Upton House
Market Street
Charlbury
Oxfordshire, OX7 3PJ
United Kingdom
tel +44 (0)1608 810374
fax +44 (0)1608 810093
e-mail info@gwp.uk.com
www.gwp.uk.com

SOUTH TARAWA, RAINWATER HARVESTING ASSESSMENT

For

GOVERNMENT OF KIRIBATI

FINAL

November 2010

GWP Consultants LLP
Registered No. OC326183
Registered Office: Upton House, Market Street, Charlbury, Oxfordshire, OX7 3PJ, UK

Report Title: **South Tarawa, Rainwater Harvesting Assessment**

Client: **Government of Kiribati**

Job: KIRI

Report Number: 101104

Version: v.01

Issue Status: Final

Issue Date: 19th November 2010

Prepared by: John Sutton

Approved by: Clive Carpenter Date: 19/11/10 Signature:

Issue History:

Issue No.	Issue Date	Description	Prepared by	Approved by
v.01	19/11/10	South Tarawa Rainwater Harvesting	John Sutton	Clive Carpenter

This document is based on GWP report template v1.00 and Normal template v2.03 19/08/10

CONTENTS

TABLES

APPENDICES

SOUTH TARAWA, RAINWATER HARVESTING ASSESSMENT

1. INTRODUCTION

In Kiribati, freshwater is a precious and finite resource critically impacted by climate variability and climate change. In Tarawa, in recent times, especially in urban areas, population pressure due to inward migration and natural population growth has stimulated contamination of local groundwater sources, causing an increase in water-borne diseases and forcing households to rely on water delivered from government managed water supply schemes pumped from distant, safer groundwater sources. The reticulated supply system in South Tarawa is only able to supply water to houses intermittently and consequently total daily water consumption is often provided by multiple water sources.

Rainwater harvesting, if provided and managed effectively can offer a safe, sustainable and reliable source of fresh water for private households drinking and cooking requirements. It is, comparatively, an expensive source of water (White and Falkland, 2009), due to installation and maintenance costs, as such where cheaper (but perhaps more likely contaminated) water sources are available, such as domestic wells in South Tarawa, collected rainwater is more effectively used solely for drinking and cooking (*e.g.* 5 L/pers/day).

Priority water resources issues recognised in the National Water Resources Policy (MPWU, 2008) are listed below:

1. The high rate of preventable deaths and illnesses due to water-borne diseases;
2. Contamination of fresh groundwater sources by human settlements and sanitation;
3. Impacts of climate variability and change on the availability of fresh water;
4. Difficulties in protecting, conserving and managing freshwater sources;
5. Growth in demand for water especially in urban areas;
6. Inequities in provision of services to schools, hospitals, clinics, rural, outer island and urban communities;
7. Limited collection and use of rainwater;
8. Large unaccounted for losses and leakages in water reticulation systems;
9. Financially and hydrologically unsustainable water supply systems;
10. Constraints on development due to limited water supplies;
11. Inadequate knowledge and monitoring of the nation's freshwater resources;
12. Decrease in the number of trained water specialists and technicians;
13. Limited community participation in freshwater management and conservation;
14. Limited community understanding of responsible water use and protection; and
15. A need for enhanced water education in schools.

The growing impacts of human settlements and those of climate variability and change on freshwater resources and the linkage between development, poverty alleviation and water availability require a commitment by the community and continued determination and leadership by the national government to protect and use wisely the nation's scarce water resources.

As well as augmenting household water supply, by strategically providing communal freshwater through rainwater harvesting, a safe, reliable, and sustainable water supply is available either for regulated 'normal' use or for use as a 'reserve' supply during drought conditions. Rainwater harvesting can be an effective communal resource, but only if a commitment and 'ownership' is in place: the water resource can be under the direct control of the community and therefore water use can be regulated, maintenance can be carried out systematically, to limit the risk of contamination, and conservation messages are clearly signalled by the decreasing volume of water in the storage tank.

1.1 Scope of assessment

This rainwater harvesting assessment has been produced under the Kiribati Adaptation Programme, phase II (KAP II) under the component FS07, *Improving the sustainability and supply of freshwater*.

This assessment has been designed to review the current rainwater harvesting facilities and practises on South Tarawa, including private, community and government buildings, and assess their effectiveness, appropriateness and sustainability.

Examples of good and poor rainwater harvesting practises in South Tarawa will be considered and recommendations made in terms of design, cost, availability of materials, durability, and practicality. Consequently the specific constraints to rainwater harvesting in Tarawa shall be evaluated which can guide further KAP II project phases – South Tarawa communal rainwater harvesting design and construction works; Kiribati building code review (with respect to rainwater harvesting); and production of Kiribati specific rainwater harvesting guidelines.

A brief review of the literature is included to ensure that work previously completed (particularly within the KAP II project itself) is not duplicated.

1.2 Rainwater harvesting in Tarawa, background

This brief review of the literature highlights the key themes, relating to rainwater harvesting, previously undertaken in Kiribati, and Tarawa more specifically.

Table 1: Summary of key advantages and disadvantages (After SOPAC, 2004)

Advantages	Disadvantages
Convenience Provides a supply at the point of consumption. **Low running costs** Almost negligible. **Relatively good water quality** Better than traditional sources, particularly if roofs are used for the catchment. **Low environmental impact** Rainwater is a renewable and sustainable resource – no damage is done to the environment or future supplies through its introduction. **Ubiquitous supply** Rainwater collection is always a water-supply alternative wherever rain falls. **Simple construction** The construction of rainwater catchment systems is simple and local people can easily be trained to build these themselves. This reduces cost and encourages community participation. **Flexible technology** Systems can be built to almost any requirement. Poor households can start with a single small tank and add more when they can afford it.	**Expensive** When compared with alternative water sources, where these are available, the cost per litre of rainwater is frequently higher. **Supply is limited** Both the amount of rainfall and size of catchment area. **High initial costs** The main cost of rainwater catchment systems is almost wholly incurred during the initial construction **Unattractive to policy makers** Widespread rainwater projects are invariably more cumbersome to administer than single large projects, *e.g.* a dam. **Supply is susceptible to droughts** Occurrence of long dry spells and droughts will adversely affect the performance of rainwater harvesting systems **Water quality vulnerable** The quality of rainwater may be affected by air pollution in the vicinity of certain industries. Contamination from animal and bird droppings, insects, dirt and organic matter can also be a problem. Avoiding contamination requires regular inspection and maintenance.

In Kiribati, most rainwater collection systems are located at private houses, but there are also some larger systems which collect rainwater from communal buildings. Falkland (2005) suggests that rainwater collection from roofs should be regarded as a source of high quality supplementary freshwater, rather than the main source of freshwater. Reasoning that, due to the variability in rainfall across Kiribati, the use of rainfall for all freshwater needs would require construction of very large storage facilities when compared with utilising the naturally occurring (on most islands) freshwater lens which have much larger storage capacities, and cost nothing to construct.

Having said this, it is recognised, and PUB actively encourage (PUB, 2004), maximising the use of rainwater due to the limited public water supply which is dependent on the Bonriki and Buota freshwater lenses. Additionally, in South Tarawa, the high population density that prevails increases the risk of contamination of local groundwater.

Increasingly, in South Tarawa, there is scope for expanding rainwater harvesting at both the household and community level as the number of 'permanent' (as opposed to thatch) roofs in South Tarawa is increasing. Interestingly the Kiribati Housing Corporation is currently upgrading a number of houses, which originally had thatch roofs, with galvanised iron sheet roofs, presumably with the intention of replacing all thatch roofs.

As an indication of current interest in private rainwater systems, Falkland (2005) states that 710 loans for household rainwater tanks and associated gutters and downpipes were arranged through the Kiribati Housing Corporation for people on South Tarawa in the years 2002-2004. These loans are provided from a revolving fund and repayments are made over a period of 1-2 years depending on household income. The maximum loan amount is A$1,500. Another (albeit less direct) indication of the current interest in private rainwater systems is that two manufacturers of polyethylene rotational moulded tanks (will be abbreviated to 'polytank' for the remainder of this report) have set up in Tarawa, this suggests there is a viable market to sustain these enterprises - it is however noted that a proportion of their contracts may be with large aid funded projects. As a result, due to reduced transport costs, the cost for procurement of polytanks has recently reduced.

In 2005, the Water Resources Investments Report (Falkland, 2005), which was prepared in preparation for KAP II, three of the points of focus with respect to the expansion of rainwater harvesting were as follows:

i Review the existing legislation requiring new buildings to be fitted with rainwater storages and, if necessary, update. The legislation should in future be enforced, particularly for new houses and buildings.

ii Update the Kiribati Building Code to reflect Kiribati rainfall conditions. The requirements for storage should be based on simulation of rainwater collection systems using data on roof area, volume of tank, expected demand and probability of failure.

iii Implement rainwater harvesting systems at large government / community buildings with 'permanent roofs' on South Tarawa and outer islands through a combination of government and possible donor funds.

By reviewing the current state of rainwater harvesting in Tarawa, this report aims to provide the basis for implementing these three points of focus under component FS07 of KAP II.

The Water Master Plan for Tarawa (White and Falkland, 2009) which was produced under KAP II focuses on the potential role of rainwater harvesting as a water resource in Tarawa, notably it further recognises the need for a review of the national building code and its enforcement, as well as the legal requirements for rainwater harvesting in the Council Bye-Laws. Additionally, through a detailed analysis using monthly and daily water balance models, it is concluded that, in South Tarawa for the average household size, and for reasonable roof areas and storage volumes, rainwater harvesting is only capable of providing a relatively modest 5 L/pers/day without risk of excessive rain tank failures. This supports the previous suggestion that rainwater harvesting is most useful as a supplementary water source in Tarawa.

The report also provides a discussion of the historic use of rainwater harvesting in Tarawa, and detailed analysis of monthly and annual historic and projected rainfall variability, and spatial distribution. Additionally, see NIWA (2008) for a detailed analysis of rainfall intensity and drought and their respective probability of occurrence (frequency and duration), as well as a discussion of future climate change scenarios for Kiribati and their impacts on rainfall intensity and drought.

1.3 Data and information sources

To guide this assessment data and information has been gathered from a variety of sources. Namely from the Government of Kiribati - the Ministry of Public Works and Utilities (MPWU) specifically the Water Engineering Unit (WEU) and the Kiribati Meteorological Service (KMS) – but also from external sources - such as SOPAC and other consultants to the Government of Kiribati (*e.g.* NIWA). Additionally formal and informal discussions with other relevant parties have informed this report, including advisors to the Government of Tuvalu, the owners of business on Tarawa (including the construction and tourism industry), Tarawa based NGOs, administrators of government buildings, and most importantly householders. We acknowledge the input from all these relevant parties.

2. GENERAL ASSESSMENT

A detailed general assessment of rainwater harvesting systems in Tarawa was conducted in country. This involved a specific field survey covering the length of South Tarawa, from Bikenibeu to Betio, looking out for good and poor rainwater harvesting practises (See Appendix 1 for an inventory of photographs of rainwater harvesting systems in South Tarawa), and discussing rainwater harvesting with I-Kiribati members of the various communities in South Tarawa. Additionally time was spent with many I-Kiribati (community members, government workers, and members of the construction and tourist industries) and ex-patriots discussing rainwater harvesting issues and solutions specific to Tarawa.

Given that droughts are frequent in Tarawa, that many households have galvanised iron roofs (particularly in urban South Tarawa), and the public water supply is intermittent, the percentage of households with working rainwater harvesting systems is low. In 2000 the Asian Development Bank (ADB, 2000; cited in Falkland, 2009) conducted a survey of rainwater harvesting facilities, and only 28% of households in South Tarawa had working rainwater harvesting systems. Judging by a ‘walkover’ assessment, this figure has not greatly increased in the last decade. And of the systems observed very few are efficient at collecting and storing water, often the collection system is a temporary structure constructed from scavenged materials.

Government buildings such as schools, clinics, hospitals, and ministries generally have rainwater harvesting systems which are in varying states of repair, generally dependent on the age of the building (which suggest poor maintenance). Furthermore, unless a specific use is determined for the collected rainwater and a supply system is implemented, the collected water often runs to waste *via* overflows as it is not used. Reticulated supply systems have been installed in some locations, but it was found that these systems are poorly designed and the flows provided are low, or they are poorly maintained.

The majority of communal buildings visited with permanent roofs (such as church maneabas) had some simple form of rainwater collection and storage, but the collection and storage was poorly maintained and often inadequate for the number of users.

2.1 Catchment

According to the ADB (2000), 60% of houses surveyed had metal roofs suitable as rainwater catchments. Through unsystematic observation only, it is suggested that the percentage of roofs suitable for collecting rainwater is increasing. Our observations in the urban areas of Betio Bairiki and Bikenibeu suggest that ‘permanent’ roof structures appropriate for rain collection are found on more than 90% of buildings. Corrugated galvanised mild steel sheet is ‘cold rolled’ in country and is widely available in Tarawa. This galvanised steel sheet roofing of varying quality makes up the majority of roof catchments suitable for rainwater harvesting (see Appendix 1).

Good quality imported (from Australia, New Zealand or Fiji) zincalume® galvanised steel roofing is used on a small number of the more modern public buildings and private buildings (see plates A1.1.17, A1.2.1, A1.4.2) such as ex-patriot homes and the Moroni churches and buildings. It has a far longer lifespan (3-4 times). The cost of zincalume sheet is around A$25-30 (per m^2), compared with A$5-10 (per m^2) for cheaper galvanised steel (often also imported from China, see plate A1.1.4, as well as rolled in country).

Roofing materials will vary dependent on the construction budget, however it is very unlikely (and was not observed during surveys) that households or community buildings will be able to afford roof upgrades using zincalume® sheet, without significant contributions from external sources.

2.2 Collection (guttering)

Guttering systems were often found to be in a poor state. To provide good rain water collection gutters require a fall (of at least 1 in 500) towards a downpipe; leak proof joins between lengths; they need to be well supported (firmly attached to the fascia board or roofing sheet); they need to be free of debris (requiring regular cleaning – and preferably easy access); rust (or corrosion) free; and securely connected (watertight) to a downpipe. Often rainwater collection systems in South Tarawa would not meet one of these criteria, thus rendering the system much less efficient.

Guttering in South Tarawa, particularly on low maneaba roofs, is particularly vulnerable to disturbance. As such (through discussions with various stakeholders) it is recommended that when the manufacturer of a gutter specifies the distance between gutter brackets (or clips), that this distance is halved, thus the number of brackets is doubled.

There are 4 main types of guttering used in South Tarawa: split PVC pipe, PVC, galvanised steel, and zincalume®.

2.2.1 Split PVC pipe

PVC pipe is cheap and relatively easy to procure in South Tarawa. It is split along one side and affixed using metal straps to the corrugated roof sheets to channel water to a transmission pipe (see plates A1.1.2, A1.1.9). PVC pipe costs A$10-15 per metre depending on diameter and pressure rating.

The installation of these gutters is very simple however it is difficult to maintain a fall on the gutter towards downpipes, and to clear the gutters out would require removing the pipe entirely from the roof, cleaning and replacing. This poses difficulties, as gutters should be regularly cleared when used for rainwater harvesting. As it is a cheap and easy to install option, it is a useful method for householders to collect rainwater; its use should not be widely advocated though.

2.2.2 PVC

PVC guttering is cheap but is not readily available in South Tarawa (see plates A1.1.6, A1.1.8, A1.1.12). PVC guttering comes in set lengths which can be cut to fit and is fitted to fascia board with specific brackets which are also PVC, all connections are made with solvent primer and cement. End pieces, corner pieces and gutter outlets can be procured to fit various shaped roofs and transmission systems.

PVC guttering tends to be not wholly UV resistant thus has a relatively short lifespan (5-15 years) as gutter lengths and brackets can become brittle. It is however widely used in Tarawa, and the pacific more generally, as it is cheap at A$5-10 per meter (including fittings).

Often PVC guttering has a smaller cross-section so is particularly applicable to smaller buildings such as private households, primarily due to cost.

2.2.3 Galvanised steel

Galvanised steel guttering (see plates A1.1.1, A1.1.4, A1.1.7, A1.1.10, A1.1.13) is not readily available in south Tarawa and gutter lengths and fittings can be imported. Galvanised steel sheet is available in South Tarawa and thus it is often bent to create makeshift gutters. These are seen quite widely and are often poorly joined due to the uneven cross-section created. The gutter lengths require joining by riveting which requires specific tools and skills to install guttering to a high standard.

One particular problem with installing metal gutters is galvanic corrosion or galvanic action, which occurs *via* electrochemical processes through water, consequently drainage infrastructure is particularly susceptible. Direct contact is not necessary and water draining from one metal surface onto another may produce galvanic corrosion capable of ruining the integrity of a drainage surface. As such it is best to completely avoid using a metal where there is potential for galvanic corrosion (see Table 2). Generally, the use of stainless steel, brass, bronze, copper, lead and zinc should be avoided when constructing guttering or drainage systems with galvanised steel. Aluminium can be used for roof sheeting (*e.g.* it is used widely in Banaba) but there is little potential for galvanic action between aluminium and galvanised steel, and therefore this is not an issue.

Specially designed and procured galvanised steel gutters can be used to collect rainwater from very large roof catchment areas (see plates A1.1.18, A1.1.20) without necessitating a large number of downpipes. Generally this will be designed into building construction and is not suitable for retrofitting rainwater harvesting systems.

Table 2: Matrix of potential for galvanic action between common construction metals

	Aluminium	Brass	Bronze	Copper	Galvanised steel	Iron/steel	Lead	Stainless steel	Zinc
Aluminium		3	3	3	1	2	2	1	1
Copper	3	2	2		2	3	2	3	3
Galvanised steel	1	2	2	2		1	1	2	1
Lead	2	2	2	2	1	1		2	1
Stainless steel	1	3	3	3	2	2	2		3
Zinc	1	3	3	3	1	3	1	3	

1. Galvanic action will occur
2. Galvanic action may occur
3. Galvanic action is insignificant between these two metals

2.2.4 Zincalume®

Zincalume® guttering can be imported to South Tarawa (see plates A1.1.3, A1.1.11, A1.1.15). Generally it has a relatively small cross-section and thus requires downpipes at regular intervals. The gutter lengths are joined by rivets and corner pieces and gutter outlets can be procured to meet any design. The gutters are fastened to fascia boards with brackets specific for each gutter design supplied by the gutter manufacturer. This increases the durability and strength of the guttering and reduces the potential for galvanic action. Zincalume® gutter provides the best solution but will not always be applicable due to the greater cost, at approximately A$10-15 per meter (including fittings).

Zincalume® gutter designs often have a higher outer wall to reduce splash losses and can have an overflow slot to direct water away from the fascia board and building interior during a very intense storm event.

2.3 Transmission (downpipes)

In South Tarawa, smaller buildings tend to have downpipes above ground which are directly linked to tank and the water flows from the gutter to the storage tank *via* gravity. Better designed, larger systems tend to have underground transmission pipes (see plate A1.1.11) where flows from gutter to tank are under pressure but driven by gravity (as a result of a difference in hydraulic head). Generally PVC is ubiquitous as the material for water transmission – it is easy to work with and durable. Painting PVC may extend its lifetime by reducing is susceptibility to UV damage.

2.3.1 Above ground downpipes

These systems are suitable for small rainwater collection systems. However it is necessary to fully support any pipework, preferably using brackets against the building wall (see plate A1.2.1, A1.3.8). This was observed as a very common component to cause failure in rainwater harvesting systems in South Tarawa, particularly when downpipes are 'hanging' suspended between gutter and tank (see plates A1.1.4, A1.1.7, A1.1.8, A1.1.10). Reinforcing this, many discussions held with 'experts' as well as members of the I-Kiribati public identified proper downpipe support as the crux of rainwater harvesting systems. As such, wherever practicable, underground transmission pipes should be considered, as this issue is thus removed from the system.

2.3.2 Underground transmission pipes

This setup reduces the chance for failure due to breaking or removal of transmission pipes by human or animal activity, or wind. However, between storm events water is stored in the underground transmission pipes and stagnation can occur when long periods elapse between storm events. It is very important that these pipes are joined (using PVC primer and cement) without leaks as the water will be transmitted under pressure. Trenching pipes creates additional work, but ensures transmission pipes can not be interfered with, a common cause of system failure (see plates A1.1.22, A1.1.21, A1.3.3).

2.4 First flush mechanisms or filter screens

Contaminants such as debris, leaves, dirt (including bird faeces) and dust collect on roofs during dry periods and during the initial period of rainfall this material is washed into the storage tank. Following this initial 'fist flush' of contaminants the water collected is much cleaner and safer to drink.

Our observations provided little evidence that first flush systems are used on rainwater harvesting systems in Kiribati. Only one manually operated downpipe first flush system was observed during the assessment (see plate A1.2.1) on South Tarawa. This system stores the initial 'flush' in an excess section of vertical downpipe, which can be emptied between storms by removing the PVC end cap.

This manual system is ideally suited to Kiribati as it has few or no moving or mechanical parts. Automated systems require maintenance, and in practise often create problems and can be a 'weak link' in the water collection system. SOPAC (2004) recommends that very simple first flush mechanisms are used on Pacific Islands. It is far more important that a system works during rainfall events than the first flush is removed.

Furthermore, from observations, seemingly there are few birds on South Tarawa and limited air pollution, which may be the underlying reason for the lack of first flush devices (as if water quality suffered this would be realised by the public). However, in discussions with MPWU staff and householders, it became apparent that after sustained dry periods dust accumulates on roof catchment areas and collected rainwater can be discoloured after the first rainfall event.

Instead of automated first flush mechanisms which divert a percentage of water away from the storage tank, manual systems which direct the initial rainfall event of the 'wet season' or 'wet period' should be employed. Thus after long dry spells, a single rainfall event can be manually directed away from the storage tank and subsequent storms can provide the harvested rainwater.

If a percentage of water were diverted to losses during every storm event significant quantities of water can be lost and this practise is often impractical when large catchments are involved (*i.e.* maneaba roofs).

Organic pollution of rainwater tanks (caused when leaf litter collects in gutters – see plate A1.1.12) is probably the most common form of contamination of rainwater harvesting systems in Tarawa. There is no simple solution to negate this apart from regular clearing of gutters and roofs and trimming overhanging vegetation. Leaf screens (see plates A1.2.2. A1.2.3) are useful in this respect but still need clearing. Self-cleaning screens should be trialled in Tarawa, however, regular gutter cleaning is still essential.

2.5 Storage

There are a variety of different storage tank types. Again due to lack of maintenance, in Tarawa it is suggested that water, where possible, is stored above ground. Underground tanks require pumps to lift the water which require skilled and regular maintenance. Additionally, it is difficult to detect leaks in underground storage tanks and there is a risk of groundwater ingress and associated contamination of the water source. Where possible tanks should make use of gravitational potential energy and be situated in an elevated position below gutters (see plate A1.3.8).

Table 3 compares a range of tanks types, their cost, potential lifespan and other issues associated with their construction or installation.

Table 3: Comparison of different storage tank types

Tank type	Indicative price	Maximum capacity	Life expectancy	Notes
Ferro-cement	A\$2000* for 10m^3	150m^3	40 years**	Very variable build quality depending on contractors experience and materials. Fairly skilled contractor required. Coral sands not ideal for concrete construction. Large sizes require welded mesh or bar and roof supports. Minimum 8 days for installation – labour intensive. (see plates A1.3.3, A1.3.7)
Reinforced concrete	A\$3000* for 10m^3	No limit	50 years**	Can be pre-fabricated or cast on site. Requires an experienced contractor. No upper limit on size, but may require heavy plant during construction. Maintenance and lining can increase lifetime significantly. (see plate A1.3.7)
Galvanised steel	A\$700 for 10m^3	50m^3	20 years**	Lifespan can be less than 2 years in particularly corrosive environment, such as Kiribati. Galvanised steel tanks should be painted inside and out.

Tank type	Indicative price	Maximum capacity	Life expectancy	Notes
Polytank	A$1500 for 10m^3	50m^3	25 years**	Resilient to transport - particularly for shipping to Outer Islands. UV resistance and thus lifespan is improving. Supplying shade with a roof can prolong life to 20+ years. No joints, lightweight and non-toxic food grade plastic. Complete with inlet, outlet and overflow fittings. Currently 2 No. polytank Manufacturers in Tarawa. Can be 'stacked' to reduce transport costs. (see plates A1.3.1,A1.3.4, A1.3.6, A1.3.8, A1.4.1, A1.4.2)
Bladder	A$4000 for 9m^3	10m^3	25 years**	Bladder tanks can be used in varying spaces.
Fibreglass	A$1800 for 10m^3	20m^3	25 years**	High shipping costs due to fragility. Can permit UV penetration. Complete with outlet, inlet and overflow connections. (see plate A1.3.5)
Brick and blockwork	A$1300* for 10m^3	175m^3	20 years**	Constructed on site usually using local skills and materials. Uses more cement than equivalent sized ferro-cement tank, but a simpler build.
Wooden	A$3000* for 10m^3	100m^3	Tank: 80 years Liner: 20 years	Constructed on site, can use local labour. Large tanks can be constructed in almost any location due to lightweight parts. Concrete ring beam foundation required. Requires mobilisation of a specialist, experienced contractor.

** Indicative costs dependent on labour costs*
*** If well constructed and well maintained*
N.B. Prices are indicative and based on estimates, not including ground investigation or support structures. Site specifics must be investigated, including materials and contractors transport and mobilisation.

Seemingly there is a trend towards the use of polytanks in Tarawa. This is possibly due to recent developments in technology increasing the lifetime of polytanks but also because of their flexibility, cost, and ease of transport. To increase the lifetime of polytanks it is recommended that a simple low cost roof is provided to protect the tanks from UV deterioration.

Tank-banks can be constructed by joining multiple polytanks with equalising pipes at their base (see plate A1.3.2). Appropriate fittings should be used for this and it must be possible to isolate each tank for maintenance (through brass ball valves – plastic fittings tend to become brittle and fail when exposed to corrosive atmospheric conditions or direct sunlight), and so that the whole system is not compromised in the event of a tank or tap leaking, or even a tap being left on.

2.6 Supply

Discussions and observations informed that supply taps can be of poor quality, often leaking, or left on by users, often too low to fill a water container, and without a splash protection slab beneath the supply point. Good quality, imported, quarter turn or push-flow taps to should be supplied to ensure reasonable lifetimes. Taps should be replaced when necessary, this requires isolating tanks as previously discussed.

Supply points should be fenced off to protect the taps from roaming animals and taps should be 0.4m above a concrete slab for ease of use.

2.7 Overflow

All rainwater storage tanks should be provided with an overflow to prevent water backing up into the collection system. Overflows should be flapped or screened to prevent mosquito or rodent entry. Additionally overflows should be routed clear of the base of the tank to prevent any subsidence or erosion beneath the tank. Where possible, overflows should be routed to a nearby well to promote recharge the freshwater lens. If a nearby well is not available, a soakaway of nominal volume can be provided. Significant volumes of freshwater can overflow from rainwater harvesting systems when tanks are at capacity. See tables 4-11 for indicative values of mean monthly overflow.

2.8 Other

Limited skilled workforce available.. maintaining and installing pumps . simple systems are good – Hospital rw supply now not working

Need a water use before implementing a system. Even though it is in the building code, this is not good enough, if the water is not used it runs to waste and the system is obsolete and a waste of money. For each new building that is not a private house or building where the use is obvious, a water use needs to be defined otherwise it is a waste of money… (see plate

This cannot be implemented by byelaws or building codes but discussions have shown that many communal or government buildings which are potentially significant water sources are not used. This needs to be addressed before a great deal of money is wasted implementing unused rainwater harvesting schemes on public buildings.

All parts of a rainwater harvesting system require constant surveillance and maintenance. For this reason, rainwater harvesting is ideally suited to household water supply systems, because it is very apparent when a system is not properly functioning. The responsibility for replacing or maintaining parts is solely with the householder.

In community situations, ownership of the system must be promoted and a monitoring and maintenance scheme implemented, roles and responsibilities should be clearly defined to ensure the longevity of a system which is capable of providing a safe and sustainable water source.

3. SPECIFIC RAIN WATER HARVESTING ASSESSMENT AND DESIGN

To provide a more specific assessment at a range of sites and building types, private, public, communal, government at a range of locations 10 No. sites were assessed in detail for their rainwater harvesting potential and current practise. Additionally this detailed assessment was to determine suitable sites for implementing pilot communal rainwater harvesting improvement projects under KAPII. These pilot projects will utilise best practises identified within this assessment. Additionally, by implementing schemes at selected sites, further constraints with respect to procurement and construction of large and medium scale rainwater harvesting systems in Kiribati will be identified. These constraints will assist in developing Kiribati-specific rainwater harvesting guidelines which are also to be produced under KAPII.

3.1 Analysis

3.1.1 *Tank sizing and risk of failure*

To inform the rainwater harvesting potential at the 10 No. sites in South Tarawa a monthly water balance was performed using a spreadsheet (created: White and Falkland, 2009) ‘calculator’ based on equation 1, below:

$$V_t = V_{t-1} + CAP_t - DNd_t \qquad \text{(Eq. 1)}$$

Where V_t is the volume of storage at the end of month t ; V_{t-1} is the volume of storage at the end of the previous month; C is the catchment runoff coefficient; A is the available, guttered, catchment area; P_t is the historic monthly precipitation in Tarawa (Jan 1947 – Dec 2009); D is daily per capita demand (L/pers/day); N is the number of users; and d_t is the number of the days in the month. The required input parameters for calculation are illustrated in Figure 1. This simple spreadsheet calculator (see figure 1) is a useful tool for estimation of storage requirements and risk of failure of rainwater harvesting systems in Tarawa, and has been made available to all MPWU and PUB staff and the construction industry (White and Falkland, 2009).

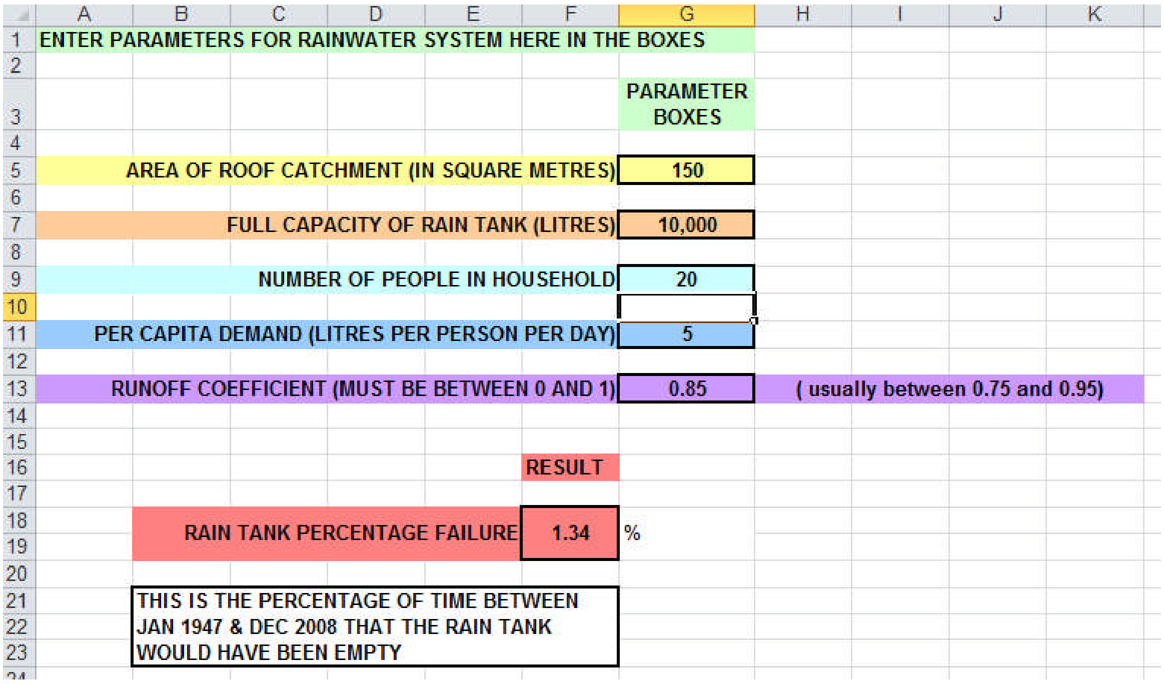

Figure 1. User interface of simple (monthly water balance) rainwater harvesting 'calculator'. Created by White and Falkland (2009).

As the systems are designed as new, 0.85 was used in the runoff coefficient input box, and the per capita demand was entered as 5 L/pers/day for all calculations (the reason for this limited water supply is discussed in section 1). For schools, per capita demand was entered as 0.5L/pers/day to provide drinking water for students unnecessarily large water storage volumes.

This monthly water balance model was tested against a daily water balance model and was found to be in good general agreement (see White and Falkland, 2009 for discussion).

3.1.2 Gutter size Vs number of downpipes

The conveyance of a gutter (its ability to carry water) depends upon the cross-sectional area, the slope, the roughness of the gutter (a nominal coefficient for a smooth gutter surface), and the frequency of downpipes. The frequency of downpipes determines the roof catchment area that is drained by the gutter; as such, by specifying a gutter cross-sectional area, the number of downpipes necessary to can be determined. Using Manning's open channel flow equation (Equation 2) below is used to determine the catchment area (which is drained by each downpipe) for a given gutter cross section, and thus the number of downpipes necessary, as the total roof area is fixed, for each building.

$$Q = A\,R^{2/3} S^{1/2} / n \qquad \text{(Eq. 2)}$$

Where A is the cross-sectional area, R is the hydraulic radius (Wetted perimeter / Area), S is the channel slope, and n is a nominal 'Manning's' roughness coefficient.

Using the rational runoff method, assuming that all rainfall discharges to the gutter, a rainfall intensity is required to estimate the flow in the gutter, and consequently the required cross-sectional area. NIWA (2008) for KAPII produced a future rainfall intensity calculator, which accounts for climate change, and was used to provide the input rainfall. For a mid-range emissions scenario, projected forward to 2050, the 10 minute (duration), 20 year return period rainfall event is 35.4mm, this corresponds to a rainfall intensity of 212.4mm/h. If gutters are sized to accept this event, they will rarely fail, and consequently rainwater harvesting systems will be more efficient. Figure 2 illustrates the required gutter cross-section in mm^2 for the catchment area drained by each downpipe. From this the number of downpipes required at each building (with a known area) is determined.

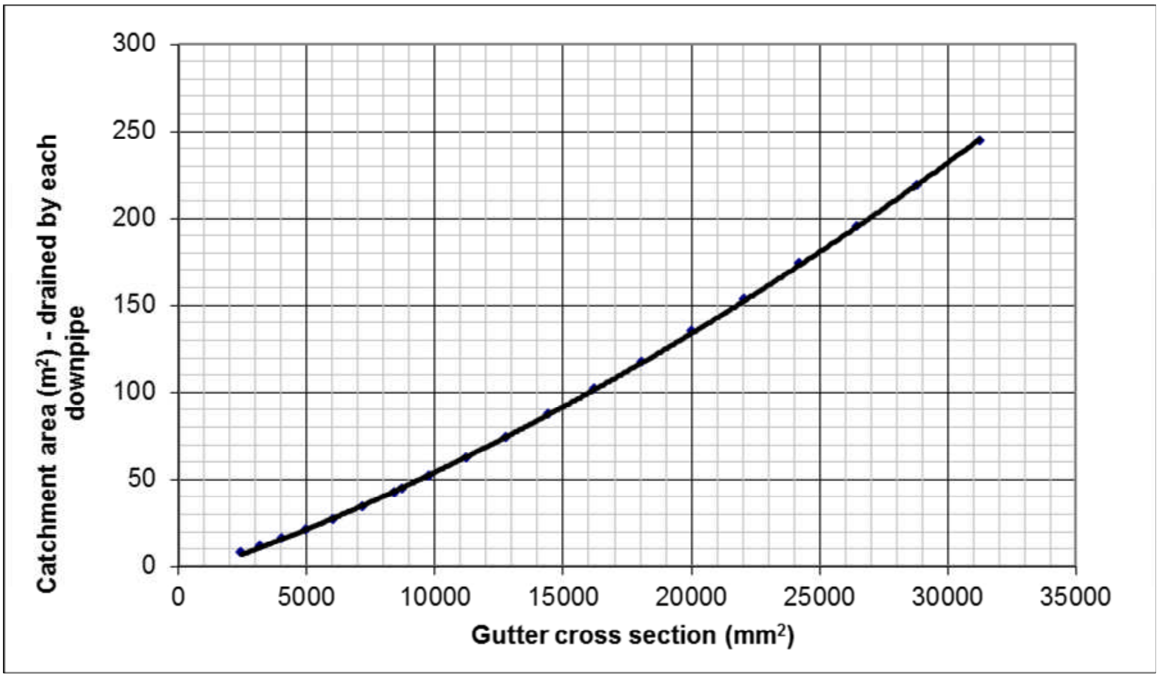

Figure 2: Catchment area drained for a given gutter cross-section (height x width).

3.2 Specific assessments

3.2.1 Abaiang Outer Island maneaba, Betio

See Appendix 2.1 for detailed site assessment details. To provide 5L/pers/day at this site with a limited chance of failure requires re-guttering the whole roof area providing 8 No. new downpipes and an underground transmission system to 3 No. 5000L polytanks.

Table 4: Abaiang Maneaba rainwater harvesting potential parameters

Potential catchment area (m^2)	487.5
Users	40
L/pers/day	5
Daily demand (L)	200
Storage to be provided (L)	15,000
% failure (tank empty at end of month)	0.3%
% of monthly demand met on average	99.8%
Dry spell (months in a row where < 60% demand met)	1
Mean monthly overflow (L)	64,002
Gutter length (m)	89.0
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	0
Number of downpipes required	8

3.2.2 Abamama Outer Island maneaba, Temaiku

See Appendix 2.2 for detailed site assessment details. To provide 5L/pers/day at this site with a limited chance of failure requires re-guttering the whole roof area providing 6 No. new downpipes and an underground transmission system to 10 No. 5000L polytanks. There is not space for this type of tank-bank within the land allotted.

Table 5: Abamama Maneaba rainwater harvesting potential parameters

Potential catchment area (m^2)	306
Users	65
L/pers/day	5
Daily demand (L)	325
Storage to be provided (L)	50,000
% failure (tank empty at end of month)	0.9%
% of monthly demand met on average	99.5%
Dry spell (months in a row where < 60% demand met)	2
Mean monthly overflow (L)	34,095
Gutter length (m)	71.8
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	0
Number of downpipes required	6

3.2.3 Abaonamo Primary School

Two buildings were assessed for their suitability for rainwater harvesting improvements. The maintenance of roof and fascia board condition was too poor to consider retrofitting of systems on other school buildings.

See Appendix 2.3 (Building No. 1) and 2.4 (Building No. 4) for detailed site assessment details. Building No. 1 already has rainwater harvesting although limited. Suggestions for improvements are limited to building 4 which could supply drinking water for the whole student population.

To provide 0.5L/pers/day using building 4 as the rainwater catchment, with a limited chance of failure, requires re-guttering the whole roof area providing 8 No. new downpipes and an underground transmission system to 4 No. 5000L polytanks.

Table 6: Abaonamo Primary School rainwater harvesting potential, building 4

Potential catchment area (m^2)	523
Users	500
L/pers/day	0.5
Daily demand (L)	250
Storage to be provided (L)	20,000
% failure (tank empty at end of month)	0.7%
% of monthly demand met on average	99.2%
Dry spell (months in a row where < 60% demand met)	2
Mean monthly overflow (L)	13,092
Gutter length (m)	107
Gutter cross section (mm^2)	12,000
Approximate fascia length required (m)	20
Number of downpipes required	8

3.2.4 Dai Nippon Primary School, Betio

The Dai Nippon Primary School, Betio is composed of 4 No. main buildings and a maneaba. One of the buildings is disused and 2 others have poor roofs and trees overhanging. The maneaba is in poor condition. Buildings 1 and 2 towards the rear (lagoon/north) side of the site were further assessed to jointly provide the catchment for rainwater collection.

See Appendix 2.5 (Building No. 1) and 2.6 (Building No. 2) for detailed site assessment details.

To provide 0.5L/pers/day using buildings 1 and 2 as the rainwater catchment, with a limited chance of failure, requires re-guttering the whole roof areas providing 12 (total) No. new downpipes and an underground transmission system to 4 No. 6000L polytanks. Due to the height of the roof eaves, greater than 2m, this site would be ideal for trialling self-cleaning leaf/debris screens. Overflows could be routed to purpose built soakaways.

Table 7: Dai Nippon Primary School rainwater harvesting potential, buildings 1 & 2

Building	**1**	**2**
Potential catchment area (m^2)	304	304
Users	620	
L/pers/day	0.5	
Daily demand (L)	310	
Storage to be provided (L)	24,000	
% failure (tank empty at end of month)	1.3%	
% of monthly demand met on average	99.5%	
Dry spell (months in a row where < 60% demand met)	1	
Mean monthly overflow (L)	78,001	
Gutter length (m)	66.0	66.0
Gutter cross section (mm^2)	12000	12000
Approximate fascia length required (m)	0	20
Number of downpipes required	6	6

3.2.5 *Catholic Maneaba, Betio*

See Appendix 2.7 for detailed site assessment details. To provide 5L/pers/day at this site with a limited chance of failure requires re-guttering half of the roof area providing 5 No. new downpipes and an underground transmission system to 4 No. 3000L polytanks. Using shorter 3000L tanks allows the tank stand to provide elevation for supply. 25m of fascia will need replacing as it is rotten/missing. Overflows can be routed underground to the block work tanks storing church roof water.

Table 8: Catholic Maneaba rainwater harvesting potential parameters

Potential catchment area (m^2)	326
Users	30
L/pers/day	5
Daily demand (L)	150
Storage to be provided (L)	12,000
% failure (tank empty at end of month)	0.5%
% of monthly demand met on average	99.8%
Dry spell (months in a row where < 60% demand met)	1
Mean monthly overflow (L)	42,306
Gutter length (m)	24.8
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	24.75
Number of downpipes required	5

3.2.6 *War Memorial Primary school Maneaba*

See Appendix 2.8 for detailed site assessment details. To provide 0.5L/pers/day at this site with a limited chance of failure requires guttering all four sides of the maneaba, providing 8 No. new downpipes and an underground transmission system to 4 No. 5000L polytanks. 56m of fascia will need replacing as it is rotten/missing. Overflows could be routed to a purpose built soakaway.

Table 9: War Memorial Primary School Maneaba rainwater harvesting potential

Potential catchment area (m^2)	390.5
Users	820
L/pers/day	0.5
Daily demand (L)	410
Storage to be provided (L)	20,000
% failure (tank empty at end of month)	3.9%
% of monthly demand met on average	98.0%
Dry spell (months in a row where < 60% demand met)	3
Mean monthly overflow (L)	47,286
Gutter length (m)	55.9
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	56
Number of downpipes required	8

3.2.7 KHC Houses, Bairiki

See Appendix 2.9 for detailed site assessment details. Two KHC houses in Bairiki have just been upgraded with new galvanised steel roofs, which are ideal for collecting rainwater to supplement the household water supply (drinking and cooking). To provide 5L/pers/day at each site with a limited chance of failure requires guttering both sides of the main house building (smaller pvc guttering should be sufficient at this household scale), providing 2 No. new supported downpipes to 1 No. 5000L polytank. 10m of fascia will need replacing as it is rotten/missing. Overflows could be routed to a shared well between the houses.

Table 10: War KHC Houses rainwater harvesting potential parameters

Potential catchment area (m^2)	48
Users	7
L/pers/day	5
Daily demand (L)	35
Storage to be provided (L)	5000
% failure (tank empty at end of month)	0.4%
% of monthly demand met on average	99.9%
Dry spell (months in a row where < 60% demand met)	1
Mean monthly overflow (L)	6,131
Gutter length (m)	17.2
Gutter cross section (mm^2)	10000
Approximate fascia length required (m)	10
Number of downpipes required	2

3.2.8 KPC Maneaba, Temaiku

See Appendix 2.10 for detailed site assessment details. To provide 5L/pers/day at this site with a limited chance of failure requires guttering all four sides of the maneaba, providing 8 No. new downpipes and an underground transmission system to 4 No. 5000L polytanks. 80m of fascia will need replacing as it is rotten/missing. Overflows could be routed to a purpose built soakaway.

Table 11: KPC maneaba Temaiku rainwater harvesting potential

Potential catchment area (m^2)	387
Users	50
L/pers/day	5
Daily demand (L)	250
Storage to be provided (L)	20,000
% failure (tank empty at end of month)	2.6%
% of monthly demand met on average	98.9%
Dry spell (months in a row where < 60% demand met)	2
Mean monthly overflow (L)	48,098
Gutter length (m)	80.0
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	80
Number of downpipes required	8

3.2.9 Gascony Maneaba, Bikenibeu

See Appendix 2.11 for detailed site assessment details. Currently no rainwater harvesting on site. Little space for tanks and roof very low. To provide 5L/pers/day at this site with a limited chance of failure requires guttering all four sides of the maneaba, providing 6 No. new downpipes and an underground transmission system to 10 No. 3000L squat polytanks. This is unfeasible at this site. 72m of fascia will need replacing as it is rotten/missing. Overflows could be routed to a well to the north.

Table 12: Gascony Maneaba Bikenibeu rainwater harvesting potential

Potential catchment area (m^2)	326
Users	60
L/pers/day	5
Daily demand (L)	300
Storage to be provided (L)	30,000
% failure (tank empty at end of month)	2.7%
% of monthly demand met on average	98.7%
Dry spell (months in a row where < 60% demand met)	3
Mean monthly overflow (L)	37,839
Gutter length (m)	72.2
Gutter cross section (mm^2)	12000
Approximate fascia length required (m)	72
Number of downpipes required	6

3.2.10 Clinic, Bairiki

The clinic already has a reasonable collection system although overhanging vegetation has meant that organic matter has contaminated the tank. The water smalls and is therefore not used. A 1000L polytank located on the second building is used for supply. The system needs maintenance, not overhaul. See appendix 2.12

3.2.11 Bahi Centre, Betio

The Bahi centre had very poor condition roof not suitable for rainwater harvesting.

3.2.12 Sports Centre, Betio

The sports centre has a very large roof catchment area and a large underground reinforced concrete cistern (assumed to be $550m^3$). According to discussion with staff the water is only used for showers in the centre itself. If fully utilised, the sports centre could provide 3500L/day, equating to cooking and drinking water for 700 people in Betio, with a failure probability during a drought of < 1%. This shows the potential for use, and that it is vastly under-utilised. Betio, has the greatest freshwater scarcity in Tarawa and this centrally located rainwater harvesting system could alleviate this greatly, potentially reducing the pressure on the PUB water supply.

4. RECOMMENDATIONS

i. Better maintenance is required; this is ubiquitous for rainwater harvesting systems across Tarawa. Better maintenance requires better knowledge dissemination, guidance, community ownership and community consultation, intervention when necessary, and perhaps external funding. When/if pilot projects associated with KAPII are implemented it is necessary that there is some monitoring and evaluation of long term performance, and of operation and maintenance of schemes.

ii. It is important that building code and council bye-laws are enforced, but consideration of the use of any collected water is required (*e.g.* the Betio sports centre, see section 3.2.12) so that crucial water supply infrastructure is not unused.

iii. Where possible, high grade galvanised sheet should be used for roofing. Households will commonly not be able to afford imported roofing materials - any clean 'permanent' surface can be utilised for rainwater harvesting.

iv. Larger communal structures and all new public and government buildings should be fitted with zincalume® guttering (with additional brackets) due to its strength and longevity in corrosive environments. Where more expensive guttering is not required or available due to cost, such as at households, PVC guttering presents a good option, though may not be as sustainable.

v. Where possible downpipes should be routed to underground transmission pipes. Where underground transmission is not practicable downpipes should be well supported to reduce the probability of critical failure.

vi. Screens are a useful simple mechanism for helping maintain tanks free of organic material, one of the main contaminant sources in Tarawa.

vii. First flush devices should be simple and not mechanical. True (diverting) automated first flush devices are not appropriate for large catchments, and in general not appropriate in Tarawa due to maintenance issues and practicality.

viii. Where possible tanks should be elevated from the ground. Polytanks are suitable to Tarawa due to cost, ease of use, and durability and they can be connected with isolating valves to make tank-banks. Where possible roofs should be provided to shade tanks.

ix. Tank stands/bases should be flat.

x. Durable 'quarter turn' taps should be used at supply points.

xi. Supply points should be at least 0.4m above ground and fenced to prevent animal entry.

xii. Where possible, overflows should be routed to wells or soakaways to enhance local groundwater recharge and freshening of the freshwater lens.

5. REFERENCES

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GWP CONSULTANTS
NOVEMBER 2010