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Preparation of Water Master Plan for Tarawa

KAPII Component 3, Freshwater Resources. Project 3.2.1

Report on the Protection and Management of Water Reserves, South Tarawa

Bonriki Island and Water Reserve, South Tarawa Kiribati (Google Earth)

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Summary

The Water Master Plan for Tarawa, being conducted for the Kiribati Adaptation Project Implementation Phase II (KAP II) Component 3, Freshwater Resources is required to: *Review current water management, protection and monitoring procedures and recommend, as appropriate, additional mechanisms to ensure that the groundwater resources are usable by present and future generations*. This report has undertaken that review. It has found that there are five main threats to the long term viability of Bonriki and Buota water reserves, Tarawa's only current major groundwater sources for reticulated water supply. These are : *Lack of effective protection of water reserves, despite adequate regulations; Ineffective management of water reserves; Failure to engage the local landowners and communities in protection and management of water reserves; Continued settlement on the water reserves; and inappropriate landuse and vandalism on water reserves.* Unless these problems are attacked with determination, future water supplies from these water reserves cannot be guaranteed. It is a salutary reminder that the declared water reserve in Tearoraereke had to be abandoned due to the encroachment of settlers as long ago as 1987.

It was found, in general, the present legislation and regulations for the protection of existing water source areas in Tarawa, the Bonriki and Buota water reserves, appear adequate for the legal protection of these water reserves. It is enforcement of the regulations that is problematic. The existing organisational arrangements for the protection of the water reserves are demonstrably ineffective. While the responsibilities of Ministries in the water sector were clarified in 2004, that has not improved cooperation and collaboration in the protection of reserves. Government agencies are reluctant to enforce regulations. When they do, the effect is very short-lived and encroachment on the water reserves remains a fundamental problem. The National Water and Sanitation Committee was meant to enhance coordination and cooperation between the government water agencies, to entrain the community in management and protection of water resources, to improve protection and to act as a reporting channel back to government on the state of the nation's water resources. It meets irregularly, excluded community nongovernmental organisation representatives, has no work plan and no agenda and does not report regularly to government.

A community-government Committee for the Management of Water Reserves in Bonriki and Buota was set-up in 2002 to improve management and protection of the Bonriki and Buota water reserves. It appears to have met once in February 2002 and is now defunct. The lack of engagement and cooperation between the local landowners and communities and government agencies, has led to the continued decline in the health of the water reserves, despite the existence of strict regulations.

The government through MELAD currently pays almost $1 million as rental to landowners at Bonriki and Buota, but the landowners have no responsibility for caring for the land. It has long been suggested that payment of lease fees should be seen as a contractual agreement between the government and the landowners. In this arrangement, payment would be conditional on the landowners acting as custodians and protectors of the water reserves. Problems in the management of the water reserves are exemplified by the lack of review of the amount of groundwater being pumped from water reserves. PUB staff have done an excellent job at measuring and recording data electronically, however there has been limited analysis of the data and there appears to be no mechanism for reporting results or informing government. ,

Groundwater at Bonriki has been pumped at 17% greater than the estimated sustainable extraction rate since 2006. During long droughts there is a significant risk that salinisation could cause the failure of the public water supply. The report has also documented continued threats to the major Bonriki water reserve which have included: Planning failures, with approved developments on the water reserve in contravention of regulations; Increasing settlement on the reserves; Continued sand and gravel mining in water reserves; Inappropriate land use on water reserves including: Digging of open water wells; Continued use of graveyards on the water reserves; Raising of pigs on reserves; Growing crops and babwai which use animal manure and fertilisers; Direct pollution of galleries; and Vandalism of infrastructure. These on-going problems were shown to have direct impact on the quality of pumped water from infiltration galleries. The current best practice for providing safe water supplies to consumers is to place multiple barriers between the consumer and any contaminants. A fundamental first step in that process is to ensure that water source areas are as pristine as possible and are protected from on-going contamination. The Kiribati Development Plan, 2008 – 11, offers limited ideas for addressing these problems. What is needed if these water reserves are to be protected and managed into the future is a radically different approach to the problem and one that includes the local landowners as part of the solution. Several recommendations follow.

Recommendations

1. Make protection of water reserves the highest priority, superseding all other considerations (this acknowledges that good quality water is essential for life)
2. Appoint a single water reserve manager in the lead water agency whose sole task is to ensure the protection, improved management and monitoring of water reserves in Tarawa
3. Form a multi-agency monitoring team under the manager to visit and inspect water reserves regularly, monitor, analyse and report to the National Water and Sanitation Coordination Committee, NWSCC on: the rates of extraction of groundwater compared with the sustainable yields of water reserves; microbiological, salinity and other water quality parameters; the condition of water reserves including number of settlers and land use activities on water reserves
4. Ensure that the NWSCC meets regularly to discuss the above issues and to prepare a succinct annual report to Cabinet
5. Review all regulations and legislation relevant to the declaration and protection of water reserves and ensure that they are applicable to all potential water reserves throughout Tarawa and Kiribati and make deliberate pollution of public water sources a serious offence.
6. Reform and resource the community-government *Committee for the Management of Water Reserves in Bonriki and Buota*, ensuring that local landowners and their communities participate in the management and protection of water reserves.
7. Make payment of lease fees to landowners a contractual agreement between the government and the landowners with payment conditional on the landowners acting as custodians and protectors of the water reserves who will improve management and protection[1]
8. Introduce school curricula on the protection and care of public water sources
9. Provide alternate venues for burials so that the cemeteries on water reserves are no longer used.
10. Ensure that all groundwater pumps are operating at the design sustainable rate
11. Fill in all domestic water wells, babwai pits and sand and gravel pits on the water reserves
12. Install a backflow stop valve between Bonriki and Buota.

[1] Simple performance indicators for improved management and protection

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1. Introduction

The first and second major policy goals of the Kiribati draft National Water Resources Policy, NWRP, are to

> ***Provide safe, socially equitable, financially and environmentally sustainable water supplies to enhance the welfare and livelihood of I- Kiribati,*** and
>
> ***Protect and conserve freshwater sources for public water supplies.***

Two of the main objectives under these policy goals, and elaborated on in the draft National Water Resources Implementation Plan, NWRIP, are to

> ***Achieve sustainable water resource management***
>
> ***Improve protection of public freshwater sources***.

The Water Master Plan for Tarawa, being conducted for the Kiribati Adaptation Project Implementation Phase II (KAP II) Component 3, Freshwater Resources is a specific response to the NWRP and NWRIP covering both urban South Tarawa and rural North Tarawa. Task six under the terms of reference (TOR) is to:

6. *Review current water management, protection and monitoring procedures and recommend, as appropriate, additional mechanisms to ensure that the groundwater resources are usable by present and future generations.*

This report, carried out under KAPII Water Component project 3.2.1, Preparation of the Water Master Plan for Tarawa examines the current management and protection of water reserves in South Tarawa.

2. Sources for Public Water Supply in Tarawa

Modern best practice in providing safe water supplies is to place multiple barriers between the consumer and any contaminants. A fundamental first step in that is to ensure that water source areas are as pristine as possible and are protected from on-going contamination. In low coral islands, the major source and store of freshwater are shallow groundwater lenses, which normally lies less than two metres below the surface of highly transmissive coral sands and gravels. These shallow groundwaters are easily contaminated by surface wastes and activities and are therefore very vulnerable to inappropriate land uses. In addition these shallow lenses overly seawater so that over extraction of groundwater can lead to salinisation of the fresh groundwater

Shallow groundwater pumped from 22 infiltration galleries at Bonriki (see front piece), and 6 galleries from Buota island water reserves[2] is the only source of public, treated[3], reticulated freshwater in Tarawa (Falkland, 1992). Since Tarawa has over one third of the nation's population, it is vital for the current population and absolutely essential for the future that these two water reserves are protected and managed well. We examine procedures in place for protecting the reserves, the success of those procedures, threats to water reserves and provide recommendations for improvements in protection and management. This report places particular emphasis on the Bonriki water reserve since it supplies about 87% of the treated, reticulated water for South Tarawa.

[2] At present, no groundwater is being pumped from Buota due to the breakage of the pipeline when the Buota-Tanaea bridge collapsed.

[3] Treatment involves air sparging to remove H_2S from the groundwater followed by chlorination. Currently air sparging is not operating and chlorine levels at Bonriki have been increased three-fold..

3. Water Reserves in Tarawa

The Laws of the Gilbert Islands, 1977 (Chapter 83, page 20) declared water reserves on South Tarawa in Betio, Tearoraereke, Nawerewere to the east of Bikenibeu and Bonriki for the purpose of public water supply from the groundwater lenses in these islands. Increased settlement at Betio forced the early abandonment of this reserve and Tearoraereke (Figure 1) was similarly abandoned by 1987. The shortages of available land, termed *baki-aba*[4], and freshwater have been problems throughout history in the Gilberts (Talu *et al.*, 1979). The site east of Bikenibeu was relinquished for construction of the Tungaru Central Hospital, completed in 1991. It seems that Buota, in North Tarawa, has been subsequently declared a water reserve, although the source for this declaration is currently unknown and was certainly not in the 1977 Laws.

Figure 1. Teaoraereke, South Tarawa. The water reserve here was abandoned due to encroached by settlers (Google Earth).

The Public Utilities Ordinance, 1977, under the Public Utilities Board (PUB) Act, 1978, prohibit settlement on water reserves and allow eviction of existing dwellers and land owners from the declared reserves by the PUB. This regulation is highly contentious, since land is the principal form of wealth, sustenance and identity in Kiribati, and is a continuing source of tension and disputes between affected land owners and the Government[5]. The regulations under the PUB Act also allow for the compulsory purchase of land on water reserves. Compulsory purchase is an anathema in Kiribati and has never been used for water reserves. Instead the Government pays commercial rents to land owners in Bonriki and Buota for the use of land in water reserves,

[4] Land-hunger (Talu *et al*., 1979).

[5] Disputes have frequently resulted in the vandalism of infrastructure such as the burning of groundwater pump stations and the destruction of monitoring boreholes (white *et al.,* 1999b).

reported to be currently close to $1 million per year[6]. An additional source of contention, particularly in Bonriki, is the belief amongst landowners that groundwater pumping from the lenses decreases the productivity of traditional subsistence crops such as coconuts and babwai[7] (swamp taro), despite the fact that groundwater measurements show this to be unfounded (White *et al.*, 2002).

The abandonment of the water reserves in Betio and Tearoraereke emphasises the contentious nature of the water reserve regulations, the general reticence to enforce them and the pressures on available land in South Tarawa. The payment of lease fees also raises the impression that the reserves are 'government-land' and their resources, particularly those at Bonriki, are used by non land owners throughout South Tarawa.

Encroachment by settlers and squatters on water reserves is a continuing threat to the remaining reserves, despite the regulations, because of increasing population, particularly through inward migration, and the absence of available land for settlement in South Tarawa. Further abandonment of the existing water reserves in Tarawa is not an option without additional sources of water being found either in North Tarawa, or through expensive new sources such as desalination. Since the PUB regulations only apply to the current declared water areas, it appears that public groundwater sources in North Tarawa, as well as all outer islands, are, at present, unprotected.

Because of the lack of available land for settlement, and the hardships experienced by landowners in water reserves, Falkland (1992) suggested that settlement in Tearoraereke, Bonriki and Buota could be permitted in a peripheral area close to the ocean where the groundwater lenses discharge to the ocean, provided strict conditions were adhered to. It was recommended that a 50 m strip of land close to the ocean side of the islands be made available for settlement provided pigs were kept within 10 m and houses within 20 to 30 m of the high tide mark and wells were within the 50 m strip. It was suggested that the 50 m strip should be separated from the water reserves by a road and that regulation changes were necessary to allow this settlement. During the Asian Development Bank, ADB, Sanitation, Public Health and Environment, SAPHE, Project, which was completed in 2005, this proposal was carried out in Bonriki, and the boundary road on the northeastern side of the island can be clearly seen in the aerial view on the front piece.

There are other regulations and bye-laws that prohibit certain activities on water reserves that are detrimental to the reserves and water quality. In low density, rural and outer island locations, it is the practice to defecate on the beach or bush or now more rarely from over-sea latrines. The Council (Public Health) Bye-Laws 1977 prohibits defecation otherwise than in a latrine, whose location and construction are specified in the Bye-Laws. There appears to be a regulation the provisions of the Land Planning Act (Cap 48) that no development will take place within 250m of a designated Water Reserve.

In May 2007, the Kiribati Parliament passed the Environment Amendment Bill 2007 which amended the Environment Act 1999 (Amendment Act) and was assented to by Te Beretitenti in September 2007. This more adequately addresses waste management and pollution control, environment impact assessment and conservation and management of natural resources through protected areas and species. Regulations under this Act prohibit acts which pollute or degrade the environment, such as the mining of sand and gravel from beaches and water reserves.

[6] It has been claimed that there is no legal basis for paying this rental. Landowners view the rental fees as payment of compensation for their loss of amenity rather that lease fees.

[7] Part of the decline of coconuts is because many trees on Bonriki are senile. Babwai declines were caused by infestations of the babwai beetle.

As we shall show in this report, the current regulations and Acts, whilst are sufficient on paper to protect the water reserves, are largely ineffective.

4. Management of Water Reserves

The *Directions Assigning Ministerial Responsibility,* dated 5 August 2003, assigned the following responsibilities:

- Minister for Public Works and Utilities – water management; sewerage systems
- Minister for the Environment, Lands and Agricultural Development – environment and conservation; waste and pollution management
- Minister for Health and Medical Services – health inspectorate services and environmental health.

The Ministry for Public Works and Utilities, MPWU, has been identified as the lead government ministry for water management. It carries out that responsibility through the Water Engineering Unit, WEU, which is responsible for monitoring and assessing the nation's water resources and for supplying water in rural communities in North Tarawa and outer island communities (except Kiritimati which is the responsibility of the Public Works Division within the Ministry of Line and Phoenix Development, MLPD[8]). The WEU monitors periodically the salinity and thickness of the freshwater lenses in Bonriki and Buota water reserves as well as potential new water source areas in North Tarawa at Abatao and Tabiteuea.

The PUB is a statutory authority within MPWU whose responsibility is the supply of water, sanitation and electricity services in South Tarawa and water and electricity in parts of North Tarawa[9]. The the protection and security of the water reserves is the responsibility of the PUB under the Public Utilities Ordinance, 1977. PUB staff at the Bonriki water treatment plant carry out routine monitoring of the volume of groundwater and its electrical conductivity, EC (a measure of salinity) pumped from the Bonriki and Buota water reserves, and the residual chlorine concentration after treatment in the combined production stream. They also monitor daily rain at Bonriki and the EC of water produced from the individual pump stations at Bonriki and Buota.

The Ministry of Environment, Lands and Agricultural Development, MELAD, carries out conservation and pollution control through its Environment and Conservation Division, ECD. This Division has recently convened the National Water Quality Committee to coordinate the monitoring and reporting of the nation's freshwater quality. Also within MELAD, the Lands Division, is responsible for mapping both the legal water reserves as well as property boundaries. It also is responsible for the payment of annual commercial rent to landowners for the leasing of water reserves. The payment of the nearly $1 million in lease fees by the government carries with it no obligations on the landowners to ensure that the rented land is in good condition and appears to be in the absence of lease agreements.

The Ministry of Health and Medical Services, MHMS, through its Environmental Health Unit, EHU, is responsible for monitoring the microbiological quality of the public water supply in South Tarawa. Because of problems in processing samples, this monitoring is normally episodic, conducted after disease outbreaks.

Despite these responsibilities there appears to be no coordinated and cooperative responsibility for the protection of the water reserves. The head offices of the management agencies are remote from the reserves, with the PUB and MPWU offices in Betio 30 km away. Landowners and the local communities are not involved in the management of water reserves despite recommendations that this was essential (White *et al.,* 1999, Jones, 2002). In general, there is

[8] The statutory basis for MLPD management of water is unclear.

[9] Recent discussions have suggested that the PUB will take over responsibility for water and electricity services in Kiritimati

reluctance within some government agencies to form partnerships with local communities to assist in the management and protection of water resources.

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 then Ministry of Home Affairs and Rural Development with secretariat provided by the Land Management Division within the Ministry. The Committee met in February 2002 to discuss Terms of Reference (Jones 2002) but appears not to have met since and is certainly now defunct. Some government agencies are still uncomfortable with the notion of community participation. The reactivation of this Committee is seen as essential.

Another strategy proposed to improve the management and protection of the water reserves and involve local landowners in the process was, instead of paying lease fees to the local landowners, paying the landowners to be custodians and managers of the water reserves with the lease payments being linked to performance criteria (White *et al.* 1999) such as the absence of settlers, houses and animals, gravel and sand mining, and of crop planting, the infilling of wells, babwai pits and mining pits, 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.

5. The Kiribati Development Plan, 2008-11 and Future Management and Protection of Water Sources

The Kiribati Development Plan, KDP, 2008-11 provides an outline of key policy areas, significant issues that need to be addressed and broad, planned strategies for development for the next three years. Several of these are directly linked to the water sector and to the management and protection of water reserves.

Under the key policy area ***1 Economic growth and poverty reduction***, the KDS identifies *Low investment in productive sectors* as an issue. One of the strategies identified to correct this issue is to *invest in economic infrastructures, such as in electricity, water, transport, etc.* MPWU and Ministry of Finance and Economic Planning are identified as being responsible for this strategy for the water sector.

Within the key policy area ***3 Health***, the KDP identifies *High child mortality rate* as a priority issue. One of the strategies identified to correct this issue is to *develop and implement strategies to promote safe water and improve sanitation to improve child survival.* MHMS, MELAD and the PUB are identified as being responsible for this strategy. Also under this key policy area, the issue of *Increase in hepatitis cases* is addressed through several strategies, one of which is to *promote awareness of the seriousness of hepatitis and preventive measures, e.g. use of clean water* to be carried out by MHMS and PUB.

Under the key policy area ***4 Environment*** the KDP singles out the issue of *Increase in waste and pollution.* Amongst the strategies the KDP proposes are (responsible agencies in parentheses):

- *Implementation of solid waste management strategies* (MELAD, Island Councils)
- *Enforcement of Environment Amendment ACT* (MELAD, Attorney General's Office)
- *Increase public awareness on waste disposal and reducing pollution* (MELAD)
- *Incorporate environmental issues in school curriculums* (MELAD, Ministry Education Youth and Sport Development)

Also under this policy area, a key issue is *Decline in quality and supply of ground water.* The strategies identified (together with responsible agencies) are:

- Consolidation and coordination of national water quality guidelines (MPWU, MELAD)
- To enhance the water quality monitoring system (MPWU, MELAD, PUB)
- Public awareness on the sustainable use of water and the protection of water reserves (PUB. MPWU, MELAD)
- To enforce water regulations as stated in the Environment Act (MELAD, PUB)
- Enhance capacity of PUB section that deals with water (MPWU, PUB)
- Secure and fence off more water reserves[10] (MPWU, PUB)

Finally, under this policy area another key issue is *Urbanisation.* One of the suggested strategies for this is to *upgrade and maintain water and sanitation systems* (MPWU, PUB).

Within the key policy area ***5 Governance*****,** the KDS identifies *Absence and outdated legal frameworks and poor enforcement* as one of the issues to be addressed. Three of the strategies suggested to address this are:

- Review, update and develop of regulations/legislations and strengthened enforcement mechanism at all levels (OB, AGO)
- Promote awareness and understanding of legislations and regulations through seminars, workshops, and education system (AGO, Judiciary, Police)
- Involve the police and other relevant authorities in the management and enforcement of legislations and regulations (Police, AGO, Judiciary).

It can be seen from the above list of issues that water remains a continuing priority concern. It addition, the Kiribati Development Strategy 2008-11 clearly recognises that many of the strategies required to address these issues require collaboration and cooperation between several ministries. In the past, Ministries in the water and sanitation sector in Kiribati have a poor record of cooperation.

In an effort to address this and to increase community participation in the protection and management of water, the National Water and Sanitation Coordination Committee, NWSCC, was re-formed in 2007 under the chair of MPWU[11] with suggested representatives from the lead government agencies and NGOs[12]. Its draft terms of reference include to:

- Coordinate and enhance the strategic activities of Government Ministries in the water and sanitation sector to ensure sustainable management.
- Coordinate and facilitate an annual, national, island-based assessment report on the quality and quantity of water resources, water consumption, rainwater harvesting and demand for water and encourage strategic systematic monitoring.
- Coordinate and facilitate assessments of risks in the water and sanitation sector and possible adaptation strategies in relation to global change and extreme events.

Unfortunately, the NWSCC meets infrequently and appears to have no work plan or agenda.

Since many of the above issues identified in the KFS 2008-11 also appeared in the National Development Strategy 2003-7, it would appear that progress in issues related to water and the protection of water sources has been slight.

[10] In the consultant's visits to Kiribati over the last 12 years at least three fences have been erected at Bonriki International Airport to prevent ingress of local villagers onto the runway. Some of these lasted only a few weeks and none now remain. Fencing at Bonriki is totally ineffective,

[11] In the original proposal it was suggested that OB chair the NWSCC as water was a national strategic resource, whose management and conservation cut across many ministries.

[12] At the inaugural meeting of NWSCC its was stated that water was government business and NGOs were not invited onto the committee,

6. Groundwater Extraction from Bonriki and Buota Water Reserves

Groundwater underlying the Bonriki and Buota water reserves has been intensively studied and estimates of the sustainable yield for extracting groundwater from both islands have been refined over time using a variety of techniques (Falkland, 1992; Alam *et al.*, 2002; White *et al.*, 2002; Falkland 2003a,b). Table 1summarises estimates of the sustainable yield from Bonriki and Buota water reserves.

Table 1. Estimates of the daily sustainable groundwater yield from Bonriki and Buota water reserves.

Year	Estimates of Sustainable Yield (kL/day)			
	Bonriki	Buota	Combined	Reference
1973	110			Mather (1973)
1978	<85	<85	<170	Richards & Dumbleton (1978)
1982	750	250	1000	DHC (1982)
1992	1000	300	1300	Falkland (1992)
2002	1350	350	1700	Alam *et al* (2002)
2002-3	1660	350	2010	White *et al.* (2002), Falkland (2003a)

By taking into account the salinity of water produced from the infiltration galleries, later studies have permitted identification of maximum pumping rates for all of the infiltration gallery pumps on both water reserves (Falkland, 2003a). In general, the maximum pumping rate from any individual gallery was set out 85 kL/day in Bonriki and 70 kL/day in the smaller and more saline Buota with the suggestion that some pumps on both islands be restricted to a maximum of 55 kL/day. Overall the mean pump rate suggested for the combined galleries of Bonriki and Buota was 70.6 kL/day.

Inspections carried out during and at the end of the SAPHE project during 2003 showed that replacement of pulleys on pumps had resulted in individual pumps having rates as high as 140 kL/day with the mean all galleries being 88 kL/day, nearly 25% above the estimated sustainable mean pumping rate.

The PUB records total daily flow rates from both the Bonriki and Buota water reserves. Whilst early data is patchy, this is a complete record of daily flows from 2004 to the present. The data reveals some problems with the record. For example there are considerable periods when zero flow was registered from Buota. It is not certain whether this was due to no groundwater extraction from Buota or merely the failure of the flow meter there. The flow data from Buota also shows some negative flows. A note on the record explains that this is caused by back-flow of water from Bonriki when there are power failures at Buota[13].

Figure 2 shows the available record of groundwater pumping from the Bonriki and Buota water reserves. It can be seen that daily data is missing during the critical drought period mid 1999 to the end of 2000 and also for late 2002 and all of 2003. Despite these gaps clear signals can be seen in the figure. There seems to have been no significant increase in pumping from Buota between late 1998 and 2008. In contrast, the flow record from Bonriki, after 2002, shows significant variations. Highly variable and decreasing flows occur in late 2002. These could have been due to the upgrading of facilities carried out during the ADB SAPHE project. After the record restarts in January 2004, a relative steady increase in extraction rate occurs until early 2006 after which the flow rate remains relatively constant.

[13] This is a clear indication that a backflow stop valve should be installed between Bonriki and Buota. Currently, with the pipeline between Bonriki and Buota broken, at least two pumps in Bonriki have had to be switched off to prevent backflow because of the absence of a stop valve.

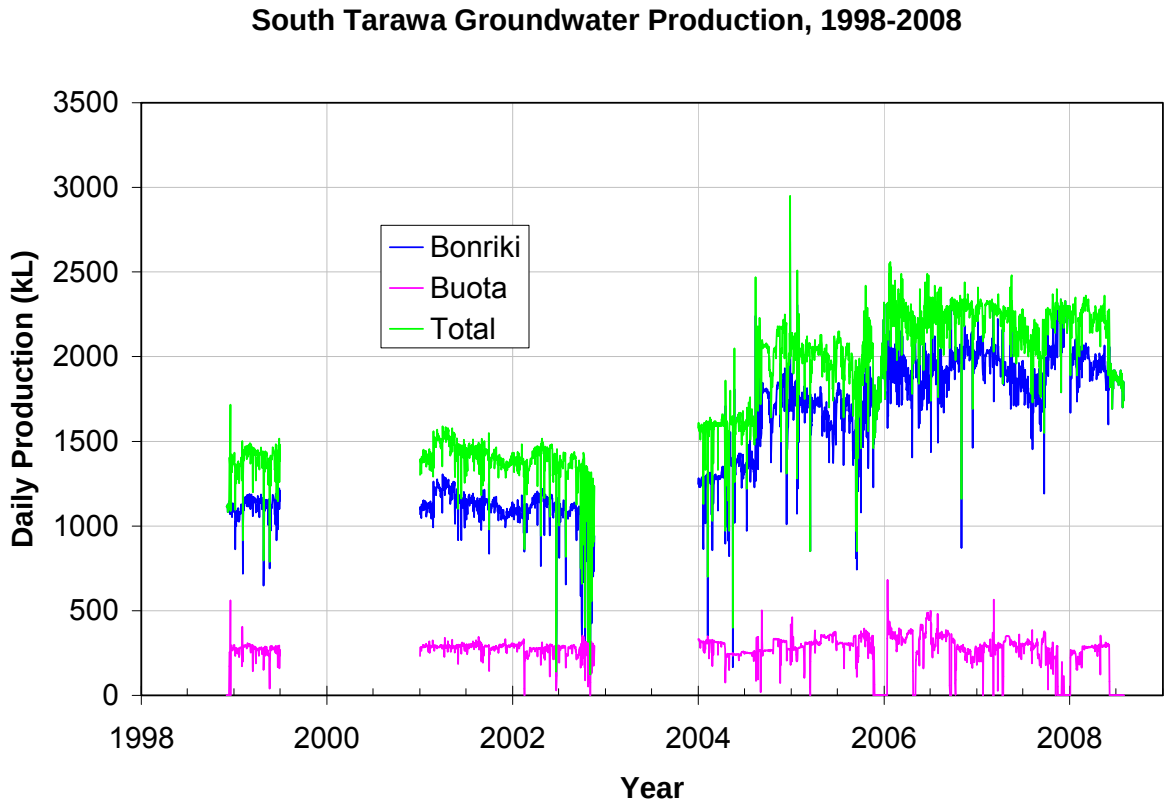

Figure 2. Daily pumping of groundwater from the Bonriki and Buota Water Reserves and combined production for 1998 to 2008,

Annual and partial monthly data are available for other years and Table 2 and Fig summarise the approximate mean daily flow rate for periods between 1992 and 2008.

Table 2. Mean daily pumping of groundwater from Bonriki and Buota water reserves, 1992-2008

Year	Bonriki			Buota			Total Production		
	Mean Daily Production (kL/day)	St Dev Daily Production (kL/day)	CV (%)	Mean Daily Production (kL/day)	St Dev Daily Production (kL/day)	CV (%)	Mean Daily Production (kL/day)	St Dev Daily Production (kL/day)	CV (%)
1992[1]	975	n/a	n/a	325	n/a	n/a	1300	n/a	n/a
1998[2]	1107	24	2	171	153	89	1278	158	12
1999[3]	1105	114	10	267	51	19	1372	139	10
2001[4]	1137	67	6	287	20	7	1423	76	5
2002[5]	1055	172	16	267	50	19	1322	210	16
2003[6]	745	n/a		291	n/a		1036	n/a	n/a
2004[4]	1463	267	18	278	47	17	1741	276	16
2005[4]	1686	178	11	275	109	40	1960	187	10
2006[4]	1928	148	8	300	114	38	2228	141	6
2007[4]	1961	168	9	240	110	46	2201	121	6
2008[7]	1937	88	5	262	54	21	2129	179	8

[1] From Falkland (1992) for April 1992. [2] From PUB data for December 1998 only. [3] From PUB data for Jan to end Jun 1999. [4] From PUB data for full year.[5] From PUB data for Jan to 18 Nov 2002. [6] Annual Data only from PUB summary. [7] From PUB data for Jan to 1 Aug 2008 for Bonriki and to 5 June 2008 for Buotal.

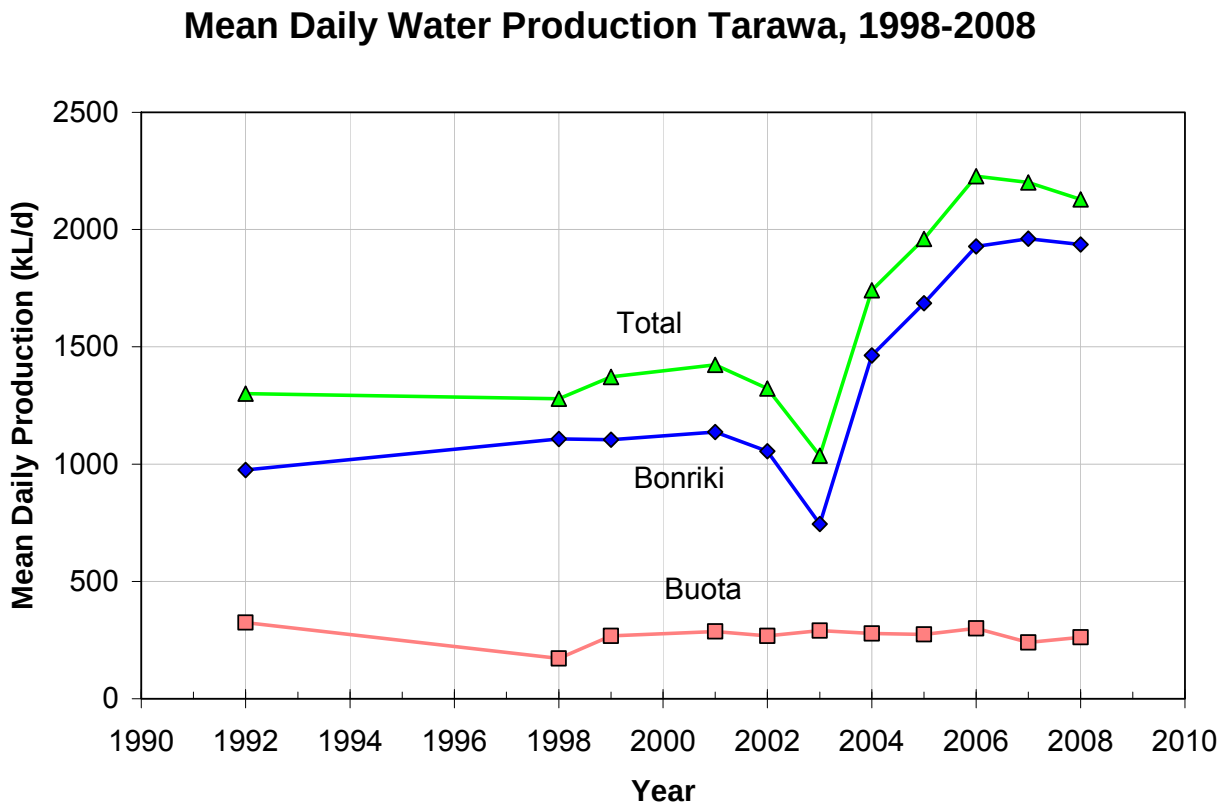

Figure 3. Mean daily groundwater pumping from Bonriki and Buota water reserves, 1992-2008.

The general features seen in the daily record in Figure 2 are apparent in the longer mean record in Figure 3. Recorded mean daily pumping of groundwater from Buota dropped between 1992 and 1998 while that at Bonriki increased by about 10%. During the 1998-2000 drought, recorded mean production at Bonriki remained relatively constant, while that at Buota increased by nearly 60% to close to the rates estimated in 1992[14]. In 2003, during refurbishments under the SAPHE project, there was an apparent nearly 30% decrease in annual production at Bonriki, but Buota production remained relatively constant. Indeed in the period 1999 to 2006 the production at Buota has been relatively constant with a slight decline in 2007 and 2008. The decline in total mean daily production from the combined water reserves in 2008 is partly due to the collapse of the Buota bridge and the break in the pipeline which occurred around 5 June and involved the shutdown of at least two Bonriki galleries on the Buota-Bonriki treatment station pipeline.

The coefficient of variability, CV, of mean daily production rates in Table 2 provides a measure of the reliability of the water supply. It can be seen that the water supply (or meters measuring the flow rate) from Buota is much more variable and therefore less reliable than that from Bonriki. Since the total production from Buota is less than 15% of the combined freshwater production from both reserves, this variability at Buota has a small effect of the variability of the combined flow. Following refurbishments of pump stations after the SAPHE project, the variability of mean production rate at Bonriki was halved from its early values.

The current, almost 100% increase in pumping from Bonriki above the 1992 rates following the refurbishment of the water supply SAPHE project is evident. The data in Table 2 show that the average daily production rate at Bonriki for the recent period 2006 to 2008 is 1943±146 kL/day.

[14] It is uncertain if this is a real increase or due to installation of a new flow meter.

The latest estimate of the sustainable daily pumping rate for Bonriki in Table 1 is 1660 kL/day, so the pumping rate has been 17% greater than the long term sustainable rate for the past 2½ years[15]. At Buota over the same period, the average daily production rate is 268±108 kL/day, only 77% of the estimated sustainable production of 350 kL/day in Table 1.
While a 17% over production above the estimated long-term sustainable yield at Bonriki may not be a problem during normal to wetter rainfall years, there is a significant risk during severe droughts that this increased pumping rate will cause salinisation of the lens at Bonriki. What is disturbing about this overproduction is that there appears to be no mechanism in place that requires the PUB to report to lead water agencies (and they to the government) on the rate at which water is being pumped from Bonriki and Buota compared with the estimated sustainable yield[16].
The impacts of over-pumping can be measured by monitoring the salinity and thickness of the freshwater lenses in both islands.

7. Groundwater Salinity at Bonriki and Buota Water Reserves

Salinity of the pumped groundwater at Bonriki and Buota is monitored routinely by PUB staff located at the chlorination plant in Bonriki by monitoring the electrical conductivity, EC, of the pumped water[17]. This monitoring takes the form of daily measurements of the salinity of the combined outputs from all gallery pump stations in Bonriki and Buota water reserves prior to chlorination as well as periodic measurements of the EC of individual pumping stations on both water reserves. Measurements at individual pumps are necessary because of the spatial variation of salinity in across the islands. In Bonriki, salinity is generally higher towards the western end of the island close to the two large ponds (Figure 4).

Figure 4. Salinity of pumped groundwater at Bonriki is highest near these ponds at the western end of the island (Google Earth).

[15] This increased pumping rate is due to the wrong size pulleys being installed on pumps during the SAPHE project
[16] In this section we have ignored any leakages between the infiltration gallery pumps and the flow meters. This is because any leakages will be returned rapidly to the local groundwater.
[17] The approximate relationship between total dissolved salinity, tds, in mg/L and EC in µS/cm is tds ≈ 0.6 x EC

In addition to the monitoring by the PUB, the consultants have also measured the EC of the combined output as well as at individual pump stations. Staff from the Water Engineering Unit within MPWU also monitor the salinity and thickness of the freshwater lens in specially constructed salinity monitoring boreholes across both islands. Here we shall use the PUB data.

Figure 5 shows the measured EC of the combined output from the Bonriki and Buota pump stations between 1996 and 2008.

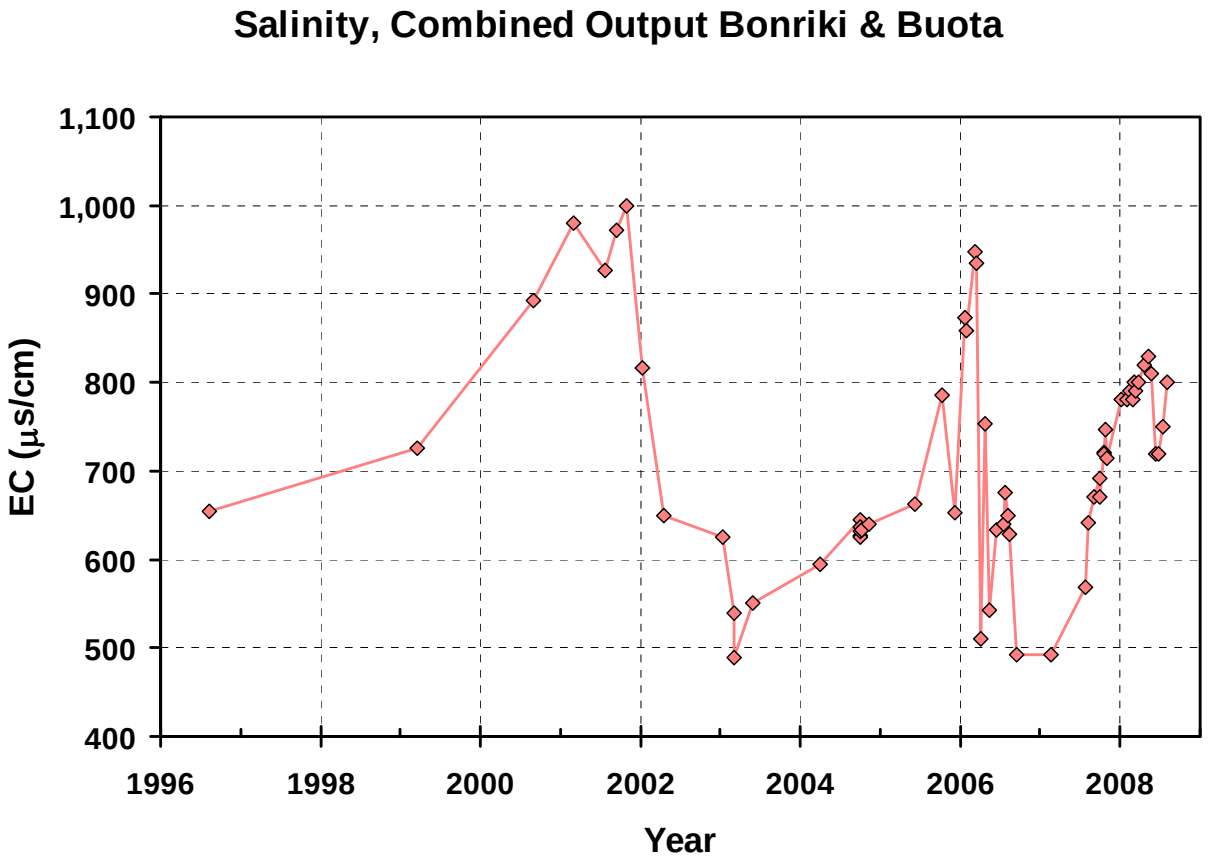

Figure 5. Electrical conductivity, EC, of the combined water pumped from Bonriki and Buota water reserves from 1996-2008.

There are several notable features about the data in Figure 5. Prior to 2001 there are few measurements of salinity, despite the fact that the worst recorded drought occurred between 1998 and 2001. After the end of the drought the EC of the combined output water continued to climb and reached a maximum in late 2001. Persistent heavy rain led to a rapid decrease to a minimum in EC in early 2003 after which salinity again generally rose to a peak in early 2006 but then declined rapidly to another minimum in late 2006 and early 2007. The onset of another ENSO-related drought in the latter half of 2997 and early 2008 again saw an increase in EC although it was nowhere near as high at that at the end of the 1998-2001 drought.

During the period covered by the EC measurements in Figure 5, the combined output from both islands rose from an average daily pumping rate of about 1300 kL/day to 2200 kL/day, with all the increase being from pumps in Bonriki. Despite this, it is difficult to discern any increase in the combined salinity because of the major impact of drought on EC and possibly the confounding effect of the almost constant pumping rate from Buota whose mean salinity always exceeds that of Bonriki.

In order to see if any impact of increased pumping on the salinity of pumped groundwater can be discerned, the salinity pumped from an individual gallery at Bonriki will be examined. Pump station, PS 18, an old, very short infiltration gallery, was installed during the mid 1970s. It is located very close to the chlorination plant and has the longest record of EC of any pump station in Kiribati. Table 1 shows measured pumping rates before and after its refurbishment in the SAPHE project. This demonstrates that the pumping rate at this gallery has been increased by a factor of between 2 and 3 times. Falkland 2003 recommended that the maximum pumping rate at this gallery should be restricted to 85 kL/day and the minimum be 55 kL/day.

Table 3. Measured pumping rates at Bonriki gallery PS18 before and after refurbishment in the SAPHE project.

Timing of Measurement	Date	Pumping Rate (kL/day)
Before SAPHE	24-Feb-97	40
	3-Mar-03	68
After SAPHE	7-Oct-04	139
	6-Mar-08	120

Figure 6 shows the complete record of salinity at Bonriki PS 18 between 1977 and July 2008.

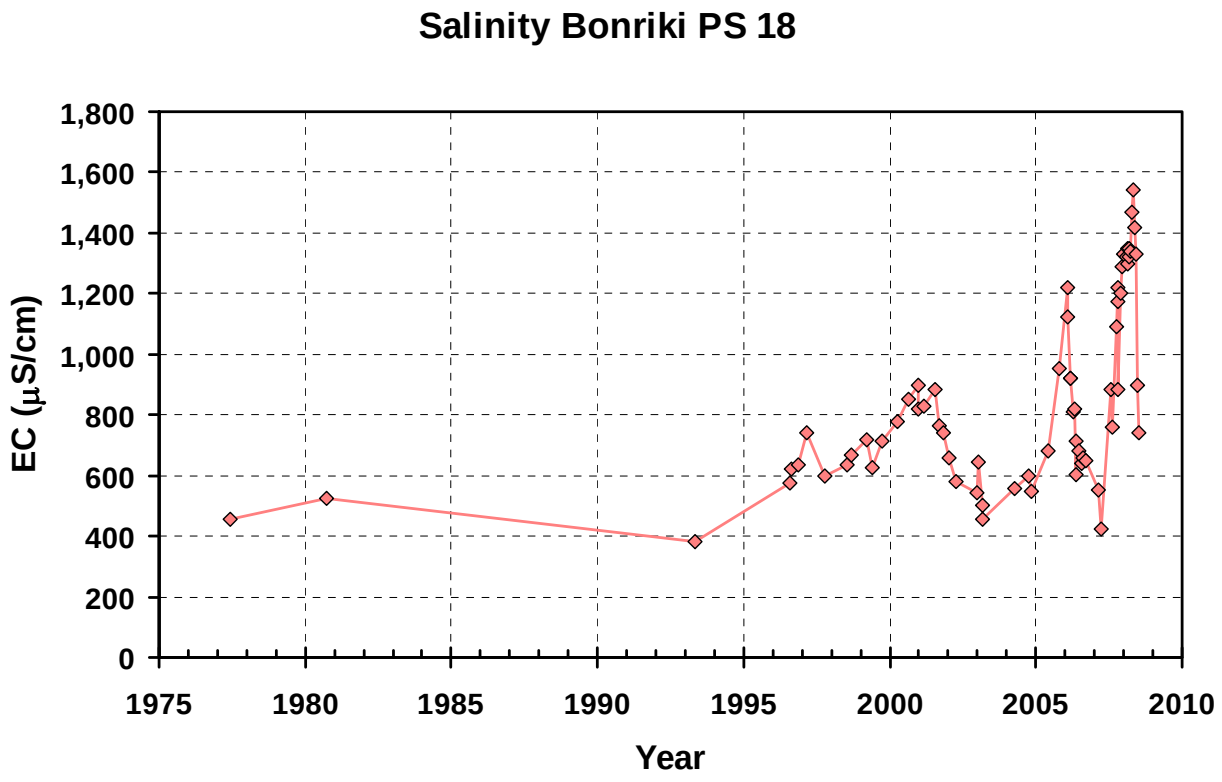

Figure 6. Salinity from an individual gallery pump station, PS 18, at Bonriki, located beside the chlorination plant for the period 1977 to 2008.

Again, there is scant data before 1996. The data does suggest that in the early pumping of the Bonriki water lens the salinity at this gallery pump station was relative low. The minimum in EC in 1993 reflects a record wet period in Tarawa. From this low, the EC systematically rose until it peaked in 2001, at the end of the severe 1998-2001 ENSO drought. The breaking of this drought

resulted in a rapid decline in EC until early 2003 when the salinity of the pumped groundwater was comparable to that in 1977. The salinity then rose steeply to peak in January 2006 whose EC was 33% higher than the peak in EC in late 2000-early 2001 at the end of the 1998-2001 drought, the worst drought on record. Rainfall again rapidly reduced the EC of the pumped groundwater to almost 1993 levels in March 2007. After that, the onset of the 2007-8 ENSO drought is evident, with a rapid increase in EC to a record maximum of 1540 µS/cm in May 2008. This is 70% higher than the peak at the end of the 1998-2001 drought.

The 2007-8 drought was relatively short-lived compared with the major 1998-2001 drought. In terms of impact on the salinity of the groundwater it should therefore have had a lower peak salinity. The increased peak ECs in Figure 6 after 2003 appears to be evidence that the 41 to 64% higher than design pumping rates at this gallery are causing significant local upcoming of salinity in the region around PS18. Because there is no analysis of the data, and no system of reporting to government of this, the government is unaware of the risks being run by the higher than sustainable pumping rates being used at Bonriki.

We shall now examine the current threats to the Bonriki water reserve.

8. Current Threats to the Bonriki Water Reserve

The threat to the water reserves of inappropriate land use and squatter settlement as long been recognised in Tarawa (Falkland, 1992). Visual inspections of the Bonriki water reserve were carried out in March 2003, October 2004, December 2005, August 2006, February 2007, September 2007, March 2007 and August 2007. The last three visits corresponding with work on the current project. A pattern of increasing encroachment and misuse of the water reserves has been observed. While squatter houses tend to wax and wane, depending on spasmodic enforcement of regulations, there is a continuing declining trend in care of the water reserve at Bonriki. Some of the major misuses are discussed in the following.

8.1 Poor planning decisions

The Bonriki Airport control tower, constructed under an EU project in 2004, was cited on the northern edge of the airport runway within the Bonriki water reserve (Figure 7) because of line of site requirements and space availability. A government steering committee for the project included the lead water and environment ministries who approved the plans despite it clearly contravening the water reserve regulations and public health bye-laws. To make matters even worse, the septic tank toilet for the control tower is located directly over one of the two infiltration gallery arms leading to Bonriki pump station, PS 7 as shown in Figure 8.

If the treated groundwater supply from water reserves for Tarawa is to be preserved for the future, protection of water reserves must be seen as paramount, eclipsing the best intentions of aid donors and lenders. Planning mistakes as illustrated in Figure 7 and Figure 8 must be strenuously avoided.

8.2 Settlement and encroachment on the water reserve

At the time, the suggestion to allow settlement in a 50 m buffer strip along the ocean-side perimeter of water reserves (Falkland, 1992), seemed a just and equitable solution to *baki-aba.* At Bonriki, however, this settlement has accelerated encroachment on the water reserve (Figure 9). Some of the houses on the water reserve are substantial (Figure 10).

Figure 7. The Bonriki International Airport Control Tower (circled) located on the water reserve (Google Earth)

Figure 8. The septic tank toilet for the Control Tower is located over one of the infiltration gallery arms leading to Bonriki pump station 7 in the foreground right

Figure 9. Encroachment of houses onto the Bonriki water reserve across the 50 m boundary road in the northeast. The Bonriki water treatment and pumping plant near the centre of the reserve is circled in yellow and an active cemetery is circled in red (Google Earth).

Figure 10. A typical house erected illegally on the Bonriki water reserve.

8.3 Sand and gravel mining on the water reserve

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 little opportunities for generating income. Sand and gravel are currently in very short supply in Tarawa. Sand and gravel mining, although illegal, therefore provides settlers and particularly squatters with an opportunity to earn some income and to many the Bonriki water reserve appears to be an ideal source for materials.

The impacts of sand and gravel mining can be seen in aerial photos (Figure 11) and is endemic across the reserve. Mining has significant impacts on the water reserve:

- Destruction of vegetation (Figure 12)
- Increases vulnerability of groundwater to pollution as less soil overlies the watertable
- Increases direct evaporation losses from the watertable
- Threatens to undermine pumping stations (Figure 13)
- Has completely destroyed salinity monitoring boreholes (Figure 14)

On repeated inspections of the reserve, the impacts of mining have been found to progressively worsen and constitute a significant threat to South Tarawa’s reticulated water supply.

8.4 Other inappropriate land uses on the water reserve

Increased settlement on the Bonriki water reserve also leads to other inappropriate land uses:

- Digging of open wells (Figure 15). These expose the groundwater to direct contamination and lead to algal blooms in the water.
- Active graveyards (Figure 9 and Figure 16). There are several active graveyards on the Bonriki water reserve which expose the shallow groundwater to the risk of pollution.
- Raising of pigs (Figure 17). There are estimated to be about 2.4 pigs per household in Kiribati. The faecal contaminant load from pigs on the reserve poses a significant threat to water quality.
- Growing crops (Figure 18). This is particularly prevalent on the western, lagoon side of the water reserve where the soils are fining textured. The use of fertilisers and animal excrement to provide nutrients to the crop poses a significant groundwater pollution threat.
- Growing *babwai* (Figure 19). Recultivation of *babwai* (swamp taro) has commenced on the western side of the Bonriki water reserve near PS 14 and PS 13. Babwai pits are excavated directly into the watertable and fertiliser and animal wastes are added directly to the groundwater. This poses a major threat to groundwater quality and increases evaporative losses.
- Direct pollution (Figure 20). The terminal wells of gallery pump stations can be opened and these have been used as rubbish dumps and as toilets. The risk to Tarawa’s water supply from this is immense.
- Vandalism of infrastructure (Figure 21). Vandalism is a continuing problem in the water reserves. Pumps have been burnt and salinity monitoring boreholes, essential for tracking the impacts of pumping are regularly destroyed. This points to significant problems in the management of the water reserves.

Figure 11. Sand and gravel mining within the Bonriki water reserve and close to gallery pump station PS1. The boundary road is again on the northeast ocean side (Google Earth).

Figure 12. Sand and gravel mining on the Bonriki reserve. Note the undercutting of coconut trees which eventually leads to death of the tree.

Figure 13. Gravel mining beside Bonriki gallery pumping station PS1 on the eastern end of the reserve.

Figure 14. Sand and gravel mining has completely destroyed salinity monitoring borehole BN 16 (beside PS 7), one of the oldest and the deepest borehole in Bonriki.

Figure 15. Open well dug down to the groundwater near PS 1. This has algal blooms growing on the water surface.

Figure 16. Active graveyard on the Bonriki water reserve close to the centre of the reserve and between PS 6 and PS 8.

Figure 17. Raising of pigs on the Bonriki water reserve between PS 14 and PS 15.

Figure 18. Growing vegetable crops on the Bonriki water reserve near PS 13.

Figure 19. Babwai (swamp taro) growing on the western side of the Bonriki water reserve. It is grown and fertilised directly in the groundwater.

Figure 20. Rubbish thrown down the terminal well of PS 7.

Figure 21. Vandalism to infrastructure is a reoccurring problem in water reserves. This was Bonriki salinity monitoring borehole BN4B. The steel lid has been smashed off and the piezometer tube and salinity monitoring tubes have all been removed.

9. Some Impacts on Groundwater Quality at the Bonriki Water Reserve

The inappropriate uses of the Bonriki water reserve have direct impact on the water quality of groundwater in the Bonriki water reserve. These can be examined by monitoring the water quality produced by each pump station. In the past we have measured a range of properties to determine the impacts of land use on water quality. One of the most important indicators for water supply quality is those that show the presence of human faecal contaminants in the water supply. We have chose to test for the presence or absence of the faecal contaminant indicator *E. coli.* Figure 22 shows the distribution of where positive *E.coli* in pumping stations in Bonriki were found in October 2004 (White *et al.*, 2007). While we expect that the spatial variation will vary with time. This does indicate that even in late 2004, contamination of the groundwater being pumped from Bonriki to the water treatment plant was a problem.

Another way of examining potential pollution of groundwater is to determine the ratio of dissolved organic carbon, DOC, to total dissolved nitrogen. When the value of the molar ratio is close to 2.9 (the Redfield ratio), this indicates the presence of micro-organisms or algae. When it is significantly less than 2.9 it indicates pollution by other sources of inorganic nitrogen. Figure 23 shows the distribution for both in Bonriki, in October 2004, indicating significant pollution of the groundwater.

While we expect that the distribution of pollutants will shift with time as landuse patterns vary on the water reserves, these results suggest that continued encroachment on the water reserves will lead to progressive deterioration of the quality of Tarawa's water supply. If allowed to continue it may well lead to the abandonment of the last remaining water reserves in south Tarawa.

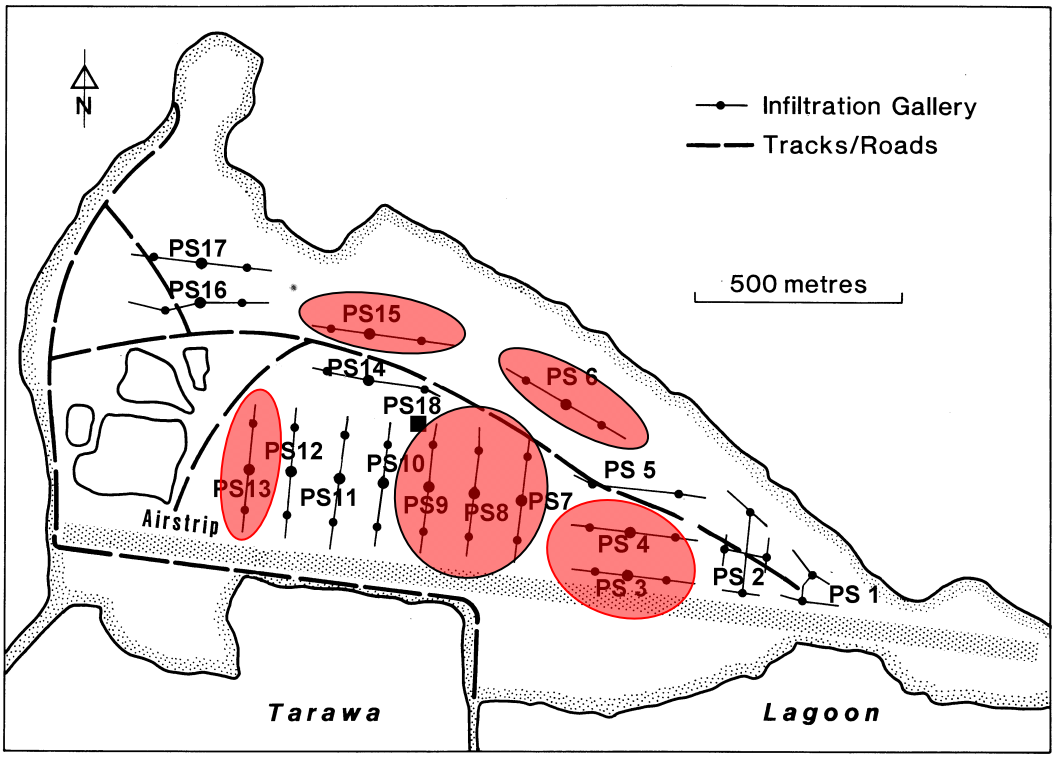

Figure 22. Distribution of positive *E. Coli* water samples from pumping galleries on Bonriki

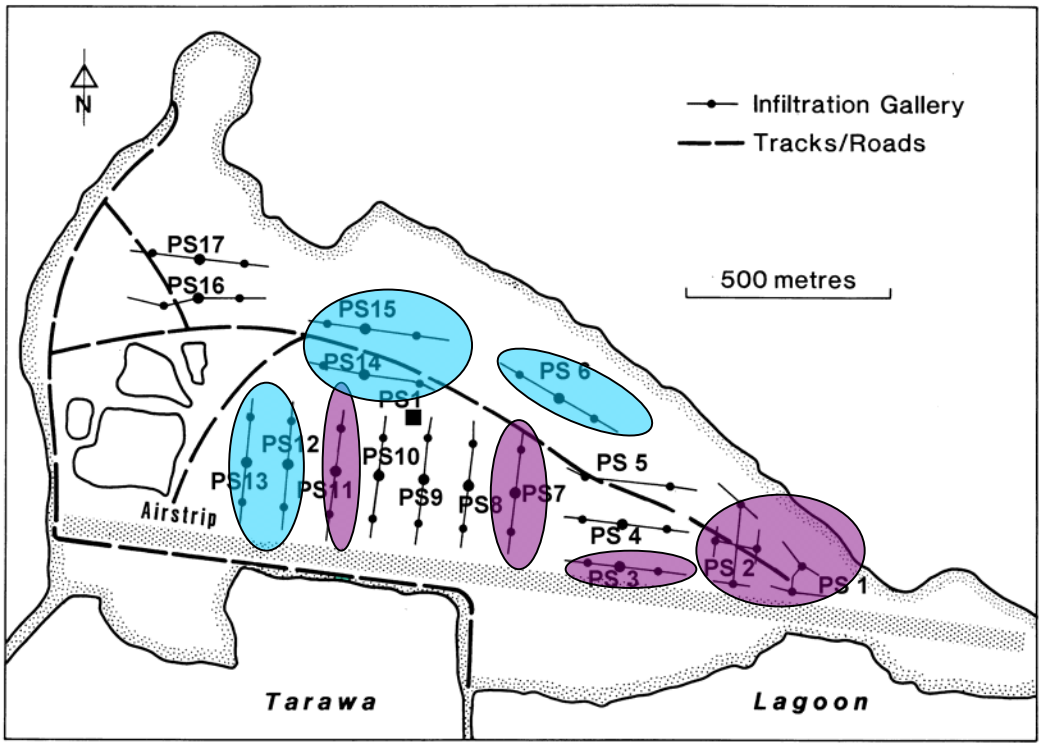

Figure 23. Pumping galleries on Bonriki with DOC/TDN ratios close to the Redfield ratio for micro-organisms (blue coloured) and significantly lower than (< 2.9) the Redfield ratio suggesting inorganic sources of TDN (purple coloured).

10. Concluding Remarks

The Water Master Plan for Tarawa, being conducted for the Kiribati Adaptation Project Implementation Phase II (KAP II) Component 3, Freshwater Resources is required to:

> *Review current water management, protection and monitoring procedures and recommend, as appropriate, additional mechanisms to ensure that the groundwater resources are usable by present and future generations*.

This report has undertaken that review. It has found that there are five main threats to the long term viability of Tarawa's current only major groundwater sources for reticulated water supply at the Bonriki and Buota water reserves:

- Lack of effective protection of water reserves, despite adequate regulations
- Ineffective management of water reserves
- Failure to engage the local landowners and communities in protection and management of water reserves
- Continued settlement on the water reserves, and
- Inappropriate landuse and vandalism on water reserves.

Unless these problems are attacked with determination, future water supplies from these water reserves cannot be guaranteed. It is a salutary reminder that the declared water reserve in Tearoraereke had to be abandoned due to the encroachment of settlers as long ago as 1987.

It was found, in general, the present legislation and regulations for the protection of existing water source areas in Tarawa, the Bonriki and Buota water reserves, appear adequate for the legal protection of these water reserves. If the further creation of water reserves in North Tarawa is required, then the legislation and regulations will need revision as they appear specific to Bonriki and Buota only. It is enforcement of the regulations that is problematic.

The existing organisational arrangements for the protection of the water reserves are inadequate. They are demonstrably ineffective. While the responsibilities of Ministries in the water sector were clarified in 2004, that has done nothing to improve cooperation and collaboration in the protection of reserves. Because of the significant and on-going problem of the declaration of water reserves over privately owned land, government agencies are reluctant to enforce regulations. When they do, the effect is very short-lived and encroachment on the water reserves remains a fundamental problem.

The National Water and Sanitation Committee was meant to enhance coordination and cooperation between the government water agencies, to entrain the community in management and protection of water resources, to improve protection and to act as a reporting channel back to government on the state of the nation's water resources. It meets irregularly, excluded community nongovernmental organisation representatives, has no work plan and no agenda and does not report regularly to government.

A community-government *Committee for the Management of Water Reserves in Bonriki and Buota* was set-up during the SAPHE project to improve management and protection of the Bonriki and Buota water reserves. It met in February 2002 to discuss its Terms of Reference but appears not to have met since and is certainly now defunct. The authors view this committee as vitally important to the protection of the water reserves. The lack of engagement and cooperation between the local landowners and communities and government agencies, has led to the continued decline in the health of the water reserves, despite the existence of strict regulations.

The government through MELAD currently pays almost $1 million as rental to landowners at Bonriki and Buota, but the landowners have no responsibility for caring for the land. It has long been suggested that payment of lease fees should be seen as a contractual agreement between

the government and the landowners. In this arrangement, payment would be conditional on the landowners acting as custodians and protectors of the water reserves.

The problems in the management of the water reserves are exemplified by the lack of review of the amount of groundwater being pumped from water reserves. PUB staff have done an excellent job at measuring and recording data electronically, however there has been limited analysis of the data and there appears to be no mechanism for reporting analyses, either to the lead water agency or to the government. The lead water agency MPWU also periodically monitors the salinity and thickness of the fresh groundwater lenses. Again, however, analysis of data is limited and reporting of the results nonexistent. As a consequence, groundwater at Bonriki has been pumped at 17% greater than the estimated sustainable extraction rate since 2006. While this over pumping is not expected to cause salinity problems during wet years, during long droughts there is a significant risk that the salinisation will cause the failure of the water supply.

Our analysis showed that the salinity of the combined flow of groundwater from Bonriki and Buota did not seem to be affected by this over pumping, partly due to the dominant influence of climate on salinity and partly due to mixing with higher salinity water from Buota. This is not the case when the salinity of pumped water from an individual infiltration gallery pumping station, where the pumping rate had doubled or tripled since 1997, was examined. There, the salinity of the produced water during the short 2007-8 drought was significantly higher than during the major 1998-2001 drought. This indicates the impact of pumping at up to 64% higher than the design sustainable rate.

The report has also documented continued threats to the major Bonriki water reserve which have included:

- Planning failures, with approved developments on the water reserve in contravention of regulations
- Increasing settlement on the reserves, encouraged in part by permitted 50 m ocean-side strip development
- Continued sand and gravel mining in water reserves, increasing groundwater loss by evaporation and increasing the risk of contamination
- Inappropriate land use on water reserves including:
- Digging of open water wells, which increases pollution and evaporative losses of groundwater
- Continued use of graveyards that exposes shallow groundwater to increased risk of pollution
- Raising of pigs with their resultant faecal contaminant load posing a significant threat to water quality in the water reserves
- Growing crops where the use of animal manure and fertilisers poses a significant groundwater pollution threat.
- Cultivation of babwai (swamp taro) directly in the watertable with fertiliser and animal wastes added directly to the groundwater posing a major threat to groundwater quality and increasing evaporative losses.
- Direct pollution with rubbish thrown down the terminal wells of infiltration galleries.
- Vandalism of infrastructure, including pumps, pipes and monitoring boreholes.

These on-going problems were shown to have direct impact on the quality of pumped water from infiltration galleries, with some showing the presence of the faecal contamination indicator, *E.coli*, and others showing the presence of micro-organisms and nutrients. While the water is treated at Bonriki, before it is pumped into the supply pipeline for South Tarawa, the above factors do increase the risk of serious water quality and health problems, particularly should the chlorination plant at Bonriki breakdown as it has at Betio recently.

The current best practice for providing safe water supplies to consumers is to place multiple barriers between the consumer and any contaminants. A fundamental first step in that process is to ensure that water source areas are as pristine as possible and are protected from on-going contamination. The Kiribati Development Plan, 2008 – 11, identifies concerns over the quality of water supplied to communities. The most relevant strategies chosen to address this issue of widespread concern are:

- To enhance the water quality monitoring system (MPWU, MELAD, PUB)
- Public awareness on the sustainable use of water and the protection of water reserves (PUB. MPWU, MELAD)
- To enforce water regulations as stated in the Environment Act (MELAD, PUB)
- Enhance capacity of PUB section that deals with water (MPWU, PUB)
- Secure and fence off more water reserves (MPWU, PUB)

While some of these may slightly improve the situation, others will not. Regulations have been periodically enforced over the past 10 years. Their affects are short-lived. A fence around the water reserve would be expensive and would last about as long as fences around the Bonriki International Airport lasted. What is needed if these water reserves are to be protected and managed into the future is a radically different approach to the problem and one that includes the local landowners as part of the solution. Several recommendations follow.

11. Recommendations

1. Make protection of water reserves the highest priority, superseding all other considerations (this acknowledges that good quality water is essential for life)
2. Appoint a single water reserve manager in the lead water agency whose sole task is to ensure the protection, improved management and monitoring of water reserves in Tarawa
3. Form a multi-agency monitoring team under the manager to visit and inspect water reserves regularly, monitor, analyse and report to the National Water and Sanitation Coordination Committee, NWSCC on: the rates of extraction of groundwater compared with the sustainable yields of water reserves; microbiological, salinity and other water quality parameters; the condition of water reserves including number of settlers and land use activities on water reserves
4. Ensure that the NWSCC meets regularly to discuss the above issues and to prepare a succinct annual report to Cabinet
5. Review all regulations and legislation relevant to the declaration and protection of water reserves and ensure that they are applicable to all potential water reserves throughout Tarawa and Kiribati and make deliberate pollution of public water sources a serious offence.
6. Reform and resource the community-government *Committee for the Management of Water Reserves in Bonriki and Buota*, ensuring that local landowners and their communities participate in the management and protection of water reserves.
7. Make payment of lease fees to landowners a contractual agreement between the government and the landowners with payment conditional on the landowners acting as custodians and protectors of the water reserves who will improve management and protection[18]
8. Introduce school curricula on the protection and care of public water sources
9. Provide alternate venues for burials so that the cemeteries on water reserves are no longer used.

[18] Simple performance indicators for improved management and protection

10. Ensure that all groundwater pumps are operating at the design sustainable rate
11. Fill in all domestic water wells, babwai pits and sand and gravel pits on the water reserve
12. Install a backflow stop valve between Bonriki and Buota.

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