PACIFIC HYCOS
PACIFIC HYDROLOGICAL CYCLE OBSERVING SYSTEM

ASSESSING THE VULNERABILITY OF SHALLOW GROUNDWATER DOMESTIC WELLS IN NAURU

March – April 2010

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SOPAC Secretariat

SOPAC Technical Report 435

July 2010

SOPAC

DISCLAIMER

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This report has been prepared by Louis Bouchet and Peter Sinclair for Pacific Island Applied Geo-Science Commission (SOPAC) under the Pacific Hydrological Cycle Monitoring System (HYCOS) and The Disaster Risk Reduction in Eight Pacific ACP States (B-Envelope) projects.

The assessment presented in this report has been supervised by Peter Sinclair (SOPAC) and coordinated by Louis Bouchet (SOPAC) in collaboration with the Republic of Nauru (RoN) Department of Commerce, Industry and Environment (CIE) and RoN Department of Health. The survey has been undertaken by Reuben Dongobir, Daniel Raidinen, Ofiu Isamau (RoN Department of Health) and Louis Bouchet.

The results presented on this report follow field work undertaken in Nauru from March to April 2010.

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LIST OF ABBREVIATIONS AND SYMBOLS

ACP	African Caribbean Pacific
ADB	Asian Development Bank
ADWG	Australian Drinking Water Guidelines
AMU	Aid Management Unit
ARMS	Atmospheric Radiation Measurement Station
BoS	Bureau of Statistics
CIA	Central Intelligence Agency
CIE	Department of Commerce, Industries and Environment
DB	Database
DPPD	Development Planning and Policy Division
DWSP	Drinking Water Safety Planning
EDF	European Development Fund
EHC	Eigigu Holding Corporation
EPA	Environmental Protection Authority
EU	European Union
FMS	Fiji Meteorological Service
GDP	Gross Domestic Product
GIS	Geographic Information System
GoN	Government of Nauru
GPS	Global Positioning System
HH	Households
ICT	Information and Communication Technologies
IWRM	Integrated Water Resource Management
LLEE	Live and Learn Environmental Education
MED	Multi Effect Distillation
MIS	Management Information System
MLS	Ministry of Lands and Survey
MOH	Ministry of Health
MPN	Most Probable Number
MS	Microsoft Software
MYA	Million Years Ago
NBS	Nauru Bureau of Statistics
NPC	Nauru Phosphate Corporation
NRC	Nauru Rehabilitation Corporation
NSO	Nauru Statistics Office
NUA	Nauru Utilities Authority
PDF	Portable Document Format
PRISM	Pacific Regional Information System
OPC	Offshore Processing Centre
RO	Reverse Osmosis
RoN	Republic of Nauru
WMO	World Meteorological Organisation
SOPAC	Pacific Islands Applied Geoscience Commission
SPREP	South Pacific Regional Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organisation

ACKNOWLEDGMENTS

First and foremost we would like to thank the people of Nauru for their support and generosity, in allowing the survey to be undertaken.

We would also like to thank the RoN government, especially The Ministry of Commerce, Industry and Environment as well as The Ministry of Health and Medical services.

We would like to particularly thank the following persons:

Mr Russ J Kun / Secretary of CIE
Mr Bryan Star / Director of Projects, CIE
Mrs Mavis Depaune / Project Coordinator, CIE
Mr Haseldon Buraman / Project Coordinator, CIE
Mr Norman Powell / Strategic Health Planner, MOH
Mr Ofiu Isamau / Environmental Health Officer, MOH
Mr Jiosese Mailulu / Lab Manager, MOH

Also we greatly appreciated the support of Capelle and Partner, Od-n-Aiwo Hotel and everyone who helped in making our stay in Nauru easier. Finally, we would address a special thanks to Binui Raidinen and Reubeun Dongobir for their hard work, friendship, and help in conducting the survey and overall logistic.

EXECUTIVE SUMMARY

Nauru's water resources are limited and under stress with an expected increase in prolonged dry periods due to climate variability. There are no fresh surface water sources and Nauru relies mostly on rainwater for its potable water needs. Desalinated water is currently supplying about 20% of the population water requirements but during period of prolonged drought, where rainwater is limited, the communities reliance on desalinated water can increase to more than 90%. At current maximum capacity, desalinated water is able to produce about a third of Nauruan water needs; moreover, this technology is consuming a significant amount of energy.

Groundwater is a limited natural freshwater source available on the island which is relied upon for domestic use and plays an important role in the water budget of the island with potential for increased development in the future.

In order to improve our knowledge on the actual reliance and use of the groundwater resource and to assist in its future development, a groundwater survey was undertaken in Nauru from March to April 2010, along with a sanitary survey of domestic wells. Shallow groundwater is particularly vulnerable to faecal contamination from surface activities and wastewater disposal. The sanitary surveys were used to identify major risks and threats to contamination and to inform the community on risk mitigation options.

337 wells were identified and an estimated 350 wells are located in the low-lying coastal plain area. 230 were in use and at least 40% of the population has access to groundwater at the time of the survey. An estimated 298 KL of groundwater is currently abstracted each day in Nauru and this usage is likely to increase in dry periods. This usage indicates that groundwater is currently the second most important water resource in volumes abstracted in Nauru, with harvested rainwater being the most important. Groundwater in the main is being used for non potable purposes including washing clothes, showering/bathing, outdoor uses, flushing toilets, washing dishes, and to a lesser extent cooking, with a few households using it for drinking purposes.

Salinity records and bacteriological (E-coli) levels have been collected for about 280 wells indicating that groundwater quality is a serious issue in Nauru. Salinity is highly variable, depending on rainfall and tidal mixing and can dramatically increase during extended dry periods.

Whilst salinity variability will limit the beneficial use in most circumstances, the risk from faecal contamination is of particular concern and may have a more serious limiting impact on potential use. Over 63% of all the wells surveyed present an E-coli level greater than 20 (MPN), which using Australian guidelines (EPA 2003), would result in serious limitations of use. The main source of faecal contamination is likely to come from surface activities and in particular, onsite wastewater disposal practices.

Hydrocarbon contamination is also present in Aiwo, affecting at least 4 domestic wells and extending over an estimated area of 400 m². Recommendations have been made to further investigate this plume and to develop options to restrict the impact on domestic users and the environment.

This assessment and report aims to provide information which will help to maximize the potential beneficial uses of groundwater in Nauru and thereby reduce some of the stress on other freshwater sources.

1. PROJECT OVERVIEW

1.1 Project background

The groundwater vulnerability assessment for Nauru is a component of work identified by the Government of Nauru (GoN), and supported by the Pacific Hydrological Cycle Observing System (HYCOS) and Disaster Risk Reduction, B-Envelope projects. Additional financial support for the sanitary survey was provided by Australian Aid (AusAID) under the Drinking Water Safety Plan project (DWSP).

The Pacific HYCOS project is a project managed by SOPAC in partnership with the World Meteorological Organisation (WMO), Fiji Meteorological Service (FMS) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The European Union has contributed €2.52 million Euro towards supporting rainwater, surface water and groundwater monitoring networks to provide valuable resource-based data thereby improving development and sustainability of natural water resources in the Pacific through the Pacific HYCOS project. The project is being implemented in 14 member countries namely Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. The project which commenced in December 2006 will be completed in December 2010.

The *Disaster Risk Reduction in Eight Pacific ACP States* project (B-Envelope) is a Multi-Country project funded by the European Union for Federated States of Micronesia, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands, Tonga and Tuvalu. The 4 year project was commenced in January 2007. The overall objective of The *Disaster Risk Reduction in Eight Pacific ACP States* project (B-Envelope) is poverty alleviation and sustainable development through disaster risk reduction. The groundwater vulnerability assessment aims to identify the vulnerability of water resources and water supply systems to climatic hazards and proposes approaches to mitigate against these risks.

1.2 Objectives and expected outcomes

The Nauru shallow groundwater vulnerability assessment aims to reduce the vulnerability of shallow groundwater to contamination through increased awareness of the risk of contamination from surface activities, improved understanding on the reliance and use of the resource, and aims to assist in the future development of the resource. The assessment will seek to enhance the capacity of the local communities to adopt improved water resource protection measures and provide information on the use of groundwater in future development and protection of the countries water resources.

Expected outcomes as follows are detailed in the Logical Framework Analysis (Annex I) and include:

- Establish baseline information on
  - Location of wells
  - Ground water quality
  - Infrastructure for abstraction
  - Usage and reliance of shallow groundwater
- Identify areas of groundwater contamination and related sanitation issues
- Increase awareness on the risk of contamination from surface activities
- Help local communities and individual householders to reduce risk to wells
- Assist in the future development of resource.

1.3 Activities

1.3.1 Groundwater survey

The groundwater survey aims through direct observation and interviews to gather information about the domestic wells in Nauru. It sought to identify 95% of the islands domestic wells and gather information about the infrastructure, reliance, usage, and water quality, including salinity and bacteriological activity, of the wells. Additionally it identified primary drinking water sources and treatment measures at the household level. All the data collected have been integrated into the SOPAC and CIE GIS data bases.

1.3.2 Sanitary survey

A sanitary survey has been undertaken along with the groundwater survey, as an independent assessment, following the World Health Organisation (WHO) format developed with SOPAC and Live and Learn Environmental Education (LLEE) for the Pacific. The survey was used to assess site condition, well features and environmental characteristics. It identified the risks and threat to groundwater from contamination.

1.3.3 Workshops

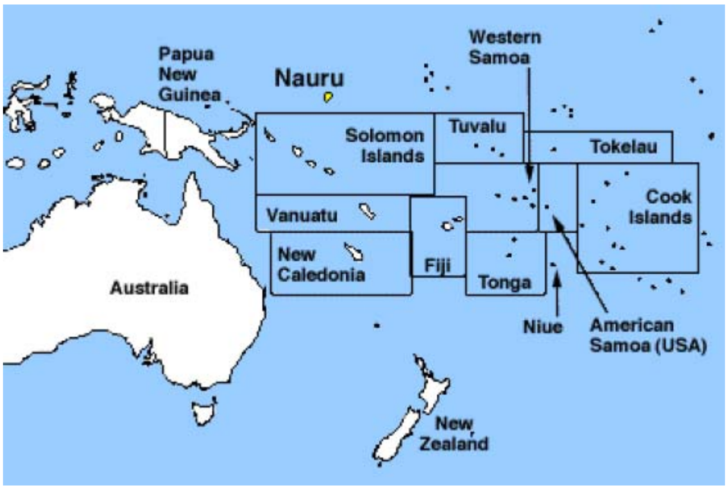
One component of the project work was to provide the opportunity to feedback to the community, and in particular well users, through a series of workshops. The workshops presented preliminary results from the survey and the opportunity to discuss with well users the findings from the individual sanitary surveys. Advice to communities was provided on how to undertake their own sanitary survey and how to adopt measures to reduce the threat and risk to their well from contamination.

2. COUNTRY BACKGROUND INFORMATION

2.1 Description

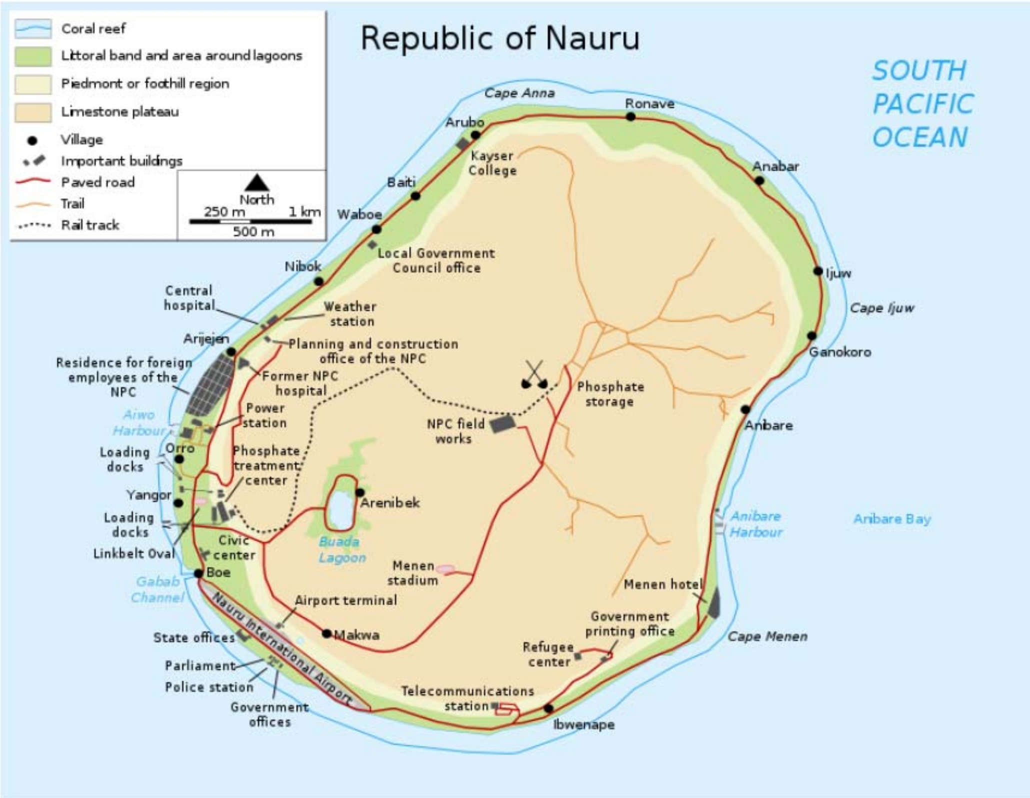
2.1.1 Location

Nauru is a small isolated raised coral limestone island located latitude 0° 32'S (60 kilometres south of the equator) and longitude 166° 56"E. The island is about 6 kms north south and 5 kms east west with an area of 22 square kilometres (2,200 hectares) (NPC 1988).



Map 1. Nauru and the South Pacific islands.

The coastal plain circling the island is 150-300 m wide and abuts a coral limestone escarpment which is approximately 30 metres above sea level forming the perimeter of the elevated plateau known as “Topside”. The maximum elevation is 71 m above sea level. There is one major depression Buada Lagoon, a major karstic subsidence feature, located in the south-west of the island which covers approximately 12 hectares and is close to sea level. The “Topside” plateau is composed of a dolomitic limestone which was covered by large deposits of high grade tricalcium diphosphate which are now largely mined out. The mined out land exposes a karrenfeld of karst pinnacles. The island is surrounded by fringing living coral reef which varies in width from 120-300 metres wide. The depth of water immediately adjacent to the reef is some 4000 m (Falkland 2009, Jacobson and Hill 1997, NPC 1988).



Map 2. Republic of Nauru.

2.1.2 Climate

Nauru’s climate is hot and humid throughout the year with mean daily temperatures of 29-31°C and mean daily minimum temperatures of 24-26°C (NPC 1988).

Rainfall records are available from 1894 although there are significant gaps with no information, in particular 1907-1910, 1914-1915, 1940-1946 and some missing data in 2007 and 2008. The data for annual rainfall for 1946-2008 (Falkland 2009) indicates a mean annual rainfall of 2,117mm. The maximum and minimum annual rainfall recorded being 4,588mm (1930) and 278mm (1950) respectively indicating a high degree of variability. The “wet” season extends from December to April where more than 200mm of rain per month is common (Falkland 2009).

The El Niño Southern Oscillation events have a significant impact on rainfall in Nauru. A negative Southern Oscillation Index SOI results in higher rainfall (El Niño event) whilst a positive SOI will result in reduced rainfall (La Niña event) (Falkland 2009).

El Niño refers to the irregular warming in the sea surface temperatures from the coasts of Peru and Ecuador to the equatorial central Pacific. This causes a disruption of the ocean-atmosphere system in the tropical Pacific with consequences for weather around the globe. This phenomenon is not totally predictable but on average occurs once every four years. It usually lasts for about 18 months after it begins.

A rainfall residual mass curve was generated from the available data to indicate the periods of monthly rainfall which is above the monthly average rainfall, “wetter” periods and “drier” periods where monthly rainfall was below the average monthly rainfall over the record period from 1946 – 2010 (Figure 1).

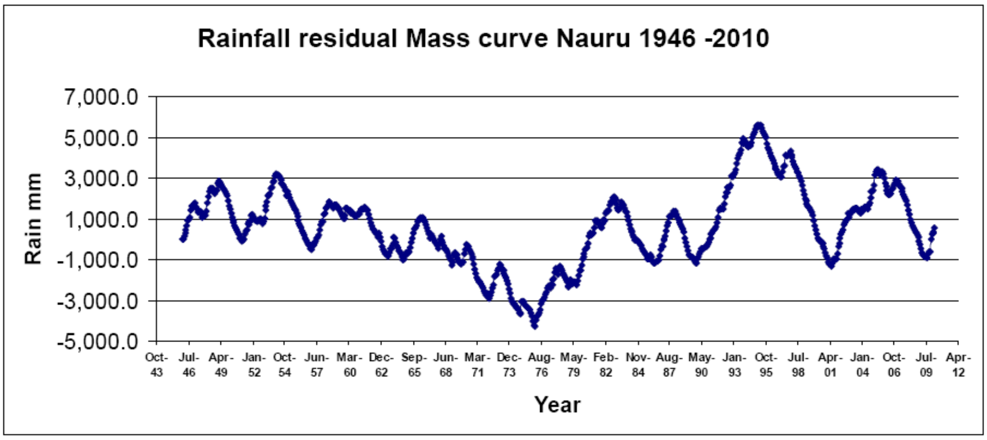


Figure 1. Rainfall residual mass curve – Nauru 1946 -2010.

A declining trend suggests that rainfall is below the monthly average indicating a drier period, whilst an inclining trend indicates a wetter period where rainfall is consistently above the monthly average. In recent times, the period 1997 to 2001 is indicated as being a dry period, followed by a wet period to mid 2005. Most recently the period February 2007 to October 2009 is indicated as a prolonged dry period with below average rainfall which has resulted in an impact on the freshwater lens in response to reduced recharge to the groundwater. Since November 2009 there has been significant rain, above the average, which has resulted in a freshening up of the groundwater lens in Nauru over the last six months, since Nov 2009.

A graph of the monthly rainfall and average monthly rainfall since 1997 is provided (Figure 2), note the dry period January 1998 - June 2001, and more recently June 2007 – October 2009.

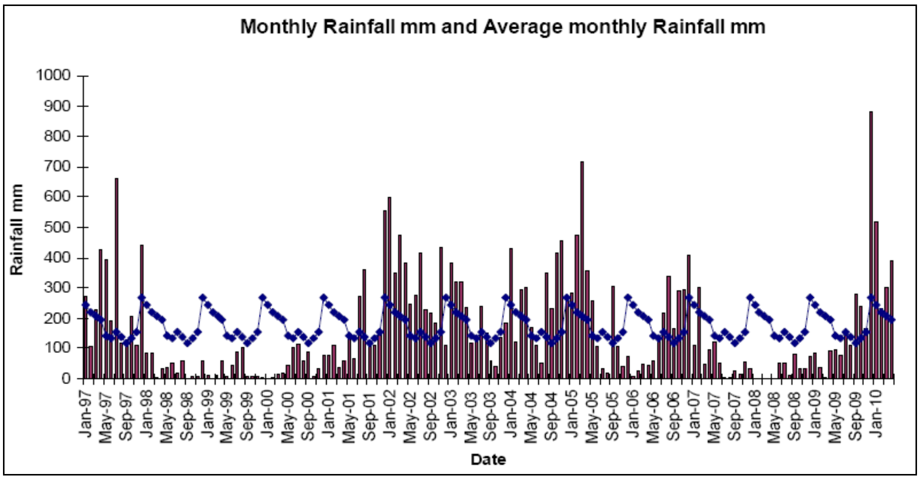


Figure 2. Monthly rainfall versus average rainfall – Nauru (adapted from various sources).

2.1.3 Geology

The island of Nauru is a raised coral atoll comprised of dolomitic limestone with a mantle of phosphate which is mostly mined out (Figure 3). The limestone extends to a depth of about 500 m (Jacobson and Hill 1997) which is believed to overly a volcanic mount. According to Jacobson and Hill (1997) the limestone is intensely karstified to a depth of 55 m below sea level with phosphate cavity fillings suggesting that Nauru has been above sea level for much of its recent history.

According to Jacobson and Hill (1997) the geological evolution of Nauru is as follows:

- Uplift of volcanic complex in Mid – Late Cretaceous approximately (100 - 70 million years ago mya).
- Seafloor eruption of basalts from rupture in Pacific Plate or hot spot resulting in Nauru Volcanic pedestal Mid – Eocene to Oligocene (45 – 35 mya).
- Erosion of volcano and growth of carbonate platform as volcano subsides Oligocene to Pleistocene (35 – 2.8 mya).
- Nauru uplifted and carbonate platform exposed as Pacific plate passed over thermal anomaly. Phosphatic guano deposited from 0.3 mya. Karstification while emergent island (2.8 - 0.126 mya) Pleistocene.
- Coastal terrace formed during high sea level (+ 3 m) continued karstification. (0.0114 mya – present) Holocene.

Nauru's phosphate was one of the largest deposits in the world. It is generally accepted that it was deposited by bird guano which altered to form the phosphate minerals mined, predominantly apatite. Rainwater reacted with the apatite to produce acidic phosphate solution which is likely to have caused some of the large solution cavities observed on the island (Jacobson and Hill 1997).

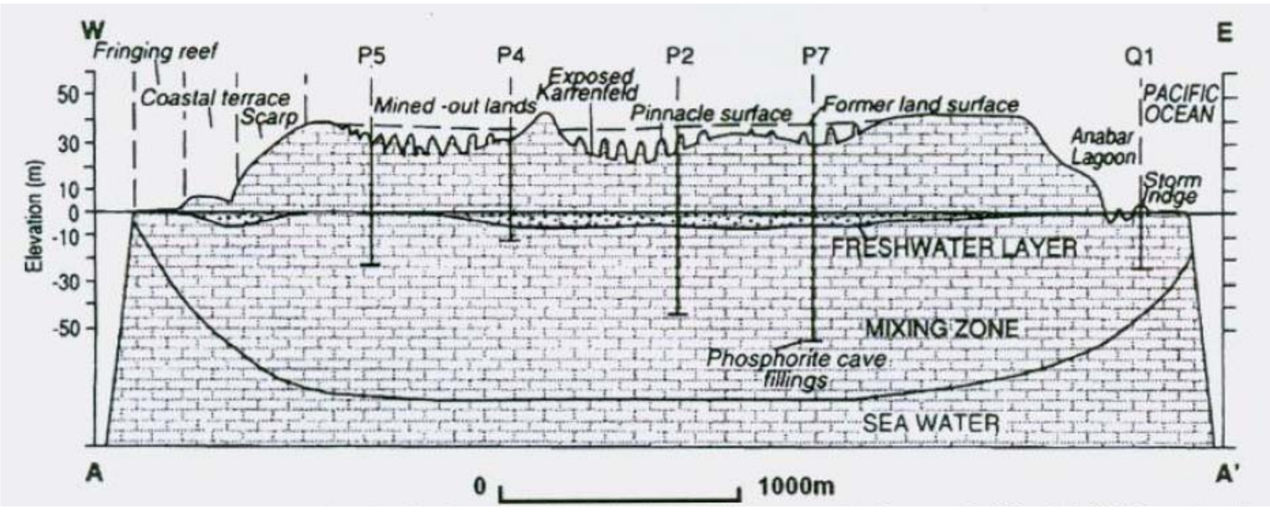


Figure 3. Cross section of Nauru (Jacobson and Hill 1997). Raised coral limestone with thin lens of freshwater with thick transition or mixing zone after heavy rainfalls in 1987.

2.1.4 Soils

Phosphate mining has removed much of the topsoil that was found within the raised part of the island, "topside". The topsoil has been stockpiled, in anticipation for rehabilitation activities and development of a small agriculturally productive area. The soils of Nauru are dominantly coarse textured, sands, sandy loam and loams, where moisture retention is low and with varying amounts of gravel and stone (Morrison 1990).

In the undisturbed areas, the soils of Nauru are generally quite fertile with high levels of organic matter where nitrogen content is sufficient to maintain non-intensive cropping. In the mined out areas, the organic material is able to build up quite quickly if left undisturbed (Morrison 1990).

Specifically Morrison (1990) refers to three separate soil series which were based on investigation from undisturbed areas.

- Lithic Haplustoll – a dark horizon (15-38 cm) overlying a layer of mixed surface material and broken limestone which in turn overlies limestone rock substrate.
- Lithic Ustorthent – thin(<10 cm) dark horizon directly overlying limestone rock substrate.
- Typic Haplustolls – phosphatic material accumulated between limestone pinnacles.

Morrison also refers to a fourth soil being the shallow sand deposits located mainly along the coast. It is these areas of shallow sand deposits dominated by calcite where the majority of the population lives and where the cesspits/septics are located and which are considered a significant threat to the underlying groundwater. These soils are skeletal by nature and are expected to be porous, offering very little adsorptive capacity and therefore minimal protection from infiltration of contaminants from the surface.

2.1.5 Hydrogeology

Groundwater investigations were undertaken in 1987 by Jacobson and Hill, and in most recent times by Falkland in 2008. Monitoring bores were drilled in each investigation to assess the groundwater potential of the island in order to to determine if additional freshwater resources are available and could be developed. The 1987 investigations were undertaken at the end of a relatively wet period and indicated useable quantities of fresh groundwater, up to 7 m thick (Jacobson and Hill 1997). In contrast the 2008 investigation (Falkland 2009) took place after an extended dry period, and indicates very limited fresh groundwater resources at the time of the investigations. The results from the two surveys reflect the influence that rainfall, in addition to the permeability and subsequent tidal mixing, has on the size and extent of the freshwater resources at any given time.

These previous investigations and the current groundwater survey suggest that the fresh groundwater resources of Nauru are limited and are unlikely to be able to be relied upon for significant supplies of freshwater during extended dry periods. A surprisingly thin freshwater lens is observed with a relatively thick brackish zone which is indicative of highly permeable sediments in an atoll situation. The domestic well survey of March - April 2010 indicates that the average thickness of freshwater around the coastal fringe is 0.77 m (median 0.72 m), that is thickness of freshwater for those wells with an electrical conductivity of less than 2,500 µS/cm.

The karstic nature of the dolomitised limestone, as indicated by Jacobson and Hill (1997) has resulted in a highly permeable limestone being developed. This highly permeable limestone allows for freshwater that has infiltrated through the limestone along solution cavities to easily mix with the underlying seawater. The open karst cavities in the limestone allows seawater to move freely throughout the substructure of the island allowing, through tidal movements, the freshwater lens to mix by diffusion and create the observed thick “transition” zone of brackish water.

During the course of the survey, it was observed that the shallow groundwater around the fringing coastal plain is of quite variable quality and that only about half the wells, at the time of the survey, would have access to water from wells below 2,500µS/cm which is considered to be the upper limit of freshwater.

The tidal influence on groundwater was also observed during the groundwater survey. At times domestic wells had very limited water in them and householders were unable to utilise the pumps during certain periods of the day, when water levels had dropped due to tidal impacts leaving the pump inlet out of the water.

According to Jacobson and Hill (1997), tidal effects on the groundwater levels are substantial, being close to half the amplitude of the ocean tidal stage throughout the island. The tidal movement of the water table is commonly 0.5 m and the lag of the tidal peak in boreholes in the centre of the island is 1.5-3 hours. Tidal lag impact for wells on the coastal fringes is expected to be an 1 hour or less.

2.2 Culture and socio-economic environment

2.2.1 Brief history

The indigenous people of Nauru are Micronesians and thought to have been castaways who drifted to Nauru from another Pacific island. The island has been probably inhabited for up to 3000 years or more. As there is evidence of Melanesian and possibly Polynesian influence, the Nauruan language is quite distinct from other Pacific languages. The first reported discovery of Nauru by Europeans was made by Captain John Fearn of the whaling ship Hunter in November 1798. The island was named Pleasant Island in reference to the lush vegetation and friendly inhabitant (CIA 2009).

Recent history of Nauru is inherently linked with the extraction of phosphate. The first relations with Europeans started in the 1830s with trading and whaling ships visiting the island. In 1988, Nauru was annexed to Germany, following the 1886 Anglo-German convention. Phosphate was soon discovered and started to be mined in 1906 by the Pacific Phosphate company, a German-British consortium. After being occupied by Australia during World War I, Nauru became a League of Nation mandate. Phosphate continued to be mined with the creation of the British Phosphate Commissioners.

After World War II and a brutal occupation by Japan who deported 1200 Nauruan to Caroline Island, Nauru became a UN trust territory under Australia in 1946. Nauru purchased the asset of the British Phosphate Commissioners in 1967 and became an independent republic in 1968. The Nauru Phosphate Corporation started is operation in 1970. In 1999, Nauru joined the UN as the world's smallest independent republic (CIA 2009).

2.2.2 Language and education

Nauruan language is a Micronesian language estimated to be spoken by at least 7000 people, more than 50% of the island population. Nauruan is the official language of Nauru but almost all speakers are bilingual in English. Literacy rate is 97% (France Diplomatie 2010).

School is compulsory for children from 5 to 16 years old and provided free by the government. An extension centre of The University of South Pacific (USP) also offers few under-graduate courses (France Diplomatie 2010, USP 2010).

2.2.3 Land tenure

Land tenure has been subject to various interpretations and policies under both German and Australian administrations. The mechanism of land ownership distribution is described in The Nauru Mission's Ninth Annual Report: "Children inherit from parents, uncles and aunts. People

who have no children leave their property to nephews and nieces. Rich landowners give part of their land to poor relatives, even if they have children of their own. Many fathers give their land to their sons before death if they take good care of them" (MacSporran 1995).
As there is basically no government owned land[1], land tenure could become a critical issue for natural resource management and overall development. Under the Lands Act 1976, if landowners refuse to lease land for public purposes, there is no provision for its compulsory acquisition (MacSporran 1995).

Natural resources are considered to be owned by the landowner as in the case for phosphate. There is no legislation covering the abstraction and "ownership" of groundwater (MacSporran 1995).

2.2.4 Population

Nauru's population has been based on available information from Nauru's Bureau of Statistics and updated estimates from SPC Pacific Regional Information System PRISM. A census is held in Nauru every 10 years. The most recent census was in 2002 with a mini census held in 2006.

Table 1: Population (2002-2010).

Year	Population	Source
2002	10,065	2002 census (NBS 2009)
2006	9,086	2006 mini census Nauru Bureau of Statistics Fact sheet (NSO, 2006)
2009	9,771	Pacific Regional Information System (PRISM 2010)
2010	9,976	Pacific Regional Information System (PRISM 2010)

2.2.5 Households

The number of households (HH) on Nauru is provided in the 2002 census and 2006 mini census (NSO 2006, NBS 2009).

[1] Excepting the government buildings in Yaren.

Table 2: Households (2002-2010).

Year	Number of households	Average number of people per household	Source
2002	1,667	6	2002 census (NBS 2009)
2006	1,538	6	2006 mini census (NSO 2006)
2010[2]	1,663	6	Estimate based on July 2010 data (PRISM 2010)

2.2.6 Socio-Economic development

Exports of phosphates have traditionally been the sole source of income on the island and until 1980's Nauru was considered to have one of the higher GDP per inhabitant in the world (ADB 2010).

Being extensively mined during the past 50 years, operations stopped in 2003 with the end of primary phosphate supply. In 2005, an Australian company entered into an agreement to exploit the few remaining supplies. Serious issues such as rehabilitation of mined land and replacement of incomes from mining activities threaten Nauruan future (ADB 2010).

In anticipation of the exhaustion of phosphate resources, Nauru developed trust funds to help secure Nauru's economic future. Mismanagement of these trust funds through poor investment advice left the government to face virtual bankruptcy in the late 1990s and for much of this decade. The state is heavily indebted and Nauru's economy relies on foreign development grants. Since Australia closed the Offshore Processing Centre[3] (OPC) in 2008. There are really few opportunities to generate income except through employment in the public service or state - owned enterprises (ADB 2010). Nauru unemployment rate is 22.7% (PRISM 2010). Deterioration of housing, hospital and other capital plant and infrastructure is a significant concern (CIA 2009), including access to water and adequate sanitation.

It is important to bear in mind that during the economically prosperous times, government used to provide a range of free (or at very low cost) services such as medical, water and electricity to the population. There is a common belief that government were directly responsible for the mismanagement of phosphate incomes that lead to the current economic situation, and further failed to honour land rents. In addition there is a general perception that government should be in charge of running costs and maintenance of numerous facilities, including water supply and sanitation, which is still a strong perception among the Nauruan (Audoa and Tilling 2010).

2.3 Water and sanitation overview

2.3.1 Water resources

According to Hebblethwaite 2009 and Russ and Wallis 2007, water resources and services are as follows: Apart from Buada lagoon, a slightly brackish lake, and a few brackish ponds on the coastal strip, there are no surface waters in Nauru. Freshwater resources come from: rainwater desalinated (RO) water, imported water and groundwater. Sea water and brackish groundwater are also mainly used for non potable purpose.

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[2] The number of households decreased as population decreased. However household population remained the same. Utilising the density of population per household, an estimate of the number of households was made for 2010.

[3] The OPC was a centre for refugees.

Harvested rainwater is the most relied upon fresh potable water resource when there is sufficient rainfall. According to the rainwater harvesting survey undertaken for SOPAC in 2007, roofs are mainly connected to private or community water tanks. Numbers of tanks have increased during the past years but numerous houses are still waiting to buy or be provided with tanks (Booth et al. 2007).

Desalinated (Reverse Osmosis, RO) water is produced by Nauru Utilities Authority (NUA), a government owned company, and is distributed by tanker trucks. During drought periods, desalinated water becomes the first and most reliable potable water resource on the island, and rainwater tanks are used to store desalinated water. There are two other known small RO plants in operation, notably RoN hospital and Capelle's and Partner buildings in use at the time of this survey. NUA is using up to 3 plants at any one time, each of a capacity up to 120 KL/day. Maximum capacity for desalinated water production by Utilities is therefore 360 KL/day. However, as at March 2010, usually 2 RO plants were operating on a 5 day/week basis, depending on demand. NUA also has a large dysfunctional multi-effect distillation (MED) desalination plant which utilises waste heat to produce steam from the old generators at the power station. The unit was capable of 1,200 kL/day at design but produced approximately 650 KL/day during operation in 2002. Whilst the MED is operable the power station does now not produce enough waste heat to run it and NUA are trying to sell it.

Groundwater: Some wells are known to remain with low salinity during drought period, especially in Ewa and Anetan districts. Groundwater is mainly used for non-potable purposes.

However during the survey, in a relatively wet period, two houses were recorded to drink water from their wells. As discussed in part 2.1.5 Hydrogeology, the fresh groundwater resources are limited and are unlikely to be able to be relied upon during extended dry periods for significant supplies of freshwater.

Approximately 350 wells are tapping the groundwater on the coastal plain area, supplying up to half of the population. Wells are owned by the owner of the land upon whose land the opening to the well was found. Groundwater is commonly shared, where one well will supply the non-potable water needs of to up to 15 households.

As indicated, salinity is extremely variable, depending on rainfall patterns, proximity to the coasts and tidal mixing. Groundwater quality is also a major concern due to high risk of faecal contamination from unlined septic tanks or cesspits where effluent is able to leach without detention directly to the soil and groundwater.

Imported water: During the economic prosperity of Nauru, along with phosphate mining, reliance on imported water was particularly high. Unladen phosphate ships returning from Australia would import water which would be offloaded into large storages in Nauru. There is no data available on imported bottled water consumption for the past few years but the survey suggests that a very small percentage of Nauruans rely on it (0.2%) for domestic potable water requirements.

Sea water: Seawater used to be reticulated throughout the 'Location' area, in Denig district, for toilet flushing. 'Location' was the residential area for the NPC workers and which now houses lower income Nauruan and non-native Nauruan, including the Chinese community. The original network, which consisted of pipes pumping up water to storage tanks on Command Ridge and a distribution pipeline network to houses, is no longer operational. However, seawater remains an important resource in Nauruan's daily life, especially for bathing.

2.3.2 Sanitation facilities

According to the 2002 census, 83% of the households are using flush toilets, 12% are using external tank or pour-flush facilities and 2% do not have access to any sanitation facility. 55% of the households (HH) direct their sewage effluent to ''septics'' which are actually mostly cesspits[4] and 39% of households (mainly in 'Location' area in the Denig district) directly divert their waste to sewerage network that release the waste into the sea (NBS 2009).

True septic tanks are limited to some government owned building and few houses (Hebblethwaite 2009). According to Eigigu Holding Corporation (EHC), an estimated 1000 cesspits are currently used in Nauru (Hebblethwaite 2009) and are mostly 2 m deep with no lining at the base (Q Alona 2010 pers. comm.). They are present a significant threat to groundwater quality and human health. NRC is currently in charge of sewage sludge management and disposal. The sewage sludge is collected with a truck, recently donated by AusAid, where the sludge is then pumped to the ocean via an existing ocean outfall pipe.

Picture 1: Sludge truck and sewerage pipe to the edge of the reef which the sewage sludge is pumped to.

3. GROUNDWATER SURVEY

3.1 Objectives

The groundwater survey objective is to improve the understanding on use, reliance, abstraction method, baseline water quality and impact to the groundwater in Nauru. The sanitary survey was used to assess the vulnerability of the domestic groundwater to bacteriological contamination. The information collected has been included into a spatial database to assist in the accessibility and application of the information. The information will be linked to the existing Nauru Rainwater Harvesting (RWH) database.

4 Cesspits are rocks or concrete blocks lined holes allowing wastewater to infiltrate into the porous ground. A cross section of a cesspit is shown in Figure 20.

3.2 Methodology

As there was no significant information available on the number of domestic wells and their location in Nauru, a door to door survey approach was chosen to identify as many wells as possible.

A questionnaire (Annex II) was developed to gain an overall understanding of the well locations, features, users and uses. The questionnaire is detailed in part 3.

A series of field maps at 1:1914 scale (Map 3) were created from rectified 2005 satellite imagery. Each map was numbered and for each building a roof ID was created and this was used as the primary unique identifier for each well. Wells were located and attached to the closest Roof ID and then each well was assigned a unique number associated with that particular map, eg Map no.014 and well no.03. The well was recorded on the field map along with the location of any known septics located near to the wells. This field map was used as a source to ground truth against the GPS readings entered into spatial database, with modifications made to the final locations recorded in the database as required.

Map 3: Field Map Ewa district, North-east Nauru 2005 imagery.

Two survey teams were used consisting of at least one native Nauruan speaker. A survey questionnaire was used to record the information collected including physical information such as well characteristics, water quality information, sanitary survey, as well as observations provided by landholders on usage and reliance on groundwater.

3.3 Questionnaire design

The questionnaire was designed for this survey in consultation with SOPAC and Nauruan field and technical officers. The survey was divided into seven distinct topics namely Site, Well water usage (volumes of groundwater abstracted), Wastewater disposal, Well water use (purpose of water abstracted), Drinking water, Well construction and Well water quality. The survey form was field tested and modified prior to its application. Each topic is detailed below.

3.3.1 Site

Provides location, ownership, respondents name and well's year of construction. The year of construction was an accurate date where known, and an approximation for the decade where possible or otherwise identified as unknown.

3.3.2 Well water usage

Provides householders users names and number of people per houses as well as number of children under 5 years old, and number of water using appliances and outlets connected to or using groundwater.

This information was the basis for estimating the volume of water abstracted and reliance on groundwater.

3.3.3 Onsite wastewater disposal

Provides the number of septics/cesspits identified within 20 metres of the well and the distance from the closest septic/cesspit to the well. A comments box was used to capture information about the septic conditions or other relevant observations.

This information was used to assess the likelihood of a bacteriological contamination from onsite wastewater disposal.

3.3.4 Well water use

Provides information on the water use, that is its purpose and how the water was abstracted, ie pump, bucket, etc. This section is complementary to *well water usage*.

This information allowed differentiation between how the groundwater is being used and also serve as a cross match check with the water usage section.

3.3.5 Drinking water sources

Provides information about primary and secondary drinking water sources for each household that uses groundwater, including information on the frequency and type of water treatment used, and an estimation of the scarcity for primary drinking water source, at the time of the survey (i.e. March-April 2010), after a wet period.

Understanding what sources the population relies upon for its drinking water will assist in developing actions which better serve the community for its water needs, especially during dry periods.

3.3.6 Well construction

Provides information on physical attributes of the well including diameter, depth to water, total depth, casing type and headwork. The headwork section is a subjective evaluation and requires further explanation:

A well is considered:

- *Uncovered* if there is no cover at all on the top.
- *Covered* if the cover does not allow any outside material to enter the well and if the cover is high or heavy enough to not be easily removed by children or animals.
- *Poorly covered* if the cover is not fitting the above "*covered"* criteria.

Also a well is considered:

- *Abandoned* if the state of the well clearly makes it un-usable or it has been filled in (e.g. if it is filled with rubbish or completely cover by vegetation restricting its use).
- *Unused* if householders do not regularly use the well and were not using the well at the time of survey. However the well is still accessible and could be used if required.
- *Occasional* if householders relies on the well occasionally or periodically, during dry periods, (e.g. for washing clothes when the rainwater tank level is getting low).

3.3.7 Well water quality

Provides information on groundwater quality. Samples were taken either from the well or the closest tap connected to a pressure pump. Salinity from the well was taken approximately 0.4 m from the base of the well to coincide with the most likely position of the pump inlet. The salinity and sampling procedure are detailed in Section 3.5.

A comment box allowed any additional information to be recorded.

3.4 Implementation

3.4.1 Field work

Two teams of two carried out the field survey over the five weeks needed to complete the island. Daniel Raidinen and Reubeun Dongobir, two local labourers, teamed up with Ofiu Isamau Environmental Health officer and Louis Bouchet, Junior Professional and team leader.

Each team working off a specific field map would move from one house to another, locating wells and completing the survey questionnaires. In this way more than 95% of wells in Nauru are thought to have been captured. A survey was completed for each well identified. This well was referenced to the closest roof ID and when possible the well owner identified.

Most of the interviews were done in Nauruan as most respondents preferred to speak in their mother tongue. However as most Nauruans also speak English, the two non-local team members could also take part in the collection of survey information. After the interview, which normally took between ten to twenty minutes, the team recorded the well features and undertook water quality analysis and sampling.

The salinity and temperature were recorded using a calibrated TPSWP 84 or WP 81 conductivity meter. Measurements, sampling and analysing procedures are detailed in section 5. Locations of wells and septics were also recorded in the map for incorporation in the GIS data base.

3.4.2 Response rate

The survey was particularly well received. Of the 423 Households surveyed, only one refused the interview (i.e. response rate superior to 99 percent).

3.5 Measurements, sampling methodology and analysis

3.5.1 Well features measurements

Diameter, depth to water and total depth were recorded using metal tapes.

Most of the wells in Nauru are cylindrical and their diameter was measured from the inside wall of the well. Other shapes with equal widths have also been recorded in the diameter section, measured from one side to the other. However, other shapes such as rectangular wells have been recorded as NA. The depth to water was recorded from the top of the well to the water surface. The total depth was recorded from the top of the well measuring point, top of the raised wall, to the bottom.

In some cases, measurements could not be recorded for one of the following reasons:

- The well is securely covered
- The well is inaccessible (e.g. covered by vegetation)
- The well is filled with rubbish

3.5.2 Salinity measurements

Salinity was recorded in the field using a TPS WP 84 or WP 81 with a five meter cable.

As the salinity could vary significantly between the water table and the bottom of the well and in order to collect uniform data, the salinity was recorded from a purged sample from the closet tap to the well, when possible. When the wells were not connected to a pump, the salinity measurements were taken at an estimated 0.4m from the base of the well where possible. This depth was considered to coincide with the most likely placement of the pump inlet for the majority of wells and allowed comparison of salinity data between wells.

Each morning of the survey the TPS conductivity meters were calibrated. One of the TPS salinity meters developed an error and failed to calibrate during the last week of the survey, requiring one of the teams to use a small Hanna EC salinity meter in its place to take field measurements. Therefore, a small number of well temperatures (42) were not recorded.

3.5.3 Sampling methodology and analysis

The Colisure method was used to evaluate E-coli and Total-coliform levels. Each team was trained to undertake the agreed sampling procedures (Annex III).

As for the salinity measurements, water samples were taken from the tap where possible. If not, samples were taken directly from the well using a bottle dropper.

Samples were then stored in a cool pack and transferred to the MoH laboratory fridge at 1pm. All samples were processed around 5 pm after the afternoon field work. The colisure method whilst providing a result within 24 hours was found to provide a more reliable result and was easier to interpret after 36 hours.

E coli and Total Coliform are measured in the units MPN/100ml or Most Probable Number/100 ml. E coli is an indicator bacteria that is found in the gut of warm blooded animals and can survive for a relatively short period outside the gut, less than 30 days under most conditions. It is used as an indicator of faecal contamination, where the higher the number of E-coli indicates an increased risk of faecal contamination. The higher the number of E-coli the greater the risk of contamination.

3.6 Summary

A total of 423 households have been identified with access to a well which represent 26% of households (2010 estimates) (Table 3).

Table 3: Total households having access to wells, depth to water and salinity, by district.

District	No .of wells (GW Survey 2010)	No. of households using wells and groundwater (GW Survey 2010)	No. of households with well access but not using groundwater (GW survey 2010)	Total no of households with well access (GW Survey 2010)	Avg depth to water m	Median Salinity µS/cm
Aiwo	32	37	9	46	3.99	2400
Anabar	21	14	2	16	2.56	2320
Anetan	23	18	9	27	2.89	1776
Anibare	16	15	3	18	2.09	1665
Baitsi	18	20	5	25	4.53	3160
Boe	38	54	15	69	3.45	2565
Buada	32	34	9	43	3.46	3875
Denig	13	23	1	24	5.08	2400
Ewa	21	21	3	24	3.23	1601
Ijuw	10	2	2	4	3.09	1810
Location	0	0	0	0	NA	NA
Meneng	43	31	6	37	2.49	2430
Nibok	24	24	10	34	4.44	4450
Uaboe	7	15	2	17	3.92	1982.5
Yaren	38	43	6	49	2.71	1785.5
TOTAL	**336**	**351**	**82**	**433**		
Average/ Median					**3.4**	**2510**

Table 4: Estimates of usage and access to groundwater 2006 and 2010 populations.

Population	% of HH using wells	% of HH with access to wells	% of population using groundwater (houses only)	% of population access to groundwater (houses only)
2006 mini census	23%	28%	35%	42%
2010 estimates	21%	26%	32%	38%

4. SURVEY RESULTS

4.1 Well features

4.1.1 Casing type and Headwork

Most of the wells identified are built using concrete pipes with an average diameter of 0.8 metres (Picture 2). Coral rock, brick and a few fibreglass pipes were also recorded (Figure 5). More recently drilled, with the help of the NRC drilling rig, are a few wells constructed with PVC pipe of smaller diameter (i.e. 0.3 metres). This bore construction type is relevant for households located in relatively high areas, along Command Ridge and Topside needing deeper bores, >5 m, to access the groundwater table.

Picture 2: Concrete well with metal sheeting for well covering.

However it is relatively expensive (i.e. $1,500 AUD for a 10 m deep bore) compared to a well where excavation costs for 3-5 m deep wells are less.

Concrete cylinders are particularly robust and therefore the most common construction type, representing more than 87% of all well casings in Nauru. They also the cheapest option for well construction.

Headworks are often simply metal sheeting laid on the top of the well offering minimal protection. Whilst some wells are securely sealed or covered with a concrete top, in general only 35% of wells have adequate covering, with more than 65% of all wells being poorly covered or having no covering at all, and providing very little protection against ingress of surface water and other contaminant access.

Pressure pumps are also often poorly protected. Commonly, pieces of wood are used as the only support to the pump. They are regularly stolen in some areas and stolen pumps is considered a significant risk to access by the well owners (see Annex IV wells pictures).

For this survey, headworks were considered in term of their security to the water quality and their safety. They are therefore sorted by 3 categories:
Covered, Poorly covered and Uncovered (Figure 4).

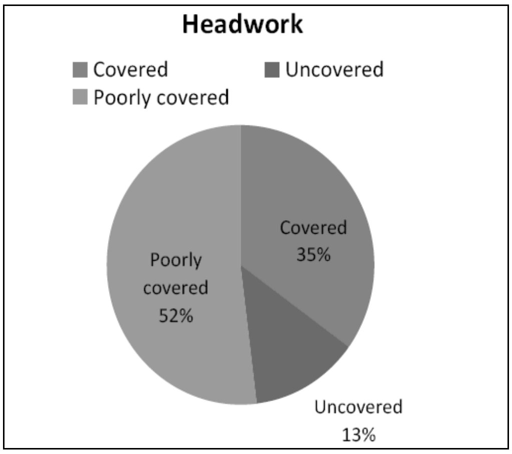


Figure 4. Well headwork types.

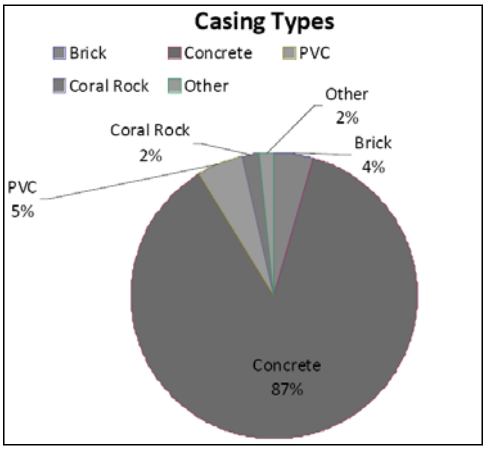


Figure 5. Well construction casing materials.

4.1.2 Depth to water and total depth

The average depth to water for the domestic wells across Nauru is 3.4 meters while the average total depth is 4.4 meters. The height of the casing above ground was not recorded for each well, but it is estimated that average casing height is approximately 0.4 m above ground suggesting that from ground surface the average depth to water would be approximately 3 m and the total depth of the well would be approximately 4 m (Figure 6).

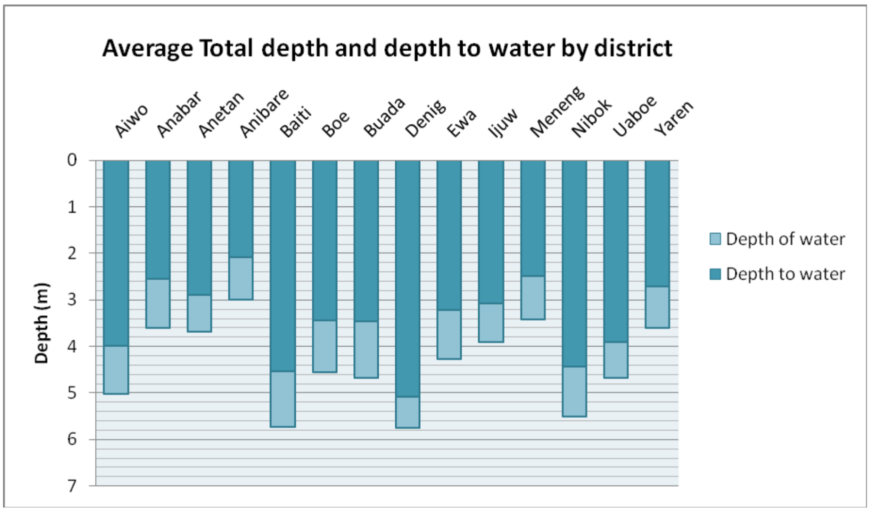


Figure 6. Average total depth of wells and depth to water by district.

The depth of water within the well during the survey is on average 1 m. The difference in total depth and depth to water between districts is believed to be mostly due to the ground elevation. It was noted that most of the houses surveyed in Anibare were very close to the sea, and therefore at lower elevation. The houses surveyed in Nibok, Denig or Baiti are in slightly more elevated areas.

4.1.3 Abstraction type

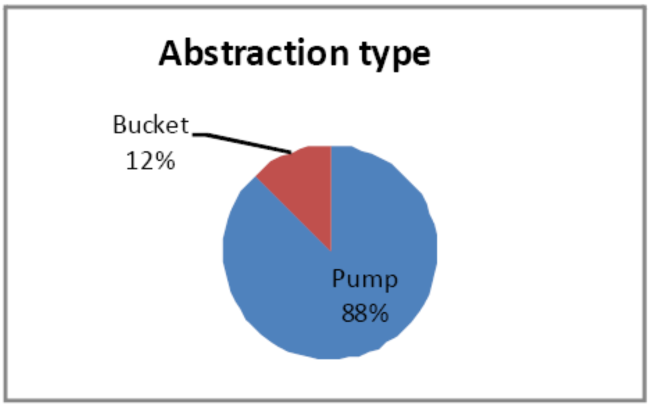


Figure 7. Abstraction method from surveyed wells.

Groundwater in Nauru is in the most part accessed by small pressure pumps. It was observed that 88% of all households accessed their groundwater from electric pumps. The remaining 12 percent of the houses surveyed are using buckets to access their well water (Figure 7). Electric pumps are mostly ''Davey'' brand and vary in power between 60 KW to 90 KW. Capelle and Partner, a local retailer, are the sole distributor of pumps on the island.

During the survey, teams came across incidences of pumps being stolen, especially in Boe and Aiwo, two relatively ''densely'' populated areas. Stolen pumps was considered by many owners as a significant risk to their security of access to well water.

In some cases households were not using groundwater due to missing pumps. Where they were unable to afford replacement or repairs to pumps their access to well water was significantly affected. Where the well was left unused, householders relied on rainwater or other sources for water needs.

4.2 Shallow groundwater quality

4.2.1 Salinity levels

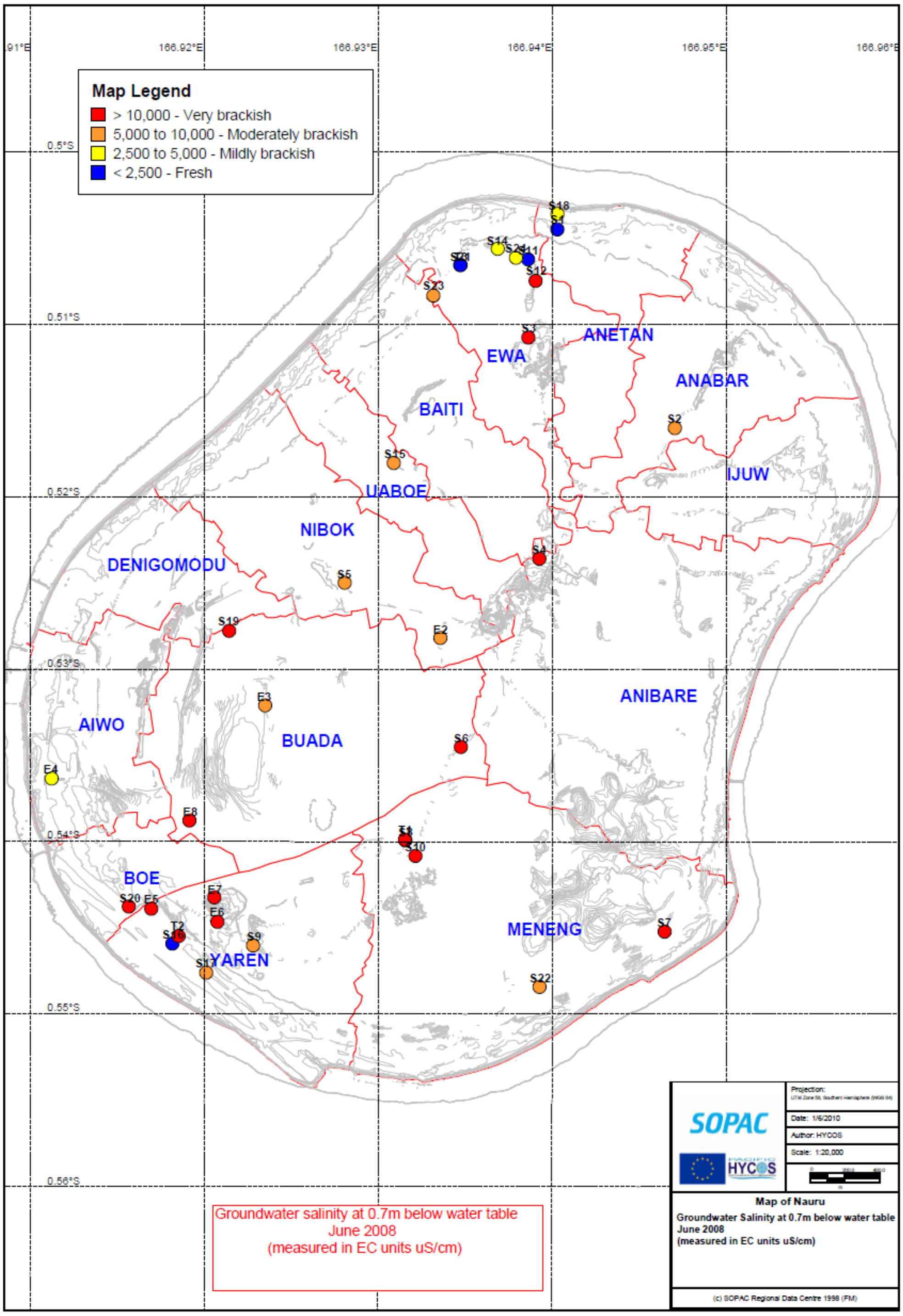
Salinity levels were recorded for 283 wells across Nauru during the March - April 2010 period. The measurements were taken from taps connected to wells (54% of samples), or directly from the well (46% of samples).

The tap samples were taken from the closest tap to the well. The tap was run for a few minutes prior to sampling to ensure that the sample better represented the groundwater at the pump inlet. Where possible, measurements taken from wells, were measured at 0.3-0.4 m above the bottom of the well, to reflect the most likely placement within the well of the pump inlet.

During the period of March - April 2010, the median salinity of all sampled wells was 2500 µS/cm. Of the wells sampled 88 wells or 31% of the wells had salinity below 1500 µS/cm. Groundwater monitoring bores constructed by NRC and Falkland in 2008 and monitored approximately every quarter provide a good indication of the salinity of the groundwater across the island over time. Utilising groundwater quality data compared against the rainfall gives a good indication of both the distribution of fresh groundwater around the island, and its reliance and sensitivity to rainfall.

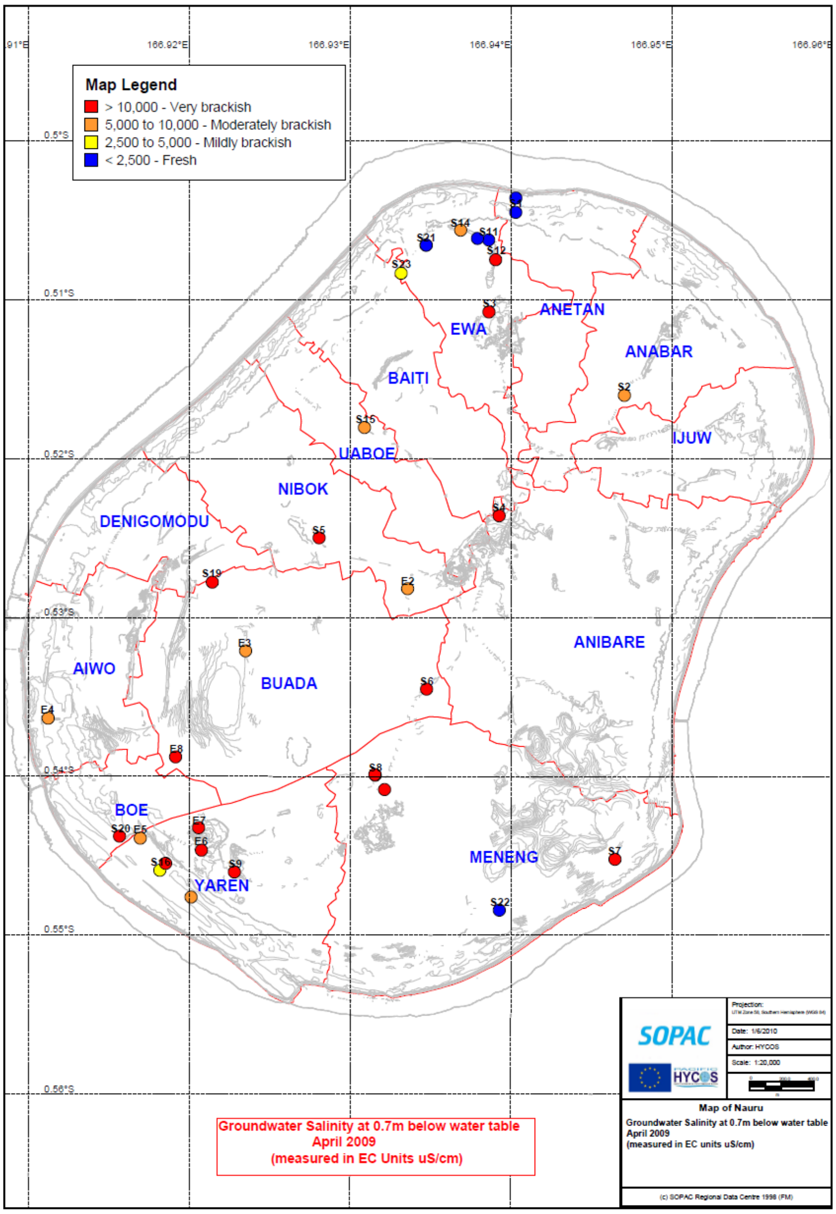
Salinity maps of selected monitoring bores were constructed for the period June 2008, April 2009, and March - April 2010. In each case the salinity values used were calculated based on the available data to represent approximately 0.6 – 0.7 m below the top of the groundwater, representing the most likely placement of any pump inlet point and allowing groundwater values from monitoring bores to be compared with the values taken from the domestic wells.

The June 2008 monitoring was taken at the end of a very dry period in Nauru, consequently all the bores indicate moderately brackish to very brackish water, with the exception of bores in the north which suggest that there is fresher groundwater still present in the Ewa and Anetan Districts during this period (Map 4).



Map 4. Groundwater salinity at 0.7 m below water table-June 2008.

The April 2009 monitoring is a similar representation of groundwater salinities, where rainfall continued to be below average and where there is no significant recharge to the groundwater (Map 5).



Map 5. Groundwater salinity at 0.7 m below water table-April 2009.

The rainfall chart for Nauru for January 2004 – May 2010, which is derived from various sources including the ARMS manual rain gauge records in Denig and the manual station installed at NRC office Topside, indicates that below average rainfall has been experienced since early 2007. The salinity readings from the April 2009 monitoring suggest that groundwater quality is significantly affected by this extended dry period (Figure 8).

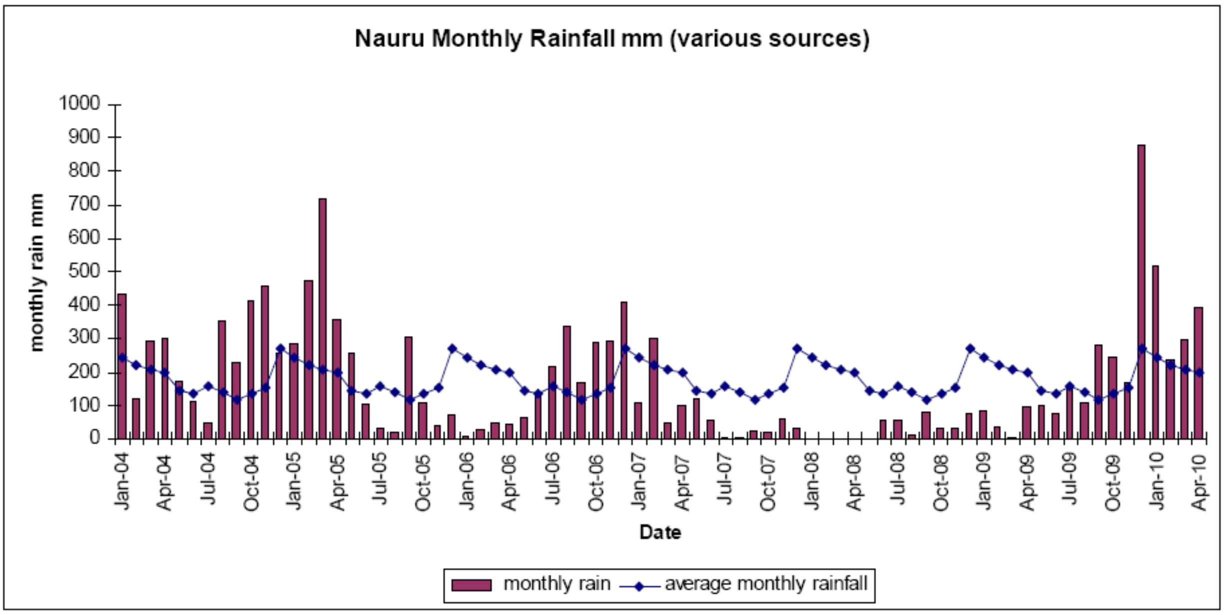
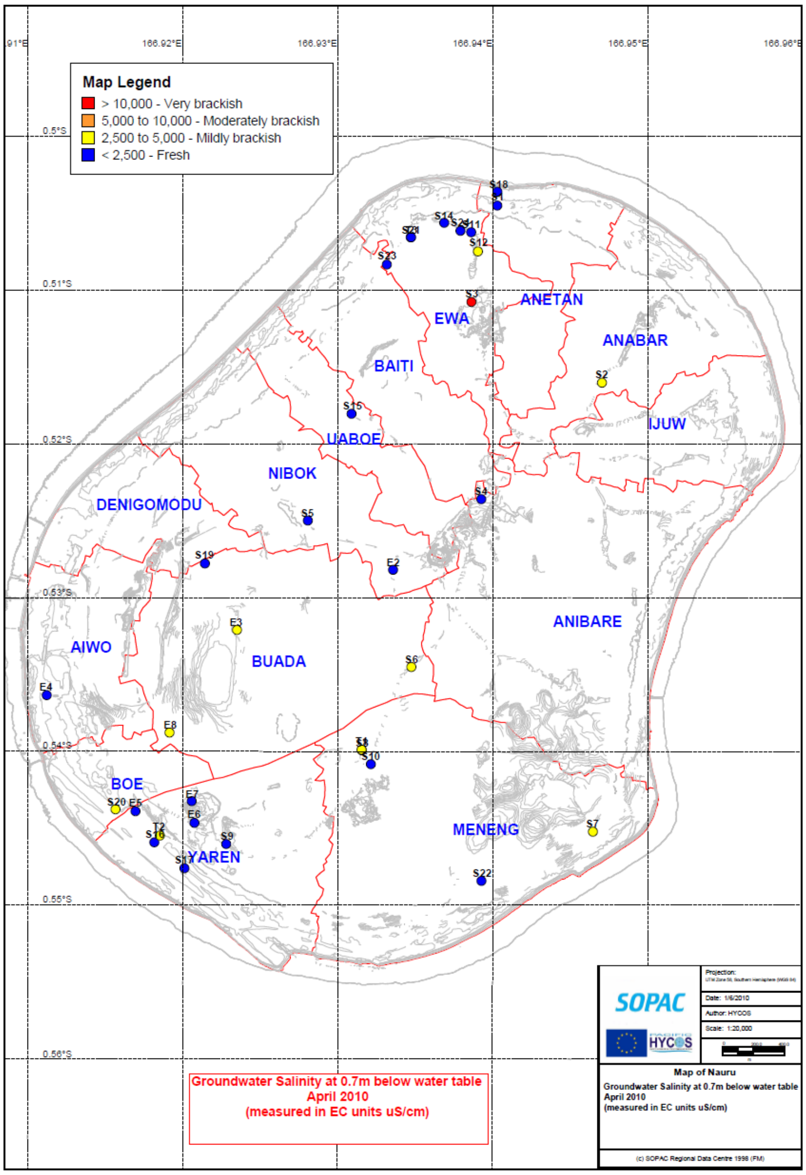


Figure 8. Nauru monthly rainfall January 2004 – May 2010 (various sources).

April 2010 monitoring of the NRC monitoring bores by contrast was taken at the end of a period of over 8 months of above average rainfall. December 2009 rainfall recorded at the ARMS manual rain gauge site in Denig indicates the largest December rainfall recorded for Nauru. (Note that rainfall stations Topside indicated 758 mm NRC manual gauge, and 783mm at TB3 automatic station NRC workshop).

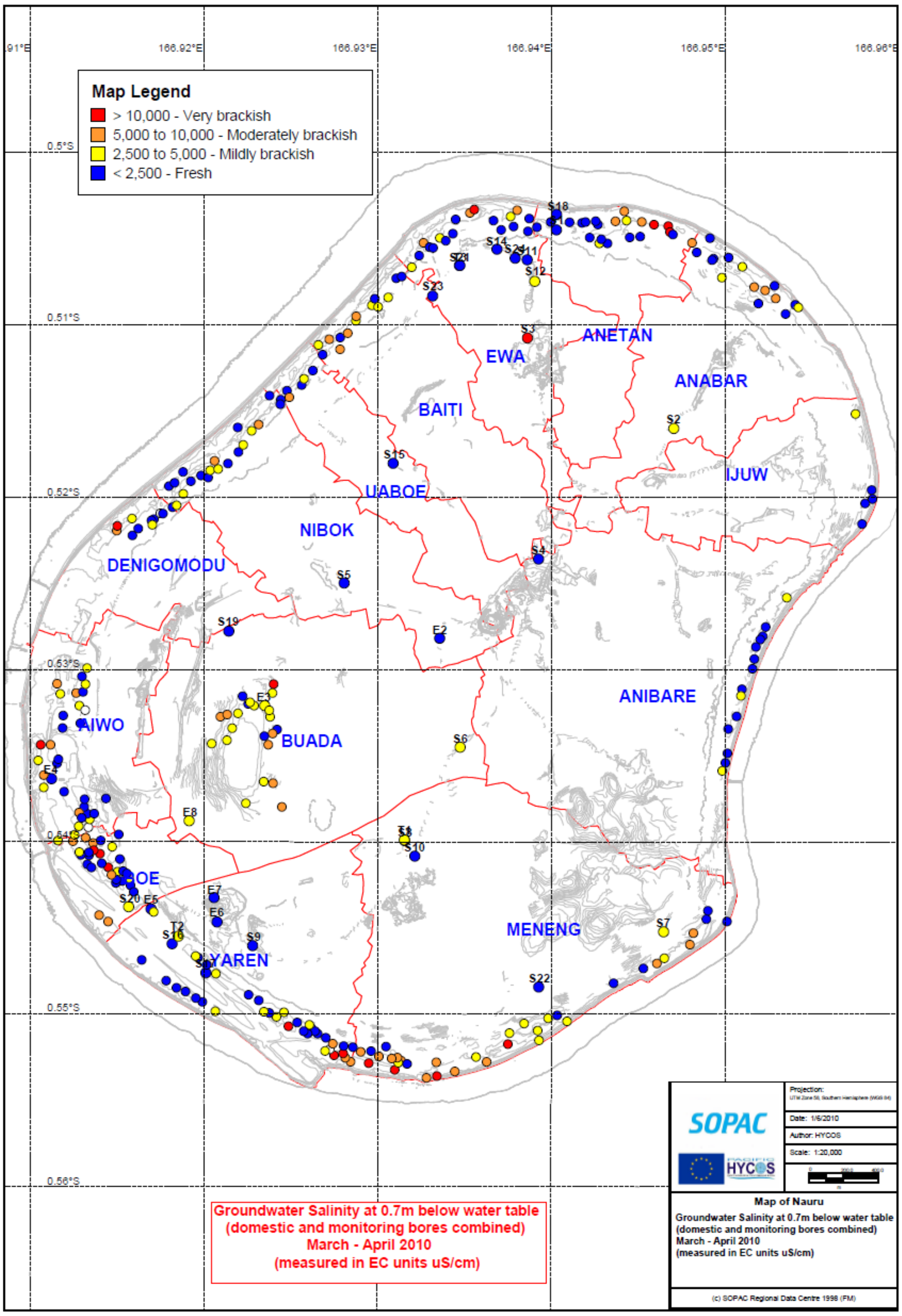
The impact on the groundwater salinity in response to this period of rainfall is quite dramatic with all of the NRC bores monitored in April 2010 demonstrating a considerable freshening of the groundwater when compared with the April 2009 groundwater monitoring. The rainfall over the previous 12 months, and in particular the last 4-5 months since the December 2009 event, has resulted in significant recharge to the groundwater system, where groundwaters at 0.7 m depth were considered to be very brackish are now considered to be fresh.

It is worth noting that the monitoring bores around Buada have not responded as well to a freshening of the groundwater as other monitoring bores, suggesting either slower recharge response in that area or an area of greater “mixing” with the underlying seawater, and larger brackish zone (Map 6).



Map 6. Groundwater salinity at 0.7 m below water table-April 2010.

The March – April 2010 groundwater survey of domestic wells provides valuable additional information on the shallow groundwater along the coastal terrace, where the majority of groundwater is currently being abstracted. Aswith the NRC monitoring bores, the majority of the wells indicate fresh groundwater, in response to the rainfall over the last 4-5 months. The most noticeable exceptions to this include Buada, parts of Meneng, and the coastal bores of Anetan which have wells which are accessing more brackish groundwater (Map 7).



Map 7. Groundwater salinity at 0.7 m below water table (domestic and monitoring bores combined)-April 2010.

The comparison of the salinity in the monitoring bores from NRC indicates the strong relationship between shallow groundwater quality and rainfall. Above average rainfall over the preceding 4-5 months has had a significant impact on the shallow groundwater quality with a freshening of the groundwater across nearly the entire island through increased recharge. These maps demonstrate the large variability in groundwater quality that can be expected, and more importantly, the relatively rapid response time between rainfall and impact on groundwater. In this recent survey, above average rainfall for 8 months prior to the survey was sufficient to provide a significant freshening and improvement in the groundwater resources, (where previously identified brackish bores now indicating freshwater).

This comparison indicates that salinity of groundwater resources are highly, variable in Nauru, and unlikely to be reliable during extended dry periods to provide useable freshwater. In order to maximise the use of the groundwater as a freshwater resource groundwater could be abstracted and stored during periods of low salinity and made available for use in times of need.

It is estimated that from the coastal “bottom side” 65 ML of fresh groundwater would have been available at the time of the 2010 survey. This estimate considers domestic wells with access to freshwater less than or equal to 2500 µS/cm, and based on an effective specific yield of 25% for the coastal plain area and assumes that sufficient storage would be available at the household level to store pumped water. Based on these assumptions up to 23 weeks of freshwater suitable for non potable purposes could be provided for households using ground water at the time of the survey. Timing of the abstraction and storage of the pumped water are limiting issues that would need consideration, especially where existing domestic wells are used for abstraction. However the 2010 survey indicates that during the March April 2010 period over 40% of the wells have on average 0.8 m depth of freshwater, with less than 2500 µS/cm EC that could be used to abstract freshwater for use at a later time.

Groundwater abstractions from towards the centre of the island are likely to be greater at certain times. Exploitation of this variable resource potential would require specifically designed bores and storages and guidelines for when and how long these bores could be operated. However there is potential for opportunist use of fresh groundwater abstraction and storage for national supply purposes.

4.2.2 E-coli levels

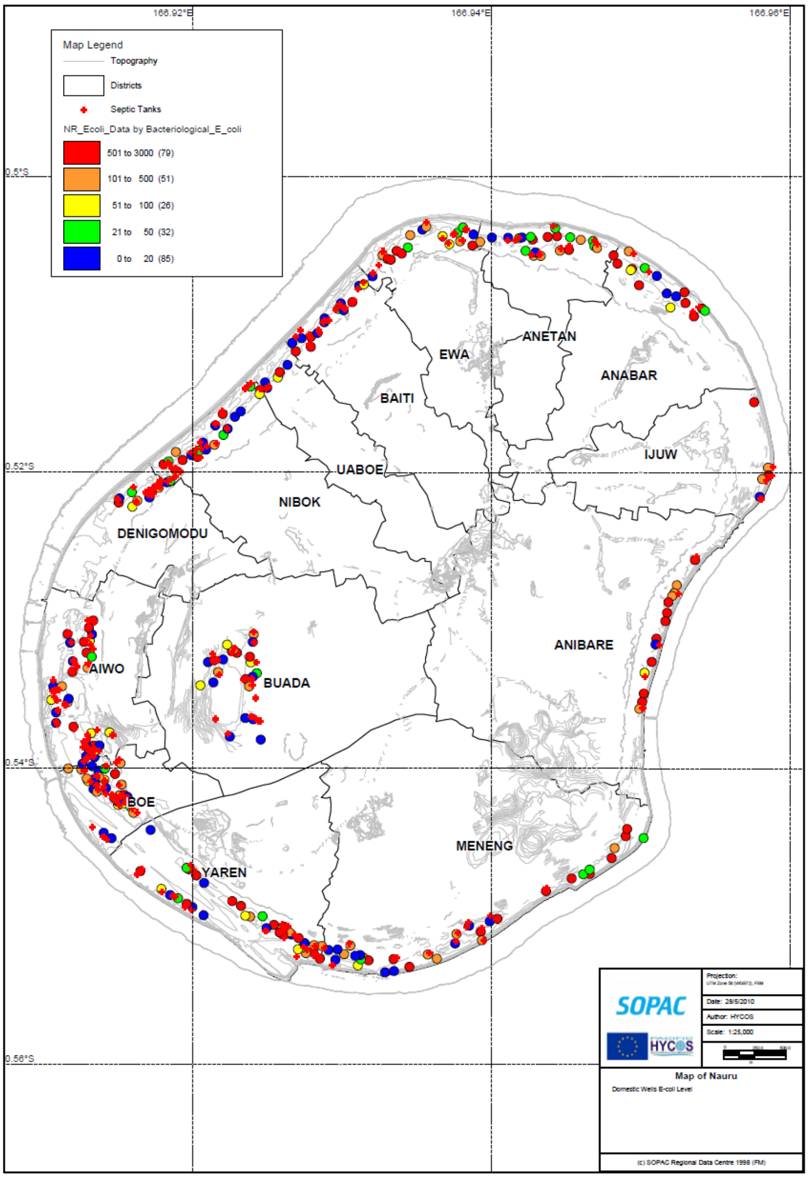
Groundwater has been sampled from 274 wells across Nauru. The measurements were taken from taps connected to wells (54%), or directly from the well (46%).

The tap samples were taken from the closest tap to the well. The tap was run for a few minutes prior to sampling to ensure that the sample better represented the groundwater at the pump inlet and to avoid bacteria that might be present in the pipe to contaminate the sample.

Samples were processed in the RoN Hospital Laboratory using the ‘’IDEXX Colisure’’ method. The Total Coliform/E-coli test is an easy process involving five steps. Small cartridges of reagent are first added in the 100 ml sampling bottles. After inclusion of the reagent, the water sample is transferred into the ‘’Quanti-tray’’, a 97 cells tray which is then sealed and put in incubation for 24 hours up 48 hours.

Results were easier to read and more conclusive after 36 hours, a period of 36 hours incubation was adopted for all subsequent analyses.

After 36 hours, counting the cells’ colours gives the most probable number of E Coli bacteria per 100ml (MPN/ result: yellow for negative, magenta for Total Coliform positive and fluorescent, (under a UV light), for E-coli.



Map 8. *E-coli level of domestic wells-April 2010 (Unit: MPN/100 ml).*

A review of the data indicates there is considerable risk of faecal contamination in the groundwater abstracted from the domestic wells (Map 8).

This is likely to be in response to a combination of open septic pits which allow pathogens to travel freely to the groundwater, the close proximity of wells to sceptics', and the relatively easy accessibility of wells to surface water ingress.

An analysis was made of the E coli measured values from the groundwater in wells and the distance to the closest septic, as well as E coli and salinity of the well water. No obvious relationship between these parameters was observed.

The general observation is that the current septic construction techniques are having considerable impact to the potential application or use of groundwater in Nauru. The relationship between increased health issues such as diarrhoea and use of contaminated groundwater has not been investigated. As the majority of groundwater is used for personal bathing, laundry, and toilet flushing, with minor use for cooking and almost none used for drinking then the risk of exposure to pathogens associated with E coli is reduced where risk of ingestion is reduced.

However, users should be aware that non-potable uses of contaminated water could still be threatening to health. According to the ‘‘Guideline for environmental management, use of reclaimed water’’ (EPA 2003), acceptable uses of recycled water of different qualities[5] (class A to D) are particularly restricted for E-coli level above 10 MPN/100 mL (Table 5).

Table 5. Acceptable use of water for different E-coli levels.

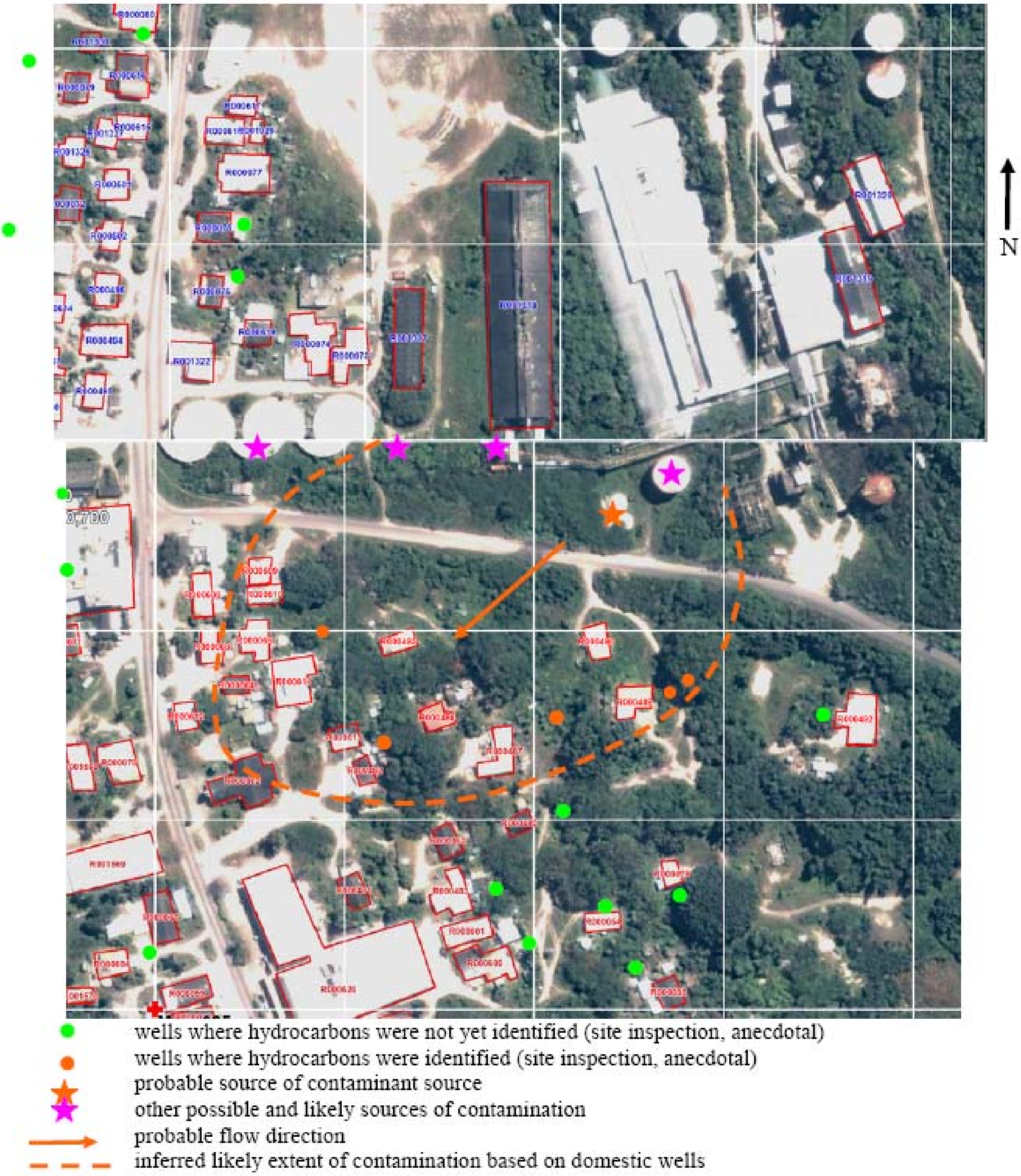
E-coli levels	**Acceptable uses[6]**
<10 MPN/100 mL	• Residential uses e.g. toilet flushing, washing machine, gardens • Raw human food exposed to the water (e.g. water, lettuce) • Livestock drinking (excluding pigs) • Cooked/processed human food or selected crops not directly exposed to water • Non-food crops
<100 MPN/100 mL	Livestock drinking (excluding pigs) • Cooked/processed human food or selected crops not directly exposed to water • Non food crops
<1000 MPN/100 mL	• Cooked/processed human food or selected crops not directly exposed to water • Non food crops

These guidelines are likely to be too restrictive for use in Nauru, e.g. where the use of waters for toilet flushing is restricted to waters with an E-coli level <10 MPN/100 mL. It is recommended that pragmatic interim guidelines be developed for use in Nauru as part of a water and sanitation policy for Nauru.

4.2.3 Hydrocarbon contamination

During the course of the survey hydrocarbon contamination was observed in a number of locations around Nauru (see Annex V for a detailed review). The main location is in Aiwo (Map 9) where it is currently affecting at least 4 domestic wells and over an estimated area of 400 m².

5 Water quality parameters taken into account are: Biological Oxygen Demand (BOD), suspended solids, turbidity, pH, residual chloride and E-coli level. E-coli is the parameter used to evaluate risk to human health.
6 For more details on acceptable uses, refer to EPA 2003.



Map 9. Probable extent of hydrocarbon contamination in Aiwo district-April 2010.

This hydrocarbon contamination is impacting at least 4 domestic wells in Aiwo, 3 of which are no longer able to be used due to the level of contamination experienced. The extent of the contamination and direction of flow, inferred from domestic well inspections and anecdotal information, is to the SE, from the assumed source.

The most likely source of the contamination is from the fuel storage and handling facilities located below the current phosphate processing plant. In particular the 4-6 concrete storage tanks next to the large steel bulk storage tank, B4. The status of these concrete tanks and their history of fuel

The total abstraction per well, per capita using the well, and the use of groundwater, have been used to determine the importance of groundwater in Nauru. Given that a third of the population at the time of the survey was using the groundwater on a daily basis, knowing their consumption per capita per day and the purposes for which they use the groundwater, provides us with insight into the importance of groundwater and its reliance throughout the island.

storage or waste oil is unknown and requires investigation. Based on anecdotal information from landholders on the age of their wells and the first detection of contamination it is expected that the main contamination took place in the late 1990's.

The spread of the contaminant plume would appear to be relatively slow moving, where the plume has spread some 250 m over the last 8-12 years. Low hydraulic gradients are expected in this area.

Where this plume is left unattended, and whilst there is potential for continued contamination from a currently unidentified source, the plume will continue to spread, threatening other wells in the area and the shallow marine environment into which it may potentially discharge.

More site specific information is required to verify the extent of the groundwater contamination, flow direction of the groundwater and the type of hydrocarbons. The study should consider options on how to contain the spread of the plume and reduce the impact on the existing wells and the environment. Contaminant monitoring bores will be required to assess the movement of the plume over time. Investigations to identify the age and source of the contamination and if the current fuel handling is still contributing to groundwater contamination should also be undertaken.

A review and reconciliation of furnace fuel storage in particular B4 and the concrete tanks between 1994 and 2001 will assist in identifying if there are any significant losses that have occurred during these times and estimation of the volume of these losses. A reconciliation of fuel storage in B4 over the last 12-18 months would assist in identifying if B4 may still be contributing to any groundwater contamination.

4.3 Groundwater uses

4.3.1 Percentage of people using well water

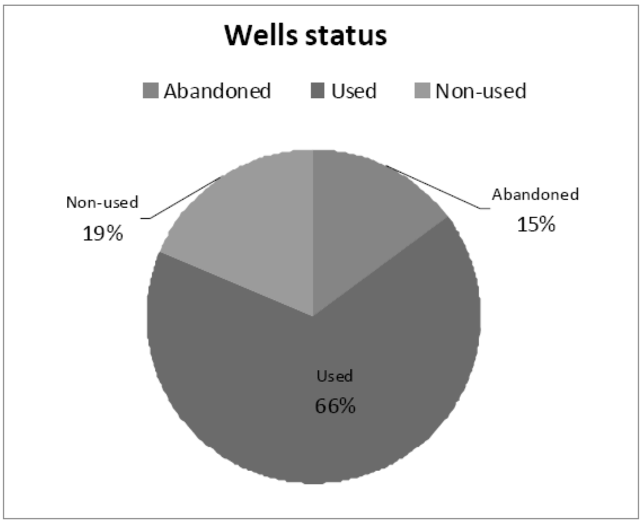


Figure 9. Wells status.

A total of 36% of the population (2010 estimates) have been identified as using well water. This figure includes students at 3 schools which are using groundwater mostly for flushing toilets. At a household level, 21% of the households have been identified using well water which represents 32% of the population in households (excluding schools).

It is estimated that 67% or two thirds of all wells surveyed were currently in use at the time of the survey, (Figure 9). The main reasons encountered for unused wells are:

- The pump is not working
- The pump has been stolen
- The water is polluted (e.g. hydrocarbon)
- Another water source is sufficient to cover all the household needs.

Rainfall plays an important role in the reliance on groundwater and it's impact. Groundwater use increases during a drought period and as the need for alternate water sources rises so does access to the groundwater increase. Note that there had been abundant above average rainfall in the months leading into the groundwater survey resulting in sufficient rainwater collected from roofs for many household requirements, thereby likely to reduce the reliance on the groundwater.

4.3.2 Water abstraction

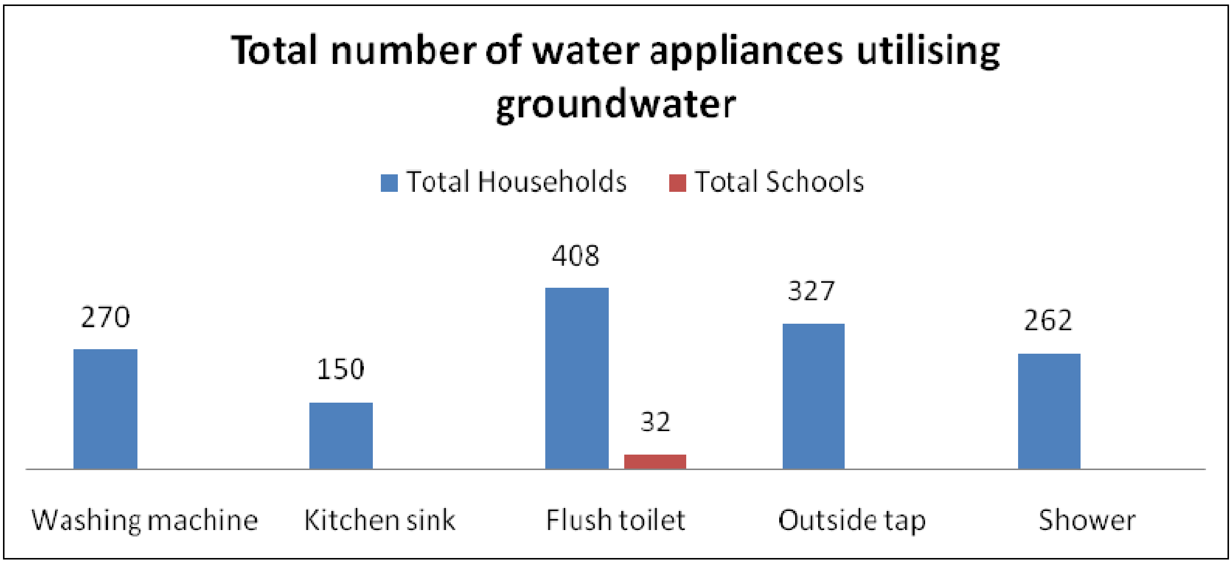


Figure 10. Total number of appliances utilising well water.

4.3.3 Water usage estimations

The following table has been designed to estimate the water abstraction per capita (Table 6).

Table 6. Water appliances consumption estimations.

Water Appliance	Consumption MIN (L/min)	Consumption MAX (L/min)	Consumption MIN per use (L)	Consumption MAX per use (L)	Usage MIN (min/capita/day)	Usage MAX (min/capita/day)	Consumption MIN(L/capita/day)	Consumption MAX(L/capita/day)
Shower	7.00	9.00	NA	NA	3.00	5.00	21	45
Kitchen tap	8.00	10.00	NA	NA	NA	NA	8	12
Outside Tap	8.00	10.00	NA	NA	2.00	5.00	16	50
Washing machine	NA	NA	90.00	150.00	NA	NA	18	30
Flush toilet Dual C1	NA	NA	6.00	6.00	NA	NA	9	9
Flush toilet Dual C2	NA	NA	10.00	10.00	NA	NA	15	15

Estimations used in this table refer to referenced documents with adaptations to Nauru conditions, based on observations and anecdotal discussions. In order to get an average estimation of the abstraction, a Minimum and Maximum consumption is considered for each category above.

All the assumptions are detailed below:

Shower flow rate: Based on "Domestic Water Use Study: In Perth, Western Australia 1998-2001", the flow rate for a shower varies from 7 L/min for waterefficient shower to 9 L/min for normal flow shower (Loh and Coghlan 2003). Assumption made for Nauru: Showers are likely to be normal flow shower but the water pressure is likely to be lower. A flow range of 7L/min to 9 L/min is considered appropriate.

Shower usage per minute: According to Loh and Coghlan (2003), 7 minutes shower was identified among the study. Assumption made for Nauru: Showers are mostly using 'cold' water so we assume that showers will be shorter. The range chosen is from 3 to 5 min per shower.

Shower consumption per capita per day: Assumption for Nauru: For each household using a shower connected to groundwater, an average of 1 shower per capita per day has been considered, based on anecdotal information

Kitchen tap flow rate: According to "Water efficiency, Domestic Appliances and Hydraulic design for on-site systems" a water efficient tap can reduce flow to about 8 L/min (Patterson 2004). Assumption for Nauru: As Kitchen taps would be mostly non-water efficient but because water pressure from the well is likely to be lower than a centralised connected system, a range of 8 L/min to 10 L/min has been assumed.

Kitchen taps consumption per capita per day: According to "Household the big picture", the average use of water from the kitchen sink for each meal is 5 L per capita. So considering 3 meals a day its 15L per capita (Victorian Women trust 2006). Assumption for Nauru: Based on large households, 8 to 12 L per capita per day has been assumed.

Outside tap flow rate: According to Patterson (2004) and as for the Kitchen tap flow rate, outside tap flow rate will range from 8 L/min to 10 L/min.

Outside tap usage per minutes: Considering the relatively high salinity level of groundwater which reduces the suitability of well water for watering gardens and the limited number of gardens, a range of 2 to 5 minutes use per capita per day has been assumed. This figure will be high for large houses but it includes washing boats and pig pens for some houses.

Washing machine consumption per use: Based on "Comparison of wash and rinse for front loaders and top loaders", the average water consumption for a normal wash is 120 L for top loader washing machine up to 7.7 Kg (ACA 2008). Assumption for Nauru: Most of the washing machines are top loader and less than 7.7 kg load. Assuming this average consumption per wash, provides water consumption ranging from 90 to 150 L per washing.

Washing machine consumption per capita per day: Based on "Water budget", a study from the USA, the average use of the washing machine for a family of 3 is 0.3 loads per capita per day (Sustainable sources 2010). Assumption for Nauru: Based on large households, we assume a rate of 0.2 load per capita per day.

Flush toilet consumption per flush: According to Loh and Coghlan (2003) the average volume per flush is 6L for the small cistern and 10L for the large one of a dual flush toilet. Assumption for Nauru: Toilets are likely to be dual flush. 6 L and 10 L cisterns will be considered here.

Flush toilet consumption per capita per day: According to Loh and Coghlan (2003), the average flush of the small cistern is 1.5 times per capita per day as well for the large cistern.

Assumption for Nauru: The 1.5 factor per capita per flush type will be applied to both the large flush and the small flush. That is 1.5 * 6 L, and 1.5 * 10 L, per person per day.

4.3.4 Estimation of groundwater abstraction

Utilising the estimates of per capita groundwater use as identified above and the survey information on number of water using appliances per household and population of households it is possible to get estimates of total abstraction, household abstraction, and per capita abstraction of groundwater in Nauru (Table 7).

Table 7. Total groundwater usage summary, active wells in 2010.

Minimum volume of groundwater abstraction L/day (households only, schools excluded)	Maximum volume of groundwater abstraction L/day (schools included)	Average volume of groundwater abstraction L/day (households only, schools excluded,)	Average volume of groundwater abstraction per active well L/day (households only, schools excluded)	Average volume of groundwater abstraction per capita/day (households only, schools excluded)
215,144	401,642	297,557	1,328	94

The average total abstraction of groundwater for domestic uses is **298 KL per day** where schools abstracting groundwater are excluded. This represents a consumption of **94 L per capita per day** of people using well water (2010 estimates).

The percentage of groundwater use within the household for households using wells has been calculated. (Figure 11).

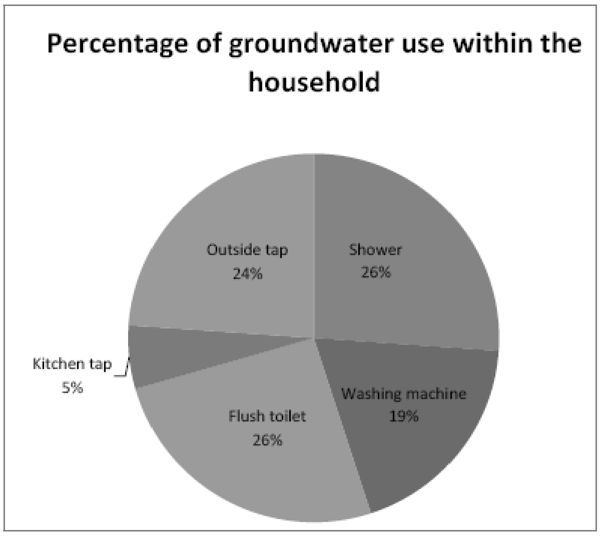


Figure 11. Comparison of groundwater use by activity within the household.

This analysis of groundwater use within the household has been compared with other studies to test its validity (Figure 11). According to the NZ Ministry for Environment 2009[7], an average

[7] http://www.sustainability.govt.nz/water/typical-household-water-use

household consumption is toilet (25%), shower-bathroom (25%), garden (20%), laundry (20%), kitchen (10%). Kitchen sinks are generally not connected to groundwater sources in Nauru. Groundwater is generally considered in Nauru as being unsuitable for use in the kitchen. This perception in Nauru of the groundwater helps to explain the reason for the low use of groundwater in the kitchen, calculated to be 5%.

4.3.5 Total household water consumption

Estimates of water needs per person have been derived from the estimated potable needs and calculated non potable needs. This data has been summarised in Table 8. Based on the survey data for 2010 and assumed potable water requirements as 20 L/day/person, a range of total water needs of 88 to 141 L/person/day is estimated, (potable water requirements refer to the water consumed for drinking (5 L/p/d) and cooking (15 L/p/d)). These estimates compare reasonably well with estimates from Falkland 2009, of 100 to 150 L/p/day per person.

Table 8. Water usage estimates 2010.

	Minimum L/day/person	Maximum L/day/person	Average L/day/person
Groundwater	68	121	94
Potable water (desalination or rainwater)	20	20	20
Total water needs	**88**	**141**	**114**

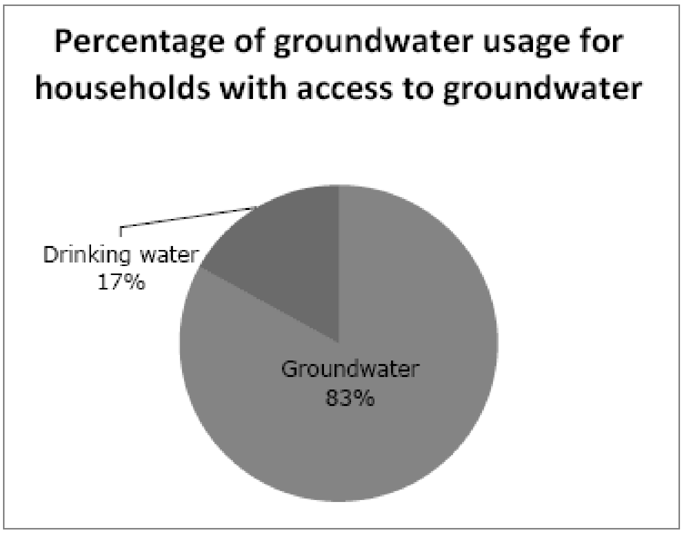


Figure 12: Estimate of percentage of water usage for households using groundwater for non potable needs.

On average groundwater accounts for about 83% of the estimated total water consumption in household with access to groundwater (Figure 12).

4.3.6 Reliance on different water sources

With an average abstraction of groundwater estimated at 298 KL/day for household needs only, and using the estimates of water requirements as determined in Table 7 for March – April 2010, an estimate of reliance for the March - April 2010 period can be calculated. Groundwater is calculated to account for 26% of all water used in Nauru in March - April 2010. Rainwater is calculated at providing 59% of water needs, with RO water providing 15% of water needs (Figure 13). During dry periods, where stored rainfall diminishes, the reliance on groundwater and desalinated water will increase; total water usage is expected to decrease.

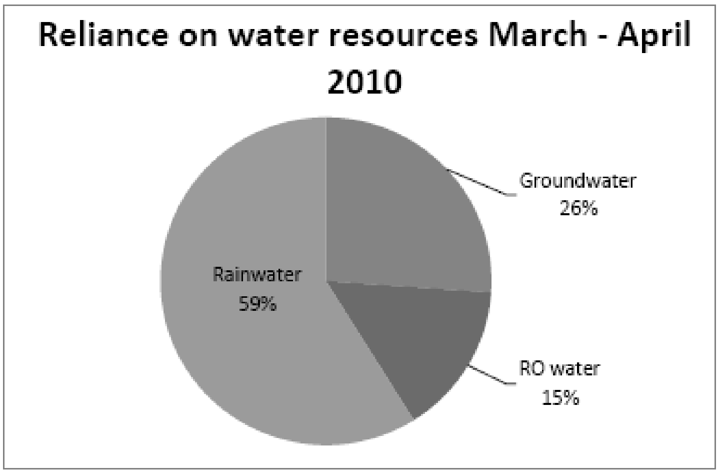


Figure 13. Reliance on water resources March - April 2010.

4.4 Drinking water sources

4.4.1 Primary and secondary water sources for drinking purpose

At the time of the survey, when rainwater was readily available, Nauruan households indicated that, when available, they will rely upon rainwater harvesting for the majority of their potable water requirements. The survey suggests that Nauruans rely on RO water only when their primary potable water source, rainwater, is not available. Bottled water is rarely relied upon as a water source for household potable water needs. (Figure 14; Figure 15).

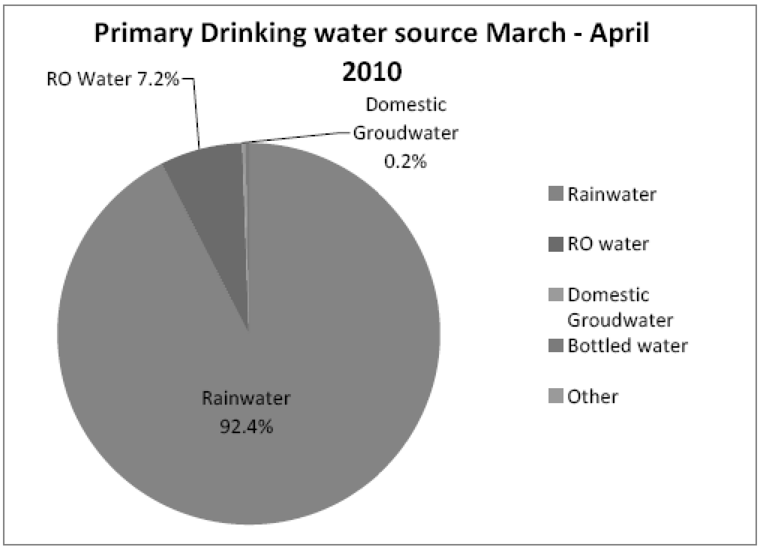


Figure 14. Primary potable water source March – April 2010.

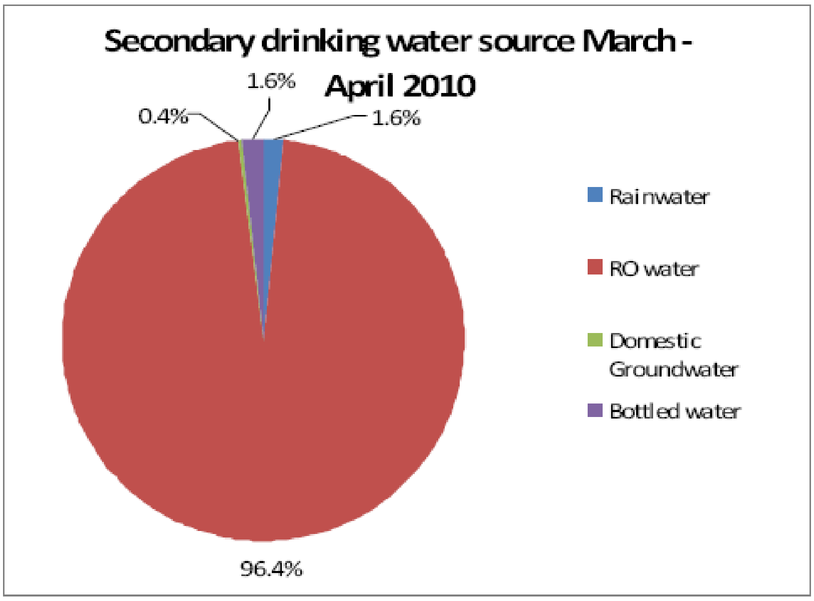


Figure 15. Secondary potable water source March - April 2010.

Comparisons were made with the 2007 Demographic and Health survey which surveyed 389 households on Nauru. The groundwater survey of March – April 2010 surveyed 433 households. The DHS survey 2007 also represented approximately 25% of all households (NBS 2009). The data compares well between the two surveys, which is reassuring given that the population samples would have been different (Table 9). This provides some confidence in the source of potable water sources identified.

Table 9: Primary drinking water source (2007 and 2010 survey).

	Primary Drinking Water Source			
	Rainwater	Desalinated water	Groundwater	Other (including bottled)
2007 DHS survey	89%	8.5%	0.3%	2%
2010 Groundwater survey	92.4%	7.2%	0.2%	0.2%

4.4.2 Water treatment

Householders do not always treat their water before drinking it. The 2010 survey recorded water treatment by type and frequency.

Of the households surveyed more than 40% indicated that they would “mostly” to “always” treat their water before drinking it. This included rainwater as well as desalinated water received from the RO plant. It is estimated that less than 30% of the households did not treat their potable water or rarely treated before consumption. The remaining 30% indicated they “quite often” treated their potable water which was noted in most cases as mostly boiling water for children only.

Boiling and filtering have been identified has main water treatments, boiling being by far the most common.

Boiling accounts for 96% of water treatment methods for both rainwater and RO water. Around 3% of households are using filter methods only and 1% are both boiling and filtering their water. On the only two households identified as drinking the groundwater, one is filtering the water while the other is boiling the groundwater before consumption. Both of them always treat the groundwater before drinking it.

Frequencies of treatment were recorded according to the following range: Never, rarely, quite often, mostly, and always (Figure 16 and 17).

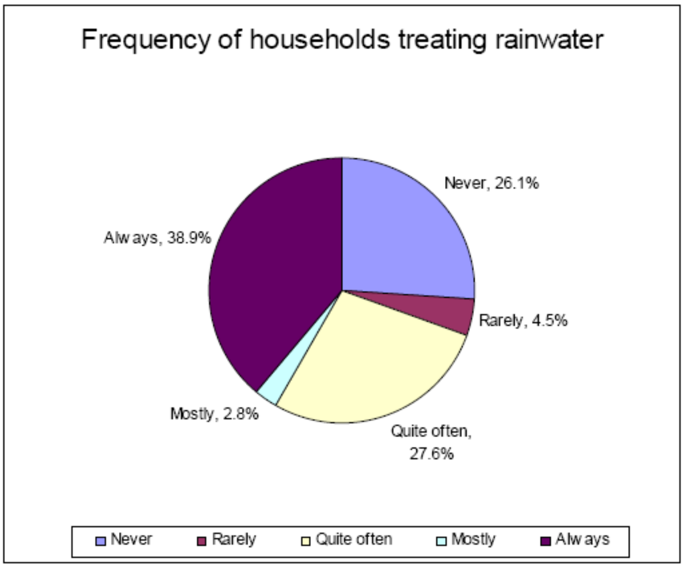


Figure 16. Frequency of households treating rainwater March - April 2010.

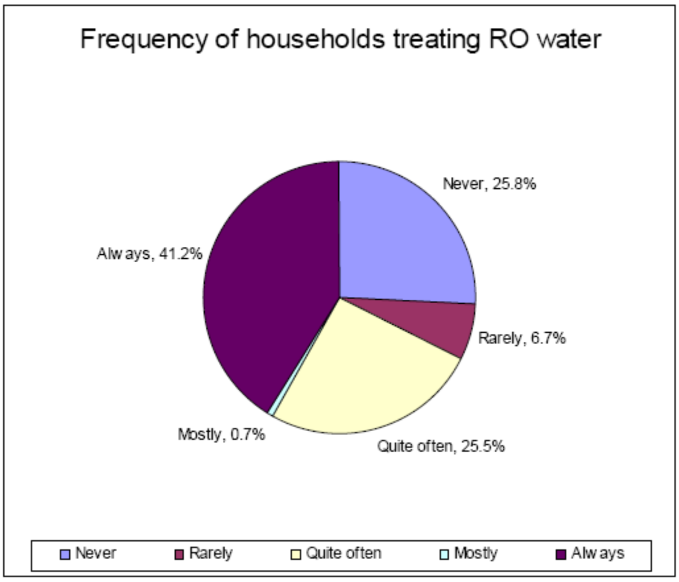


Figure 17. Frequency of water households treating RO water March - April 2010.

4.4.3 Scarcity of primary potable water source

Scarcity of primary drinking water source has been recorded for 416 households, People were asked how often they ran out of their primary water source during the last few years, using the following range: Never, rarely, quite often, mostly, and always. Of the 416 surveys where a primary potable water source was recorded, 248 or 60% indicated a reliance on a secondary potable water source (Table 10).

From the analysis of scarcity data it is interesting to note that there is a relatively large number (136 or 33%) of surveyed households who consider themselves never to run short of potable water from their primary water, and who have not mentioned or needed reliance on a secondary potable water source.

Whilst other households, 8%, consider their primary potable water vulnerable to scarcity, but do not have an alternative secondary potable water source available.

Table 10: Frequency of scarcity of primary water source.

Scarcity of primary drinking water source	**Primary drinking water source**				**Secondary drinking water source**			
	Rain water	RO Water	Well water	Bottled water	Rain water	RO Water	Well water	Bottled water
Never	149	7	1	1	0	19	0	3
Rarely	198	13	0	0	3	186	1	1
Quite often	22	3	0	0	0	19	0	0
Mostly	12	3	0	0	0	11	0	0
Always	4	3	0	0	0	4	0	1
Total[8]	385	29	1	1	3	239	1	5

5. SANITARY SURVEY

A sanitary survey is an on-site inspection of the water supply system assessing the risk or threat from contamination. A survey is made of the site conditions, set up, and practices in a water supply system that poses an actual or potential danger to the health and well-being of the consumer. There are sanitary surveys for rainwater tanks, piped water systems, wells, and drums to help assess the risk of the water source from contamination.

The sanitary survey designed for this groundwater assessment has been undertaken for each of the 224 domestic wells used on a daily basis in Nauru at the time of the survey (wells which were identified as abandoned, not used or where access was only occasional did not have a sanitary survey undertaken).

5.1 Sanitary survey design and implementation

This sanitary survey developed for Nauru is based on the World Health Organisation (WHO) format and developed with SOPAC and Live and Learn Environmental Education (LLEE) for the Pacific (Annex VI). It consists of a series of 13 “yes” or “no” type questions used to help identify threats and risks from the well and to groundwater quality.

In order to facilitate the progression of the groundwater assessment, the sanitary survey has been integrated into the questionnaire and was undertaken in conjunction with the groundwater survey. The survey team members conducted the sanitary survey, and the results are based on their observations.

[8] On the 420 households interviewed, 4 were non respondents for this questions.

5.2 Sanitary survey review

The following section reviews the questions used in the survey, detailing their significance and the risk or threat to the well from contamination. In this survey “risk” refers to the positive or negative impact a particular action or set of conditions may have on a well and its water quality from a potential hazard or threat. A covered well will reduce the risk of contamination where as an uncovered well will result in a higher risk of contamination. “Threat” refers to what the potential hazard source is, which threatens the well and its water quality.

Q1: Is there a septic tank or pit toilet within 10m of the well?

Septic tanks or pit toilets around the well are important sources of faecal contamination to groundwater. Leaking septic and pit toilets allow contaminated wastewater to leach into the ground. Permeability of soils and depth from the contamination source to the groundwater table are important considerations to evaluate risks to contamination.

In Nauru, the shallow depth to groundwater coupled with the highly permeable limestone soils increases the risk of groundwater contamination. The threat of septic significantly increases where the septic are unsealed as is considered to be the majority of septic pit construction in Nauru. With consideration to threats, 10 m is considered a relatively small distance identifying increased risk to groundwater. The 10 m distance was kept as per the original guidelines and is likely to indicate a high risk of contamination from this potential threat. The groundwater survey identifies the distance to the closest septic or pit toilet to the well.

Q2: Is the nearest septic tank or pit toilet on higher ground than the well?

Groundwater will naturally move from a higher head to a lower head. The assumption made is that where the septic is located at a higher ground any contaminant reaching the water table will naturally migrate down gradient towards the well. In the case of Nauru the gradient of the water table is very low in addition to it being a karstic environment and relatively low lying and with little variation in topography for the coastal plain where septics and well are located. In Nauru’s case this question is not especially insightful as to determining risk to the well.

Q3: Is there any other source of pollution (e.g. animal excreta, rubbish) within 10 m of the well?

Animal excreta are a direct source of bacteriological contamination and potential threat. Rubbish often contained organic matter and attracted animals that contributed to the potential threat of contamination. When the ground is flooded, bacteria may enter the well.

Q4: Is the drainage around the well poor, allowing water to pond within 2 m of the well?

Poor drainage around the well will increase the potential for ponding of water and the water borne diseases to survive and access the groundwater and well via direct infiltration or ingress to the well. Ponded water is considered a threat to the well and its water quality. During the survey, drainage was considered poor if there were indications of ponding around the well.

Q5: Is the wall around the well not properly raised above the ground?

A wall around the well assists in reducing surface water ingress directly into the well during flooding event. It will also assist in other material and potential contamination accessing the well. Absence of a wall increases the potential risk to contamination. During the survey, a wall was NOT considered properly raised if its height was less than 30 cm.

Q6: Is the wall around the well damaged or cracked or rusted allowing surface water to enter?

As per question 5, a damaged well wall allows surface water to enter into the well and is a risk for increased contamination.

Q7: Is the concrete floor around the well absent?

A concrete floor correctly sealed around the well will assist in reducing the potential for water to enter into the well through infiltration. Creating a buffer zone around the well reduces the direct connection of any potential contaminant from accessing the well. Absence of concrete floor around the well is a risk to the well.

Q8: Is the concrete floor less than 1 m wide around the well?

A meter concrete apron around the well is a nominal practical distance considered to reduce direct leakance/infiltration into the well and therefore risk to that well.

Q9: Is the concrete floor cracked allowing water to enter the well?

A damaged concrete floor has increased potential to allow contaminated water to enter the well and will represent an increased risk to the well.

Q10: Are the inside walls of the well poorly sealed at any point 3 m below ground?

Poorly sealed walls are considered a risk to potential contaminants entering into the well. A well which does not have cracks in the well wall will reduce this risk.

Q11: Are the bucket and rope left in a place where they may get contaminated?

A bucket is at risk of contamination especially if it is left on the ground near the well. During the survey, bucket and rope were considered as a risk if they were not stored in safe environment.

Q12: Is there a need to fence the well area (due to animal activity etc)?

Fencing, by restricting access to the well area, assists in reducing the risk from contamination by preventing animals and children to enter the well and helps reduce the potential for rubbish to be thrown into the well. Where animal, excreta or rubbish was observed near or around the well, the survey team recorded a need for fencing.

Q13: Is the mouth of the well not securely covered?

A secure well cover is important in minimising the risk of contamination to the well. Unsecure covers represent a risk to groundwater quality.

During the survey, the mouth of the well was considered securely covered where the cover was well fitting and sufficiently heavy to prevent being moved by animals or children; and if the cover is in a good condition, without any cracks.

Two extra questions were added to those provided by the sanitary survey pro forma. These questions were designed to capture people's perception of the dominant risks and threats to their well. These gave an opportunity for the surveyor to feedback to the well owner the assessment of the potential risks and threat that were observed and to inform the well owner on possible options to reduce these threats and risks.

5.3 Sanitary survey results

The positive responses were then summed and the resulting “risk assessment” was then determined. The minimum risk assessment was 0 whilst the maximum risk assessment possible was 13. The higher the risk assessment the greater the vulnerability or susceptibility of the well to contamination from surface activities.

It was assumed that where a higher risk was assessed for the well there would be a trend towards an increased level of E coli activity observed in the sampled groundwaters.

A comparison between the risk assessment and E-coli levels however did not identify any obvious trend in increased risk assessment and increased E coli activity in sampled waters.

Figure 18 compares the risk assessment for each well, as identified during the sanitary survey, and the log value of E coli taken from the sample for that well. The data does not indicate any obvious correlation between risk and threats, and E coli values.

However this supposes that each risk is equal and would lead to the same impact on groundwater quality. Differences in the geology (permeability), proximity to septics, capacity of septics to store and polish the effluent, and the salinity 10 of the groundwater are likely to contribute to the variation in risk assessment and E coli values observed.

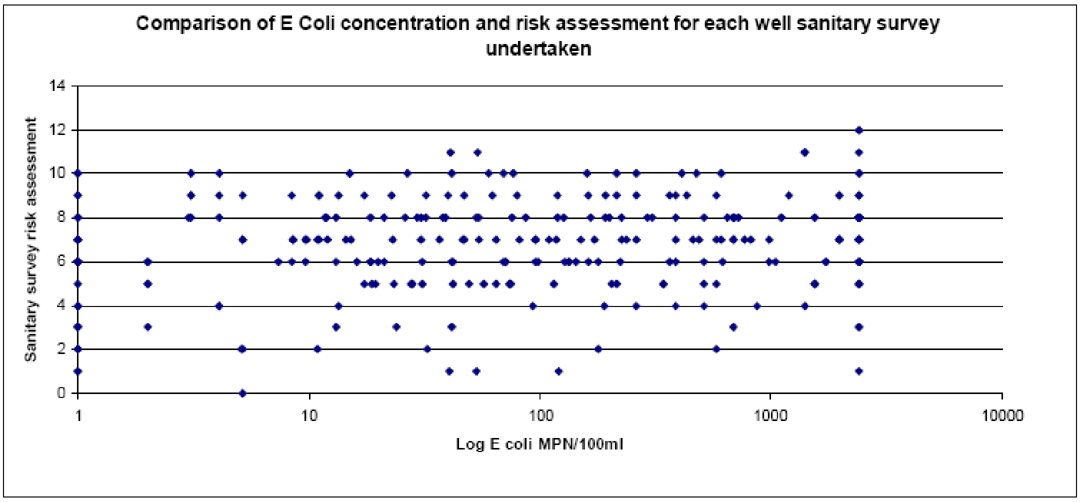


Figure 18. Risk assessment versus E Coli value (Log).

Whilst the sanitary survey does not demonstrate a strong correlation between identified risk and level of faecal contamination in groundwater, however it does indicate a normal distribution of risk for wells surveyed (Figure 19). More than 80% of the wells surveyed have a total of 5 or more on the risk assessment scale as determined from the sanitary survey risk.

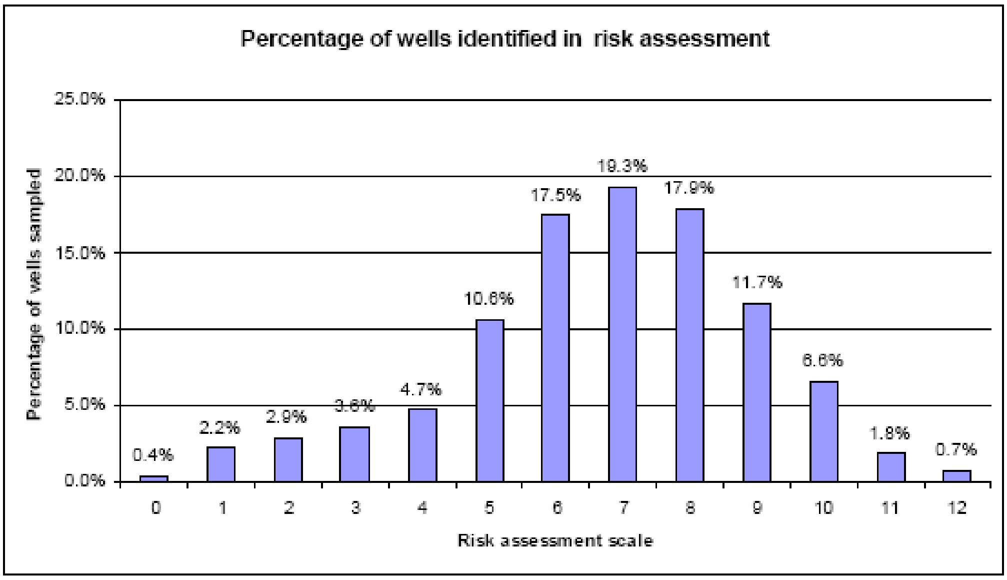


Figure 19: Percentage of wells in each risk assessment ranking.

Considering the soil features and sanitation facilities, cesspits are considered the dominant source of faecal contamination identified within domestic well groundwaters across Nauru. Cesspits are estimated to be about 2 m deep (Q Alona 2010 pers. Comm., 20 March). The average depth to water table from the surface is about 3 m. The depth from the base of the cesspit to the top of the water table is estimated to be about 1 m. This 1 m thin "barrier" to the groundwater, coupled with the high permeability of the limestone geology provides very little, buffering or protection to the groundwater from faecal contamination from the cesspits
The combination of shallow depth to groundwater, high permeability of the soils, and unlined underground cesspits makes the shallow groundwater at particular risk to faecal contamination (Figure 20).

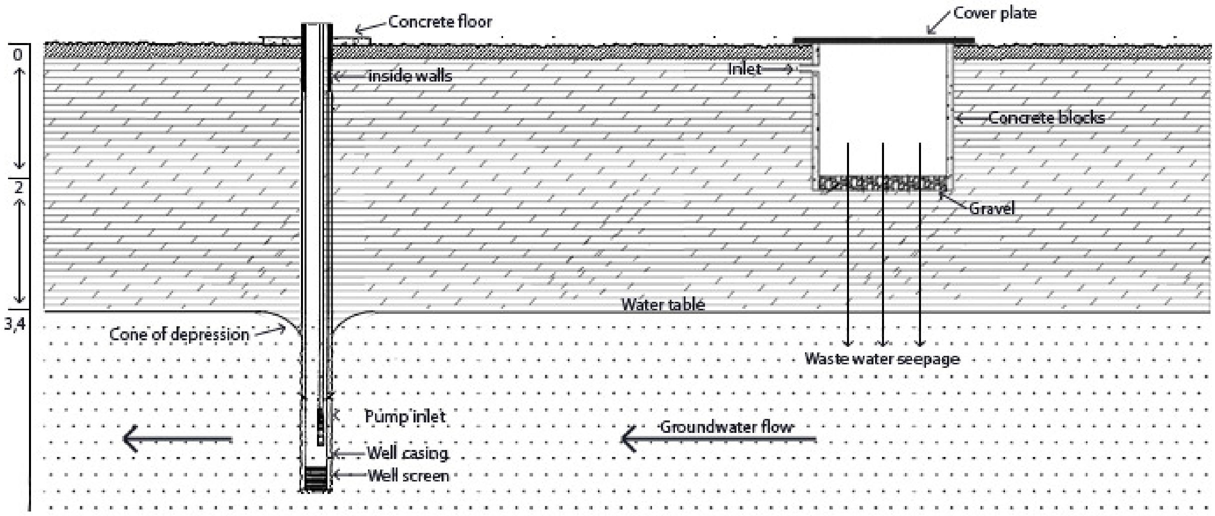


Figure 20: Cross section of cesspit contamination to domestic well.

Other surface activities also impact on groundwater quality. In order to develop awareness to the well users on groundwater quality and protection measures against surface activities, a series of workshops were held for the well users and the community in general following the survey. The following recommendations for well improvement options were presented at these community based meetings.

5.4 Recommendations for well improvement options

Based on the sanitary survey results, observations in Nauru and the community tool developed by SOPAC and Live and Learn Environmental Education (LLEE) for Pacific islands, some recommendations for well improvement at a domestic level have been identified as being suitable for use in the Nauruan context. All of these recommendations have been presented to householders during community workshops (see chapter 6). They are detailed below:

- **Raise the wall around the well minimum of 500mm and make sure it is adequately sealed.**
- **Repair all cracks to the well walls.**
- **Ensure a secure cover over the well.**
- **Keep well buckets off the ground and clean. (e.g. bleach bucket once a week).**
- **Build a concrete floor around the well.**
- **Keep clear of rubbish.**
- **Fence the immediate area.**
- **Reduce the threat by improving the design and construction of septic tanks/cesspits so that they are lined and outflow from tank is just below surface so that there is greater uptake of effluent and nutrients and resulting improved buffer to groundwater**
- **Relocate and improved designed/constructed septic tanks to greater distance from domestic wells > 20 m (nominal value)**

5.5 Salinity and well head protection options

Salinity and well head protection options were also identified to assist with the conditions identified in Nauru. These recommendations have also been presented to householders during community workshops (Chapter 6). They are detailed below:

- **Direct clean rainwater tank overflow into the ground next to well**

This measure will induce recharge near the well and likely to increase the dilution of salts over a short period of time. Given the impact of tidal influence in Nauru on the groundwater mixing, this measure will not reduce significantly the long term level of salinity within the well but will help reduce the salinity during wet periods. It is important that the water that is directed towards the well is of equal or better quality to the existing groundwater to ensure contaminants are not introduced to the groundwater or well.

- **Construct well just below the water table. Avoid constructing deep wells**

As indicated, the fresh water lens is particularly thin in Nauru. Construction of a well that penetrates the lens to deep will increase the risk of saline water entering the well/bore.

- **Place the pump inlet just below the water level identified at low tide**

Ensuring that the pump inlet is located at just below the water level in the well at low tide ensures that the water abstracted is the freshest that is available and will still be accessible in most instances. As discussed previously, water is less salty at the top of well. Avoid placing the pump inlet too deep into the well.

- **Rate of pumping should be low enough to avoid over pumping and dragging saltier water to well**

Over pumping can increase the salinity level within the well. **Abstraction of water at low rates** will minimise potential for salinisation of the well through over abstraction.

6. WORKSHOPS

6.1 Objectives and content

The workshops provided a further opportunity to meet with the community and give feedback on the survey and develop awareness around groundwater issues.

During the survey, most of the households interviewed were interested in their groundwater quality results. The workshops were considered a useful mechanism to provide results of the bacteriological testing and salinity (Annex XII – sample of result sheet provided) to those interested and provide the explanation of the results and develop the well users and the general communities understanding of groundwater and water quality.

The sanitary survey component was central to the workshop and efforts were made to structure the workshop and information to develop people's capacity to undertake their own sanitary survey and their ability to identify threats and risk to their wells and water quality. An exercise involving people in small groups, (gender based), to identify risks to water quality from different pictures was thought to be particularly useful to participants. It was followed by a review of options aimed at improving well protection and reducing risk of contamination (Annex VII).

The presentation was supported by a power point slide show (Annex VIII). A handout of the slides and a summary of findings were also delivered to the attendees. Light refreshment and snacks (i.e. bottles of water and biscuits) were also provided.

6.2 Outcomes

Four workshops were delivered, (Annex IX), to a total of 40 people, which is fewer than anticipated. Logistics issues (Annex X) certainly impacted on the number of attendees. Considerable efforts were made to inform householders about the workshops with radio and TV interviews, and flyers were delivered to many of the well users. Information was provided to landholders throughout the survey whilst the teams were in the field, and this would have contributed to raising awareness.

Poor attendance was an issue where we intended to develop a widespread awareness among groundwater issues on the island. However, all those who attended the workshop were householders using well water. Considering that there are 224 domestic wells currently in use on Nauru, the participation from the workshop represented up to 18% of the wells. Moreover, at least one person from each district was present during the workshops, also able to further pass on the information to his/her community.

Concerns and questions from the community (Annex IX) were mostly related to sanitation, particularly about the new sanitation options presented by Kasenga Hara for the IWRM sanitation project. People were concerned about the option's capital costs, cost sharing and new technology (e.g. compost toilet) and associated problems with new practices. Community involvement will be essential in addressing concerns and sustainability of the action, where they are to be introduced in the future.

In Aiwo, there is concern about the possible contamination of the rainwater by the dust deposit on roofs, associated with the phosphate processing activities. In order to assess the likelihood of contamination, ten water samples from raintanks were taken from selected roofs (i.e. 7 from Aiwo, 1 from Nibok, 1 from Yaren and 1 from Meneng). Cadmium is likely to be the main health concern associated with phosphate dust. Cadmium concentrations as well as lead were measured in each of the ten rainwater tank samples. For all samples, and all analyses, concentrations of cadmium and lead were below the detection limit indicating no health risks associated with this potential threat. (Annex XV and Annex XVI).

Feedback from the workshop was positive with people being particularly pleased that time was taken to detail the purpose of the groundwater survey in Nauru and to give them relevant information about groundwater and related issues. Moreover, the small attendance was put to advantage with additional time available to provide specific advice to individuals and further explain the results.

Some attendees who were particularly interested in reducing their risks to contamination, indicating that they will use the advice from the workshop to improve their well safety and water quality.

The workshop was also an occasion for us to find out if any wells were overlooked during the survey. One lady from Aiwo reported that her well was not included and this was remedied the following afternoon.

Attendees were informed that water quality results and workshop slides are available at CIE for any householder interested in learning more about their groundwater quality and how to reduce risks to faecal contamination.

6.3 Lessons learnt and recommendations for the workshops

It is critical to ensure logistics are well planned when undertaking workshops. Last minutes changes could have been avoided with more careful planning by the project team. All venues should be checked in advance for the appropriate amount of seating, access to electrical power, sufficient space and easily accessed.

Advertising should be carefully considered and planned in advance. Last minute changes in our schedule required the team to re-advertise at short notice, impacting on the number of people present. All opportunities to advertise and promote workshop should be considered. Local TV and radio is effective, whilst a leaflet written for and delivered to a target group was found to be particularly effective.

Many Nauruans identified that where lunch is provided, (rather than just refreshments and snacks), it will attract more people. Date and time should also be considered when implementing a workshop as evening or weekend workshops would increase attendance as many people are unavailable during regular business hours. However, the workshops were scheduled during the day as political meetings occurred every evening during the week, keeping most of the Nauruan residents busy during these times.

CIE should consider advertising the results and advice for well improvement using local media whilst also informing the community that the survey information is held at CIE, and that CIE officers are available to discuss the results. Additionally a leaflet, of Frequently Asked Questions FAQ, including relatively simple measures to improve water quality and reduce risk of contamination to the well could be developed with, or by CIE, and increase awareness to the community and their access to this information.

7. CONCLUSIONS

7.1 Groundwater is a major water resource in Nauru

Groundwater is currently the second most important water resource in Nauru after rainwater in terms of volumes consumed. There is an estimated 35011 wells in Nauru, located in the low lying coastal area or around Buada lagoon. At least 40% of the population has access to groundwater (residential only) and at the time of the survey up to 36% of the population were relying and using groundwater on a daily basis (schools included).

An estimated 298KL of water is currently abstracted each day from around 230 wells in Nauru, and this figure is likely to increase during dry periods. For those households utilizing groundwater they rely on groundwater for about 83% of their total water consumed.

The main drinking water source is currently rainwater but past droughts have highlighted the need to have reliable alternatives available. Desalinated water supplies become the only reliable drinking water source available during prolonged dry periods. However, RO water is expensive to produce and the actual maximum capacity of 'Utilities' RO plants is currently 360 KL/day whilst the minimum estimated water demand for Nauru is 880 KL/day. Groundwater, due to its relatively high salinity and high feacal contamination, is unlikely to provide for all water needs, however, it has an important role in providing for the non potable water requirements and thereby reducing overall water demands on potable water sources.
Nauruans that don't have access to groundwater and can't afford to collect or are unable to access desalinated water during dry periods are particularly vulnerable. Increased access to groundwater will assist with reducing water demands on these potable water sources, especially during extended dry periods. It is essential that future development of the resource should be accompanied with an awareness campaign towards groundwater use and protection.

7.2 Groundwater quality is a serious issue

Groundwater in Nauru is perceived by many as ''dirty''. This perception both underestimates the importance of the brackish groundwater as a resource and also highlights the cultural value placed on the resource by Nauruans.

Where efforts by GoN, and others, is made to improve on the perception of this resource and its perceived value, it will likely result in improved access and quality of the groundwater, whereby community and users will attach greater value to the resource and are likely to afford greater protection. To initiate any change in the community on the perception of the resource, will require a sustained awareness campaign. Any campaign should include demonstrating the existing reliance by communities on groundwater, lack of affordable alternatives, the uses of groundwater, how land practices especially wastewater disposal can impact on the water and what actions can be taken to safeguard well water quality.

Salinity of groundwater in Nauru is highly variable, being dependent on rainfall patterns and the amount of tidal "mixing" that takes place. Salinity can increase dramatically during prolonged dry periods for most of the wells in Nauru. Over abstraction may also allow saline water intrusion and lead to an increase in salinity levels at wells.

Whilst salinity variability will limit the sustainability of use in many circumstances, the risk to faecal contamination is a particular concern and may have a far more reaching limiting impact on potential use. Nearly 70% of the wells surveyed, present an E-coli level greater than 20 (MPN) which, using Australian guidelines, would result in serious limitations for use. The main source of faecal contamination is likely to come from surface activities and in particular existing sanitation facilities.

General awareness of the impact of contamination to the groundwater from surface activities and in particular septic pit construction is likely to assist in changing the attitude towards protection of the groundwater resource, as well as the reliance on this resource. Building guidelines for new and replacement septic tanks, with supporting information, including leaflets and workshops for installing improved septic tanks will be a practical approach to reducing impact on the resource through improved standards and specifications.

To ensure that groundwater can continue to play a role in Nauru providing 40% of the population with 80% of their water needs planning guidelines should be developed for the construction of new and replacement septic pits, incorporating new and improved technologies. Government has a key role in developing an effective policy and strategy to encourage the use of the improved sanitation and wastewater disposal options which consider their impact to the groundwater. Development of effective planning guidelines and policy for onsite wastewater disposal should be undertaken as a matter of urgency and will support sustainable use and development of groundwater in Nauru.

Hydrocarbon contamination in Aiwo has been known about for some time. Mapping the extent of impact on domestic wells was undertaken during the course of this survey, (Bouchet and Sinclair 2010). Recommendations have been made which include an audit of fuel storages to identify possible fuel losses as well as the timing of the losses, with recommendations for a separate and specific groundwater contamination investigation to be undertaken which would develop options to potentially remediate the contamination and advise on how to restrict the impact on groundwater to domestic users and the environment.

7.3 Communities at risk from water sources

Groundwater is used in households for washing clothes, showering/bathing, outdoor uses, flushing toilet, washing dishes, to a small extent cooking, and for a few households drinking water.

Salinity is not considered a health threat, rather aesthetic taste threshold parameter. However, observed faecal contamination occurrence is likely to indicate the presence of bacteria and viruses that could lead to waterborne pathogenic diseases like diarrhoea, particularly threatening for children under 5 years old. More than 80% of all samples (299) taken, tested positive for the presence for E Coli, with more than 1MPN/100 ml.

Groundwater in Nauru should not be consumed for drinking water purposes without treatment such as boiling. In general it is necessary only to bring the water to boil for the water to be considered safe for drinking from potential faecal contamination.

Other non-potable uses are also pose risk of contamination from bacteria, where *exposure to contaminated groundwater from personal bathing may become an unacceptable risk for some users where there is a chance of ingestion of the water*.

Reducing risks and threats to contamination is therefore critical in maximizing the potential beneficial uses of groundwater in Nauru. Where groundwater can be safely relied upon for certain uses will assist in reducing the reliance on other water sources for that use. Increased reliance on groundwater is likely to reduce the reliance on RO water, thereby with the potential to save on RO production costs during wetter periods, and increase the efficiency of distribution during drier periods where the water consumed from the RO plant is required only for potable needs. Additionally where safe and sufficient water supplies are available a reduction in skin disorders and diarrhoea is expected, where improvements in the quality of groundwater will assist in health of the community.

Health concerns over drinking rainwater collected from roofs where phosphate dust accumulates were not confirmed. The communities of Aiwo and Boe expressed concerns over the health impacts from accumulated phosphate on roofs and its impact on water quality in rainwater collected from these roofs. Cadmium, and to a lesser degree lead, were considered the main health concern associated with phosphate dust. Water samples were taken from 10 rainwater tanks which collected water from roofs both within and outside the areas of concern. Cadmium concentrations as well as lead were measured in each of the ten rainwater tank samples. *For all samples, and all analyses, concentrations of cadmium and lead were below the detection limit indicating no health risks associated with this potential threat.*

7.4 Groundwater monitoring to improve water quality in Nauru

Groundwater is monitored by NRC at 33 sites in Nauru. Each site with its purposely constructed monitoring bores allows accurate levels of salinity to be measured and recorded at discrete depths through the profile of the freshwater lens. These monitoring bores are, in the most part, constructed “Topside” and provide useful information on the status of the freshwater lens across the island, such as maps 4, 5, and 6 presented in this report. These bores are monitored approximately every 3 months.

As indicated the majority of the population lives on the 100-300 m wide coastal plain surrounding the island where an estimated 350 domestic wells are located.

Information on groundwater quality, in addition to the NRC monitoring bores, will provide useful insight into the range of groundwater salinities expected over time and for those areas which groundwater is currently being used. This information can be used to assist in identifying areas of better quality groundwater and the changes in quality expected over time. Information can be used to determine areas of greater reliance on the groundwater and which are more suited for future development.

A review of the wells suitable for groundwater monitoring on a regular basis is provided in Annex XIV. These wells can provide a starting point for identifying additional shallow groundwater wells for a new or existing monitoring program. Criteria for inclusion of the wells for regular monitoring purposes is based on the accessibility of the well, its location, and its suitability to get reliable longterm monitoring data.

Information collected on groundwater should be made available to both CIE and NRC on an annual or as required, as both NRC and CIE have an interest in the groundwater quality of Nauru. Every effort should be made to promote the exchange of information between these organisations.

Monitoring the change in groundwater quality for select domestic wells to assess the impact from improved wastewater disposal facilities will need to be undertaken over a sustained period, 3 - 5 years, initially with monthly sampling. It will be necessary to detail the risks and threats which are expected to influence groundwater quality to then determine what impact any specific action may have. Baseline information would be required some 6-8 months prior to the action to establish the groundwater quality under a range of climatic conditions. The groundwater survey of March - April 2010 provides some baseline data for determining which areas are at high risk by E coli contamination. This information can be used to identify where activities to improve effluent quality or reduce effluent volumes might be best located and the wells that could be used for monitoring.

8. RECOMMENDATIONS

8.1 Hydrocarbon contamination

As detailed in Annex V, there is a need for further studies on the hydrocarbon contamination identified in Nauru to identify the current and potential extent of the hydrocarbon contaminant plume.

Investigations into the existing condition and history of storage of fuels from the 4-6 concrete tanks located next to B4 should be undertaken as a matter priority to identify if this is the source of contamination and if this potential source continues to contribute to the plume. Records available from Ronphos, Utilities and NRC should be able to assist with this historical investigation.

In addition it is recommended an audit or reconciliation on the storage of fuels be undertaken by Ronphos to account for any large losses, in particular from B4 and over the period 1994 – 2001 as well as over the last 18 months.

A groundwater contaminant investigation and drilling program will identify the contaminant source, the extent of the contaminant, the expected impact on identified wells, and the impact on the environment and timings of such impacts. The investigation should identify possible options for remediation and management of the contaminant plume.

The hydrocarbon contamination identified during the fieldwork March – April 2010, (Bouchet and Sinclair 2010), and in particular that in Aiwo, will continue to spread, impacting on additional domestic wells, and in time is likely to impact on the coastal environment. Further investigations are required to quantify these impacts and advise on possible remediation options. This work should be undertaken as soon as funding can be identified, to develop options for clean up and allow sufficient time to minimise the impact of the contaminant plume.

The oil and water mix found in the conveyor belt sumps located under the old phosphate storage sheds should be removed to reduce the threat of overflow of this contaminant to adjoining properties and possibly into wells. A functioning oil/water separator will be required. The value of the oil recovered, (in 2008/2009 estimates of recovered oil was greater than $300,000. Gideon pers comm. 2010.), can be used to offset the cost of this work and assist in the purchase the oil/water separator. The method of disposal of the hydrocarbon contaminated water from the process will need consideration to minimise the potential for groundwater contamination and exacerbate the existing contamination. It is recommended this activity be carried out in cooperation with NUA and NRC staff.

An audit of all existing underground fuel storage tanks should be undertaken to assess their integrity with the results provided to CIE to identify other hydrocarbon contamination of groundwater.

8.2 Domestic well water monitoring

As indicated in section 7.4, monitoring of groundwater salinity is being undertaken by NRC at specially constructed monitoring bores providing important information on groundwater resources across Nauru. However the majority of groundwater in Nauru is currently abstracted from the coastal plain and there are advantages to extend the existing monitoring to include some of the domestic wells located within the coastal plain.

It is recommended that a selection of suitable domestic wells be included into the existing quarterly groundwater monitoring program undertaken by NRC.

In conjunction with the IWRM sanitation project, it is recommended that requirements for a monitoring program be determined to assess the impact of current wastewater disposal practices on groundwater and identify what measurable benefits may be observed with the introduction of improved wastewater disposal in pilot areas over time.

8.3 Guidelines for water quality and well construction and maintenance

It is recommended guidelines on water quality requirements for potable and non potable uses in Nauru should be established. Criteria and guidelines should be appropriate for Nauru and the conditions that exist. The main focus of the guidelines should be to provide consistent and pragmatic advice on the use of water from different sources, options for improving the quality of water, how to best monitor water quality, and action required where water quality limits are not met.

E-coli testing equipment (IDEXX) is available for use in Nauru. Analysis of E coli, in a structured monitoring program of selected potable and non potable water sources will guide water suppliers and the community in identifying the acceptable health risk and therefore use of waters. The guidelines will help to increase awareness of potential health issues associated with water quality and should outline the procedures which should be followed where breaches of water quality are observed.

Developing water quality guidelines which can serve the community for establishing acceptable and practical levels of use will raise awareness and ultimately result in improved water quality.

Practical and specific guidelines for well construction and maintenance will assist the community with improved groundwater supply. It is suggested that best practice guidelines, or information sheets be developed which provide advice on well construction and considerations for depth and location of the well in relation to potential threats, in addition to where specific advice and information may be available. Maintenance advice for the community should be included in the suggested information sheets identifying practical measures that can be undertaken by well owners to reduce risks and threats to existing wells.

8.4 Coordination in the development and management of groundwater

Nauru does not have any specific legislation or policy regarding the development and use of groundwater. No agency has sole responsibility for the management of water and sanitation on Nauru. Responsibilities are shared amongst 11 agencies and state owned enterprises, operating under 4 Ministries. (Hebblethwaite 2009)

Aid Management Unit, AMU, under the department of Finance, is responsible for high level facilitation and coordination of all aid projects on Nauru. AMU has a lead role in the coordination of support of development assistance from donor partners.

To assist AMU in the coordination of these projects executive summaries of each project concerning groundwater development or which may impact on groundwater resources should be provided to AMU along with a copy of the report and contact details of the relevant persons to AMU (Annex XVII).

This request of AMU is fully supported, as it will assist in the coordination of activities and help minimise duplication. Further it will facilitate the collaboration between agencies and state owned enterprises, and the National Water and Sanitation Committee, where AMU is able to coordinate development assistance to agencies and potential funding.

8.5 Water and sanitation management and improvements

Current onsite wastewater disposal in unlined septic tanks, is considered to be the most likely source of bacteriological contamination identified in the shallow groundwater. Improving onsite wastewater disposal will reduce the risk of health related issues and allow for greater development of the groundwater resource. The contamination of groundwater by faecal bacteria is limiting the beneficial use of groundwater for non-potable purposes, such as bathing, washing, toilet use, etc. An important consideration to reduce the impact on shallow groundwater and improve groundwater quality will be to change the current perception that Nauruans have of their groundwater and also what are acceptable sanitation practices.

A feasibility study under the Integrated Water Resource Management Global Environment Fund, IWRM GEF, Pilot Study Project is reviewing improved sanitation techniques to reduce faecal contamination in groundwater. The project, whilst identifying technical options, will also consider the challenges faced to introduce new technologies which differ from current sanitation and wastewater practices.

Ongoing work with the EU IWRM and GEF IWRM projects and processes in conjunction with the National Water and Sanitation Committee and AMU will facilitate a coordinated approach to improving onsite wastewater contamination and ultimately improved groundwater quality.
It is recommended that building guidelines be developed which require that onsite wastewater disposal moves towards reduced risk of contamination of groundwater, such as composting toilets, dual chamber enclosed septic tanks, etc.

8.6 General awareness on groundwater reliance and quality

Community awareness, policy, and enabling legislation is required to makebimprovements to onsite wastewater disposal a priority and achieve improved water quality of groundwater. A functioning National Water and Sanitation Committee is critical to assist in the coordination of technical, financial and communication efforts between agencies to promote and progress improvements in water and sanitation and groundwater protection.

Groundwater has the potential to further reduce householders reliance on potable water for all their water needs. Accessible information will assist government and the community to make informed decisions about options available to improve the water supply and its quality in Nauru.

Dissemination of relevant information to communities on how they can improve their supply of safe water for household needs will be valuable.

Aid Management Unit has suggested that video may be a more accessible format for the community to promote better hygiene and sanitary practices and recommend alternatives to reduce water use such supplementing non potable water requirements with groundwater.

Programs which focus on water and sanitation, including Water And Sanitation Hygiene, WASH, and Drinking Water Safety Planning have awareness components which may be able to support the concept of a video. Where the video was to promote the use of sanitary assessments and provide practical advice on well improvements, reducing the threat and risk of groundwater contamination.

The survey work undertaken in March – April 2010 by Bouchet et al, its associated reporting, and the collation of this data into GIS has allowed for a deeper understanding and provided some baseline information on the shallow groundwater in the coastal plain around Nauru.

The number of domestic wells, their location, construction details what they are used for and how much water is abstracted is now more clearly understood, as is the vulnerability of the groundwater to the onsite wastewater disposal practices. The different water sources used for potable needs is also more clearly appreciated, as is total water requirements at the household level, both potable and non potable. The information obtained by this survey will assist in identifying options to meet both existing and future water demands.

In addition this survey has been able to more clearly identify extent of the extent of the hydrocarbon plume in Aiwo and provide advice on how to progress towards reducing the impact of the contaminant plume.

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ANNEX I LOGICAL FRAMEWORK ANALYSIS

Goal: Ensure that the development of the country is not compromised due to shortage of water			
Intervention Logic	**Indicators of Achievement**	**Means of verification**	**Assumptions**
Objective: **Reduce the vulnerability of shallow groundwater to contamination**	• Increased awareness in reliance, use and risks to groundwater resources among communities and government • Bacteriological test results • Sanitary surveys	• No. of surveys completed with household participation. Attendance at workshops by community and government • Ongoing monitoring of selected groundwater wells (as needs at least annual)	• Resources and political and community will to address areas of concern • Legislation enabled to assist with clean up of contamination areas
Expected result 1: **Identify areas of groundwater contamination and related sanitation issues**	• Survey wells with accessible information on contamination provided to GON	• Survey forms and data available digitally and can be queried • Identification and Report on contamination from hydrocarbons	• Resources available to assist with completion of survey • Access to wells is provided by community
Expected result 2:	• Dataset which can be queried with	• Digital data and final	• GON are able to enter

Develop datasets identifying groundwater quality and groundwater abstraction and reliance	information on well details and groundwater quality	report • GIS layer in existing Nauru Rainwater harvesting database	data and information obtained into national dataset and continues updates as required • Compatibility of datasets with existing data bases (i.e. census database)
Expected result 3: **Increased awareness on the risk of contamination from surface activities**	• Dominant Risks identified which are relevant to householders wells • Information made available to householders regarding risk reduction options	• Information on risks provided in workshops and during field survey. • No of householders which take action to reduce risks to wells in direct response to survey and workshop	• Landholders where risks identified do attend workshops or interested in reducing risk to well
Expected result 4: **Improved understanding on the reliance and use of the resource**	• Information collected on the reliance and use of resource can be queried and provides relevant information.	• Water use and reliance is reported against in final report and is contained in accessible database	• Information collected by surveyors is accurately recorded and information provided by landholders • Landholders available during survey
Expected result 5: **Assist in the future development of resource**	• Information from survey provided to GON for use in future planning	• Use of information by CIE, Bureau of statistics, planning and other govt	• Information is made accessible in appropriate formats

		agencies	
Expected result 6: **Local community and householders to reduce risk to wells**	• Community and householders provided with practical information to allow them to reduce risks to wells	• No of landholders who attend information session • No of landholders who adopt risk reduction measures	• Risk reduction measures are not practical • Resources not available for landholders to undertake risk reduction
Expected result 7: **Rainwater harvesting database ground truthing**	• Improvements in the quality of data contained in RWH database	• Database is queried and checked against field results.	• Insufficient time to undertake groundtruthing exercise • Resources from CIE not provided
Activity 1: **Collection and collation of all survey information for domestic wells**	• 90% of the island's well surveyed	• All smalls scale maps filled with well localisation • Surveyed questionnaires filled for each well • Weekly updates • Final report	• 95% of the householders are at home during the survey (week days) • 95% of the householders are kind on answering the questionnaire and allowed access to their well
Activity 2: **Bacteriological sampling of domestic wells and**	• 80% of the well surveyed sampled	• Report with test results	• Test efficient under local features

identification of areas of shallow groundwater contamination			
Activity 3: **Data entry suitable for upload to GIS**	• All the data is entered in the excel spreadsheet	• Excel Spreadsheet	
Activity 4: **Workshops (district based community focused sanitation survey workshops)**	• 80% of the 'critical' householder attempted the workshop • 40% of the householders attempted the workshop	• Participatory report • Workshop report	• Householders interested in their groundwater quality • Enough time is available to answer individual questions and help householders with their particular issues
Activity 5: **Development of GIS database on shallow groundwater resources**	• All the data is entered in the SOPAC GIS data base	• GIS data base	• The data is suitable for upload in the GIS data base
Activity 6: **Undertake ground truthing and follow up rainwater harvesting survey of selected roofs**	• Surveys completed to be mapped against the selected sample for ground truthing	• Report on the no of roofs ground truthed • Update of GIS dataset	• Sufficient time to undertake survey • Data collected is updated by GoN staff in CIE

ANNEX II GROUNDWATER SURVEY QUESTIONNAIRE

Map No:____________ **Roof ID:**_______________________________

Date:
Time:
Observers:
Notes:

ASSESSING VULNERABILITY OF SHALLOW GROUNDWATER - NAURU

SITE (OBSERVATION/INTERVIEW)

Well Location
District:________________ **Closest GIS roof ID:** ____________________

☐ *Well located on field map* *Map No.* __________ *Well No.* ___________

Southing: __________________________ *Easting:* ________________________________

Family name: **First name:**

Owner Roof ID:_________________________

Year of construction: ☐ 1970 ☐1980 ☐1990 ☐ 2000 ☐ Unknown ☐ Date:__________________

WELL WATER USAGE (INTERVIEW)

USERS

User ID	**Roof ID**	**Family name**
1		
2		
3		
4		
5		

User ID	**Total no. of people in each house**	**No. of children 5 years and under**	**How many of these items are connected to your well or using well water?**						**Waste water type**			
			Washing machine	Flush toilet	Shower bath	Outside tap	Kitchen sink	Other	Pit latrine	Flush septic	Flush reticulated	Other
1									☐	☐	☐	
2									☐	☐	☐	
3									☐	☐	☐	
4									☐	☐	☐	
5									☐	☐	☐	

Comments:

1/4

Map No:____________ **Roof ID:**______________________________

WASTEWATER DISPOSAL (INTERVIEW/OBSERVATION)	
Distance from closest septic tank/trench or pit latrine ***-locate on the map-*** **to well (m):** ________ m	**No of septic tanks or pit latrine within 20m of well:** ____________
Comments (include septic tank conditions and possible pollution sources):	

WELL WATER USE (INTERVIEW)

User ID	**Well Water Use**						**Abstraction type**		
	Washing laundry/ kitchen	Personal bathing	Cooking	Drinking	Gardening/ outdoor use	Other (e.g. income generated)	Pressure pump	Bucket	Other
1	☐	☐	☐	☐	☐		☐	☐	
2	☐	☐	☐	☐	☐		☐	☐	
3	☐	☐	☐	☐	☐		☐	☐	
4	☐	☐	☐	☐	☐		☐	☐	
5	☐	☐	☐	☐	☐		☐	☐	

Q: If you do not use the well water for any of the above purpose, why?

A:____

DRINKING WATER						
User ID	• What are your **P**rimary and **S**econdary water sources for drinking purposes? • Do you do anything to your water to make it safer to drink (**1.**Always **2.**Mostly **3.**Quite often **4.**Rarely **5**Never)? • If you treat your water, what treatment do you use (**B.** Boiling **C.** Chlorination **F.** Filtration **S.** Solar disinfectant **N.** Nil)					How often do you face shortage of your **P**rimary drinking water? **1.**Always **2.**Mostly **3.**Quite often **4.**Rarely **5.**Never
	Rainwater	Desalination Utilities	Well	Bottled	Other	
1						
2						
3						
4						
5						

Comments:

2/4

Map No:____________ **Roof ID:**______________________________

WELL CONSTRUCTION (OBSERVATION/INTERVIEW)			
Well Diameter: (m)	**Depth To Water:** __________ m **Total Depth:** __________ m	**Casing Type:** ☐ open well (unlined) ☐ coral rock (lined) ☐ concrete (lined) ☐ Steel (lined) ☐ Other: __________________	**Headworks:** ☐ Covered ☐ Poorly covered ☐ Uncovered ☐ Other: _______________

Well Use: ☐ Used ☐ occasional ☐ Unused ☐ Abandonded

WELL WATER QUALITY (OBSERVATION)

Electrical conductivity of well water

Date	**Time**	**Electrical Conductivity**	**Units** µS/cm OR mS/cm	**Temperature** °C	**source**	
					Well	Tap
					☐	☐
					☐	☐
					☐	☐

Bacteriological Sampling

Date	**Time**	**Bacteriological Sample Number**				
		Roof ID	**Well No.**	**Sample No.**	**Sample source**	
					Well	Tap
					☐	☐
					☐	☐
					☐	☐

Comments: (Include comments such as bad smells or other possible contamination)

3/4

ANNEX III DRAFT WATER SAMPLE COLLECTION – STANDARD OPERATING PROCEDURE NAURU

Sampling from a tap

1. Remove any attachments (hoses, cloths, aerators, etc.) from the tap.
2. Carefully clean the mouth of the tap with a clean cloth and bleach to remove any dirt or grease.
3. Wash hands with soap and water and dry with clean towel or use antibacterial gel.
4. Sterilize the tap by soaking tap for at least one minute in a solution of diluted bleach and sterile water, or flame tap for about 30 seconds using a conventional cigarette lighter or similar device.
5. Open the tap and flush the system for at least one minute.
6. Label sample bottle appropriately, Date, time, location.
7. With clean hands and where accessible the bacteriological sampling container can be filled directly from the tap. Where there is some concern about overfilling of the bacteriological sampling container then using the general sample collection bottle (NOT the bacteriological sampling bottle) rinse the general sampling collection bottle with water to be sampled three times, before taking sample and transferring to bacteriological sampling container.
8. With clean hands, carefully remove cap from the bacteriological sampling bottle and fill container without rinsing. Exactly 100 mL of sample must be collected. Securely close the bottle by screwing the cap back on the bottle.
9. Strongly shake sample at least 25 times to dissolve sodium thiosulfate in sample bottle, where used.
10. Collect water in bucket which has been rinsed three times with sample water.
11. Record salinity measurement, taking care to record units.
12. Record date, time, location, EC, and any relevant comments, and sampling observer/officer onto appropriate sampling sheet.

Sampling from a tank, well or borehole

1. Wash hands with soap and water and dry with clean towel or antibacterial gel.
2. Label bacteriological sample bottle appropriately, Date, time, location, .
3. The general sampling collection sample bottle should be held by a sampling device, or attachment that will allow for the bottle to be lowered into the well. Bottles should not be allowed to touch the walls of the tank or the well.
4. Submerge the general sampling collection bottle to a depth of about 30 cm (or 12 inches).
5. Rinse the general sampling collection bottle with water to be sampled three times, before taking sample and transferring to bacteriological sampling bottle..
6. With clean hands, carefully remove cap from the bacteriological sampling bottle and fill container without rinsing. Exactly 100 mL of sample must be collected.
7. Strongly shake sample at least 25 times to dissolve sodium thiosulfate in sample container, where used. Securely close the bottle by screwing the cap back on the bottle.
8. Collect water in bucket which has been rinsed three times with sample water.
9. Record salinity measurement, taking care to record units.
10. Record date, time, location, EC, and any relevant comments, and sampling observer/officer onto appropriate sampling sheet.

Sampling from a tanker

1. Wash hands with soap and water and dry with clean towel or antibacterial gel.
2. Where possible sample from tank outlet where hose is connected to fill storage, if not possible then sample direct from opening of tanker ie bulk filling opening.
3. Sterilize the outlet by soaking tap for at least one minute in a solution of diluted bleach and sterile water, or flame tap for about 30 seconds using a conventional cigarette lighter or similar device.
4. Open the tap and flush the system for at least one minute.
5. Label bacteriological sample bottle appropriately, Date, time, location,
6. With clean hands using the general sample collection bottle (NOT the bacteriological sampling bottle) rinse the general sampling collection bottle with water to be sampled three times, before taking sample and transferring sample water to bacteriological sampling bottle.
7. With clean hands, carefully remove cap from the bacteriological sampling bottle and fill container without rinsing. Exactly 100 mL of sample must be collected. Securely close the bottle by screwing the cap back on the bottle.
8. Strongly shake sample at least 25 times to dissolve sodium thiosulfate in sample bottle, where used.
9. Collect water in bucket which has been rinsed three times with sample water
10. Record salinity measurement, taking care to record units.
11. Record date, time, location, EC, and any relevant comments, and sampling observer/officer onto appropriate sampling sheet.

ANNEX IV PICTURES OF DIFFERENT WELL TYPES

Picture 3: Open well with coral rock lining.

Picture 4: Fibre glass well.

Picture 5: Concrete well with outside pump.

Picture 6: Brick lined well with outside pump.

ANNEX V HYDROCARBON CONTAMINATION – NAURU

Background

An initial assessment of potential hydrocarbon contamination of domestic wells was carried during the course of the survey. The respondent or surveyor were asked to note any smell of diesel, or fuel odour from the well or discolouration of samples and to record this on the survey sheet. This information wa used to assist with the identification of hydrocarbon contamination.

Limited additional investigation or sampling was undertaken during the survey.

Burke in 1988 undertook a mission on behalf of SOPAC to Nauru where a well was dug on the NPC compound to assess the use of groundwater for a second desalination plant. However, about 150 mm c fuel was found on top of the groundwater lens. It was recorded at the time that this was believed to be the result of a German naval ship blowing up fuel storage tanks in the late 1800's. The exact location c the well dug or the reference to the NPC compound is not known.

Investigations by Falkland under the NRC groundwater study (in prep) have indicated hydrocarbon contamination was found in 5 monitoring bores, a domestic well in Ewa, and at Anetan cave. There was one monitoring bore constructed in Aiwo E4 which had some contamination but was not considered very high. The greatest pollution identified by Falkland was E2 near the diesel fuel tanks a the NRC Topside workshops.

Preliminary Results

Two separate locations during the initial survey were identified as having hydrocarbon contamination, both in Aiwo. As noted in previous investigations (Falkland 2009 pers comm) hydrocarbon contamination of groundwater was identified in E2 monitoring bore in the centre of the island near the workshops, this site was not visited.

District	Southing	Easting	Owner	Comments
Aiwo	00°32.222'	166°54.716'	CECIL	Strong odour of "diesel" water has yellowish tinge and film of product on top. Water stopped being used 18 months ago, thought to be causing problems with pumping. Water relied upon for washing during dry period. Well believed to be constructed more than 30 years ago ie 1980s
Aiwo	00°32.260'	166°54.738'	HEINRICH	Well constructed approx 2001. Noticed contamination six months after construction, progressively worsening contamination. Well not used. Black oil like sump oil in well. Jared suspects possible source from conveyor belt sumps approx 200m N of well
Aiwo	00°32.280'	166°54.781'	DAGEAGO	Well not used for some time, where it was full of rubbish. Sample unable to be taken, suspected contamination.
Aiwo	00°32.258'	166°54.784'	DETENAMO	Well used for large market garden. Noted diesel contamination from well, anecdotally particularly noticeable during pumping during a dry period
Aiwo	00°32.246'	166°54.812'	OLSSON	Abandoned well. Well constructed in 1985 and used for 7 years and then diesel contamination and black oil was identified. Well stopped being used and

				was filled in
Aiwo	00°31.819'	166°54.774'	HARRIS	Well constructed approx 1999 strong odour of diesel . Well not used for last 9 years ie since 2001. "Tiger Gas" petrol station is probable source of contamination at front of house. Owner indicates that service station was present and operating before well was dug

The well of Harris, which is currently not used, is located down gradient of a service station "Tiger Gas" approx 30m from the well. The nearby underground storage tank is the most likely cause of the contamination. The well was believed to be constructed in 1999 and then not used since 2001 due to contamination. The service station is still in operation.

The other domestic wells which are indicating hydrocarbon contamination are clustered together indicating more extensive contamination. Wells of Cecil, Heinrich, Dageago, Detenamo and the abandoned well of Olsson all indicate some degree of contamination, with gross contamination in Heinrich well.

The age of the contamination is unknown, however based on domestic wells and landowners anecdotal information it would suggest that the first indication of contamination was in 2001. It would appear that the contamination in the wells has increased over this time with the oil found in the Heinrich well believed to be "the worst he had seen it" at the time of inspection March 2010.

Fuel Storage Facilities and Handling

The majority of fuels are stored by Nauru Utilities in a tank farm located at the top of the Command Ridge on the road leading to Buada. The tank farm stores the diesel and unleaded fuels needed for running the islands power plant and supply to fuel stations. A dedicated line is used to transfer the fuel from the ships to the tank farm. The tanks within the bunded tank farm appears to be quite sound. A report on the condition of the tanks was undertaken in 2007 by Robert Leo acting as a consultant at the time. Robert Leo, now engaged by Utilities to operate the tank farm, made a number of recommendations including the condemnation of B4 for storage of fuel and repair of damaged pipelines due to fuel theft in the 2007 report.

Waste fuel oil is purchased, stored and managed by RonPHOS to run furnaces to dry the mined phosphate ore. The waste fuel oil is currently pumped from the ships to B4, (3.4ML storage tank) which is then pumped up to the tank farm via the transfer pump, also in need of repair, where its is mixed with "dirty" diesel fuels in T8 and gravity fed to the furnace.

A fuel reconciliation is done monthly on the B4 by Ronphos.

The fuel storage facilities are being reviewed by Nauru Utilities and Ronphos. Ronphos have indicated that B4 will not be used for the storage of fuels once a suitable alternative can be found. Discussions between Ronphos and Utilities to arrange for storage of furnace fuels are proposed, (J Gearing pers com 2010).

An additional purchase of waste oil for furnace fuel is planned for mid July, estimated to be some 3ML.

Possible Contamination Source

The most likely source of this contamination is from the area immediately to the north of the wells, which has been used for handling and storage of bulk fuels including heavy fuel oils, waste oils and lighter fuels such as diesel over the years. Specifically potential source sites includes the old concrete Heavy Fuel Oil Storages, the pump transfer station, B4, the fuel pipelines, 4-6 old abandoned underground concrete storage tanks next to B4, and the concrete sumps under the old conveyor belts for the old phosphate storage sheds. B4 is currently storing waste oils for use in the furnace and the drying of phosphate.

Discussions with various sources make reference to an oil spill during WWII from bombing by the Allies of the Japanese occupied Nauru. The site of the WWII spill is believed to be in the approximately same area as the current disused concrete Heavy Fuel Oil storage tanks.

Burke in 1988 refers to interception of about 150 mm of fuel found on top of the groundwater lens after a well was dug on the NPC compound to assess the use of groundwater as an alternative source for a second desalination plant. Burke was informed at the time that this was believed to be the result of a German naval ship blowing up fuel storage tanks in the late 1800's.

However given the age of either a spill in 1800s or 1940s, the age of the wells, 1980s to 2000 which did not intercept contaminated groundwater at the time of construction, and the anecdotal information regarding when the contamination was first noticed, 2001, it is thought that the contamination source is more recent, most likely late 1990s.

It is estimated that the contamination has travelled at this stage approximately 250m. The most likely source being the 4-6 disused underground concrete storage tanks next to B4. Whilst the status of these tanks is unknown nor when these tanks were last used for storage of fuel, they are excavated into the subsoil indicating a highly probable source of groundwater contamination. Were B4, an above ground storage tank, considered to be the main source of leakage you would expect to see some evidence of leakage at the surface.

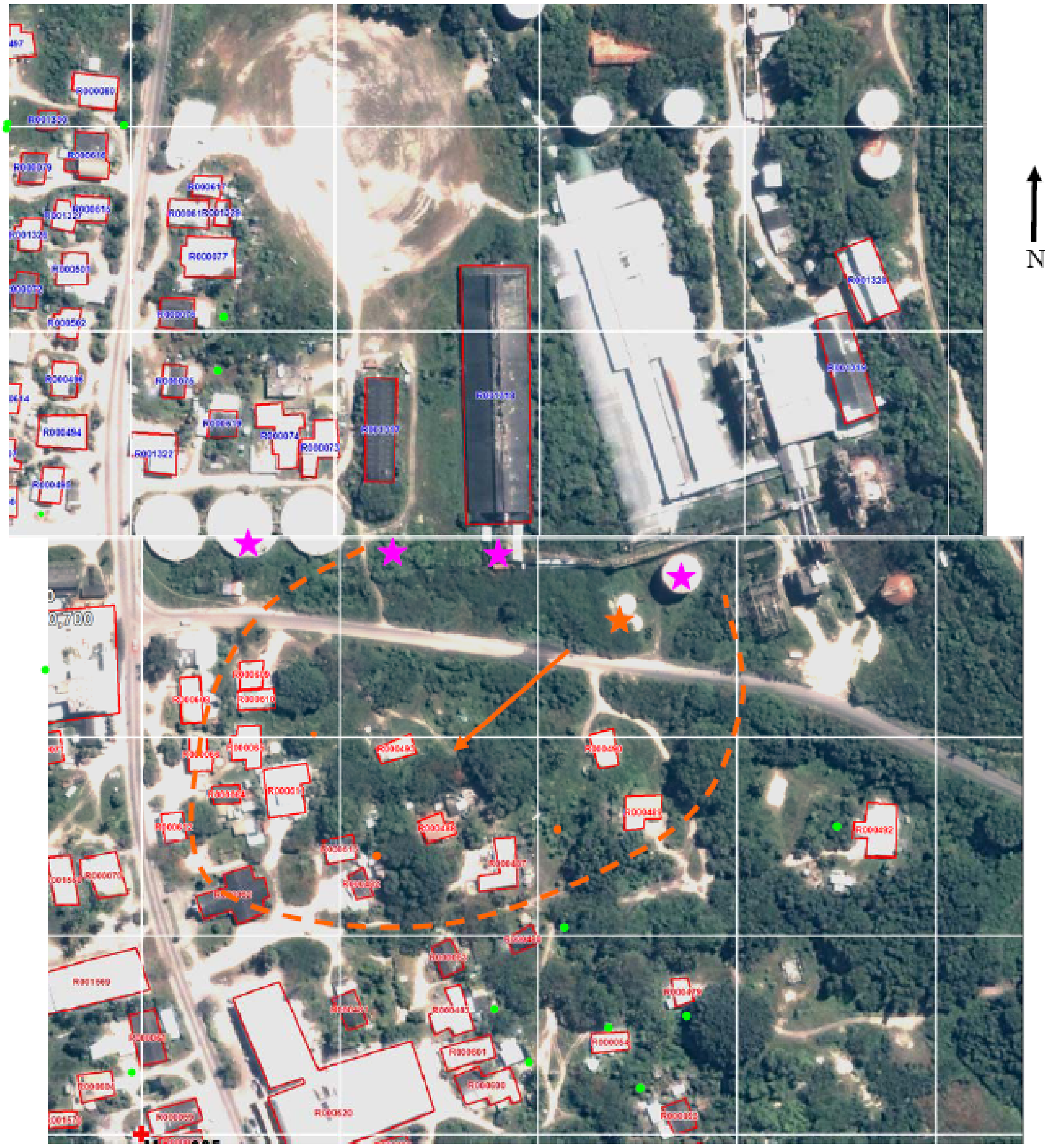
The reconnaissance inspection of the conveyor belt sumps suggests that they are not hydraulically connected to each other or the groundwater. The depth to the oil/water from the surface is less than the expected depth to groundwater in the area. This suggests that the oil/water mix in these sumps are most likely related to overland flow during periods of heavy rain. Further work on the source of this oil water mix in these sumps is required. In 2008/2009 it is understood that some 300,000L of furnace oil was recovered from the sumps and could be reused (Tasilo Gideon pers comm 2010). Observations in the field in March 2010 indicated that there is some 1.5m of water and oil mix in these sumps. The sumps are estimated at 140m long, and 2m wide indicating a volume of up to 840m^3 oil/water mix for the two sumps. The thickness of the oil is not known, however it is suggested by Ronphos that they will not be able to recover similar volumes of oil as what was recovered previously, also it is expected that an oil/water separator would be required to effectively remove the oil/water mix and that currently this is not available on the island. The recovered oil can be used to offset the cost of pumping operations and oil/water separator. An additional issue will be the disposal of the separated "dirty water" to avoid infiltration back into the groundwater causing additional contamination impacts. Removal of this oil/water from the sump will minimise the potential impact to the environment and reduce the potential for overflow during periods of heavy rainfall and spread of oilwater mix across the road and south into Aiwo.

Extent of contamination observations

The inspection of the domestic wells in the area gives some insight into the extent of the contamination, the likely direction of flow, and possible sources of contamination.

The plan suggests that contamination to date is contained within approximately 250m of the most probable source area of contamination. Flow appears to be in a SE direction, however there is currently no reliable hydraulic information to confirm this, and it is based more on concentration of contaminants and timing of the contamination in the wells. The evidence that there is a different level of contamination between wells also suggests that the hydrocarbon is travelling along preferred pathways at different rates, as would be expected in a karstic environment.

Inferred hydrocarbon contamination from domestic wells - Aiwo



- wells where hydrocarbons were not yet identified (site inspection, anecdotal)
- wells where hydrocarbons were identified (site inspection, anecdotal)
- probable source of contaminant source
- other possible and likely sources of contamination
- probable flow direction
- inferred likely extent of contamination based on domestic wells

Conclusions

Significant hydrocarbon contamination of the shallow groundwater is present in Aiwo. It is impacting at least 4 wells, 3 of which are no longer able to be used due to the level of contamination experienced. The extent of the contamination and direction of flow, to the SE, is at this stage only inferred from domestic well inspections and anecdotal information. The most likely source of the contamination is from the fuel storage and handling facilities located below the current phosphate processing plant. In particular the 4-6 concrete storage tanks next to the B4 tank are considered a probable source, although the status of tanks and history of fuel storage or waste oil is not currently known. Based on anecdotal information from landholders on the age of their wells and the first detection of contamination by the landholders and by Burke in 1998 mission it is expected that the main contamination took place in the late 1990's circa 1998.

The spread of the contaminant plume would appear to be relatively slow moving, where the plume has spread some 250m over the last 12 years. Low hydraulic gradients are expected in this area.

Where this plume is left unattended, and whilst there is potential for continued contamination from an unknown source, there is continued risk of spread of the contaminant plume which over time will impact other wells, render the groundwater unusable for any purpose, and likely to find its way to the shoreline where it would slowly disperse into the sea over an extended period of time and potential impact on the shallow marine environment.

More site specific information is required to verify the extent of the groundwater contamination, flow direction of the groundwater and the type of hydrocarbons. The study should consider options on how to contain the spread of the plume and reduce the impact on the existing wells and the environment. Contaminant monitoring bores will be required to be constructed to assess the movement of the plume over time. Additionally investigations to identify the age and source of the contamination and if the current fuel handling is still contributing to groundwater contamination.

A review and reconciliation of furnace fuel storage in particular B4 and the concrete tanks between 1995 and 2002 will assist in identifying if there are any significant losses that have occurred during these times and estimation of the volume of these losses. A reconciliation of fuel storage in B4 over the last 12-18 months would assist in identifying if B4 may still be contributing to any groundwater contamination.

Recommendations

- "Do nothing approach" – this approach is **not recommended** as it ignores the current risk to the longterm quality and current and potential use of groundwater in AIWO. The contaminated groundwater also raises potential health issues where hydrocarbon contaminated groundwater is still relied upon, as well as longterm impacts to the environment. Action should be taken in the first instance to assess the size of the problem and what options may be available to minimise impact.
- A groundwater contaminant investigation should be undertaken to assess the extent and level of groundwater hydrocarbon contamination in Aiwo. An experienced consultant contaminant hydrogeologist would be required to undertake this type of work. The Terms of Reference should include the identification of the contaminant plume extents, flow directions and estimated rate of travel of the plume, identify source of contaminant and whether it is still active. The investigation would also need to report on possible options for remediation and management of the plume.
- An audit or reconciliation on the storage of fuels in general and B4 in particular could be undertaken by Ronphos to account for any large lossess, inparticular from the period 1995 – 2002 and then over the last 18 months to assess what the current fuel storage reconciliation in B4.
- Investigate the condition and history of storage of fuels from the 4-6 concrete tanks located next to B4. Ronphos, Utilities and NRC should be able to assist in historical investigation of these storages.
- Ronphos to remove the oil water mix found in the conveyor belt sumps located under the old phosphate storage sheds. A functioning oil/water separator will be required. Oil recovered can be used to offset the cost of this work and purchase of the oil/water separator. Disposal of "dirtywater" from the process will need to be considered so as to minimise the potential for groundwater contamination.

ANNEX VI SANITARY SURVEY

Map No:___________ **Roof ID:**__________________________

SECTION E: SANITARY SURVEY - SHALLOW WELL RISK ASSESSMENT

1. Is there a septic tank or pit toilet within 10m of the well?	☐ Yes	☐ No
2. Is the nearest septic tank or pit toilet on higher ground than the well?	☐ Yes	☐ No
3. Is there any other source of pollution (e.g. animal excreta, rubbish) within 10m of the well?	☐ Yes	☐ No
4. Is the drainage around the well poor, allowing water to pond within 2m of the well?	☐ Yes	☐ No
5. Is the wall around the well not properly raised above the ground?	☐ Yes	☐ No
6. Is the wall around the well damaged or cracked or rusted allowing surface water to enter?	☐ Yes	☐ No
7. Is the concrete floor around the well absent?	☐ Yes	☐ No
8. Is the concrete floor less than 1m wide around the well?	☐ Yes	☐ No
9. Is the concrete floor cracked allowing water to enter the well?	☐ Yes	☐ No
10. Are the inside walls of the well poorly sealed at any point 3m below ground?	☐ Yes	☐ No
11. Are the bucket and rope left in a place where they may get contaminated?	☐ Yes	☐ No
12. Is there a need to fence the well area (due to animal activity etc)?	☐ Yes	☐ No
13. Is the mouth of the well not securely covered?	☐ Yes	☐ No

Any other relevant observations (risk related):

Q: What do you believe are the main risk to your well and its water quality?

A:____

Q: What do you believe you can do to improve the water quality in your well?

A:____

____

Water quality result:

Comments /Recommendations:

____
____
____
____
____

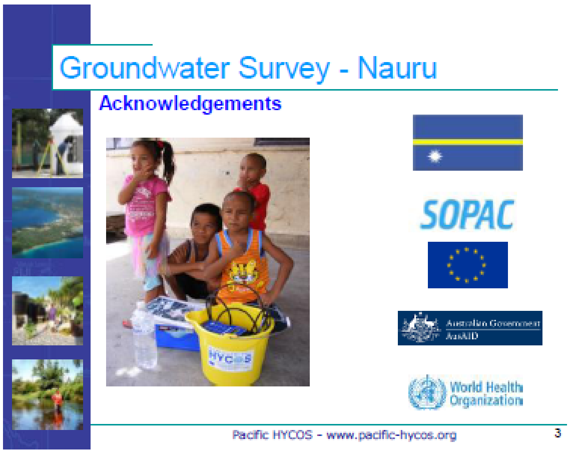
Interviewee signature: _______________________________________

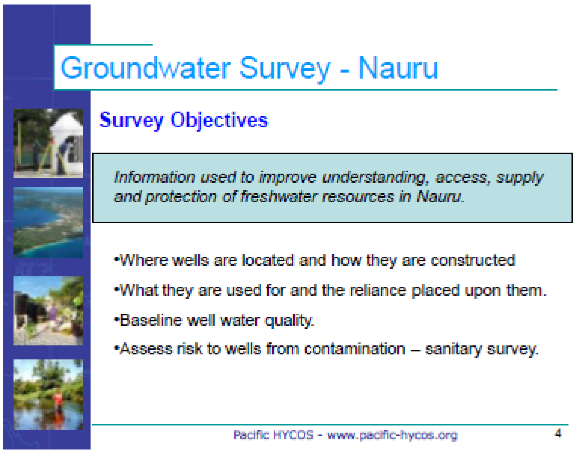
4/4

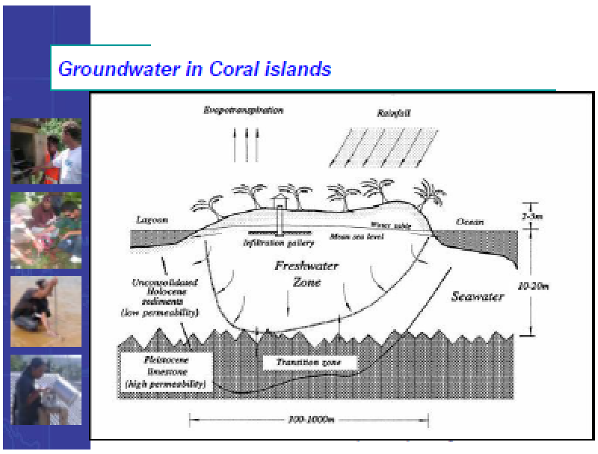
ANNEX VII WORKSHOP SCHEDULE

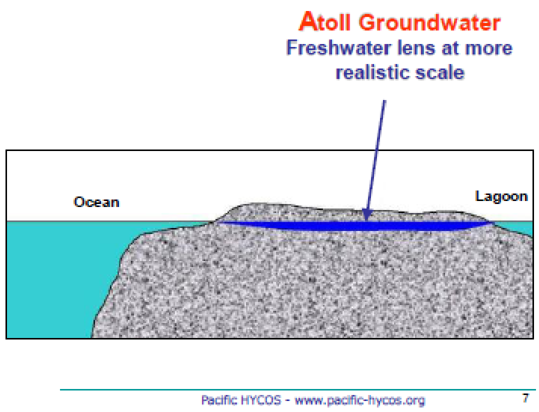
Time	Activity	Facilitator
10:00 - 10:10	**Introduction:** -facilitators -Groundwater survey objectives -Acknowledgments	SOPAC
10:10 - 10:30	**Nauru water features:** -Water cycle and groundwater basics - Groundwater in coral islands -Potential sources of contamination	SOPAC
10:30 - 11:00	**Survey results:** -Summary of finding - Salinity maps -Bacteriological contamination maps -Hydrocarbon contamination maps	SOPAC
11:00 - 11:20	**Sanitary survey – water quality:** -Sanitary survey presentation -Salinity and E-coli levels -Health related issues	HEALTH
11:20 - 11:45	**Well improvement option:** -How to undertake a sanitary survey -How to reduce risks to well water contamination -Salinity and well head protection options	SOPAC
11:45 - 12:15	**Sanitation issues:** -Nauru's global sanitation issues and district picture -Impact of sanitation on groundwater quality	CIE
12:15 - 12:45	**Domestic water quality result:** -Distribution of domestic result (as at time of sampling)to users/householders -one to one talk	SOPAC CIE HEALTH

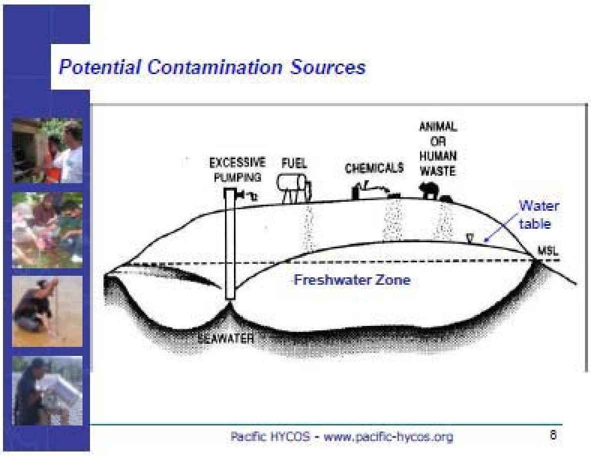
ANNEX VIII PRESENTATION SLIDES







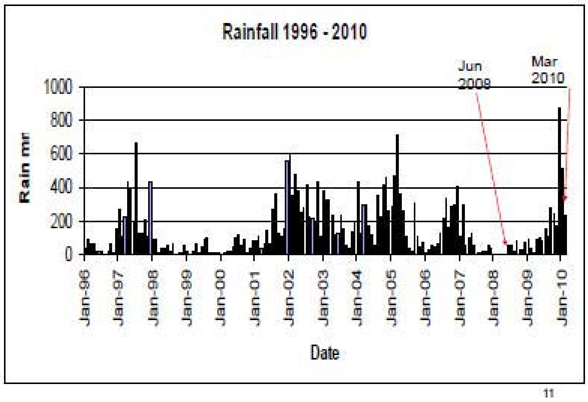


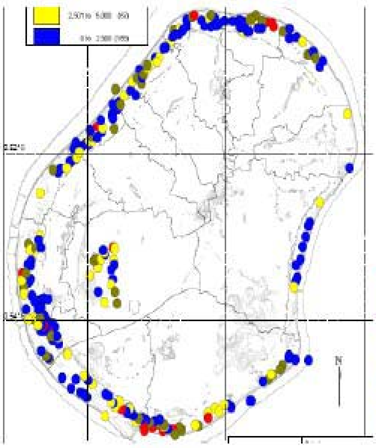


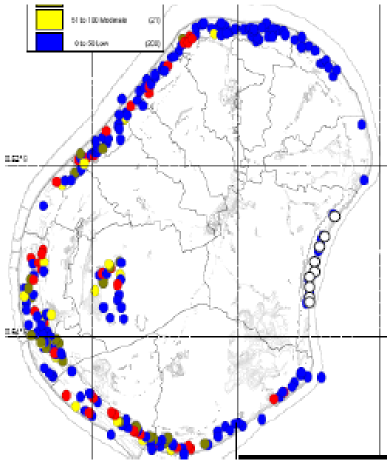
Groundwater survey summary Mar- Apr 2010 – Preliminary Results

District	No .of wells	No. of households using wells	2006 No Of Households	% of Households using wells	No of people using wells	2006 total pop.	% of pop using wells	Avg depth to water	Median Salinity µS/cm
Nibok	24	24	63	38.1%	331	378	87.6%	4.44	4450
Anibare	16	14	23	60.9%	118	157	75.2%	2.89	1665
Boe	38	51	107	47.7%	416	761	54.7%	3.45	2565
Yaren	38	41	100	41.0%	367	684	53.7%	2.71	1785.5
Ewa	21	21	57	36.8%	187	371	50.4%	3.23	1601
Baitsi	18	20	63	31.7%	207	508	40.7%	4.53	3160
Denig	13	23	76	30.3%	188	473	39.7%	5.08	2400
Uaboe	7	15	45	33.3%	123	328	37.5%	3.32	1982.5
Anetan	23	18	74	24.3%	181	500	36.2%	2.89	1776
Buada	32	34	103	33.0%	254	704	36.1%	3.46	3875
Anabar	21	13	64	20.3%	146	408	35.8%	2.58	2320
Aiwo	32	35	202	17.3%	369	1165	31.7%	3.59	2400
Meneng	43	31	251	12.4%	229	1355	16.9%	2.49	2430
Ijuw	10	1	34	2.9%	8	235	3.4%	3.09	1810
Location	0	0	276	0.0%	0	1135	0.0%	NA	NA
Total	336	341	1536	22.2%	3124 (houses only)	9086	34.4%	3.40	2510
					3884 total (2 schools)		42.7%		

10







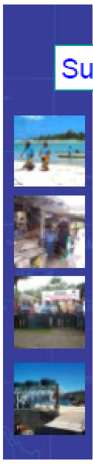
Bacteriological Contamination

E coli MPN/100ml

Bacteriological E Coli MPN/100ml

>500	High
100- 500	Moderate - High
50 – 100	Moderate
0-50	Low - Moderate
○	Results NA

15

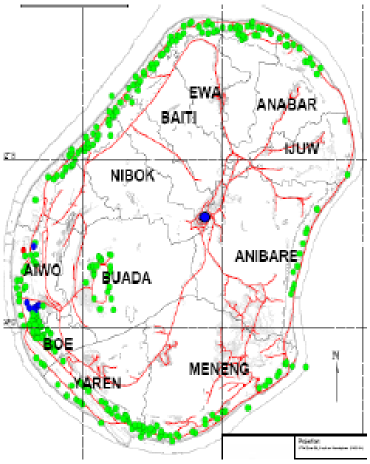


Survey results – E coli

Faecal contamination risk

Risk	MPN	No. samples	% of samples
Low- moderate	0-50	98	46%
moderate	51-100	22	10%
moderate- high	101-500	38	18%
high	>500	55	26%
TOTAL		213	

Pacific HYCOS - www.pacific-hycos.org 16



Potential Hydrocarbon Contamination

eg oil, diesel, petrol etc.

Hydrocarbon Contamination

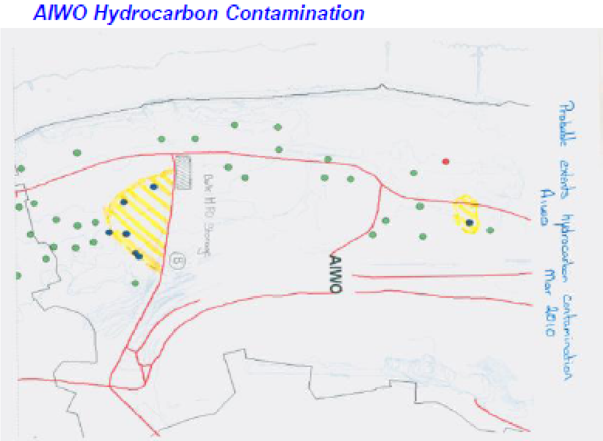
Unknown	(1)
NO	(203)
YES	(7)

17

AIWO Salinity - probable extents EC <2500µS/cm

Pacific HYCOS - www.pacific-hycos.org

AIWO Hydrocarbon Contamination



Sanitary surveys

- A sanitary survey is an **on-site inspection** of the water supply system assessing the risk or threat from contamination.
- A survey is made of the **site conditions, set up, and practices** in a water supply system that pose an **actual or potential danger** to the health and well-being of the consumer.
- There are sanitary surveys for rainwater tanks, piped water systems, wells, and drums to help assess the risk of the water source from contamination.

22

Sanitary Survey

Open Dug well Example

Sanitary Survey

Open Dug well Example

1. Is there a septic tank or pit toilet within 10m of the well?
2. Is the nearest septic tank or pit toilet on higher ground than the well?
3. Is there any other source of pollution (e.g. animal excreta, rubbish) within 10m of the well?
4. Is the drainage around the well poor, allowing water to pond within 2m of the well?
5. Is the wall around the well not properly raised above the ground?
6. Is the wall around the well damaged or cracked or rusted allowing surface water to enter?
7. Is the concrete floor around the well absent?
8. Is the concrete floor less than 1m wide around the well?
9. Is the concrete floor cracked allowing water to enter the well?
10. Are the inside walls of the well poorly sealed at any point 3m below ground?
11. Are the bucket and rope left in a place where they may get contaminated?
12. Is there a need to fence the well area (due to animal activity etc)?
13. Is the mouth of the well not securely covered?

Any other relevant observations (risk related):

Q: What do you believe are the main risk to your well and its water quality?

A:

Q: What do you believe you can do to improve the water quality in your well?

A:

25

Sanitary surveys – Water Quality

- Water quality **sampling** is used to **validate risk** assessment. If assessment indicates high risk then expect poorer water quality.
- **Risk Assessment** is used to **identify** major **threats** to, or concerns for safety.
  Develop an **action plan to reduce** the **risk** from the threats.
- **Focus** is **on reducing the risk** to the water source not on the water quality testing
- Parameters used during this survey to help determine water quality and verify risk.
  - EC – salinity
  - E. Coli –***Escherichia coli.***

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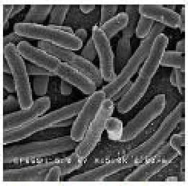
E Coli – Escherichia Coli

- Found in the gut of warm blooded animals, but can survive outside the body for a short period of time.
- Most E Coli are themselves harmless, but they are useful to test for presence of faecal contamination.
- E coli is measured in the units MPN/100ml or Most Probable Number/100ml
- The higher the number the increased risk of faecal contamination.



E coli. Rod shaped Bacteria. *Scale*

TO MAKE THE WATER SAFE – **BOIL** THE WATER

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Salinity - EC µS/cm

- Electrical Conductivity, EC, is a measure of the amount of salt dissolved in water.
- Salinity is measured by the ability of the water to conduct electricity (EC Electrical Conductivity). The more salt in the water, the more it can conduct electricity and the higher its EC.
- The standard unit for EC is microSiemens per centimetre (µS/cm)

EC Range (µS/cm)	Use
0 - 800	Rainwater
0 - 2,500	Generally accepted upper limit for drinking water, although water up to 3,000 (µS/cm) can be used for drinking.
2,500 – 10,000	Brackish waters - some use for washing
50,000 – 80,000	Seawater

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Well Water Improvement

- Sanitary surveys
- How to reduce risks to well water contamination
- How to make my well water less salty

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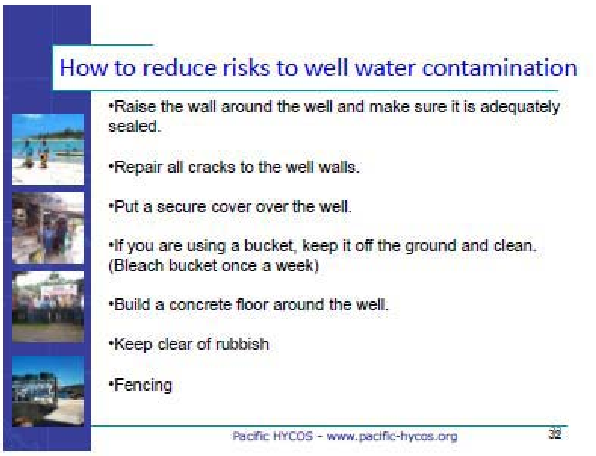
How to reduce risks to well water contamination
•Raise the wall around the well and make sure it is adequately sealed.
•Repair all cracks to the well walls.
•Put a secure cover over the well.
•If you are using a bucket, keep it off the ground and clean. (Bleach bucket once a week)
•Build a concrete floor around the well.
•Keep clear of rubbish
•Fencing
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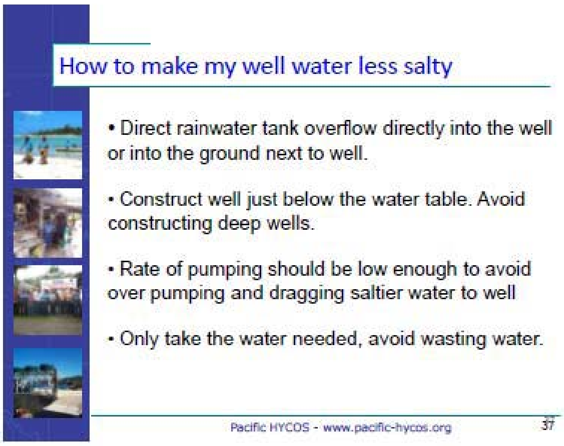
32


Concrete floor more than 1m wide around the well
Wall properly raised above the ground
Not securely covered


Wall properly raised above the ground
Securely covered
Concrete floor around the well


How to make my well water less salty
• Direct rainwater tank overflow directly into the well or into the ground next to well.
• Construct well just below the water table. Avoid constructing deep wells.
• Rate of pumping should be low enough to avoid over pumping and dragging saltier water to well
• Only take the water needed, avoid wasting water.
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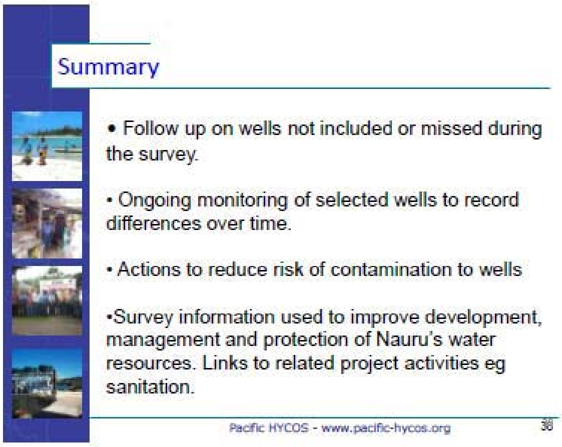
Summary
• Follow up on wells not included or missed during the survey.
• Ongoing monitoring of selected wells to record differences over time.
• Actions to reduce risk of contamination to wells
•Survey information used to improve development, management and protection of Nauru's water resources. Links to related project activities eg sanitation.
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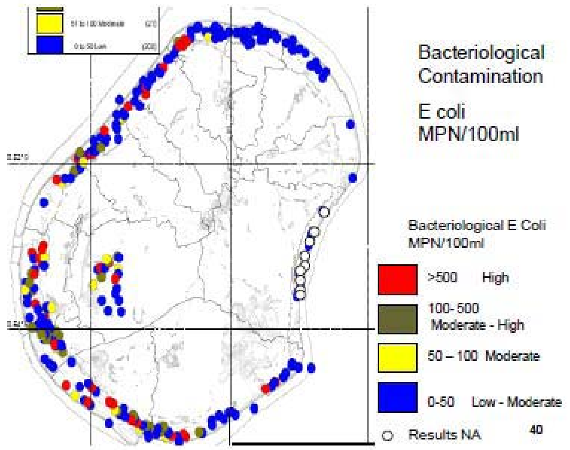
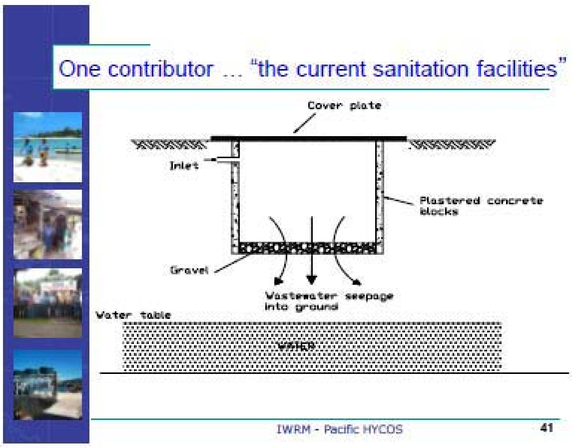
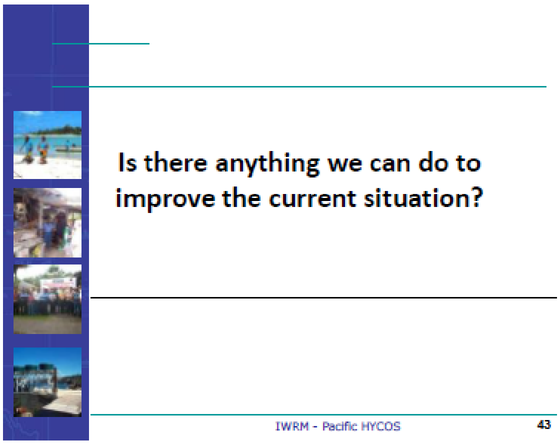
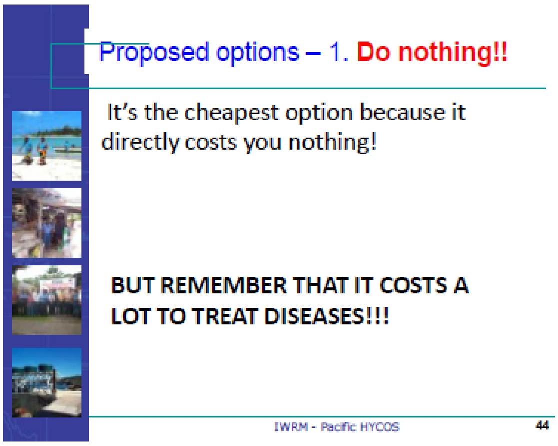
SANITATION/ WASTEWATER MANAGEMENT
The findings of the HYCOS project feed into another IWRM component on sanitation demonstration projects.
By Kasenga Hara
IWRM - Pacific HYCOS
39

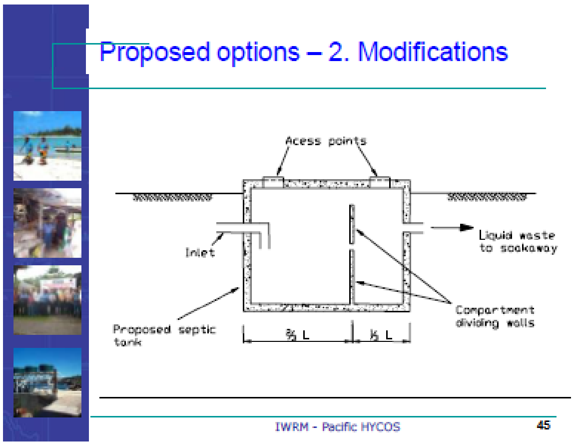

Bacteriological Contamination
E coli MPN/100ml
Bacteriological E Coli MPN/100ml
>500 High
100- 500 Moderate - High
50 – 100 Moderate
0-50 Low - Moderate
Results NA
40

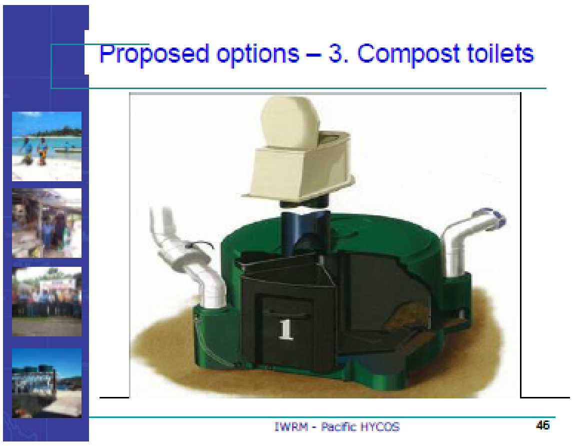

One contributor … "the current sanitation facilities"
Cover plate
Inlet
Plastered concrete blocks
Gravel
Wastewater seepage into ground
Water table
IWRM - Pacific HYCOS
41

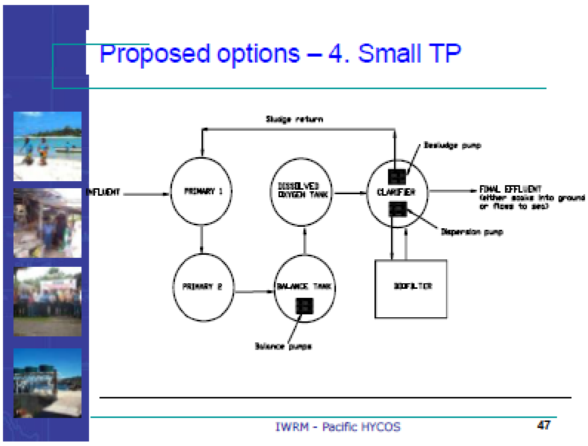

"The current practice ...."


Is there anything we can do to improve the current situation?
IWRM - Pacific HYCOS
43


Proposed options – 1. Do nothing!!
It's the cheapest option because it directly costs you nothing!
BUT REMEMBER THAT IT COSTS A LOT TO TREAT DISEASES!!!
IWRM - Pacific HYCOS
44


Proposed options – 2. Modifications
Acess points
Inlet
Liquid waste to sookaway
Compartment dividing walls
Proposed septic tank
⅔ L
⅓ L
IWRM - Pacific HYCOS
45


Proposed options – 3. Compost toilets
1
IWRM - Pacific HYCOS
46


Proposed options – 4. Small TP
Sludge return
INFLUENT
PRIMARY 1
PRIMARY 2
DISSOLVED OXYGEN TANK
BALANCE TANK
Balance pumps
CLARIFIER
Desludge pump
Dispersion pump
FINAL EFFLUENT
BIOFILTER
IWRM - Pacific HYCOS
47


WHERE TO FROM HERE???
•Review sanitation options and make a recommendation which will look at reducing current impact to groundwater.
•Ongoing monitoring of selected wells to record differences over time.
•Build from existing survey information to improve our development, management and protection of Nauru water resources.
IWRM- Pacific HYCOS
50


TUBWA KOR
THANK YOU
IWRM- Pacific HYCOS
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ANNEX IX WORKSHOP MINUTES

Date	*21 April 2010*	*22 April 2010*	*23 April 2010*
Venue	Centennial hall	Od-n-Aiwo Hotel	Od-n-Aiwo Hotel
Districts	Aiwo and Boe	All districts	All districts
Attendance	20	14	6
Start	10:15am	10:50am	10:30am
End	12:30pm	12:15pm	12:15pm
Summary	Good interaction with the Aiwo and Boe communities. Participants were particularly interested and active. All of them attended the workshop until the end and most of them have took back their well water quality results, asking relevant questions about the relation between test result (E-coli and salinity) and the possible use of the water.	We started the workshop an hour late as we figure out in the morning that the venue we had booked (Centennial hall) wasn't available. Moreover the bus who was supposed to start at 9:15 from the Centennial hall was late and just started is shift at 10:45. We end up using the back of the Od-n-Aiwo Hotel, which, with a roof top and low luminosity, was ok. Again the participation from the different communities was appreciated. Everybody stayed until the end and most of them were keen on knowing their water results and getting some more details about their own well.	Only six people attempted this workshop and the interaction was quite low during the presentation. However, one to one discussions were particularly interesting at the end. A lady from Anibare asked for the results of each well on her district, saying that she will passing on to householders.

Concerns and question from the attendance	• Well improvement: How deep should I dig my well? • Sanitation practices: What is the impact of dumping sewage into the sea? • Sanitation practices: Who will pay for the implementation and running costs of the proposed option? • Sanitation practices: A lady is asking CIE to write up a proposal for the envisaged options and to submit it to the communities. • Hydrocarbon contamination: two people from the Aiwo community are particularly concerned about their wells as they are heavily contaminated by oil. • Rainwater contamination: Various people have expressed their concerns about pollution of roofs in Aiwo by the dust coming from the phosphate processing activity.	• Bacteriological contamination: A gentleman express is concern that we were not talking about the possible contamination from the graves and buried sites near some houses. • Sanitation practices: Questions related to the compost toilet: Can we see the feacal matter inside the hole? People were also concern about the smell generated by this option. • Water improvement: What kind of material can we use to lined or well? Is fiber glass ok? And when the water gets very salty? • Water quality: How Can we clean our water to remove the smelt? Are carbon filters efficient? • Water quality: How to disinfect our water? Is bleach ok?	N/A

ANNEX X SUMMARY OF WORKSHOP ACTIVITIES

First planning
Our first plan was to hold 14 workshops, 1 for each district, in order to get an acceptable number of people for each workshop and to facilitate communication by holding it in each community district. Considering the interest shown by people during the survey we were confident on the attendance.

With the help of the CIE, 14 venues have been booked and letters announcing the workshops have been sent to each community representative/leader. A radio announcement had also been stood up.

First feedback
Our first workshop was held in the church hall of the Meneng district on Tuesday 20th of April. The venue was covered, with benches and large enough to welcome up to 50 people. Unfortunately power was out in the district when we arrived. Some of us had to run to the office to get a black board.

At 10:30, we were ready to cope with the power off and start the workshop but only one lady was present. At 10:50, we decided to start our presentation to the only person present. Being particularly disappointed by the attendance we decided to wait for the second workshop scheduled in the afternoon and reflect upon our possibilities to attract more people.

The second workshop was held in the church hall of the Yaren district. The venue was outdoor but covered. However, there was no seat available. After waiting more than an hour, nobody shows up and we decided to change our plan and do the best we can to deliver our workshops.

Reviewed planning and organisation
Our main issue was to attract more people in order to achieve a good awareness around groundwater issues among communities. We then decided to go on local TV (Peter Sinclair gave an interview to explain the upcoming workshops). Also, as our first target group was the households visited during the survey, we decide to hand out leaflets to each of the 423 households surveyed (Annex XI). This operation was actually fairly easy, facilitated by our small scale maps and well location. It took us three evening (Tuesday to Thursday) to cover the entire island.

In consultation with CIE and community leaders and because it was easier for us to have a convenient venue, cover and with seats available, we decided to book the centennial hall in Aiwo and to provide people with transport. A shuttle has been hired to pick up people in the morning and drop them off at lunch time. Bench were also hired from RONPhos.

We decided to limit our first workshop to Aiwo and Boe as they are two relatively dense populated districts at walking distance from the centennial hall. It was also a good opportunity to assess the efficiency of our new communication strategy. Moreover Aiwo is concerned by hydrocarbon contamination and we wanted to be able to focus more on this aspect.

3 workshops were finally held in Aiwo with a total attendance of 40 people. Workshop minutes are presented in the previous Annex (Annex IX).

ANNEX XI LEAFLET ANNOUNCEMENT FOR WORKSHOPS

Nauru Department of Commerce, Industry and Environment and Department of Health
in conjunction with
Pacific Islands Applied Geoscience Commission **SOPAC** and World Health Organisation **WHO**
Invite you to attend a Community Workshop
on

Risk Assessment of Domestic Wells

During the past 5 weeks, the Government of Nauru, in conjunction with the Pacific Island Applied Geoscience Commission (SOPAC), has been carrying out a survey of household wells throughout Nauru; information on 335 wells has been collected.

In order to give feedback to the community workshops will be held this week.
The survey and sampling results, will be presented. The workshop will help users to consider what the main risks are to their well water quality. Simple measures which users can do themselves will be discussed as to how they can reduce risks of contamination to their well.

You are invited to attend one of the series of workshops proposed as follows

Thursday 22 April 2010	**10am to 12pm**	**All districts**
Friday 23 April 2010	**10am to 12pm**	**All districts**

Venue for all meetings will take place at **Aiwo's Centennial Hall**, behind the Mission House.
For the Thursday and Friday workshops the Mennen Hotel shuttle bus will travel anticlockwise from Centennial Hall, around the island to make pickups between 9:15 - 9:45am.
Results from the individual sampling and sanitary surveys will be made available at the meeting.
We look forward to your participation.

ANNEX XII INDIVIDUAL TEST RESULT SHEET

SOPAC **Salinity and Bacteriological test result** PACIFIC HYCOS

Family Name:____________________ **Sampling date:___________**
Sampling number:______________ **Sampling from:__________**

Salinity (µS)	Total Coliform (MPN)	E-coli (MPN)

ANNEX XIII PROJECT OUTCOMES

1. Expected outcomes

Identify areas of groundwater contamination and related sanitation issues:

No particular areas have been identified having bacteriological contamination. Results from the sanitary survey and E-coli testing suggest that there is no widespread contamination but many potential point source contaminations. Therefore, sources should be identified case by case. However, domestic well contamination is likely due to leaking septic tanks in close proximity to the well. It could also come from ground pollution around the well.

Hydrocarbon contamination have been identified in Aiwo and reported to CIE as an individual report in the Annex.

Maps and statistical results from bacteriological and hydrocarbon contamination are detailed in this report. Septic tanks are also located on the map.

Survey questionnaires are available at SOPAC, Fiji. All information from the groundwater and sanitary survey for each well are also available digitally within an Excel spreadsheet and can be queried. A copy of this spreadsheet is available at CIE, Nauru.

Develop datasets identifying groundwater quality and groundwater abstraction and reliance

Groundwater quality has been mapped as salinity level and risk of faecal contamination. Groundwater abstraction and reliance has been estimated for entire Nauru and per capita using well.

All information from the groundwater and sanitary survey for each well are available digitally within an Excel spreadsheet and can be queried. A copy of this spreadsheet is available at CIE, Nauru.

Maps and statistical results from bacteriological and hydrocarbon contamination as well as salinity levels are detailed in this report.

GIS layers (using Map Info software) with well and septic locations are available. The GIS database also includes most of the data collected during the survey and has been used to produce some of the maps included in this report.

Increased awareness of the risk of contamination from surface activities

The poor attendance in the workshop was a threat in increasing awareness. However, during the survey, most of the householders were asked about the water sampling and we were able to provide attendees with a good understanding of the contamination risks and why we were testing the water for E-coli.

Even if we cannot claim to have significantly increased awareness around risk of contamination from surface activities, a step up have been done toward increasing awareness. Peter Sinclair was on local TV news twice to explain our project and our desire to provide communities with a better understanding of the groundwater contamination issues.

Workshops have involved 40 people from all Nauruan communities and each representative was aware of our survey and workshop activities. All representatives were informed that they could contact CIE for further information about the groundwater quality, sanitary survey and protection measures. Individual results and a detailed explanation of contamination source and protection measures, supported by a hand out of the workshop presentation slides, will also be distributed.

Improved understanding on the reliance and use of the resource and assist in the future development of resource

Estimates of water use and reliance are shown on this report. All the data used for the estimates are available through SOPAC or CIE.

Further development of water resources should take into account the importance of groundwater reliance within Nauru as well as the numerous well showing risk of faecal contamination. Groundwater is the second water resource in Nauru and is extensively used when accessible. This report stress the urge to take measures for new sanitation facilities as well as to stop the spread of Hydrocarbon contamination in Aiwo and to monitor other sensible area been recorded with contamination. Petrol stations should also been checked for leaking tanks.

Local community and householders to reduce risk to wells

Information has been provided to 40 householders who represent 18% of the wells used in Nauru. Community tools, including detailed information on reducing public health risks, are available at CIE and Aid management unit.

Poor attendance at workshops is a threat for the achievement of this component. A step up have been made toward increasing awareness among risk to contamination from surface activities and some Householder have already stated that they will make the necessary changes to improve their well safety. However, there is a need for further promotion of risk reduction measure as well as a monitoring program to evaluate progress. Power point slide show used during our workshops is available at CIE and could be use for further interventions.

2. Other outcomes

Relationship building

Considering the friendly reception from communities in the field, the exceptionally high response rate associated with the number of people met during the survey and positive feedback from people who attended the workshop, we have developed a positive relationship with the citizens of Nauru. The presence of Reuben Dongobir and Daniel Raidinen has been central to building and maintaining a strong relationship between SOPAC and the Nauruan communities.

Maintaining and expanding the relationship between SOPAC and the Nauruan communities is important to sustain actual project outcomes and facilitate further development.

Capacity building

Two local labourers were trained in groundwater and sanitary survey methodologies including sampling procedure, salinity measurement and calibration. Along with the Bacteriological sampling and testing training for two people done by The HYCOS team in November 2009 for the RWH survey, Nauru has now the capacity to undertake its own water surveys and water testing for E-coli.

ANNEX XIV SELECTED DOMESTIC BORES FOR MONITORING

A review of the 337 domestic wells identified in the groundwater survey March - April 2010 were used as the core data set from which to select a number of monitoring bores which might be considered for additional monitoring of groundwater on a quarterly basis.

The intention is that these bores would be used to collect additional information about the salinity of the groundwater and supplement the existing NRC monitoring that collects data on salinity from 33 specifically constructed monitoring bores.

The criteria for the selection of the list from which bores could be chosen from is as follows:

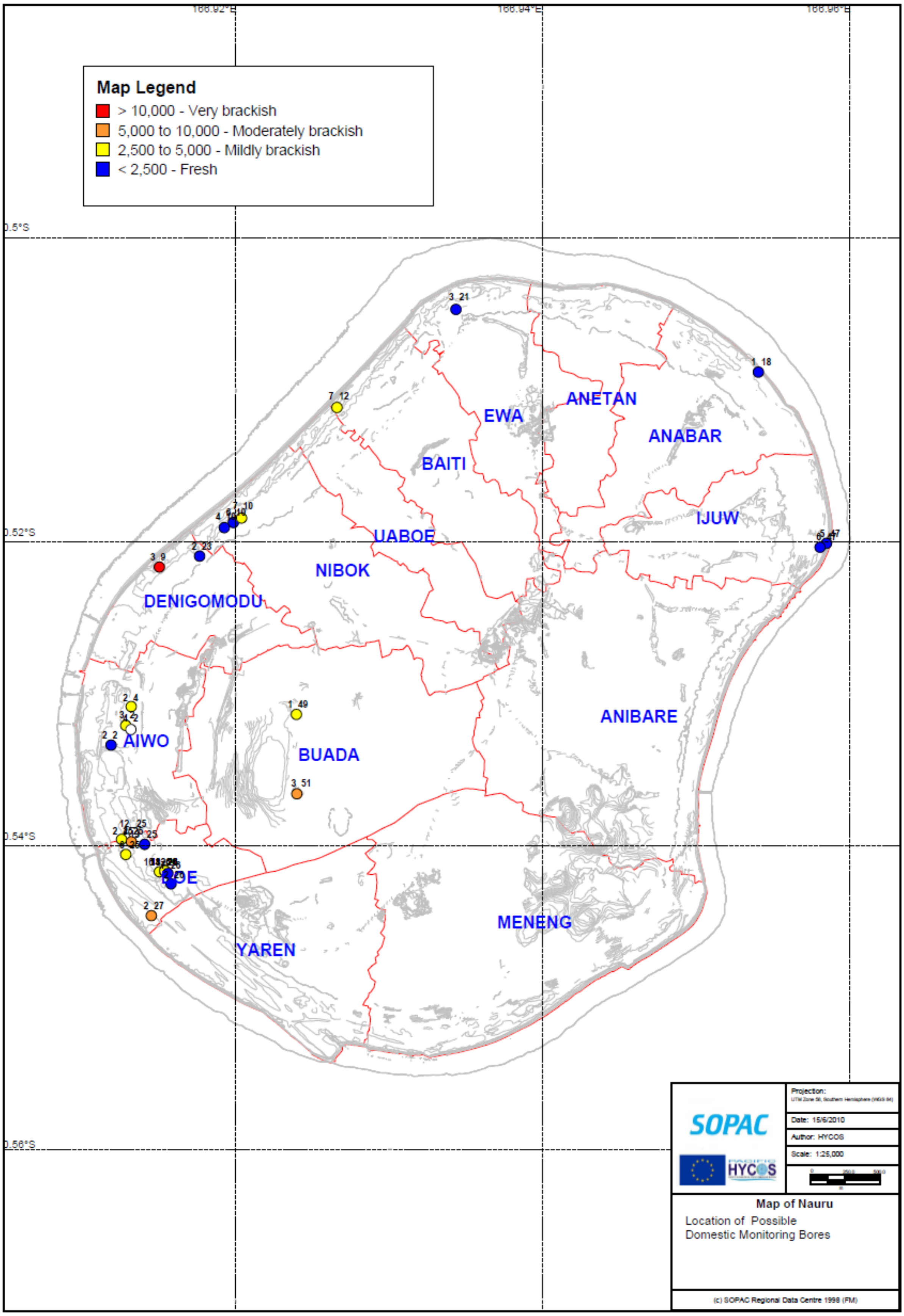
- Salinity data is available and can be obtained direct from the well
- Bacteriological data is available and samples have been taken previously
- All wells which are poorly covered or with no covering were removed
- Wells are sufficiently raised above the ground as to minimise potential for surface water ingress
- Wells which had any evidence of hydrocarbon contamination were removed

Utilising this criteria the following subset of 25 wells were identified as in the attached table.

No consideration was given in this first instance to the location of the well or to the depth of water in the well.

This list represents a selection of wells and it is not proposed that all these wells would be required to be monitored. Those wells that are considered more appropriate for monitoring have been highlighted and recommend an additional 18 monitoring wells.

It may be appropriate after consultation with GoN agencies that alternate or additional criteria can be used to identify the domestic wells suitable for monitoring, once the specific purpose of monitoring is identified. This will be easily achieved from the original dataset.



Map 10: Location of possible domestic wells for future and ongoing monitoring.

Roof ID	Map No.	Well No.	District	Southing	Easting	Family name	First name	Well use	well construction date	Well diameter (m)	Depth to water (m)	Total depth (m)	Depth of water (m)	Conductivity Measure (µS/cm)
R000508	2	2	AIWO	00°32.003'	166°54.706'	SCOTTY		A	1980	0.76	4.50	4.90	0.40	605
R000101	2	3	AIWO	00°31.926'	166°54.770'	JEREMIAH	NASIO	U	1980	0.55	2.46	4.34	1.88	4340
R000503	2	4	AIWO	00°31.942'	166°54.790'	KARLMAY		N	?	0.70	3.80	5.15	1.35	5000
R000511	4	2	AIWO	00°31.485'	166°54.788'	MOSES	THEODORE	U	1980	1.20	3.21	4.44	1.23	3560
R001379	9	3	DENIG	00°31.294'	166°54.875'	TAUPO	RICHARD	U	1970	0.77	6.04	7.22	1.18	10930
R000282	10	4	NIBOK	00°31.145'	166°55.155'	MWAREOW	ROGER	N	2000	0.77	4.55	5.79	1.24	1830
R000291	10	6	NIBOK	00°31.125'	166°55.183'	KUN	MONITA	U	1980	0.72	4.23	4.59	0.36	719
R001404	10	7	NIBOK	00°31.107'	166°55.213'	DAGAGIO	MARTIN	U	?	0.91	3.40	8.00	4.60	3310
R000346	12	7	BAITI	00°30.679'	166°55.590'	DAGEAGO	PATRICIA	U	1990	0.60	6.12	7.80	1.68	4580
R000466	18	1	ANABAR	00°30.531'	166°57.234'	DOGOUBE	PETER	U	?	NA	4.27	4.68	0.41	630
A21	21	3	EWA	00°30.283'	166°56.060'	CALEB		U	?	0.90	2.20	2.50	0.30	1090
R000275	23	2	DENIG	00°31.254'	166°55.049'	GADEANANG	ROSABEL	U	1995	0.77	5.33	5.94	0.61	2190
R000048	25	2	BOE	00°32.375'	166°54.738'	CLODUMAR	KINZA	U	1980	1.21	5.93	8.49	2.56	2630
R000593	25	4	BOE	00°32.381'	166°54.783'	BENJAMIN	NANCY	U	1970	0.80	4.60	5.90	1.30	6750
R000775	25	6	BOE	00°32.436'	166°54.767'	ADAM	DONA	U	1980	1.30	4.90	6.20	1.30	4250
R000050	25	12	BOE	00°32.351'	166°54.801'	FINCH	PAUL	U	1980	0.87	4.00	5.00	1.00	2500
R000588	25	13	BOE	00°32.398'	166°54.842'	AKUBOR	CORNA	U	?	1.10	1.80	2.30	0.50	1330
R000009	26	2	BOE	00°32.552'	166°54.944'	GARABWAN	CHANDA	U	1970	1.40	3.30	3.80	0.50	1248
R000584	26	7	BOE	00°32.516'	166°54.935'	CAPELLE	REMUS	U	1989	0.76	2.65	3.81	1.16	2490
R000016	26	10	BOE	00°32.501'	166°54.894'	SOLOMON	CURTIS	N	1980	0.80	3.20	4.79	1.59	3000
R000789	27	2	BOE	00°32.678'	166°54.867'	RAIDINEN	KRAMER	U	1970	0.90	5.70	5.75	0.05	9100
R000829	47	5	IJUW	00°31.207'	166°57.503'	KAM	MIKE	N	?	0.38	3.85	4.55	0.70	1810
R000831	47	6	IJUW	00°31.219'	166°57.471'	DIEYE	TYRONE	N	2004	NA	2.68	3.36	0.68	1580
R001197	49	1	BUADA	00°31.882'	166°55.439'	AKIBWIB	RADO	U	2006	0.80	2.50	3.60	1.10	4930
R001222	51	3	BUADA	00°32.196'	166°55.439'	KUN	ROLAND	U	1980	1.20	NA	8.00	NA	5110

ANNEX XV CADMIUM ANALYSIS FOR SAMPLED RAINWATER TANKS

Cadmium and lead concentrations in rainwater tanks

Roof Id	R000506	R000054	R000500	R000616	R000604	R001054	R000609	R000098	R000291	R001036
Householder name	Raefe Scotty	Molly Thoma	Agir	Arlon Cook	De Robert Hammer (Jeanette Appi)	Gerard Jones	Lyle Tsitsi	Demo Maaki	Paul and Monita Kun	Gordon Dagego
District	AIWO	AIWO	AIWO	AIWO	AIWO	YAREN	AIWO	AIWO	Nibok	Meneng
Easting	166°54.679'	166°54.795'	166°54.66'	166°54.664'	166°54.665'	166°55.635'	166° 54.72'	166° 54.72'	166°55.183'	166°55.778'
Southing	00°31.999'	00°32.300'	00°32.163'	00°32.061'	00°32.319'	00°33.122'	00°32.210'	00°31.976'	00°31.125'	00°33.126'
Date	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010	01/05/2010
Source	rain tank	rain tank	rain tank	rain tank	rain tank	rain tank	rain tank	rain tank	rain tank	rain tank
[1]**Cadmium ug/L**	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Lead ug/L	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5

[1]ADWG cadmium indicated concentration of cadmium in drinking water should not exceed 2µg/L ***(0.002 mg/L)***
[1]WHO guidelines for cadmium indicate concentration of cadmium in drinking water should not exceed 3µg/L ***(0.003 mg/L)***

[2]ADWG indicated concentration of lead in drinking water should not exceed 10 µg/L ***(0.010 mg/L)***
[2]WHO guidelines for Lead indicate concentration of lead in drinking water should not exceed 100 µg/L ***(0.1 mg/L)***

Note: 1mg/L = 1000 µg/L

Analysis and Interpretation

During one of the workshops, concerns were raised by residents from Aiwo and Boe that dust from the phosphate drying and processing, which regularly drifted across these districts, and landing on their roofs was entering their rainwater tanks and may be the subject for health concerns. In response to this, the project agreed to undertake some initial sampling of rainwater tanks to assess the potential impact.

Nauru phosphate is very high grade and found to have high levels of cadmium. Cadmium and lead were identified as the most likely contaminants to be present in the rainwater tanks in Nauru and with health impacts, given the composition of the phosphate.

Samples of 500ml were taken from each of the raintanks and refrigerated until they could be analysed at the laboratories in USP. The samples were analysed for Cd and Pb using Atomic Absorption Spectroscopy with a detection limit of 0.4µg/L and 2.5µg/L respectively.

In the absence of Nauru specific water quality guidelines for Pb and Cd, Australian guidelines were used. Australian Drinking Water Guidelines, ADWG, recommend that for health considerations Cd should not exceed 0.002mg/L or 2µg/L in drinking water. Australian Drinking Water guideline recommends that for health considerations Pb should not exceed 0.01mg/L or 10µg/L in drinking water.

The results from this analysis indicate that for all samples, both Cd and Pb are below the detection limit for each of these metals and below the ADWG for both Cd and Pb in drinking water.

Based on the samples taken there is no elevated concentrations of Cd or Pb in the rainwater tanks sampled. It is concluded that based on the samples taken the impact on roof collected rainwater from the phosphate dust in regards to contamination from Cd and Pb is considered minimal.

The University of the South Pacific

INSTITUTE OF APPLIED SCIENCES, ANALYTICAL LABORATORY

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All data reported herein have been performed in accordance with the laboratory's scope of accreditation

ANALYTICAL RESULT(S)
(results apply to samples as received)

Customer : **SOPAC Pacific Islands Applied Geoscience Commission**
Attention : **Mr Peter Sinclair**
Report No : **R_2S2010/429**
Sample delivered by Customer

Sample Type: Water
Date received : 20/05/10
Date reported : 11/06/10

Customer I.D. Lab No.		Hammer Derobert AIWO 2010/1996	CESILT AIWO 2010/1997	DAGEAGO MENENG 2010/1998	Lyle Tsitsi AIWO 2010/1999	Demo Maaki AIWO 2010/2000	Method Ref. No.
Cadmium	(µg/L)	<0.4	<0.4	<0.4	<0.4	<0.4	AP3113B
Lead	(µg/L)	<2.5	<2.5	<2.5	<2.5	<2.5	AP3113B

Customer I.D. Lab No.		AGIR AIWO 2010/2001	Paul Kun NIBOK 2010/2002	Gerard Jones YAREN 2010/2003	Arlon Cook AIWO 2010/2004	Molly Thoma AIWO 2010/2005	Method Ref. No.
Cadmium	(µg/L)	<0.4	<0.4	<0.4	<0.4	<0.4	AP3113B
Lead	(µg/L)	<2.5	<2.5	<2.5	<2.5	<2.5	AP3113B

Note 1 : AP = APHA, 21st Edition, 2005
Note 2 : This test report supersedes the previously issued Test Report RS2010/429 issued on 24/05/10. Lead values and logo are now included.

Usaia

Usaia Dolodolotawake
Key Technical Person

11 · 6 · 10
Date

This test report shall not be reproduced except in full

File Location : C:\IAS 2010\RESULTS\SOPAC-w2005

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ANNEX XVI CADMIUM FACT SHEETS AUSTRALIAN DRINKING WATER GUIDELINES

Fact Sheets **Physical and Chemical Characterisitics**
Australian Drinking Water Guidelines

Cadmium

GUIDELINE

Based on health considerations, the concentration of cadmium in drinking water should not exceed 0.002 mg/L.

GENERAL DESCRIPTION

Contamination of drinking water by cadmium may occur as a result of impurities in the zinc of galvanised pipes or in solders used in fittings, water heaters, water coolers and taps. Cadmium can also be released to the environment in waste water, through contamination of fertilisers, and by metallurgical industries.

Cadmium metal is used as an anticorrosive coating on steel but its use is being phased out. Cadmium compounds are commonly used as pigments in plastics, in batteries and in some electrical components.

Cadmium concentrations in nonpolluted natural waters overseas are usually lower than 0.001 mg/L.

Food is the main source of cadmium intake. The estimated average Australian adult dietary intake of cadmium is approximately 0.03 mg per day. Smoking is a significant additional source of cadmium.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies concentrations of cadmium are usually less than 0.002 mg/L.

TREATMENT OF DRINKING WATER

Cadmium can be effectively removed from drinking water by lime softening (98% removal in the pH range 8.5 to 11.3) and coagulation with ferric chloride (90% removal above pH 8 but less effective at lower pH).

MEASUREMENT

The cadmium concentration in drinking water can be determined using graphite furnace atomic absorption spectroscopy (APHA Method 3500-Cd Part B 1992). The limit of determination is approximately 0.0002 mg/L.

HEALTH CONSIDERATIONS

Absorption of cadmium in the gastrointestinal tract depends on a number of factors including the solubility of the compounds ingested, but a healthy person typically absorbs 3-7% of ingested cadmium. This figure may be higher in people with iron, calcium and protein deficiency. Cadmium accumulates in the kidney and is only released very slowly, with a biological half-life in humans of 10 to 15 years.

An extensive review and summary of the human and animal toxicity data for cadmium is available (IPCS 1992).

In humans, long-term exposure can cause kidney dysfunction leading to the excretion of protein in the urine. This may occur, in a certain proportion of people, if the amount of cadmium exceeds 200 mg/kg renal cortex tissue; about 10% of the population is estimated to possess this sensitivity. Other effects can include osteomalacia (softening of the bones). Cases of Itai-Itai disease have been reported in Japan among elderly women exposed to highly contaminated food and water. Symptoms are similar to osteomalacia accompanied by kidney dysfunction characteristic of cadmium poisoning.

Epidemiological studies have looked for a connection between lung cancer and workplace cadmium inhalation, but the results have been inconclusive.

Long-term inhalation studies with rats have reported an increase in the incidence of tumours of the lung. No increase in the incidence of tumours was found when cadmium salts were administered orally.

There is no clear evidence that cadmium is mutagenic. Many tests have reported negative results but

there have been some reports of gene mutation and chromosome abnormalities in mammalian cells. The positive results are reported as being weak and only present at high concentrations.

The International Agency for Research on Cancer has concluded that cadmium is probably

carcinogenic to humans (Group 2A, limited evidence of carcinogenicity in humans and sufficient evidence in animals) (IARC 1987).

DERIVATION OF GUIDELINE

The guideline value for cadmium in drinking water was derived as follows:

0.002 mg/L = (0.0007 mg/kg body weight per day x 70 kg x 0.1)/ 2 L/day

where:

- an intake of less than 0.0007 mg/kg body weight per day will ensure that over a 70 year lifetime, cadmium in the body will be kept below the critical amount of 200 mg/kg renal cortex tissue (WHO 1989). This figure was based on calculations that take into account an absorption rate of 5%, a daily excretion rate of 0.005% of body burden, and an adequate safety factor
- 70 kg is the average weight of an adult
- 0.1 is the proportion of total daily intake attributable to the consumption of water
- 2 L/day is the average amount of water consumed by an adult.

No additional safety factors are necessary as they have been included in the intake value. The guideline value takes into account the higher cadmium intake, per kilogram of body weight, by infants and children.

The WHO guideline value of 0.003 mg/L is slightly different due to rounding in the calculation. The difference is not significant.

REFERENCES

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IPCS (International Programme on Chemical Safety) (1992). Cadmium. Environmental Health Criteria, 134. World Health Organization, International Programme on Chemical Safety.

WHO (World Health Organization) (1989). Toxicological evaluation of certain food additives and contaminants: Cadmium. The 33rd meeting of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization Food Additives Series, 24, 163-219, Geneva.

ANNEX XVII LIST OF CONTACTS

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ANNEX XVIII EXECUTIVE SUMMARY AND CONTACT DETAILS FOR AMU

Project title: Assessment of the shallow groundwater vulnerability in Nauru

Date: June 2010

Executive summary: Nauru's water resources are limited and under stress with an expected increase in prolonged dry periods due to climate variability. There are no fresh surface water sources and Nauru relies mostly on rainwater for its potable water needs. Desalinated water is currently supplying about 20% of the population water requirements but during period of prolonged drought, where rainwater is limited, the communities reliance on desalinated water can increase to more than 90%. At current maximum capacity, desalinated water is able to produce about a third of Nauruan water needs; moreover, this technology is consuming a significant amount of energy.

Groundwater is a limited natural freshwater source available on the island which is relied upon for domestic use and plays an important role in the water budget of the island with potential for increased development in the future.

In order to improve our knowledge on the actual reliance and use of the groundwater resource and to assist in its future development, a groundwater survey was undertaken in Nauru from March to April 2010, along with a sanitary survey of domestic wells. Shallow groundwater is particularly vulnerable to faecal contamination from surface activities and wastewater disposal. The sanitary surveys were used to identify major risks and threats to contamination and to inform the community on risk mitigation options.

337 wells were identified and an estimated 350 wells are located in the low lying coastal plain area. 230 were in use and at least 40% of the population has access to groundwater at the time of the survey. An estimated 298KL of groundwater is currently abstracted each day in Nauru and this usage is likely to increase in dry periods. This usage indicates that groundwater is currently the second most important water resource in volumes abstracted in Nauru, with harvested rainwater being the most important. Groundwater in the main is being used for non potable purposes including washing clothes, showering/bathing, outdoor uses, flushing toilets, washing dishes, and to a lesser extent cooking, with a few households using it for drinking purposes.

Salinity records and bacteriological (E-coli) levels have been collected for about 280 wells indicating that groundwater quality is a serious issue in Nauru. Salinity is highly variable, depending on rainfall and tidal mixing and can dramatically increase during extended dry periods.

Whilst salinity variability will limit the beneficial use in most circumstances, the risk from faecal contamination is of particular concern and may have a more serious limiting impact on potential use. Over 63% of the wells surveyed present an E-coli level greater than 20 (MPN), which using Australian guidelines (EPA 2003), would result in serious limitations of use. The main source of faecal contamination is likely to come from surface activities and in particular, onsite wastewater disposal practices.

Hydrocarbon contamination is also present in Aiwo, affecting at least 4 domestic wells and extending over an estimated area of 400m². Recommendations have been made to further investigate this plume and to develop options to restrict the impact on domestic users and the environment.

This assessment and report aims to provide information which will help to maximize the potential beneficial uses of groundwater in Nauru and thereby reduce some of the stress on other freshwater sources.

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References: EPA 2003, Use of reclaimed water, Guideline for environmental management, EPA Victoria, Australia, ISBN 0 7306 7622 6