarawa in the past have shown that the people of Bonriki have been resented because they have been perceived as receiving unwarranted special treatment for the loss of their land. Many landowners in South Tarawa are suffering the stress of overcrowding, dislocation, and an increasing demand to accommodate and support relatives from the outer islands. It has been observed that the Bonriki community still has plenty of breadfruit trees, and could fish in the lagoon and collect food off the reef, as their shoreline is less polluted than the more populated areas of South Tarawa. In the past there has been pressure from the community on the government not to listen to the Bonriki residents, and to evict squatters off the reserve.

  - **South Tarawa: The Bonriki Community Surrounding the Water Reserve**

In the late 1990s consultations took place with Bonriki community landowners.[2] It was reported that some residents felt that they had not received sufficient compensation for the use of their land as a water reserve. They complained that they had not been made sufficiently aware of the impact that the reserve and the airport would have on their lives. Apart from the loss of the area available for housing and gardens, their coconut trees and *babwai* (taro) pits had become nonproductive. It was reported that the village was previously self-sufficient in food, and was able to sell copra, but since land has been lost to the reserve and the airport, they have had to buy coconuts and depend on money from the government and other sources to live.[3] They also complained that the water in their wells had become saline from over-pumping. Some of the discontent has arisen because the village has become seriously overcrowded with an influx of relatives from the Outer Islands (a pressure being experienced by all of South Tarawa), and the majority of these people are unemployed. Consequently space and land are in very high demand, and the cash available from the compensation or lease payments has not been sufficient for, or available to, the expanded

population. Although the residents of Bonriki receive a free supply of reticulated water, they do not consider it an advantage to not pay for this water, since "the water belongs to Bonriki anyway."

- **South Tarawa: Bonriki Households on the Reserve**

In a 2014 interview with the Bonriki councillor it was stated that the main drivers of unauthorized settlement were:

  - Relatives or offspring of landowners living in the area at the time the water reserves were declared.
  - Some settlers on the reserve who come from other places may be related to the landowners. Many are living in the reserve, on the northeast ocean side.
  - Others come from South Tarawa to take gravel and to cultivate gardens.
  - One group, from the southern Islands has been living there for about 5 years; the people who live behind the control tower are new settlers.

- **North Tarawa: Buota Community Surrounding the Water Reserve**

Buota residents are concerned with various issues concerning the water reserve:

  - Landowners are worried about future land-leasing rates.
  - There is no more habitable space for the growing population in Buota, and many families feel they have no choice but to move into the reserve.
  - The reserve is increasingly dry, and the potential for the community's subsistence is decreasing.
  - There is a need for freshwater in Buota, especially in the northeast, where well water is saline, and about 200 people are struggling to have enough drinkable water.
  - Landowners believe the compensation system is unfair because they are not being compensated for the water that is being removed from beneath their land.
  - Some interviewees were concerned that it is no longer possible to maintain the boundaries of the reserve, and suggested that the area of the reserve be reduced to allow more living space for the increasing population.

- **North Tarawa: Buota Households on the Reserve**

Unlike Bonriki, the Buota islet falls under the authority of North Tarawa. In interviews with members of the Eutan Tarawa Council for Buota in June 2014, it was stated that:

  - The main driver of unauthorized settlement was the "need for more land" from a growing number of residential families (retired civil servants with family links to Buota, and so on).
  - Most unauthorized settlers were landowners or relatives of landowners.
  - In regard to uses of the reserve, there was some harvesting of plants for traditional medicines, and collection of pandanus (palm-like tree) for thatching, mats, etc.
  - It was well known that settlement on and use of the reserve is prohibited.

- **Government of Kiribati**

The main government actors with direct interest in the two water reserves are:

  - The **Public Utilities Board** (PUB), which is responsible for the delivery of water and sanitation services in South Tarawa, and management of the two water reserves and their resources. PUB is under the authority of the **Ministry of Infrastructure and Sustainable Energy (MISE),** which is responsible for the maintenance of government buildings, regulating public utilities services, construction

and maintenance of roads, technical services, and energy management.

- The **Attorney General**, who is responsible for providing legal advice to the government, and providing legal representation for the government;
- The **Ministry for Health and Medical Services (MHMS)** which is responsible for health inspection services, monitoring of water quality, and environmental health; and
- **The** MELAD which is responsible for land management (lease payments to landowners, compensation payments to unauthorized occupiers, and land use (planning regulation) on the water reserves.

○ **Urban and Island Councils**

- The Teinainano Urban Council is responsible for urban planning and development control on the Bonriki islet; and North Tarawa's Eutan Tarawa Council is responsible for the Buota islet.

○ **Committees, Task Forces, and Councils**

A number of committees and task forces have been created over the past 20 years to address water supply issues in Tarawa in general, and the Buota and Bonriki water reserves in particular. These have been of variable durability, and have achieved limited results. ***Committees and task forces have thus far not proven to be a sustainable or effective means of achieving long-term management and governance objectives.***

- **Previous Initiatives to Conserve and Protect the Water Reserves**

The *Tarawa Master Plan (2010)* states that "The current water reserves in South Tarawa were declared over land that was privately owned. This has been highly controversial and has generated long-standing disputes between authorities and landholders and their communities. Although PUB regulations allow the compulsory purchase of land for water reserves, this has never been done by the government, because of the fundamental importance of land ownership in Kiribati. Instead, the government currently pays affected landowners annual lease payments."[4]

Numerous reports recommend that a specific management arrangement for the two water reserves be established, and that this involve community participation:

○ "Maintaining the water reserves at Bonriki and Buota will require commitment by government and the involvement of local communities.

In order to address the encroachment of settlers onto the Bonriki and Buota Water Reserves and to include local landowners in the process, a community-government *Committee for the Management of Water Reserves in Bonriki and Buota* was proposed in 2000 as a lead-in to the SAPHE project. This Committee was planned to have representatives from the water reserve villages, from the *Unimwane* (traditional elders) of Tarawa and from the lead government agencies and was to be facilitated by the Ministry of Home Affairs and Rural Development with secretariat provided by the Land Management Division within the Ministry. The Committee met in February 2002 but is now defunct. Some government agencies are still uncomfortable with the notion of community participation. The reactivation of this Committee is seen as essential." *Tarawa Water Master Plan 2010–2030 (December 2010)*.

- Another strategy proposed to improve the management and protection of the water reserves and to involve local landowners in the process was, instead of paying them lease fees, paying them to be custodians and managers of the water reserves, with the lease payments being linked to performance criteria such as the absence of settlers,

houses and animals; gravel and sand mining; crop planting; the infilling of wells, *babwai* pits and mining pits; and the removal of dwellings and other domestic infrastructure, and the absence of new burials on the water reserves. The proposal, which is politically sensitive, has never been considered (White et al. 1999).

  - The *KAP II Buota Consultations: (December 16-17, 2010)* states, with reference to community involvement in protection of the water reserves, "There used to be a committee making sure that people do not build houses on the reserve but it has not been active for at least 10 years now" and "The Unimwane strongly encourage the government to involve all the Unimwane of Buota on any decision making to prevent future damage to the infiltration galleries and the water reserve."

- **Risks**

Contamination. The most serious risk is contamination of the water reserves that could result in a very serious outbreak of a disease such as cholera, resulting in many deaths among the population of South Tarawa. There is also a risk of contamination of the reserves by toxic substances (oils, metals, chemicals reaching the water lens) that would not be eliminated by adding chlorine to the water. A high incidence of water-related diseases that result in clinic or hospital visits is now found in South Tarawa.

Increasing settlement on and around the reserves. The risks associated with settlement on the reserves are clear; however, it is also clear that the risks are different in Buota and Bonriki. **In Buota**, all of the existing structures built on the reserve are immediately inside the 50-meter boundary, and the majority of the 20 households are resident families and retired civil servants with family links to Buota: 50 percent of them have been on the reserve for more than 16 years. Coconut palms and *babwai* pits on the reserve are productive, and vegetation is thriving. **In Bonriki**, the coconut palms and *babwai* pits are not productive: in 2012, 63 percent of the 59 Bonriki households had been there for 1 year or less; and the percentage turnover of households was around 30 percent, with a net increase each year of about 13 percent. The main driver of this change is a combination of temporary and long-term demands for land on which to settle—from resident families as well as new migrants from the Outer Islands.

Land, livelihoods, and access to resources. In consultations held with the Bonriki community in 1996-97 it was reported that the government was obliged to compensate for losses associated with the use of the land, but not for anything found below ground level, including the water; hence the focus by landowners on the effect of water extraction on vegetation, and consequent loss of livelihood or subsistence. In addition to the agitation for redress, the villagers have taken practical steps to reduce their difficulties. Bonriki residents moved onto the reserve, built houses, and grew vegetables. In some cases, the plots were sold or rented to them by the landowners. In other cases, the landowners could not refuse their relatives, due to the custom of the *bubuti*, even though they had been compensated by the government for nonuse of their land.

Because the water reserves are perceived as "government land," they are often raided for their resources. Settlers at the Bonriki end of South Tarawa have few opportunities for generating income. Sand and gravel are currently in very short supply in Tarawa. Therefore, sand and gravel mining, although illegal, provides South Tarawa residents with an opportunity to earn some income, and to many, the Bonriki water reserve appears to be an ideal source for materials. But the impact of sand and gravel mining can be seen in aerial photos, and the practice is endemic across the reserve. Mining also has significant impacts on the

water reserve: destruction of vegetation; increased vulnerability of groundwater to pollution (as less soil overlies the water table); increased direct evaporation losses from the water table; and damage to pumping stations and salinity monitoring boreholes. Inspections of the reserve show that the impacts of mining are becoming progressively worse, and that they constitute a significant threat to South Tarawa's reticulated water supply.

Increased settlement on the two water reserves will lead to inappropriate land use through, for example:

- **The digging of open wells,** exposing the groundwater to direct contamination, and creating algal blooms in the water.
- **Active graveyards**. There are several active graveyards on the Bonriki water reserve, which are exposing the shallow groundwater to the risk of pollution.
- **The raising of pigs**. There are about 2.4 pigs per household in Kiribati. The fecal contaminant from pigs on the reserve poses a significant threat to water quality.
- **Growing crops**. Prevalent on the lagoon side of the Bonriki reserve, the use of fertilizers and animal waste as crop nutrients is a significant pollution threat.
- **Growing *babwai***. *Babwai* pits are excavated into the water table, and fertilizer and animal wastes are being added directly to the groundwater. *Babwai* cultivation is a major threat to groundwater quality, and is also increasing evaporative losses.
- **Direct pollution**. The terminal wells of gallery pump stations can be opened and used as rubbish dumps or toilets.
- **Vandalism to the infrastructure**. Vandalism is a potential threat in the water reserves: mitigation will involve improved management, education, and awareness.

Conclusions

Taking into consideration the points made in the present appendix, the following conclusions are proposed:

- The Bonriki and Buota freshwater reserves and lenses are critical to the economic, social, and environmental existence of South Tarawa, which is the capital of Kiribati as well as its economic and political hub; and home to about half of the population.
- The nature and extent of settlement on the Buota water reserve is very different from that on the Bonriki reserve. The Bonriki reserve is more vulnerable, more accessible, and more degraded environmentally. The Buota islet is, administratively and developmentally, a more traditional rural environment, and Bonriki a more "urban" environment.
- ***Effective protection and conservation of the water reserves has been inadequate since they were established in 1969 and 1974; it is a high priority to put into place the institutional and organizational frameworks that will provide effective protection and conservation of them.***
- Although the most likely additional source of potable water is desalination of saltwater, and this will need to be added to the water supply resources in the immediate future, it does not detract from the importance of the Buota and Bonriki water reserves as a long-term, sustainable source of freshwater for a substantial number of Kiribati's people; for its economy; and for its environmental sustainability.
- A wide range of actions may be taken to protect and conserve the Buota and Bonriki water reserves. These involve taking measures in the following areas:
    - **Initial agreement by stakeholders as to future actions, sequencing, priorities, revenues, costs, and management**, including different strategies

and actions for residents on and surrounding the Buota and Bonriki islets and reserves, and in Tarawa.

- **Immediate actions to be taken to educate, raise awareness, and inspire the behavior changes needed** to increase water yield; to physically identify and protect the water reserves; to eliminate vandalism; and to increase education and general public awareness of these issues.
- **Agreement of a sustainable management plan (SMP).** Public participation and community engagement are encouraged.
- **Development of policy, laws, and regulations** when and where required to implement the above points.
- **Find ways to increase revenues and fund costs** which arise from addressing the previous points.

B. Measures to Mitigate Risks

Initial Agreement by Stakeholders

The starting point for putting into place measures to mitigate risks to the Buota and Bonriki water reserves is divided into two sequential activities:

- **Initial Discussions**

The following matters should be considered:

1. Hold initial meetings with the government (executive & administrative[5]) and communities (Buota, Bonriki, and South and North Tarawa) to identify and agree on the approach to be taken and identify key stakeholders[6] and representatives.
2. Identify and gather current, relevant, useful data (from LMD, the Attorney General, the PUB, the Ministry of Environment, Lands and Agriculture Development (MELAD), local councils, etc.).
3. Determine the main processes, inputs, and outputs for negotiating SMPs for both reserves.
4. Identify the person(s) who will facilitate an independent, respected, capable 12-month (or longer) process, and agree on their training requirements, and how they will be supervised.
5. Identify and secure the required resources.
6. Initiate a facilitated consultative process with key stakeholders to agree on a roadmap on directions (strategy) and actions (including what, when, who, and with what resources).

- **Agreement: A Roadmap for Directions and Actions**

Define strategies and actions for residents on and surrounding the Buota and Bonriki islets and reserves.

1. Identify immediate actions, education, awareness, and the types of behavior change that is being sought.
2. Physically identify and protect the water reserves.
3. Review and agree on the strategies and actions described below, and address questions such as: What can be agreed on as a basis for discussion? What principles and criteria should be applied in order to achieve the agreement of all stakeholders? Are there any "red lines" (nonnegotiable boundaries) within which discussion must take place?[7]

C. Immediate Actions, Education, Awareness, and Behavior Change

- **Remedial Actions to Protect the Water Lens**

To reduce the potential for contamination or pollution of the lens, and to put into place (as far as possible) a minimum[8] depth of ground cover above the water lens, the following actions should be taken:

Fill in any existing pits more than 1 meter in depth. These exist as a result of excavation to extract, sand, aggregates and rocks, or to build wells and pit latrines; and 2. **Dig up existing tracks and roads** to make them impassable; keep only the limited access routes leading to the water treatment works and other sites needed for maintenance and/or security.

Note: The existing cemetery in the central (northeast) part of the reserve should not be moved. Consideration may be given to the establishment of a new cemetery site for the Bonriki and Buota village communities *outside* of the water reserve perimeter.

- **Increasing the Water Capacity of the Bonriki Reserve.**

Tree removal in Bonriki. Removal of about 1,700 deep-rooted coconut trees from the central portion of Bonriki will increase the sustainable yield of the reserve by 250 m^3/day—about 12.5 percent of the current combined Buota/Bonriki yield. Only minor modification of the existing infrastructure would be required. The advantages and disadvantages of this option are explained in the Tarawa Water Master Plan, and preliminary capital cost estimates are outlined.

Some members of the community may perceive the loss of useful assets (such as timber), although there is evidence from community leaders and local politicians that the coconuts are not productive. This measure should be explored as a negotiating point, testing acceptance or rejection by the community at an early stage. ***While the benefits of removing the trees are reasonably clear, the local resistance could be mitigated by employing local workers, or by allowing community participation in revenues generated. If, however, resistance is substantial, it may be preferable not to pursue this measure.***

Infilling ponds, western end of Bonriki. During construction of the airport runway at Bonriki, borrow pits were excavated at the western (lagoon) end of the islet. These have introduced salinity into the freshwater lens. By cleaning the ponds of organic matter and infilling with clean, dredged sand, the area and the sustainable yield of the Bonriki reserve could be increased by an additional 250 m^3/day. This option will require negotiation with landowners and with the Bonriki community; and the installation of new infiltration galleries may involve increased land rental payments.

Note. It is assumed that this activity will not be implemented. The Water and Sanitation Roadmap identified the estimated cost (in 2011) as $A2,500,000, and noted that the New Zealand Aid Program was proposed to fund it.

- **Actions to Create Barriers to Accessing the Water Reserves**

Potential physical perimeter barriers and interior ground-cover barriers include:

Perimeter barriers. Cost is a factor, as are longevity, resilience in the face of human ingenuity, and maintenance. An additional factor is whether perimeter barrier construction and maintenance can be part of community engagement, and can result in financial or other benefits to the community. Walls and fences are likely to be too costly, too difficult to maintain, and will involve little community engagement or benefit, while providing opportunities for income that result in the theft of barrier materials. The principle usually adopted is to provide multiple barriers. Suggestions include:

- Initially marking the boundary using dead or old coconut trees on the reserve.
- Planting rows of dense vegetation, preferably with thorns.
- Erecting RWH panels on the reserve boundary, near the villages.
- Erecting informational and warning signs at regular intervals along the boundary.

Interior Ground-Cover Barriers. Such barriers can prevent easy access to the reserves (for sand mining, etc.), either by making it easier to see intruders, or physically more difficult for them to gain access to the ground surface because of defensive vegetation. Three options have been identified (for Bonriki only):

- Cut all plant cover down to a low level. Pay the local community to slash and/or remove the vegetation once or twice a year.
- Plant extensively, taking care not to affect other permitted uses; or, plant dense, low-growing plants or bushes that will prevent access.
- Plant shrubs or trees that will not draw much water from the lenses, or attract human access, but will provide a useful product.

- **Actions to Prevent Vandalism**

The following actions for preventing vandalism have been identified:

- Select members of the Buota and Bonriki community to report vandalism and/or unauthorized land use, (working with village councils, church groups, Unimwane, etc.).
- Install notices around the reserve, warning of penalties.
- Engage youth and communities in promoting education, awareness raising, and behavior change.

It is suggested that an education, awareness-raising, and behavior change plan be prepared and implemented, and that regulatory warning signs be displayed. The signs would provide information to the public, both on-site and off-site, of the laws (regulations, by-laws, and so on), and the penalties that result from contravention of the laws.

The development of the plan, as part of the SMP, would incorporate the following elements:

- Education, awareness-raising, and behavior change processes, incorporating a "Forum" approach including open discussions in public meetings.
- Background and situation analysis that addresses the following questions: Where is management of the water reserves now? Where does it need to be in 1, 5, and 10 years? How do we get there?
- Objectives: overall messages and emerging themes.
- Identification of the various public audiences and stakeholders in the context of the protection and conservation of the Buota and Bonriki water reserves, taking into account the sustainable management policies, laws, regulations, procedures, and applicable operating processes.
- Goals, strategies, and actions. Messages to key audiences are drafted, considering the following questions: What do we want the public, audiences, and stakeholders to know and remember? What are the goals of a SMP? How are they measured? How are the government and the community planning to reach their goals?)
- Implementation, budget, performance targets, measurement, and evaluation of the implementation phase.

Medium and Long-Term Land Use

- **Different Approaches for Buota and Bonriki**

Agreement as to the definitions of prohibited and permitted land use within the Buota and Bonriki water reserves will not be the same at the two reserves. There are good arguments to suggest that the Bonriki reserve could be used productively for nontraditional uses that generate revenues and/or that contribute to the development of South Tarawa. The existing traditional uses (the raising of coconut palms, etc.) are too degraded to be productive. But there is an equivalent argument to suggest that the Buota reserve should be protected and conserved in its natural state as much as possible, in order to protect the reserve and to provide plant resources for the Buota community.

- **Land Uses Not Permitted Within the Water Reserves**

For both the Buota and Bonriki reserves, it is suggested that only very limited human contact should be permitted. Under no circumstances should any of the following be permitted (see also table D.2):[9]

1. Potential contamination of the water resource with liquid or solid wastes.
2. Any kind of toxic or contaminating liquid or solid that may percolate through the soil into the water lens.
3. Any kind of hole that reduces the ground cover over the lens.
4. Any areas of extensive hardstanding that place a barrier between rain and the lens, including buildings, or any other use that involves the removal of soil over the lens.

- **Permitted Uses**

Potential permitted uses on the water reserves are briefly reviewed in table D.3.

- **Perimeter and Inner Reserve Use (Bonriki only)**

Is it feasible, in terms of sustaining the water resource, to consider an additional perimeter area, say 50 meters in width (for a total of 100 meters), in which some limited uses may be permitted, that will: (1) generate revenue; and (2) provide a barrier to accessing the main inner area above the lens?

Within the perimeter area, limited, noncontaminating uses could be considered such as: warehousing, recreational facilities, places of worship, police stations, banks, post offices, magistrate courts, craft markets, and so on. In this scenario, the inner use could occupy, say 80 percent of the land over the reserve and its use could be limited mainly to open space, vegetation, and other uses that are limited and that involve very little human or animal contact.

TABLE D.2. **Potential Prohibited Uses**

Prohibited uses—To be further developed as part of water reserve regulatory framework
Solid waste—landfill, incineration, recycling, composting, etc.
Liquid waste disposal—Septic tanks, sludge ponds, wastewater reticulation and treatment
Industrial uses—Anything involving toxins. All sand, gravel, and rock mining.
Residential uses that may involve septic tanks, domestic animals, human waste.
Commercial uses that may involve the introduction of toxins, septic tanks, or hardstanding

Policy, Laws, and Regulations

Policy issues are those that may require cabinet-level decisions. They may include issues relating to the strategies to be adopted in order to implement policy. Some of the policy issues may need to be addressed and resolved ***before*** the commencement of other activities; others may arise ***during the process*** of deciding the mitigation measures and the management and governance arrangements (that is, ***during the preparation stage***); still others will be required before the measures and arrangements agreed upon can be initiated (i.e., ***before implementation***).

This report has not identified the policy issues that may arise during the preparation and implementation phases; these will be identified during the preparation phase, and in concluding agreements on water reserves SMPs.

The ***policy issues that will need to be addressed before commencement*** fall into three categories:

1. **Policies and laws regarding illegal activities on the water reserves**. The households currently occupying the water reserves are illegal in terms of Public Utilities Ordinance Chapter 83 of 1977. PUB has the power to "remove any structure or fill in any pit" upon the reserves. The public participation and community engagement approach proposes that negotiations take place with the households

TABLE D.3. Potential Permitted Uses on the Water Reserves

Uses	Advantages, Disadvantages and Comments
Buota and Bonriki Communities (including households located on the reserves)	
Approved access rights	Low impact, small numbers of humans. Potential rights to access "fruits" of the land and policing duties.
Strategic Infrastructure (for Bonriki only)	
Solar/Photovoltaic Panels	Low impact, small numbers of humans dealing with operation and maintenance (O&M). Relatively small areas occupied. Minimal hardstanding.
Industrial uses	Frees land in South Tarawa for housing. Uses with minimal people onsite. Dependent on use. No toxic liquids or substances. No oils, etc. Minimal hardstanding. (For example warehouses or storage facilities with low impact.)
Telecommunications masts	Low impact, small numbers of humans dealing with O&M. Relatively small areas occupied. Minimal hardstanding.
Electricity substations	Low impact, small numbers of humans dealing with O&M. Relatively small areas occupied.
Recreational uses: (for Bonriki only)	
Football fields	Attractive to local communities. Located on perimeter, with restricted access to field only & toilets provided
Volleyball, basketball, etc.	
Agriculture/Horticulture/Fisheries/Industrial: (for Bonriki and Buota)	
Medicinal plants & herbs	Used by the whole of South Tarawa, but could be tended by local community Low impact as long as no fertilizers is used.
Roof thatch & matting	Access for *pandanus* leaves collection. Strictly limited to women and local residents.
Commercial (Bonriki only)	Possibly limited warehousing that involves minimal human presence. No septic tanks, etc. Minimal hardstanding.
Existing Uses (for Bonriki and Buota)	
Water treatment works	Existing
Cemeteries (Bonriki only)	Too difficult to move, and of relatively little negative impact. Dedicated access to be provided to existing facilities. **No further cemetery expansion within the reserves**.

concerned, and with the Bonriki and Buota communities. ***PUB and the government may need to either decide not to enforce the law, and/or be prepared to change the law, if the outcome of these negotiations is an agreement between the communities and the government that requires changes in policy, law, or regulation.***

2. **Policy and strategies that differentiate between the two water reserves.** The government's policy is to protect and conserve freshwater sources for the public water supply. Existing law reinforces this policy direction. The economic, social, and environmental contexts in Buota and Bonriki are quite different, and it is recognized now that desalination is the only available option that will help fully meet South Tarawa's water demand. In these circumstances, and bearing in mind the inevitable growth of South Tarawa's population, adoption of a policy of "managed decline" of the water reserves could be considered.

3. **A SMP involving agreement between the government and communities.** There is no specific existing policy or legal framework that covers the end result proposed in this report, which is a legally binding agreement (contract) involving government authorities and communities, who may both

have managerial and governance responsibility; and whose authorities may share revenues and costs. Does the government agree with this open-ended approach? That is, is mutual agreement to be achieved through a consultative and facilitated process in order to achieve effective management and governance of the water reserves? If so, can the existing agreement be recognized in law? Is there any potential conflict with existing laws?

Revenues and Costs

The mitigation measures, and the management and governance arrangements that will be finally agreed upon cannot be predicted in advance. Can any of the revenues arising from use of the Buota and Bonriki water resources, or the land and vegetation above the water lenses, as well as the ocean and lagoon frontages, be shared? If so, by and with whom? Also, are there any exclusions, or strategies, that the government may wish to determine in advance of a consultative and facilitated process? Can the same question be applied to costs? Can costs be shared between the government and local communities? If communities receive financial benefits, can they also be expected to share costs?

D. Long-Term Reserve Management Governance Options

Principles

Internationally, a wide range of approaches for the management of natural resources have been tried and tested.[10] Many of these have successfully accommodated traditional or customary approaches to the ownership and management of common property resources with those involving state ownership and management. Some of the options and their potential application to the Buota and Bonriki water reserves is reviewed in table D.4.

TABLE D.4. Water Reserves Governance Options

Options	Description of option	Applicability: Pros and cons
State ownership and management	The government owns the resource–in this case a source of water–and manages the resource through state organizations and the application of laws and regulations.	This approach has been in place for 40 years. It has not succeeded in resolving the risks to the water reserves created by adjacent settlement, encroachment, and illegal occupation.
State ownership and contracted out management	The government owns the resource and contracts out management to another, usually a private firm. The state uses laws and regulations as the institutional framework for the arrangement.	This is almost certainly an expensive option with limited long-term sustainability, and probable difficulty in finding a "manager" with the appropriate combination of technical and locally applicable social skills.
State ownership and community involvement	The government owns and manages the resource through state organizations, or by contracting out. The management arrangements include mechanisms for community involvement in advising; in decision making; and in receiving benefits (financial or in-kind). The aim is to incentivize communities to protect and conserve the resource.	This is the most viable option given the need to combine management of different freshwater sources, the importance of the water supply to a substantial population, the opportunities and risks arising from communities living around the reserves; and the complex property and resource rights involved. It will involve difficult, lengthy, and complex negotiations to achieve agreement for sustainable management.
Community ownership	Ownership of the resource is transferred to the community, provided the community achieves set criteria and manages the resource, receiving the benefits—within a set of laws and regulations established by the state.[a]	This is unlikely to be acceptable politically or administratively, as it would almost certainly result in unsustainable tensions between the communities involved in "ownership" of the resources, and those benefiting from access to the freshwater supply.

a. As adopted, for example, in Zimbawe's CAMPFIRE program.

In developing long-term reserve management and governance options, and bearing in mind their implementation, a number of principles are thought to be important in determining the approach of all stakeholders for securing water resources in Tarawa generally, and to the management of these two water reserves in particular. The following principles for guiding the preparation of a SMP are proposed:

1. **Fairness to both of the communities involved**. The residents of South Tarawa need to have access to sufficient clean water to support good health, survival, and livelihoods. The communities of Buota and Bonriki that live on and next to the water resource are giving up (in part) their land and livelihoods, in order to protect the water resource. A solution that considers the different interests of the two parties can only be found through a fair process that brings these communities together to achieve a solution that will be supported by all.
2. **Consultation and participation**. The key to being "fair to all" is full and open participation of all stakeholders-the communities involved, government agencies, groups representing particular sections of society, political and traditional representatives—in discussions held at all stages of the process that result in agreement, on decisions made.
3. **Process management**. To achieve effective participation, consultation, and decision making, a carefully prepared, step-by-step process that combines thorough preparation and implementation with honest communication among all stakeholders is necessary.

Aspects of the Approach. The formal institutional and organizational framework is reasonably clear: that is, the policies, laws, and regulations are well defined and clarify how to apply them; and who will apply them. But the **consultative aspects, or means to negotiating a solution** (or agreement) that everyone supports and can accept and enforce are the missing elements. The Kiribati context emphasizes:

- **The technical** (water supply) in terms of the main organizations responsible for water supply and use (O&M) of the water reserves in South Tarawa, being the PUB and the MISE and;
- **The law** in terms of protection and conservation of the water reserves—laws (and subsidiary regulations) relating to land occupation and tenure, physical planning, development control, and environmental protection—Ministry of Environment, Lands and Agriculture Development (MELAD).

What is missing is an institutional and organizational framework for reaching agreement with all involved parties, and especially with the communities involved-both those that are on the land illegally, and those who have an interest in the land-as to a way forward that will ensure a clean water supply for all of South Tarawa's communities.

Reasons for public participation and community engagement. The importance of public participation in environmental management and planning has been well accepted internationally for at least 40 years. The reasons are:

- **The opportunity to make better decisions**, by opening up the decision-making process to a wide set of people with expertise that includes local experience, traditional knowledge, and various forms of technical knowledge.
- **Better public acceptance of and compliance with the decisions made**, because people have the opportunity to be heard, and are included in the decision-making process.
- **Social justice**—the principle that those who will be affected by a decision deserve to have input into it.

In addition, **community engagement enables the public to go beyond participation in a decision and become motivated to support a new perspective or issue,** and take appropriate actions themselves. When people are motivated to change their own practices, they can often achieve far more than is possible through legislation, policies, or programs alone.

Public Participation and Community Engagement

There is a large body of international experience on good processes for public participation and community engagement, notably Ross, Powell and Hoverman 2008. It is particularly important that the processes are well designed, and that they include genuine intent to listen to the public and take their advice. Key recommendations include:

- **Be inclusive.** The processes should be open to all relevant members of society, including women, all age sets, and minorities. They should be comfortable for the people involved. They should suit their cultures, languages, and convenience, and be held in locations where they feel at ease to speak freely.
- **Balance differences in power** as much as possible through preparation of the parties, providing the disadvantaged with appropriate resources, and facilitating discussions that encourage the less advantaged to speak out.
- **Allow enough time** for the process, so that all can be reached, and heard. People may need extra time, and repeated visits, to understand complex issues.
- **Provide facilitation**. A neutral facilitator, or a team of facilitators, who can combine process skills with knowledge of the issue, can be helpful in the process.
- **Build capacity.** Some, or all, of the parties may need assistance in order to participate effectively, through preparatory briefing and discussion.
- **Identify the benefits. I**t is important to consider each participant's perspective: Why should they participate? How can they gain from having a say?
- **Commit sufficient resources** to conduct the process well, and enable people to participate (for example, by providing travel costs and/or replaced wages).

Practitioners generally agree that there is no single "recipe" for a good participation process: it is best to customize the process according to local circumstances. It is particularly useful to seek and accept local advice while designing the process.

Sustainable Management Plans

Sustainable Management Plans for the Buota and Bonriki water reserves are expected to:

- Be **formal agreements** that are signed by all stakeholders that have the powers and responsibilities defined in the agreements;
- Be prepared through a **public participation and community engagement approach** that adopts principles and processes that are formally agreed upon by the stakeholders in advance;
- Be customized to take into account the different circumstances on the two water reserves;
- **Be facilitated** by one or more facilitators, either jointly for both water reserves, or with separate facilitators, one for each of the two SMPs;

Structure and content. The structure and content of the SMPs is expected to be as a brief, concise, and easy to understand as possible, and may contain:

- Vision and objectives;
- Governance arrangements (strategic direction and executive decision making);
- Organizational arrangements: day-to-day administrative support to the executive, and to the facilitator(s), including for the management of financial resources;

- Agreements and arrangements relating to: (1) households on the water reserves; (2) the Bonriki and Buota communities; and (3) the South Tarawa (and possibly North Tarawa) communities;
- Actions to restrict access to the water reserves;
- Actions to optimize water resources;
- Sustainable land use (prohibited, permitted, and development control).

Governance arrangements. Governance arrangements are arrangements that will provide for executive decisions regarding preparation and implementation of the Buota and Bonriki SMPs. Executive decisions include those that involve strategic direction, as well as decisions involving, for example, SMP annual budgets, and performance and actions involving government policy, laws, or regulations. It is expected that the SMPs will include terms of reference that detail the governance arrangements. Representation in the executive body may include members of parliament and local government councillors representing South Tarawa, Buota, and Bonriki; key government representatives (from PUB, MELAD, MISE, and the Attorney General's office); and traditional community representatives (Unimwane), as well as representatives of women and youth.

Management arrangements. Management arrangements will provide first for the preparation of the two SMPs, and within the SMPs, for the subsequent implementation of the agreements reached in them. It is expected that the preparation phase will take 1-2 years, and will involve employing one or more facilitators who will have primary responsibility; will provide critical continuity and support for independence; and will be supported administratively by a small unit attached to the Office of the President.

The **preparation phase** will be divided into three parts:

- Initial discussions and agreements;
- Agreement resulting in a roadmap on directions and actions;
- Preparation of SMPs for the Buota and Bonriki water reserves.

Facilitator training. The key qualities of the facilitator(s) employed to develop the SMPs are that they will be seen as neutral by the stakeholders, and will have a reputation for good judgment and communication. It ***not*** expected that they will have previously completed a similar public participation and community engagement process successfully. For this reason, it is expected that: (1) they will require training in preparing community-based action plans; and (2) they will have input into the process of developing the roadmap.

Examples of SMP preparation. A number of published guidelines provide toolkits for community engagement and public participation in the development of integrated water resource management plans that are relevant in the case of Kiribati. The processes suggested in the guidelines are outlined in table D.5.

SMP implementation costs. Estimates for various SMP options are provided in table D.6.

TABLE D.5. Toolkits for Community Engagement: Content

Toward Whole of Community Engagement: A Practical Toolkit (Australian Government)	Integrated Water Resources Management: Planning Approach for Small Island Developing Nations (United Nations Environmental Program, UNEP)
Starting Up	**Pillars**
What does good community engagement mean?	The planning cycle
Who is involved? Stakeholders, communities & others	Stakeholder participation and dialogue
Difference between engagement & consultation?	**Planning cycle**
Knowledge systems and communication strategies	**Step 1. Diagnostics to determine entry point**
Community decision makers and stakeholders	Identify the entry point and lead agency; carry out stakeholder analysis; establish means of coordination and facilitation; carry out situation analysis (economic, environmental, and social (including gender, poverty).
The community engagement process	
Values, principles, and criteria	
Selecting Tools and Techniques	**Step 2. Visioning**
General public involvement and participation tools	Problem tree analysis, objective tree analysis
Negotiation and conflict resolution tools	**Step 3. Strategizing**
Information, education, and extension tools	Scenario development—selection of sustainable management plan options (framework identification, content identification, strategy preparation)
Rapid and participatory rural appraisal tools	
Stakeholder analysis and social profiling tools	**Step 4 Planning**
Survey and interview tools	Plan preparation, action plan and budget, responsibility matrix, scheduling, setting and measuring performance targets and indicators.
Planning and visioning tools	
Team building and leadership tools	**Step 4. Implementation**
Participatory action research tools	Administrative and financial arrangements (annual work plans and budgets, reporting, recordkeeping, procurement, budgeting and expenditure), adoption of policy, laws and regulations, capacity development.
Deliberative democracy tools	
Lobbying and campaigning tools	
Participatory M&E tools	**Step 6. Monitoring, Evaluation and Documentation**
	Data collection and monitoring, reporting. Documenting lessons learned.

TABLE D.6. Matrix of Options with Cost Estimates

No.		Lead Government Agencies	Community consultation—Preparation	Community participation—implementation	Initial Costs (AUD)[a]	Annual Costs (AUD) — operational	Revenues generated
1	Immediate Actions, Education, Awareness and Behavior Change						
1.1	Remedial actions to protect the lens	PUB/MISE	Yes	Preferable	100,000	10,000	Possible but limited in amount
1.2	Increasing water capacity of the Bonriki reserve		Yes	Essential	2,500,000[b]	TBD	
1.3	Barriers to access the water reserves	PUB/MELAD/ Attorney General	Yes	Preferable	50,000	TBD	
1.4	Prevent vandalism		Yes	Essential	Include in 1.5	TBD	No
1.5	Education, awareness raising, public relations & behavior change		Yes	Essential	200,000 over 1st 5 years		
2	Medium and Long-Term Land Use						

table continues next page

TABLE D.6. continued

No.		Lead Government Agencies	Community consultation—Preparation	Community participation—implementation	Initial Costs (AUD)[a]	Annual Costs (AUD) — operational	Revenues generated
2.1	Land use planning (to develop planning policies, strategies, and regulation)	MELAD/Local Government	Yes	Essential	50,000	Not applicable	High potential (Bonriki only)
2.2	Development control		Yes	Preferable	See 2.1	25,000	Limited potential
3	Management and Governance						
3.1	Implement Sustainable Management Plan—Bonriki	New institution	Yes	Essential	100,000	Revenues to pay costs	High potential
3.2	Implement Sustainable Management Plan—Buota		Yes	Essential	100,000		Limited potential
4	Policies, Laws, Regulations, Revenues, and Costs						
4.1	Policies, laws, and regulations	PUB, MISE, MELAD, Attorney General + new institution	Yes	Limited	50,000	Not applicable	
4.2	Revenues and costs		Yes	Preferable	50,000	As above	

a. Initial and annual costs are indicative, and assume that an initial five-year budget of approximately $A500,000 is available for initial (preparation) costs.
b. Source: ADB 2011. (Note: It is assumed that this activity will not be implemented, since the estimated costs are greater than the potential benefits.)

Notes

1. Traditionally, resources under and on the land, such as water and coconut trees, are owned by the landowner as part of the land. This customary ownership can be in conflict with the approach taken in states governed by laws that reserve certain natural resources, both below and above ground, to the State.
2. Bonriki - Temaiku Consultations. South Tarawa Sanitation Improvement Sector Project Quarterly Report No. 1. January 2013. Snowy Mountains Engineering Corporation.
3. In the Bonriki water reserve, the potential to harvest coconuts, toddy, and *babwai* on the reserves has mostly or even completely disappeared. Many residents believe this is because of excessive extraction of freshwater.
4. At the end of 2014 the total annual payment to Buota and Bonriki landowners was around $A1 million.
5. Politicians (cabinet, ministers, members of parliament) and civil servants.
6. Key stakeholders may include: households on the reserves, the Buota community, the Bonriki community, the South Tarawa community, PUB/MELAD, local and national political representatives, and others (representatives of airport, etc.).
7. "Red lines" may include specific aspects of government policies as well as the provisions mandated by laws and regulations. The government will need to identify which are nonnegotiable, and which may involve flexibility. Resolution of these concerns should not delay the start of consultations; but the final agreement will need the support of all stakeholders.
8. To be defined.
9. Access is required for operation and maintenance of the water galleries, water treatment works, and for policing of the site and maintenance of site protection works.
10. A theoretical argument for the management of common resources may be found in Ostrom (2009).

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