International Groundwater Resources Assessment Centre

GROUNDWATER MONITORING

IN SMALL ISLAND DEVELOPING STATES IN THE PACIFIC

SPC Secretariat of the Pacific Community

SPREP Secretariat of the Pacific Regional Environment Programme

Groundwater Monitoring in Small Island Developing States in the Pacific

September 2016

Summary report of information shared during the workshop on "Advancing Groundwater Monitoring in Pacific SIDS" held between 29 August and 2 September 2016 in Suva, Fiji.



This report is a summary on groundwater monitoring practices in Small Islands Developing States (SIDS) in the Pacific. A brief overview is given for each Pacific SIDS to capture the current groundwater monitoring and assessment practices and their future challenges. This is a compilation of information shared during the workshop "Advancing Groundwater Monitoring in Pacific SIDS". We thank the workshop participants for their active participation and their valuable input. This report would not have been possible without their collaboration and timely contributions.

International Groundwater Resources Assessment Centre

IGRAC is the UNESCO Global Groundwater Centre, it also works under the auspices of WMO, it is a corporate IAH partner and it is financially supported by the Government of the Netherlands.

World Meteorological Organization

WMO provides world leadership and expertise in international cooperation in the delivery and use of high-quality, authoritative weather, climate, hydrological and related environmental services by its Members, for the improvement of the well-being of societies of all nations.

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1. Introduction

The workshop "*Advancing Groundwater Monitoring in Pacific Small Island Developing States*" was jointly organized by the World Meteorological Organization (WMO), the International Groundwater Resources Assessment Centre (IGRAC), Fiji Meteorological Service (FMS), the Secretariat of the Pacific Community (SPC) and the Pacific Regional Environment Programme (SPREP). The workshop took place in Suva, Fiji from 29 August till 2 September and was organised in the framework of WMO Education and Training Programme and of the Global Groundwater Monitoring Network (GGMN) programme. GGMN is a UNESCO programme, implemented by IGRAC and set up to improve quality and accessibility of groundwater monitoring information and subsequently our knowledge on the state of groundwater resources.

The workshop brought together regional (ground)water specialists from Pacific Small Island Developing States (SIDS) to review the state of groundwater resources and monitoring in their country and to learn on groundwater monitoring and assessment techniques. Around 25 participants attended the training from 11 different countries (Cook Islands, Fiji, Kiribati, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu).

The 5-day workshop consisted of the following components:

- Groundwater in SIDS and the importance of groundwater monitoring
- Groundwater monitoring and assessment techniques
- Field work
- Data analysis and interpretations
- Advanced geophysics (Professor Ian Acworth, University of New South Wales)

The detailed workshop agenda is given in Appendix I. The list of participants is given in Appendix II.

2. Rationale of the workshop

Small Island Developing States (SIDS) are constrained by their size, isolation, natural vulnerability and limited natural and financial resources. Freshwater resources, limited to groundwater in many cases, are exposed to extreme weather events, threats to water quality and increased exploitation due to increased water demand. Accessing sanitation and safe drinking water, protecting sensitive ecosystems and generating productive use of variable water resources are among the main challenges small island countries are facing. These challenges require innovative approaches and tailoring of solutions to the complex combination of geographical and socioeconomic constraints of each individual island.

There has been a significant effort in developing a sustainable level of capacity in Pacific SIDS to monitor and assess the status and trend of their water resources. These efforts aimed at providing water-related information and hazard warnings needed to support social, economic and infrastructural development and environmental protection. These were also objectives of the Pacific HYCOS (2006-2010), a project managed by SOPAC and implemented in partnership with WMO and UNESCO. One of the project findings was a ***very poor use of monitoring data to improve efficiency of abstraction and maintain water quality*** despite the fact that most Pacific SIDS (16 out of 19 countries) have ***high dependency on groundwater.*** There is a perceived lack of initiative to utilize and report on resources resulting in ***poor data collection and management*** jeopardizing future management and sustainability of the resource. Both HYCOS and the Transboundary Waters Assessment Programme (TWAP, 2014) have recently highlighted the lack of baseline groundwater assessments and the priority need for establishing basic sustainable yields, monitoring of abstraction, and the development of basic governance structures to support these resources.

The workshop provided training on groundwater monitoring and assessment techniques, reviewed the state of groundwater resources and monitoring in the Pacific SIDS and identified needs to further improve groundwater monitoring for sustainable groundwater management.

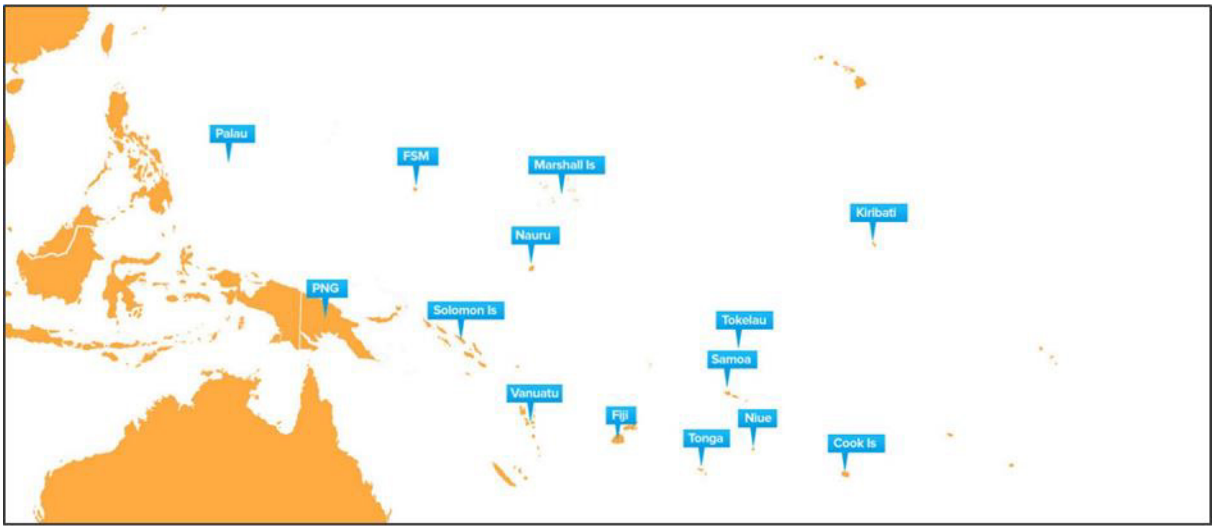


Figure 1 Map of Pacific SIDS

3. Workshop report

The workshop was officially opened by Paul Bayly, Permanent Secretary of the Ministry of Infrastructure and Transport, Fiji and Ravind Kumar, senior scientific officer at Fiji Meteorological Service. The first day covered various topics on sustainable groundwater development in SIDS and the importance of groundwater monitoring. SIDS representatives gave presentations on the current state of groundwater resources and monitoring in their respective islands states. This report covers the outcomes of the interactive sessions and gives an overview of the country presentations and describes the activities during the field visit.

Outcomes of the interactive session on "Groundwater vulnerability to future climates"

Peter Sinclair (SPC) gave a presentation on "groundwater vulnerability to future climates in pacific islands". Participants were then asked to identify threats, risks and vulnerabilities in their countries and possible proactive measures. Table 1 provides an overview of this interactive session.

- **Threat** – generally beyond people's control (e.g. cyclones, droughts, sea level rise).
- **Risk** – can be managed to either lower the vulnerability or the overall impact.
- **Vulnerability**– can be reduced by identifying weaknesses and by putting in place proactive measures (e.g. increased storage). The combination of potential impact and system adaptability provide an indication of the vulnerability.

Table 1 Main threats, risks, vulnerabilities and proactive measures identified by workshop participants

Island	***Threats***	***Risks***	***Vulnerability***	***Proactive measures***
Cook Islands	Droughts Cyclones King tides	Overtopping Coast erosion		Awareness programme Warning alerts Implementation of drought response plan
Fiji	Droughts	Over pumping		Formulate groundwater policy
Kiribati (Bonriki water reserves)	Droughts Storm surges Sea level rise	Over pumping Contamination Population growth		Monitoring & Assessment Sea wall protection of mangroves Population control Drought management plan Enforcement of laws
Samoa	Sea level rise	Increase in salinity	Lack of institutional structure	Establish spring protection zones Develop alternative water supply Public awareness: Engaging community
Tonga	Cyclones	Water shortage	Lack of Infrastructure	Increase rainwater harvesting systems
Tuvalu	Droughts Cyclones	Population growth	Limited space and storage capacity	Increase rainwater harvesting systems Disaster risk reduction
Vanuatu	Sea level rise	Population growth	Low carbonates islands	Establish water protection zones

The second part of this interactive session consisted of identifying main issues related to monitoring, data collection, data management, data analysis and dissemination. Table 2 provides an overview of the issues reported during this session. Most states identified common problems such as accessibility of monitoring sites in outer islands resulting in data monitoring gaps. Regarding data collection, management and analysis, the main issues include lack of capacity and insufficient or not functional equipment. Most states also perceived that besides monitoring and data collection, a lot more could be gained in terms of analysis and dissemination of the data. There are only few examples where data is used for the development of knowledge products which could be used by policy makers (Figure 7 andFigure 8).

Table 2 Problems associated with monitoring and data collection/management

COUNTRY	MAIN PROBLEMS	PARAMETERS MONITORED?	DATA COLLECTION	DATA MANAGEMENT	ANALYSIS	DISSEMINATION
COOK ISLANDS	- Accessibility of sites (monitoring in outer islands) - Need for capacity building on data management and analysis	- Water level - Salinity (EC)	- Data monitored for 2 years,		- Integration of surface water, climate and groundwater data	
FIJI	- Frequency of monitoring - Data gaps - Skills of technical staff	- Groundwater level, - Salinity (EC) Not monitored: water abstraction	- Lack of equipment (divers, flowmeters) - Problems with instruments - Issues around station placement	- Data processing and quality control	- Interpretation of ground-water data - The TIDEDA software is not working properly	Lack of regulations to monitor ground-water use, Currently developing a groundwater management plan Data is required for flood forecasting
KIRIBATI	- Lack of qualified people to receive the information - Ensure that skills are maintained and knowledge retention in country	- Water level - Salinity			- Issues with data analysis, mainly when it comes to in country knowledge retention	GW monitoring data used for drought response action plan
NIUE	- No analysis, or use of data - Lack of qualified people	- groundwater level, salinity (EC), pH, temperature - Monitoring every month.	- Lack of (qualified) personnel - Lack of equipment - Lack of maintenance	- Use of excel	- Lack of personnel	No dissemination, once the data is collected it is just stored in excel files
PAPA NEW GUINEA	- Some equipment is not robust and tropical resistant,	-	- Problem with land access due to property of land	-	-	
SAMOA	- Data management problems due to not functional software	- Groundwater level, salinity (EC), temperature,	- Internet connection problem and software	- Use Aqua 5 is software that is not well calibrated: problem could be technical and/or not enough training	-	
SOLOMON ISLANDS	- Problem with authority to access sites - no regulation and legislation to monitor	GW Level, EC, Temp	Data for 2 years	TIDEDA, MS Excel, MS Access	Monitor water quality for pumping of production wells	Data given upon request but data needs to be analysed and given as products
VANUATU		- Monitor weekly, only groundwater levels	- Most of above mentioned problems	- Issues with data entry (lack of personnel)		

4. Current monitoring and assessment practices in Pacific SIDS

4.1. Cook Islands

Figure 2 Groundwater monitoring wells in the Muri/Avana catchment, Rarotonga, Cook Islands (MOIP)

The Cook Islands are a Polynesian island group comprising of 15 widely dispersed islands. The climate in Cook Islands is tropical, heavily influenced by trade winds and with two distinct seasons: the dry from April to November and the wet from December to March. In the Southern Group, which includes the main island of Rarotonga, the main source of potable water supply is surface water (springs and streams). The Northern Group, which consists of coral atolls, relies on rainwater and groundwater. Groundwater has been identified as a potential supplementary water supply but there is need for further investigations and the establishment of monitoring plans. Water resources are generally adequate during normal years but can face significant stress during dry years.

Groundwater monitoring and data management

The responsibility for water management including regulation falls under the auspices of the Ministry of Infrastructure and Planning (MOIP), but other agencies also have a key interest including the Environment Service, Cook Islands Investment Corporation, Ministry and Finance and Economic Management, and Ministry of Health. The Water Works Division within MOIP is responsible for the operation and maintenance of the water supply system on Rarotonga.

In the Northern Island group, a number of monitoring boreholes were installed between 2005 and 2007 (MOIP, 2012). Four boreholes were installed in Penrhyn, six in Manihiki, two in Rakahanga and five in Pukapuka. Private wells are largely present in these islands. Seven monitoring boreholes also exist on Aitutaki Island of the Southern group (Figure 3). In 2010, the Ministry of Infrastructure and Planning installed ten shallow monitoring wells in the Muri catchment area in Rarotonga with plans to monitor groundwater levels and quality (Figure 2, NIWA, 2010).

Challenges

Contamination of groundwater due to septic tank leakage, poor sewage treatment mechanisms and agricultural practices have been identified as the main sources of groundwater pollution in Rarotonga and possibly other islands.

Poor interagency coordination hinders the management of water quality and quantity monitoring.

Capacity building is needed to train the staff of the Water Works Division of MOIP in terms of fieldwork and data analysis. Staff needs to be trained to be able to adequately estimate groundwater recharge and sustainable withdrawals. This requires knowledge on how to assess a number of parameters such as water demand, water network losses and groundwater availability.

Successful implementation of a groundwater monitoring programme is highly dependent on the availability of trained individuals. Hence, suitable training and knowledge transfer must be provided to the designated groundwater team.

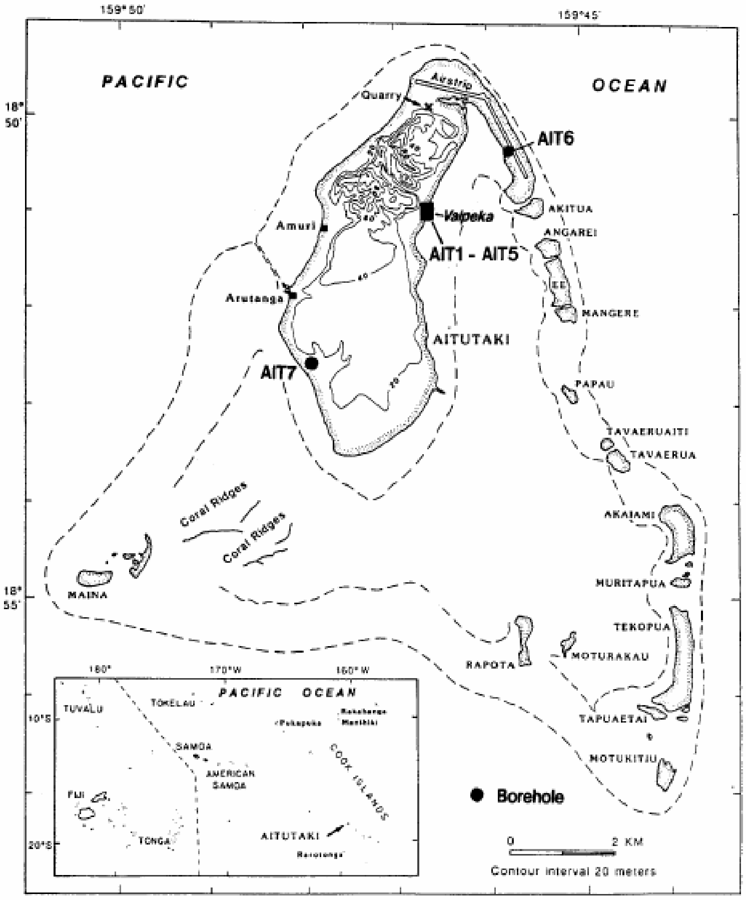


Figure 3 Map of Aitutaki showing Vaipeka area and locations of the seven monitoring boreholes, AIT1-AIT5 (modified from Hein et al, 1998).

4.2. Fiji

Fiji is an archipelago of more than 330 islands, of which 110 are permanently inhabited, and more than 500 islets, amounting to a total land area of about 18,300 square kilometres. The climate in Fiji is tropical marine and warm year round with minimal extremes.

Groundwater monitoring and data management

Groundwater investigation in Fiji started in late 1960 in response to request from villages for sources of water. First drilling for groundwater boreholes was conducted in 1971 – 1973 at Nadi. From 1978 – 1980 through British technical cooperation the development of the Nadi – Lautoka water supply was carried out.

The Hydrogeology Unit of the Mineral Resources Department (MRD) is responsible for the groundwater resources of the nation; including its monitoring and protection from abuse and contamination. It thereby plays a critical role in the development of the nation’s economy. The Unit is finally responsible for providing an alternative water supply to all Fiji, especially to the disadvantaged communities living in remote areas. In total there are more than 800 boreholes archived at MRD, and 20 – 30 strategic sites are regularly monitored.

A Hydrometric survey is carried out on a monthly basis on selected boreholes to monitor fluctuations of groundwater levels associated with aquifer recharge through rainfall, evaporation rates, geology and vegetation types. Monitoring of groundwater levels is mainly carried out in areas where groundwater is used for public water supplies and areas prone to depletion due to over-pumping or contamination from underlying poor-quality water.

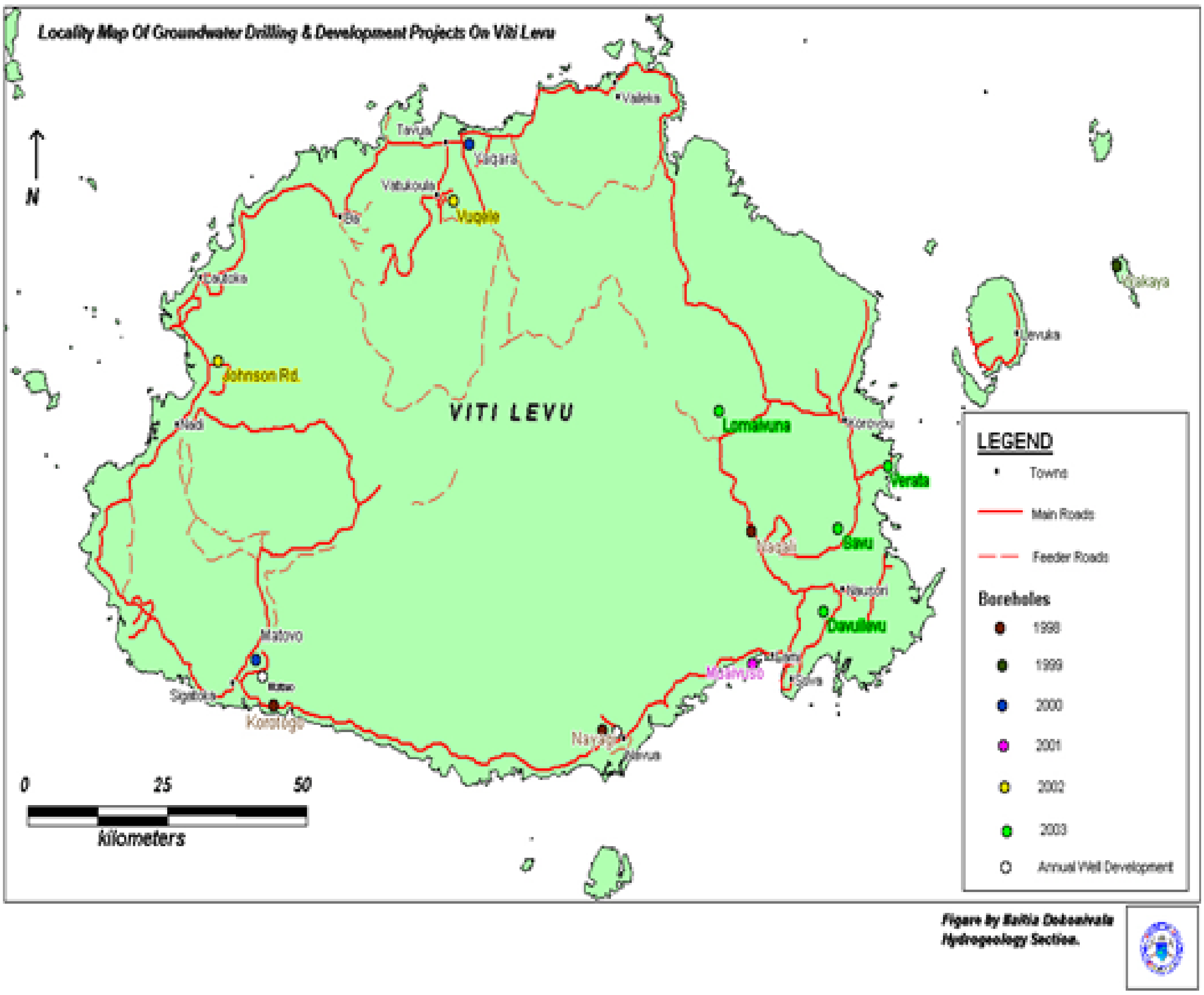


Figure 4 Groundwater monitoring sites in Viti Levu, Fiji

The government has a mandate to monitor and manage the water resources of Fiji sustainably. Monitoring data is used for the development of the “Draft Groundwater Resources Exploitation Policy” and “National Water Resources and Sanitation Policy” and hydrogeological reports. A groundwater monitoring report is developed every 5 years to consolidate all groundwater data and integrate groundwater and surface water data into a basin catchment analysis.

Groundwater data are stored in a database that consists of packages to store water levels, electrical conductivity, temperate, water quality parameters (Cations & Anions). GIS software is used to assist in data analysis.

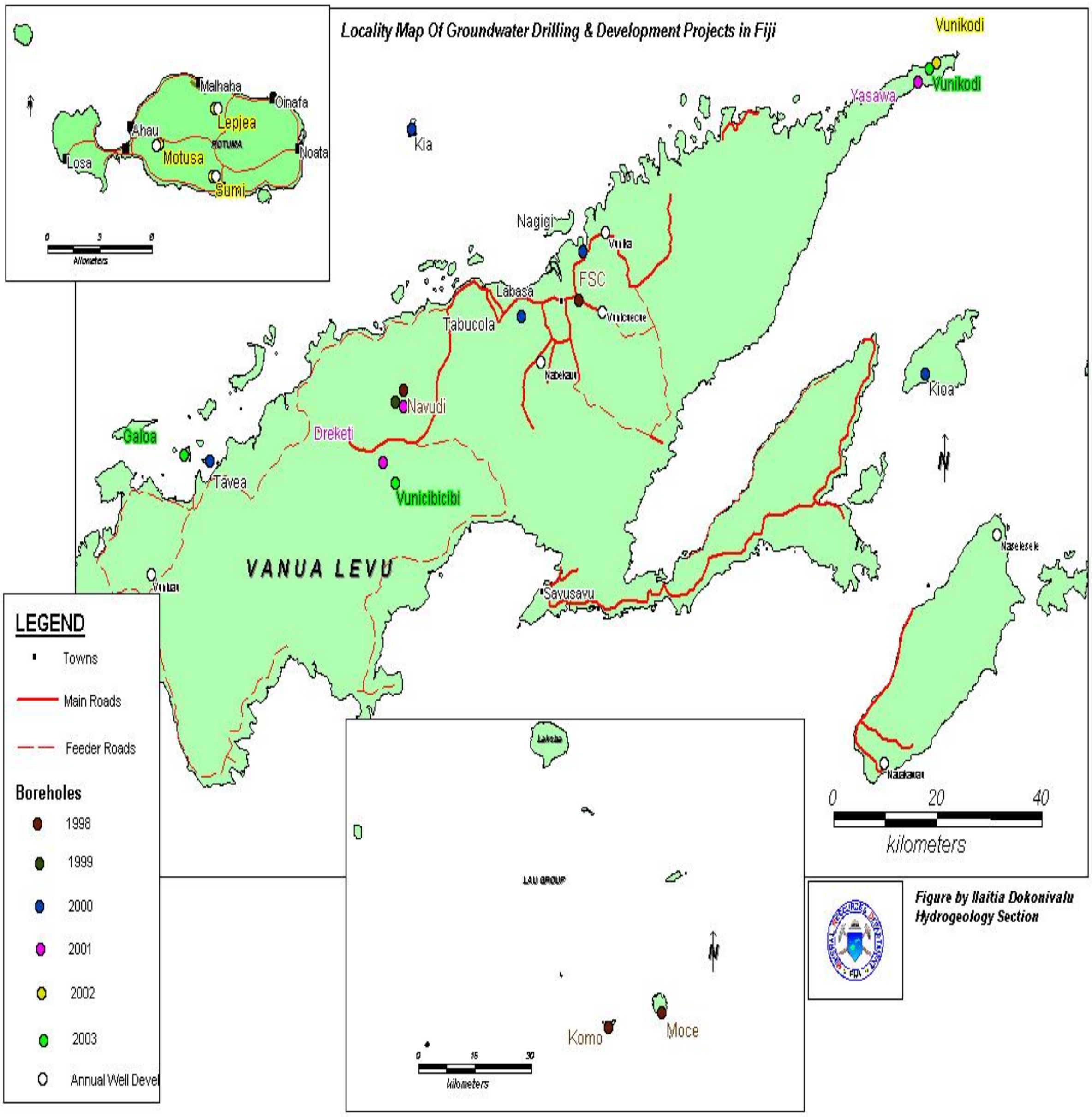


Figure 5 Groundwater monitoring sites in Vanua Levu, Fiji

Challenges

In Fiji there is currently no control of well drilling in the private sector. The government does not have any records on the private drilling companies and no permits for groundwater exploration exist. Ownership of groundwater remains doubtful as the law is unclear. As a consequence, conflicts arise between local bottled water companies.

Regular groundwater monitoring is hindered by difficult access to outer islands and occasional extreme weather events. Lack of equipment able to monitor online (e.g. divers) is also limiting the collection of data. Ideally, telemetric monitoring systems would be implemented in Fiji. Moreover, due to the limited data analysis & interpretation skills, the presence of groundwater modelling specialists would be very supportive in adequately assessing the baseline conditions of the resource. Finally, the use of an integrated online database within the Ministry of Land and Mineral Resources would solve issues related to overlapping responsibilities.

4.3. Kiribati

Kiribati consists of 33 atolls clustered in 3 island groups, the Line, Phoenix, and Kiribati groups. Kiribati islands heavily rely on groundwater. They have a total land area of 800 square kilometres and are dispersed over 3.5 million square kilometres. Most of these islands are in the dry belt of the equatorial oceanic climatic zone and experience prolonged droughts.

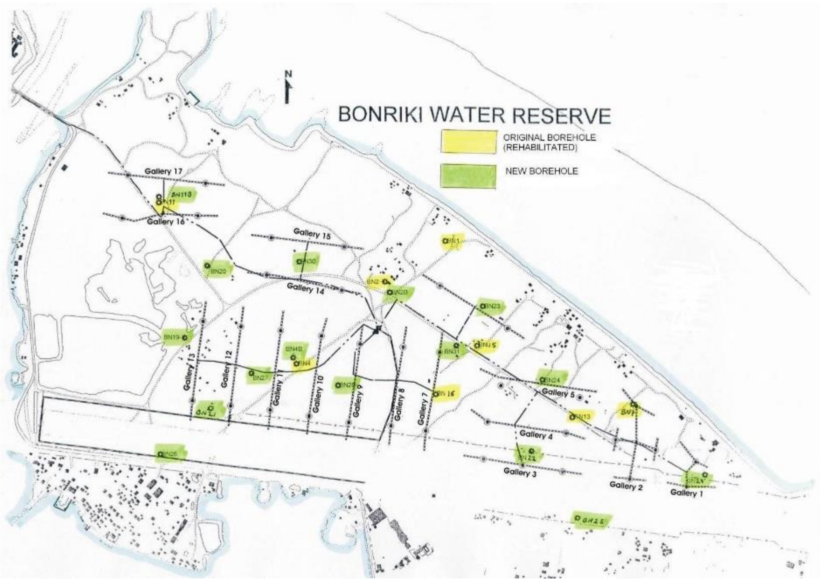


Figure 6 Bonriki water reserve, South Tarawa, Kiribati

Groundwater monitoring and data management

In Kiribati, the Water Engineering Unit of the Ministry of Public Works and Utilities (MPWU) is responsible for monitoring the salinity while the Environmental Health Unit of the Ministry of Health and Medical Services is the water quality monitoring authority. In addition there is also a National Water Quality Monitoring Committee, established in 2011, comprised of local councils and a number of ministries.

Two major water reserves are present on the main island of Tarawa, the Bonriki (Figure 6) and the Buota. These reserves supply the capital South Tarawa. Groundwater monitoring data from 21 boreholes in Bonriki dates back to 1980. On Christmas Island (Kiritimati), two water reserves (Decca Lens and Four Wells) are also monitored by means of 28 monitoring boreholes. In the outer islands of the Kiribati group, salinity measurements are taken on a monthly basis from open wells (up to 20 monitoring wells per island).

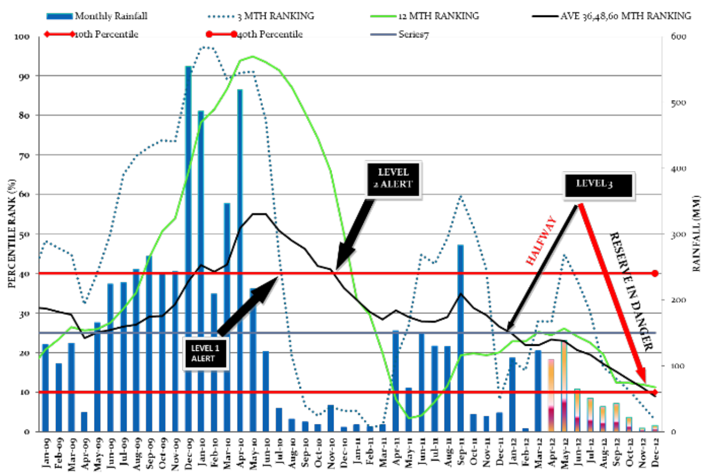


Figure 7 Example of product from the South Tarawa drought plan showing different drought alerts based on rainfall data

Water technicians are present in all 17 islands of the Kiribati group as well as in 2 islands (Teraina and Tabuaeran) of the Line group. These technicians collect groundwater salinity data and report them back to MPWU, Water and Sanitation Unit. In the Water Engineering Unit of MPWU, most of the staff are trained to use conventional EC meters and there is even some limited capacity (1-2 persons) familiar with geophysical equipment (EM 34) and borehole data analysis.

Challenges

- Groundwater in Kiribati is very vulnerable to contamination. In Bonriki, South Tarawa, there are on-going problems with people living on areas which have been designated as water reserves. This is directly linked to land ownership issues that exist in Kiribati.
- There is no comprehensive groundwater monitoring databases but various parts that need to be consolidated.
- Some of the monitoring boreholes in Bonriki are blocked and this prevents recording reliable readings
- Monitoring methods are time-consuming and tedious processes. In Bonriki it can take up to one week to cover the entire borehole network
- Water technicians in the outer islands have problems when equipment (EC meters) is damaged due to accessibility.
- It is difficult to retain skills acquired during projects and to adopt the recommendations for changes to the South Tarawa Drought Plan. These recommendations involve performing accurate assessments of pumping rates and volumes and improve the analysis of borehole data. Having in-house training in terms of borehole data analysis would help the Ministry staff obtaining the necessary skills to improve the drought plans.

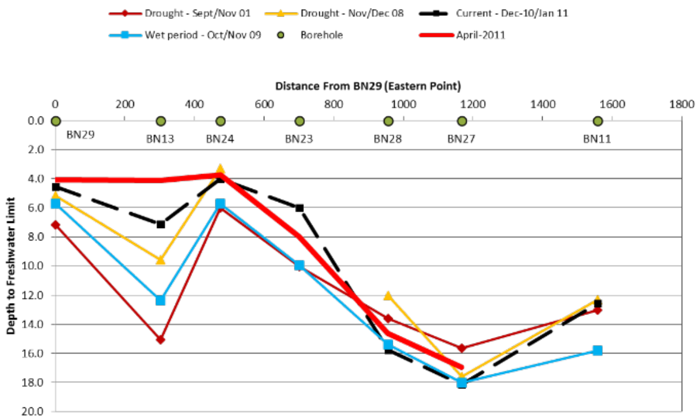


Figure 8 Data from public water reserve boreholes (Bonriki) showing the thickness of fresh groundwater supply

4.4. New Caledonia

New Caledonia is located in the southwest Pacific Ocean and has a land area of 18,576 km^2. The archipelago, part of the Melanesia subregion, includes the main island of Grande Terre, the Loyalty Islands, the Chesterfield Islands, the Belep archipelago, the Isle of Pines, and a few remote islets. The climate is tropical, with a hot and humid season from November to March with temperatures between 27 °C and 30 °C, and a cooler, dry season from June to August with temperatures between 20 °C and 23 °C. The tropical climate is strongly moderated by the oceanic influence and the trade winds that attenuate humidity, which can be close to 80%.

Groundwater monitoring and data management

In New Caledonia, the Water Resources Department (DAVAR) is responsible for monitoring the quality of groundwater resources and intervening upon emergencies. The department is also responsible for defining and monitoring water protection areas (Government Decree).

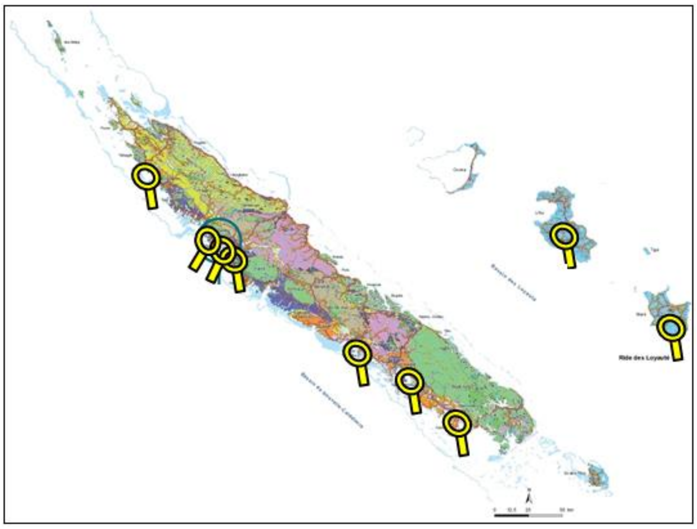


Figure 9 Main aquifers monitored in New Caledonia

Seven large alluvial aquifers have been identified in the main island of New Caledonia and 2 karst aquifers in the outer islands of Lifou and Maré (Figure 9 and Figure 10). 220 monitoring boreholes are present on the big island which are monitored twice per year (dry/rainy season) for electrical conductivity, temperature and water level. In addition, there are 20 groundwater level monitoring stations equipped with loggers. The groundwater database is maintained since 2006. The Water Resources Department additionally performs 1-2 exploratory drillings per year. Additional groundwater monitoring is performed by the mining companies and the data is soon expected to be supplied to the Water Authority.

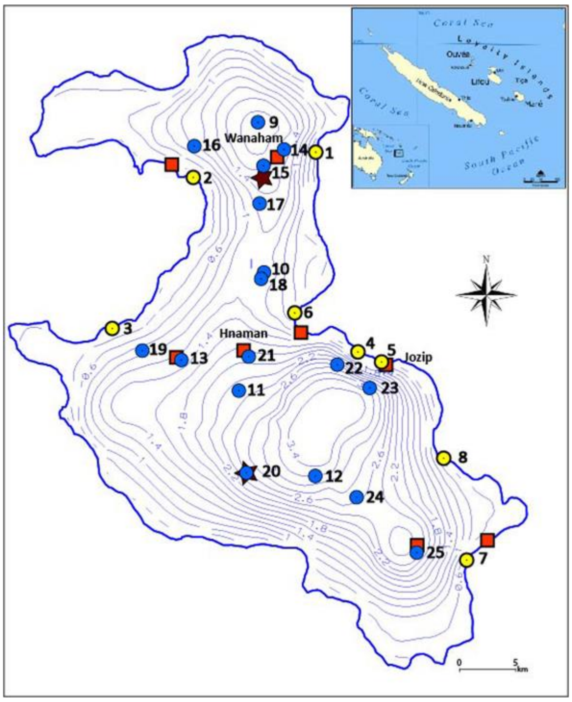


Figure 10 Hydraulic map of Lifou, Loyalty Islands. Symbols: black stars = piezometers, red squares = rain gauges, blue dots = water wells, yellow dots = coastal fresh water seeps. (after Nicolini et al., 2016)

Challenges

Main problems encountered in New Caledonia are related to groundwater quality and salt water intrusion. There are a number of on-going projects studying the impacts of mining developments on groundwater resources. It is difficult to obtain water use data from the mining industry as the industry partly uses desalinated water and partly groundwater from their own wells. In other cases (e.g. the steel industry) seawater is used for cooling purposes. A bill is currently being drafted to legally oblige the mining industry to communicate data on water consumption and abstraction from their own wells.

4.5. Niue

Niue is a 269 km^2 raised coral atoll in the southern Pacific Ocean, east of Tonga. The island consists of an upper terrace of 200 km^2 and a lower terrace. There are three outlying coral reefs. The total population consist of 1,625 people (Niue 2006 Census) with an ethnic composition of Niuean, Samoan, Tongan, Fijian, Tuvaluan and transient population of New Zealanders, Australians and tourists. The annual average temperature on Niue is around 24°C. The annual mean rainfall is ~2050 mm. Niue's climate is affected by the movement of the

South Pacific Convergence Zone and also influenced by sub-tropical high pressure systems and the trade winds, which blow mainly from the south-east.

Groundwater monitoring and data management

Niue's water supply is managed by Niue's Water Division, which comes under the Public Works Department. The main source of water supply is groundwater which is pumped from the freshwater lens just below the island's upper terrace. Groundwater is pumped through boreholes and reticulated through the island's water system to each of the fourteen villages (Figure 11). Small rainwater catchment tanks also exist and supplement the bore water supply on the island. The Department of Health has been monitoring and testing the water and the results in 2010 suggested that the lens has been free of any microbiological contamination (Siohane and Chapman 2009). It is thus deemed safe and is pumped directly to consumers without any form of treatment (WHO Pacific 2008).

Challenges

As the freshwater lens is fed by rainfall and considering the high porosity of the coral rock, the potential for contaminants to enter the groundwater system is generally high. The existence of very rapid recharge mechanisms as demonstrated by the immediate ground water response to the 12-13 February 2006 tropical storm, confirms the vulnerability of the groundwater lens to land use activities (SOPAC, 2007). Groundwater is vulnerable to surface contamination deriving from landfills, the application of agrochemicals and fertilisers, and the disposal of solid waste.

Figure 11 Borehole locations in Niue (after SOPAC, 2010)

Niue has limited human resources trainings and improved skills would be very useful for Niue Water Management. The average age of personnel is quite high, there is a need for new recruitments. Another challenges are the national Budget Restrictions. Niue is heavily dependent on financial Aid for development from overseas donors. Niue would ideally introduce modern technology for Water Sampling. Better monitoring of water quality, water demand and pumping rates.

4.6. Papua New Guinea

Papua New Guinea is an Oceanian country that occupies the eastern half of the island of New Guinea and its offshore islands in Melanesia, a region of the southwestern Pacific Ocean north of Australia. The country consists of several large high volcanic islands and numerous high volcanic and coral atolls.

Groundwater monitoring and data management

Groundwater is considered to be the safest and most reliable source for water consumption. In PNG, the Mineral Resources Authority deals with the assessment of (ground)water resources and with research and coordination activities.

In many parts of PNG and especially in the outer islands and in coastal communities of the mainland, groundwater is the only reliable source of water. It is the least contaminated source and when chlorinated, it does not need costly chemical treatment. Moreover, it can be extracted close to the users and requires only few construction materials.

Groundwater monitoring is not an essential activity in PNG as there is more than adequate surface water supply, particularly in the larger islands. There are many self-made, NGO-sponsored and development partner-funded open dug wells (and boreholes) but these are not coordinated by any responsible authority and therefore monitoring is non-existent. A number of large resource developers (mining companies) have only installed groundwater monitoring wells around project sites in order to monitor environmental impacts of their projects. The common parameters which are measured are dissolved oxygen, pH, temperature and electrical conductivity. Analysis of groundwater samples is performed by the respective developers and by CEPA approved laboratories.

Currently, the PNG Water Sanitation and Hygiene Policy is being developed to promote healthy water supplies for the rural and remote communities. All sectors are currently in the process of drafting a Bill to create an authority that will look after the affairs of rural water supply and sanitation. The Bill will be submitted by 2017 to the Cabinet for approval. Groundwater issues are expected to be addressed through this Policy and Bill.

4.7. Samoa

Samoa consists of two main islands, Upolu and Savaii as well as several smaller islands. The climate is equatorial/monsoonal, with an average annual temperature of 26.5 °C and a rainy season from November to April. Water supply in northern, eastern and southern Upolu and eastern Savaii is from surface water intakes, whereas that for western Upolu and rest of Savaii is from groundwater.

Groundwater monitoring and data management

10 monitoring boreholes are present in Upolu and 4 in Savaii (Figure 12). These boreholes are regularly monitored for electrical conductivity and temperature. Groundwater samples for bacteria can also be collected upon request but the analysis is not performed by the Ministry of Natural Resources and Environment. A groundwater database is available at the Ministry. Water consumption in Apia has been controlled through the introduction of metering.

Challenges

Water shortages are reported during the dry season, especially during extended dry periods associated with the ENSO, in the Apia area on Upolu (served by surface water intakes) and in the Falealupo Peninsula on Savaii where groundwater is often brackish saline and the population relies upon rainwater harvesting (GWP/SOPAC, 2007).

Dissemination of data is usually complicated due to the requirement of preparing simple products which can be understood by other stakeholders. These stakeholders prefer visual information such as maps of spatial distribution as opposed to graphs and diagrams. The Ministry is recently trying to shift towards this type of information products.

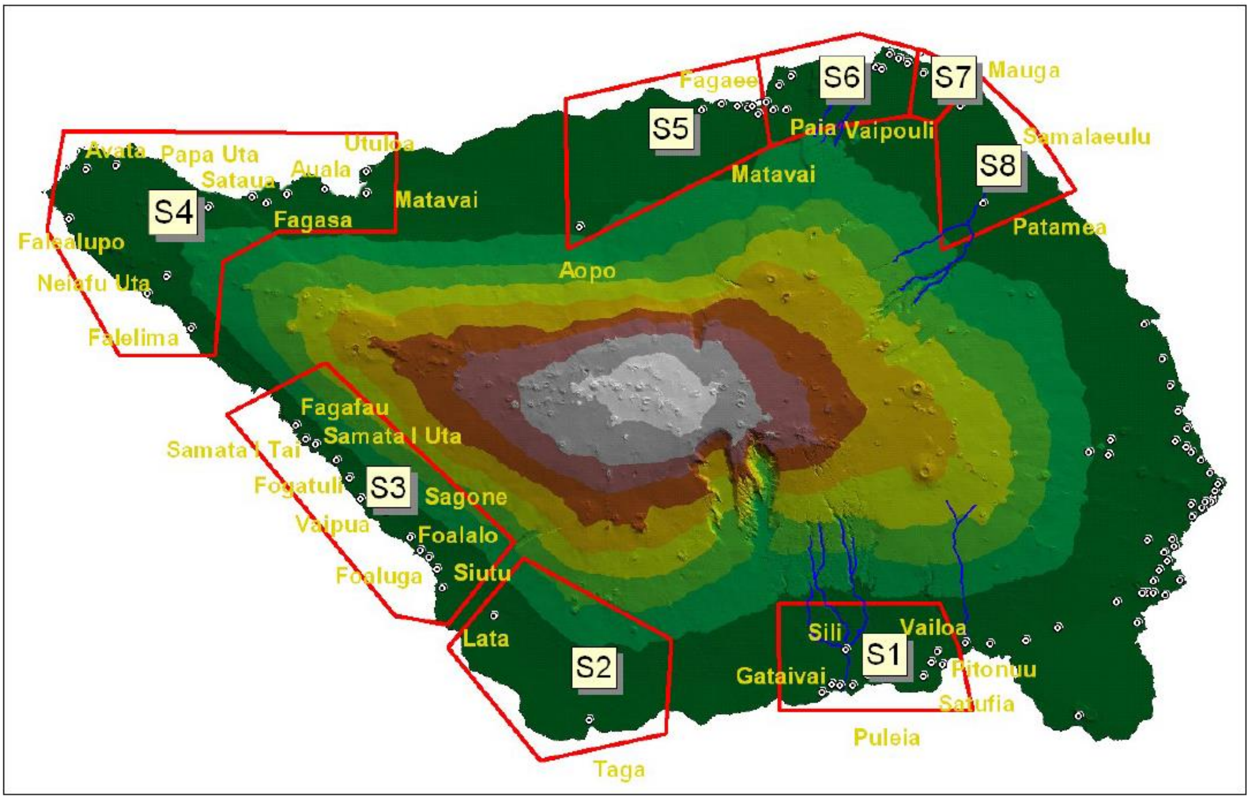


Figure 12 Map of Savaii showing topography, streams, borehole locations and water supply zones (after SOPAC, 2007)

4.8. Solomon Islands

Solomon Islands is a sovereign country consisting of six major islands and over 900 smaller islands in Oceania. The country lies to the east of Papua New Guinea and northwest of Vanuatu and covers a land area of 28,400 square kilometres. The islands' ocean-equatorial climate is extremely humid throughout the year, with a mean temperature of 26.5 °C and few extremes of temperature or weather.

Groundwater monitoring and data management

In the Solomon Islands there are three different ministries taking care of water regulation aspects. The Solomon Islands Environment Act 1998 mandates that pollution of the environment must be prevented and minimized. The Act regulates permit to discharge treated wastewater to the environment (Ministry of Environment, Climate Change, Disaster Management and Meteorology). The River Waters Act 1969 for surface waters only regulates extraction from rivers through a permit (Water Resource Division). The Environmental Health Act 1996 regulates activities to prevent pollution of water systems from resident and commercial activities (Ministry of Health & Medical Services). However, there are no clear mandates under these Acts to collect groundwater data. Furthermore, groundwater extraction is not regulated.

Groundwater monitoring is currently needs-driven and limited to locations where logistics and issues are anticipated. Efforts are currently planned to expand groundwater monitoring to more locations in the Solomon Islands. Parameters measured are water levels, temperature and electrical conductivity (Figure 13). These parameters are measured at a fixed depth (~20 m) by automatic sensors (CT2X) that record data every hour. These data are downloaded quarterly and archived.

As the fixed depth where the sensor is placed does not always match the depth of the well screen, measurements might not be representative of the aquifer due to stagnant water (inadequate recycling of water) at shallower depth in the borehole. It was suggested to have the instrument fixed at the same depth as the screen because that is where the formation water is coming through. The sensor would then monitor variations in salinity more accurately.

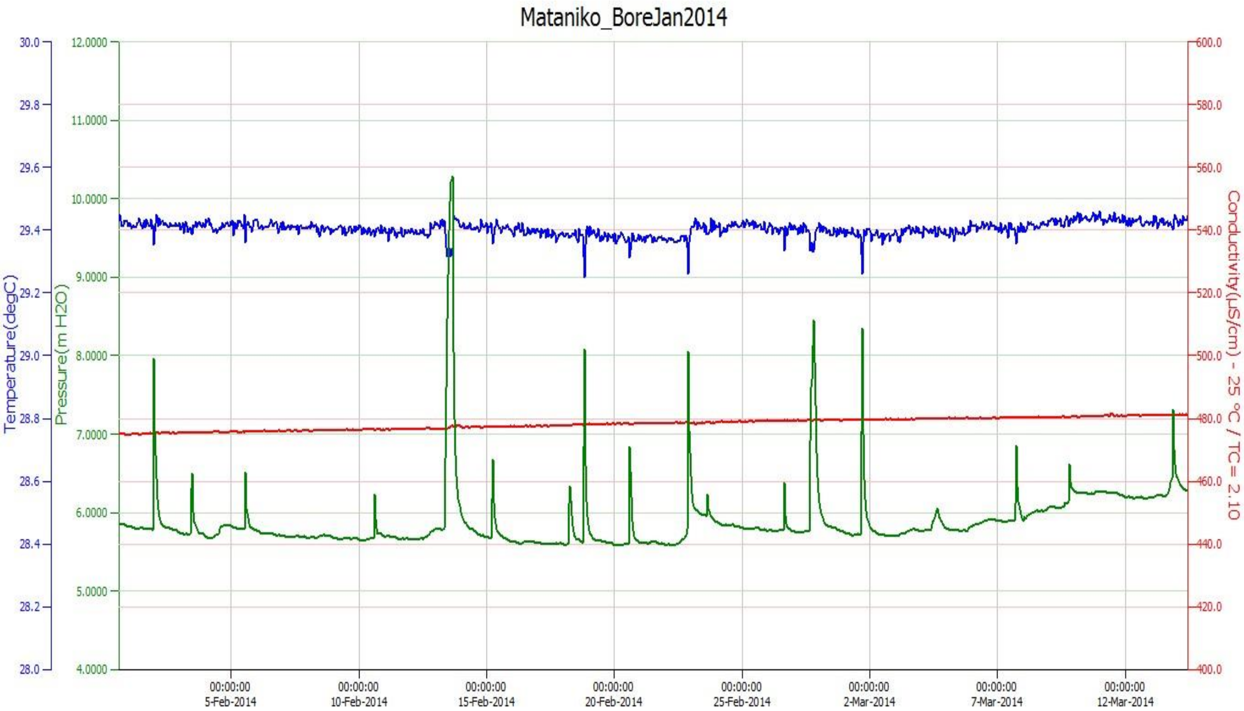


Figure 13 Mataniko field data, Solomon Islands. Spikes in the water level data indicate when the pumps are turned off and on again depending on the automatic pumping sensors

Challenges

Groundwater data in the Solomon Islands are needed to monitor mining activities, groundwater pumping, and seawater intrusion. Mining activities can result in groundwater contamination in the form of heavy metals (e.g. arsenic, cyanide). Production boreholes which are drilled within residential areas can face contamination threats from septic systems. Coastal aquifers can face salinity problems due to storm surges and sea level rise. For all these reasons, parameters such as heavy metals, coliform bacteria, total dissolved solids and chloride should be regularly monitored.

Groundwater challenges identified for the Solomon Islands

- The groundwater data is not analyzed for information dissemination yet
- Legislations and policies need to be formulated in order to drive groundwater monitoring
- Groundwater monitoring equipment is expensive, besides logistics involved in monitoring activities (e.g. accessibility to outer islands). Telemetry is an option to reduce travel costs.
- Monitoring needs to be planned properly to fully address the relevant threats and issues and to collect the right data
- Sea level rise, residential development and mining have been identified as the future threats to groundwater quality

4.9. Tonga

Tonga is a Polynesian sovereign state and archipelago comprising 169 islands of which 36 are inhabited. The climate of Tonga is semi-tropical. Tonga lies within the south-east trade wind zone of the South Pacific and its climate is dominated by south-easterly trade winds.

Groundwater monitoring and data management

The Geology Unit of the Natural Resources Department (Ministry of Lands, Survey and Natural Resources) has the responsibility for monitoring the quality and quantity of Tonga's groundwater resources. This involves the periodical monitoring of groundwater levels and groundwater quality (salinity and contaminants) at selected wells. In the main island, Tongatapu, there are 85 village water supply wells which are monitored and maintained quarterly, 39 urban (public) water supply wells which are monitored bi-annually and 16 salinity monitoring boreholes which are monitored on a monthly basis (Figure 14).

A difference from other countries is that villages in Tonga have their own water committee that manages their own water supply, while the Geology Unit of the MLSNR is only responsible for monitoring the water quality and quantity (Figure 15). If requested, groundwater samples can be analysed for additional parameters such as pH, temperature, dissolved oxygen, turbidity, bacteria, ammonia, phosphate and total nitrogen/nitrate.

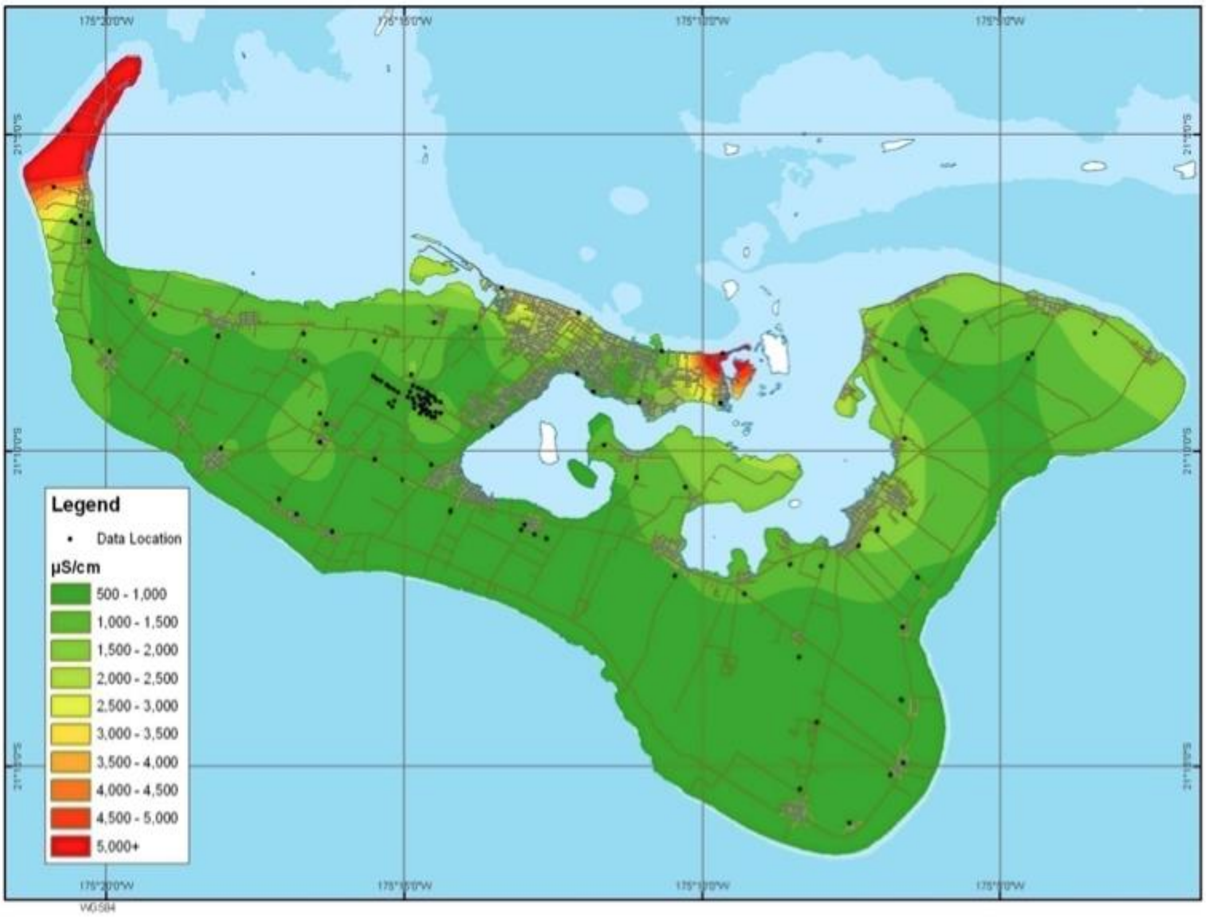


Figure 14 Spatial distribution of Electrical Conductivity in Tongatapu, Tonga

The main roles of the Geology Unit are:

- Organizing quarterly and monthly water quality monitoring field trips
- Undertaking field work and site visits for investigative and monitoring purposes including calibrating equipment
- Undertaking environmental impact assessments of groundwater abstraction and management activities
- Analyzing collected information to assess and predict the impact of activities such as landfills, construction developments, mining or agriculture on groundwater quality and resource availability
- Writing reports for clients, which can be understood by people who don't necessarily have a technical background
- Answering technical queries and providing advice to clients and the public in writing
- Responding in a timely manner to immediate water quality issues, emergencies, and pressures that may change from day to day

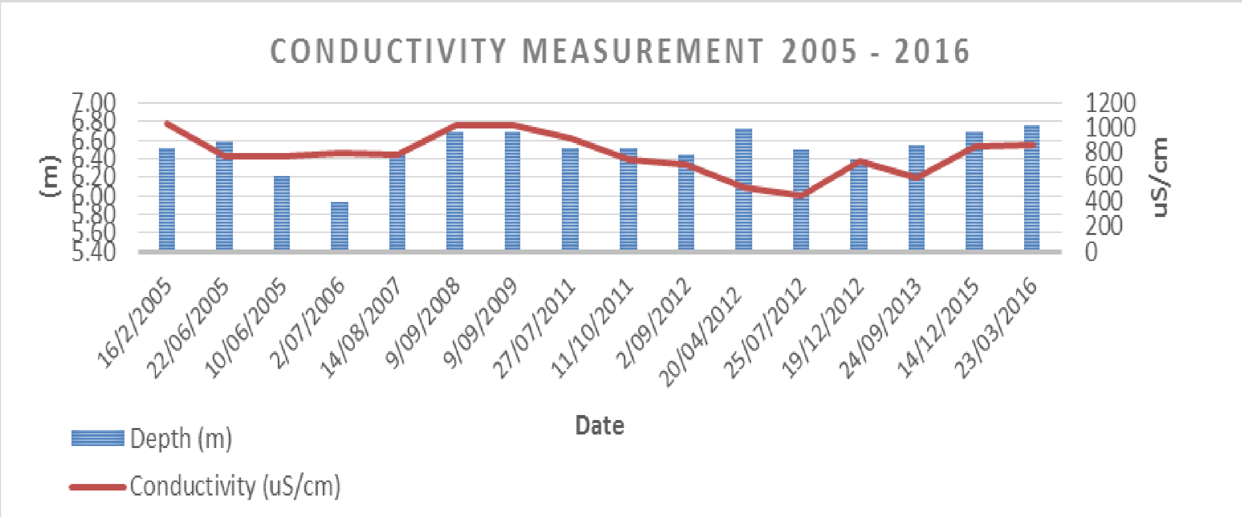


Figure 15 In the monitoring period between February 2005 and March 16, the electrical conductivity ranged between 456 and 1017 µS/cm. This is indicative of sustainable extraction by the Folaha Village Water Committee during that period.

Water Bills have been passed as a Regulation and are currently under discussion in the parliament for approval as a law. Nowadays if villages decide to drill a new well they just do it by themselves.

Challenges

Impacts of human activities encountered in Tonga include

- Saline intrusion due to over-pumping
- Chemical pollution from:
  - hydrocarbon leaks & spills
  - solid waste disposal sites
  - agricultural chemicals, particularly insecticides and herbicides
  - industrial discharges
- Biological pollution from:
  - inappropriate or poorly maintained sanitation systems
  - solid waste disposal sites
- Erosion and Sedimentation due to land clearing

Water resources in rural areas and all outer islands need to be assessed and monitored along with their performance under current stresses (e.g. droughts, groundwater pumping) and possible additional stresses caused by climate change scenarios. Proper management of the existing water resources is essentially needed in order to adapt to climate variability. Lack of funds is a challenge that obstructs the capacity to carry out complete assessment and monitoring activities. Solid and liquid waste disposal practices should be regulated to prevent contamination of the water supply.

4.10. Tuvalu

Tuvalu is a Polynesian island nation comprising of three reef islands and six true atolls. Funafuti is the largest atoll and capital of the country. Tuvalu has a population of 10,640 (2012 census) and a total land area of 26 square kilometres. Tuvalu experiences two distinct seasons, a wet season from November to April and a dry season from May to October. Westerly gales and heavy rain predominate from October to March with tropical temperatures moderated by easterly winds from April to November.

Groundwater monitoring and data management

The primary water resource in Tuvalu is rainwater harvested and banked at individual households. As a supplementary resource, desalinated water (from RO plants) is used. Groundwater is only meant for secondary usage such as lavatory cleaning and bathing, mainly during dry spells. In Vaitupu Island, groundwater is used for drinking water purposes.

In a number of islands (Nukufetau, Niutao, Vaitupu, Nanumea, Nanumaga) solar powered pumps were installed to pump groundwater and store it in overhead cisterns which are open for public use. However these pumps recently failed due to mechanical issues.

Challenges

The groundwater in Tuvalu has been recently declared by the Health Department as highly contaminated, mainly in the densely populated areas (especially in Funafuti, Figure 16). This is due to the poor geological soil structure (very coarse), the shallow water table and especially the development and life style changes. Seaweed growing vastly across the lagoon shores in Funafuti were considered as an indication of contamination.

The main sources of contamination are

- Rubbish at borrow pit dump sites
- Waste oil/fuel leakage at dump sites

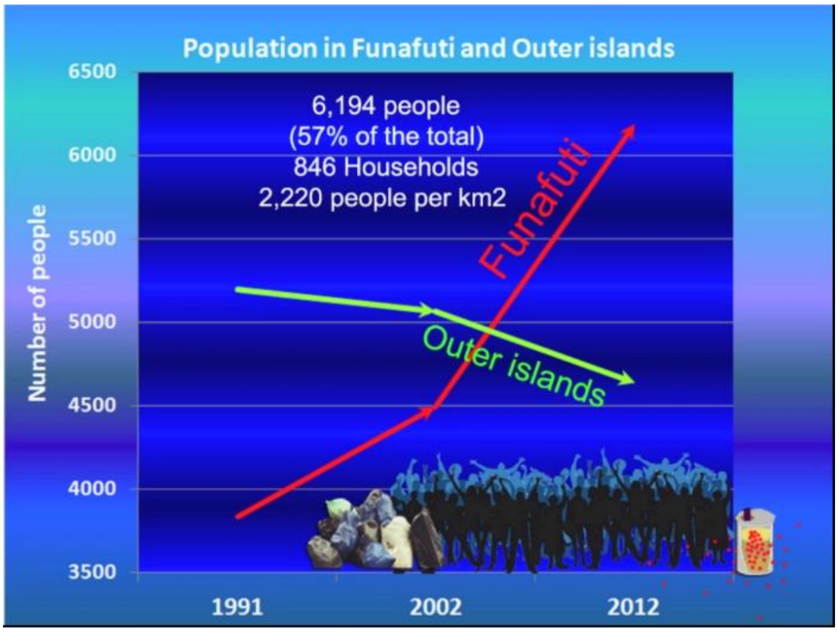


Figure 16 Population change in Funafuti and outer islands, Tuvalu

- Sewage systems associated with the growth of population growth and infrastructure development. Between 70 and 75% of septic systems have not been constructed using proper septic designs.

In terms of development needs, groundwater studies need to be conducted in all islands of Tuvalu in order to acquire a baseline understanding of the availability of groundwater resources (e.g. SPC groundwater study in Vaitupu, 2015).

4.11. Vanuatu

Vanuatu is an archipelago of over 80 islands stretching 1,176 km from north to south in the Melanesian Southwest Pacific. Total land area is 12,281 km^2. The climate is tropical, with about nine months of warm to hot rainy weather and the possibility of cyclones and three to four months of cooler, drier weather characterised by winds from the southeast.

Groundwater monitoring and data management

In Vanuatu, the Department of Geology, Mines and Water Resources under the Ministry of Lands and Natural Resources has the overall responsibility to ensure the sustainable use of the nation's water resources as mandated through the water resources management act and water supply act. The Water Resources Management team is responsible for the monitoring, management and protection of groundwater and surface water resources.

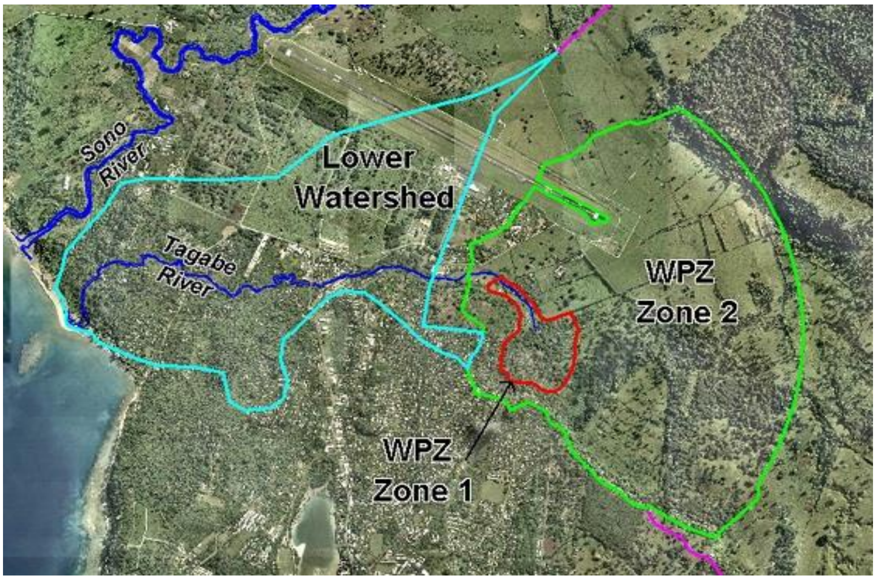


Figure 17 Tagabe catchment areas for Efate Island, Vanuatu

The DGMWR has 4 monitoring locations within the Tagabe catchment area (Figure 17, Port Vila), include 3 monitoring wells, and one production bore.

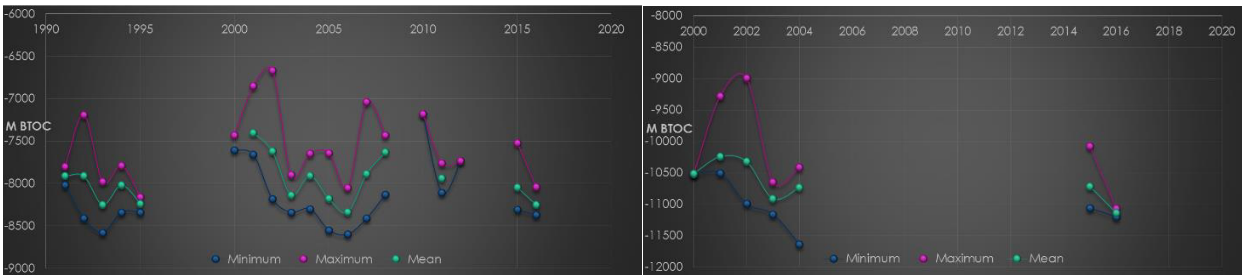
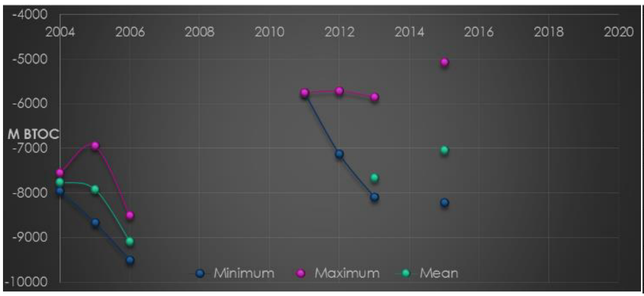


Figure 18 Monitoring well EF286 (left) and BH10 (right)



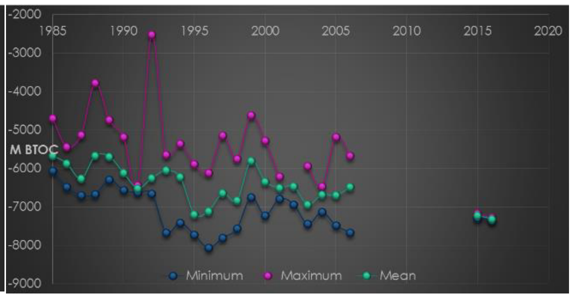


Figure 19 Monitoring well BH11 (left) and S2 (right)

Challenges

Overall, a general declining trend in groundwater levels has been recorded (Figure 18 and Figure 19). A similar trend is being observed in the river flows along that path of the river. Data records are incomplete and time frames monitored at each location are highly variable. In general, there appears to be a cessation in monitoring between 2007 and 2014.

Another limitation is that data are presented as groundwater depths rather than elevations due to absence of surveyed elevation points. The data therefore must be reviewed as spatially isolated rather than in connection.

The following steps are suggested by the DGMWR in order to improve the current dataset:

- Ensuring regular monitoring is conducted in full to prevent data gaps. This includes keeping records of all gauged levels including dry wells;
- Installing replacement wells for those that have gone dry in order to maintain the monitoring network;
- Undertake a survey of the elevations of each monitoring location (to where they are gauged from) to allow spatial comparison between data points; and
- Incorporating data gauged by UNELCO (water supply company in Port Vila) to strengthen the data set and thus its interpretation.

5. Field visit to Nukulau Island

The training course provided a demonstration of various monitoring and assessment techniques targeted for small islands. On the third day all workshop participants joined the field visit to Nukulau Island, a small island (width ~ 500m) near the coast of Suva. During the field visit, participants were trained on how to collect data and samples from piezometers, work with data loggers and carry out basic water quality field analysis. The field visit also included a geophysical survey of the entire island using electromagnetic (EM34) and electrical resistivity (ABEM Terrameter) techniques. The next day, the collected data were analysed.

5.1. Results of geophysical survey

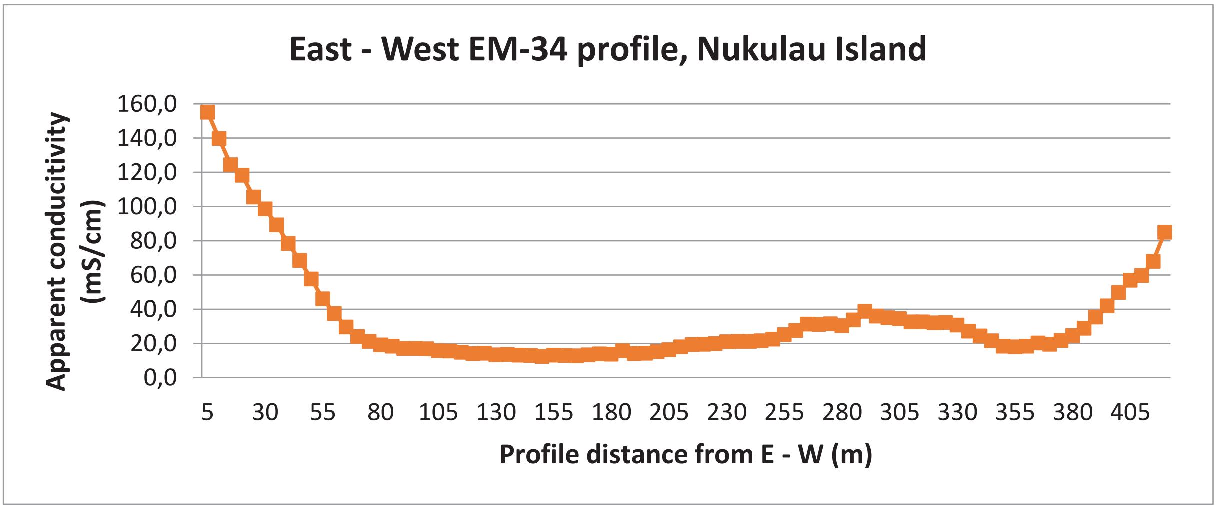


Figure 20 Results of EM-34, East West Profile (through the middle of the island) of Nukulau Island

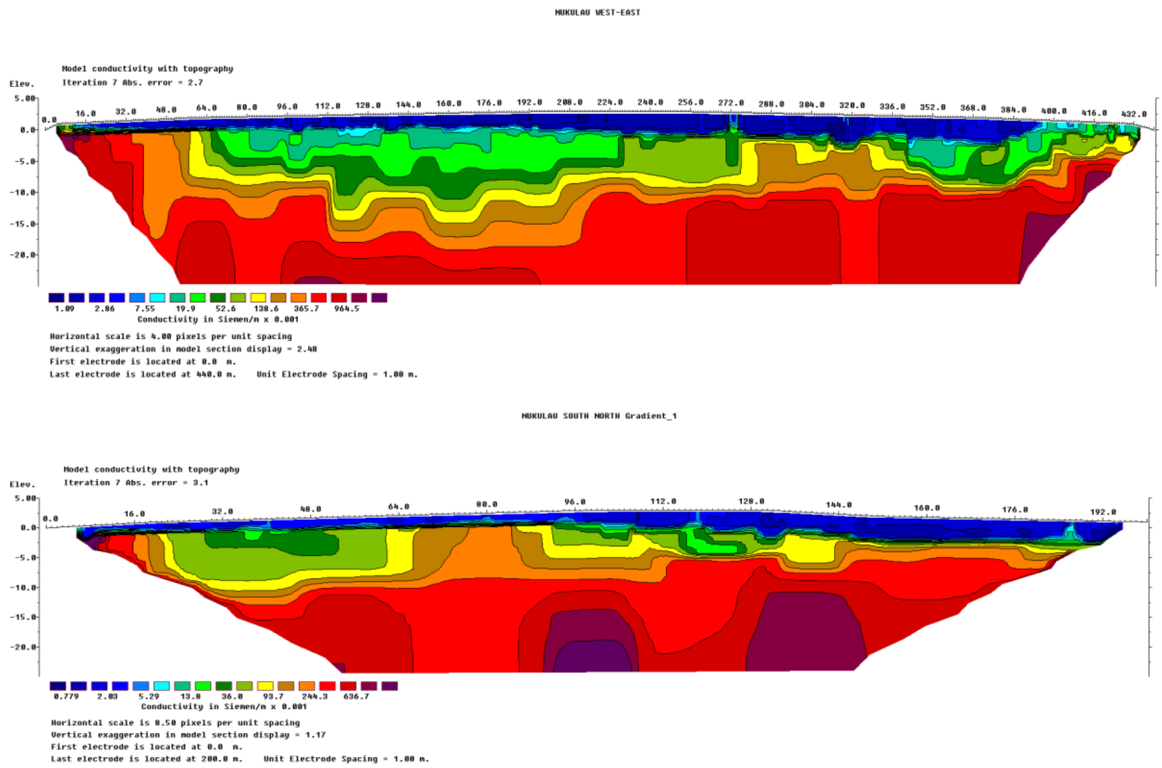


Figure 21 Interpretations of EM-34 profiles in Nukulau Island. Upper profile: west to east. Lower profile: south to north

5.2. Data analysis

Data analysis is necessary to better understand the system's dynamics. Many factors need to be considered in order to obtain a realistic interpretation of measurements. In the case of Nukulau Island it is very relevant to look at how the freshwater lens dynamics are affected by recharge. The EM-34 profile shows the presence of a thin fresh water lens along the island (blue colour). The results of the EM34 profile were validated against salinity data from the observation boreholes. The freshwater lens is less than a couple of meters thick, making it difficult to exploit. The Nukulau Island is therefore mainly dependent on rainwater for water supply.

Rain water data from Nukulau island were compared to a rainwater station in Suva. There is considerably more rain in Suva and the need for site specific rain gauges was stressed because of the high variability between locations.

SCOPIC for drought analysis

SCOPIC is a **S**easonal **C**limate **O**utlook for **P**acific **I**sland **C**ountries. SCOPIC is developed by Bureau of Meteorology (BOM) Australia and can be used for drought analysis. It contains a statistical package to predict the likelihood of rainfall. The drought analysis is based on precipitation data and is therefore reflecting analysis of the meteorological droughts. Since the impact of the drought on (ground)water resources is site-specific, it does not provide analysis on hydrological drought.

6. Workshop outcomes and recommendations

6.1. Discussion on future steps

A brainstorm session took place in view of the preparation of regional project proposals in the near future. Participants were asked what they would like to see in terms of "products" which are relevant to specific needs. These products should be useful for a wide range of stakeholders to maintain local support. The involvement of stakeholders should therefore be an important component of future projects. The stakeholders are the people and institutions that are going to use the products.

It is also important to learn from experiences obtained during previous regional projects (e.g. Pacific HYCOS). These projects may have been too ambitious in some of their components and sustainability in the long range not built in the project design. Groundwater monitoring was not everywhere established although equipment was bought (e.g. Fiji) and the maintenance of monitoring sites could not be ensured, as resources were distributed across a too wide range of activities. Once a focus with achievable goals is developed, it can be maintained and expanded using the developed products.

The discussion was structured around the following themes:

- Development of a groundwater database for pacific SIDS
- Improvement of groundwater data collection
- Products relevant for specific needs
- Foster sustainability and continuity after completion of projects
- Training
- Sustainable Development Goals

Development of a groundwater database for pacific SIDS

Improving the database for groundwater data in Pacific SIDS was one of the items discussed that could be tackled within the future regional project. Most PACIFIC Islands currently use the TIDEDA (TIme DEpendent DAta) database. The TIDEDA database is useful for storage and analysis of surface water but so far not very successful in managing groundwater data. Two options were identified

- **Develop a new database.**
  - Main identified requirements of a new groundwater database include: robustness, suitable for groundwater, especially allowing for organization of data in a three dimensional reference and compatible with surface water data.
- **Continue with TIDEDA database**
  - Improve functionality on groundwater data storage and analysis within TIDEDA
  - (+) Advantage of continuation of the TIDEDA database is that most pacific SIDS are already familiar with it. Another advantage of TIDEDA is that if the groundwater component is improved, the system provides an integrated tool for both surface water and groundwater data.
  - (-) TIDEDA is not able to cope with (x,y,z) data (groundwater level data at certain depth)
  - It is also important to consider the possibilities of TIDEDA on the long run regarding telemetric data

Generally stressed was the need of a suitable database that can meet the demand now and in the future. The familiarity of technicians using a specific database should also be taken into account to prevent the risk of having two fragmented databases. A new database should be compatible with pre-existing databases and requires sufficient training of staff. Linking groundwater and surface water data is often difficult due to different monitoring frequencies, spatial representation, etc. Hence t may be necessary to consider one database for groundwater and one for surface water, as databases designed for surface water often do not consider 3-

dimensionality (depth, geology).. An additional issue is that groundwater responsibilities is usually placed in a different sector than the surface water responsibilities. The chosen database needs to be specifically able to cope with the datasets required to be able to produce the various products. Quality assurance and data security should be a compulsory feature of the database, easily manageable by the staff.

Improvement of groundwater data collection

Equipment installed during the previous regional projects should be, to the possible extent, rehabilitated for re-use during future projects. However, despite the deployment of state of the art equipment (surface and groundwater), most pacific SIDS are still facing problems regarding data collection. The discussion aimed to understand what needs to be done to prevent failure and to improve our data collection.

Participants explained that part of the problem is getting out in the field; it can be difficult to reach some locations in the outer islands and monitoring becomes a time consuming and costly task. An example was given by Tuvalu where they need to monitor rainfall data in the outer islands but they cannot afford having staff in those locations. Telemetry could be an option in such cases. Another option could be to improve collaboration with other agencies which may be present in these islands to collect the data.

The following suggestions were given by the participants to improve data collection:

- **Telemetric monitoring**
    - Updated telemetry with Internet Protocol (IP) based technologies to assist in data collection.
- **Collaborate with agencies and/or ask inhabitants on outer islands to collect data**
    - WMO has adopted models for training farmers etc. to carry out basic rainfall monitoring in Sub-Saharan Africa.
    - Memorandum of understanding to clarify the responsibilities of the implementing agency versus the one from the governments. They have been used in the past but they are not necessarily applied, since there is not a TIF associated with it.
- **Establish different tiers for the outer islands (monthly, quarterly, six months, etc).**
    - This way resources and expertise can be distributed more efficiently. Resources for monitoring infrastructure should be strategically allocated.
- **Organisational infrastructure**
    - It is important having a team around the person who carries out monitoring tasks. In case the person leaves someone else can take over the task and skills are maintained.

Products relevant for specific needs

Various potential “products’’ were discussed.

- Seasonal outlook on the status of a hydrological droughts
    - Improved data analysis is required to compile drought management plans.
    - If a drought is only important when there is an impact, the countries are the ones who are going to determine that impact (indicators)
- Aquifer mapping and recharge quantification. In many cases this is not known, especially for the outer islands. Complete inventories of water resources are required. Maps could be produced showing for example the density of population and boreholes relative to approximate areas of a resource. It may be useful to compile Country/Island briefs which depict this information in an easily-understandable way, suitable for communication purposes (e.g. decision makers)
- Development of indicators that link the current state of a groundwater resource with its ability to provide water
- Telemetered water levels, salinity and groundwater abstractions

COUNTRY	NEEDS	OBJECTIVES	PRODUCTS
KIRIBATI	Improved data analysis	Drought management	Seasonal outlook: status hydrological drought
SOLOMON ISLANDS		Understand water availability	Aquifer mapping
SAMOA	Groundwater recharge and abstraction data. Collaborate with water supply stakeholders?	Management of particular sites, How much can be used?	Recharge mapping
VANUATU	Continuous monitoring, better outreach	Household groundwater management	Community focused awareness

Foster sustainability and continuity after completion of projects

The long-term sustainability and continuity should be an integral component in next regional projects by including development of well-defined products, sufficient trainings to have sufficient level of expertise and skill retention in the countries. Without leadership it is difficult to maintain progress and ensure sustainability. All activities and products developed within projects need to be aligned with clear policies, ownership and leadership.

Improving leadership could be achieved by providing 1) training to ensure skills and 2) ongoing support and mentoring past the end of the project. Budget allocated for support past the end of the project could be given to countries or to consultants for technical support. Continuity of funding is necessary to maintain the skills to control the quality of monitoring data, to provide meta-data, etc.

Training

It was mentioned that skills, mentoring and technical support provided during the course of previous regional projects have been very useful. SPREP mentioned that many countries prefer in-country training over regional trainings. In-country trainings are obviously more effective as they train multiple stakeholders, offices, and staff. However, these are most demanding in terms of resources. WMO mentioned that regional trainings are often conceived as training of trainers, with the goal to allow knowledge transfer to the other national experts. Another option is long-distance learning as a complement and WMO is cooperating with COMET consortium in developing several training module son hydrology. National training is not ruled out but it should be seen in a balance together with regional trainings and distance training.

Additional comments to improve training of hydrologists in pacific SIDS:

- WMO has a hydrology education and training strategy. Most trainings today consist of short courses, without getting accreditation. WMO and UNESCO ae cooperating in defining what should be the basic skills for hydrologists and hydrological technicians.
- Important to include a computing and troubleshooting component in trainings.
- YouTube videos should be considered too.

Sustainable Development Goals

Tommaso Abrate presented on the current status of the Sustainable Development Goals (SDGs) and how this could be useful for pacific SIDS. The SDGs are a country driven initiative which builds and expands over the success of the Millennium Development Goals. A specific water oriented goal with six subordinated targets has been identified addressing water supply, sanitation, water efficiency and reuse, integrated water management and water ecosystems. UN-Water, on behalf and with the inputs from the various UN agencies dealing with water related issues, is in the process of developing monitoring methodologies for assessing the progress made by countries towards the attainment of the goal. This is a powerful tool for each country to mobilize assistance and resources to ensure a sufficient level of water monitoring, management and planning. The SDG can be a very important tool which might be used complementary with the new regional projects.

6.2. Closing of the meeting

The meeting was closed by Tommaso Abrate (WMO). Tommaso highlighted the diversity of participants attending the workshop, ranging from hydrogeologists, environmental scientists, and hydrological technicians. It was a difficult task to develop a training that suits the whole audience when there is a wide range of backgrounds. The training managed to cover many relevant topics and promoted fruitful discussions and interaction among participants. Many constraints were identified and the workshop outcomes will serve as a useful source to develop new projects and provide further assistance to countries. The workshop was also a first cooperation on a groundwater training between WMO and IGRAC. Lessons were learned and things will be improved in the future to ensure a more efficient knowledge transfer from workshop participants to their colleagues back home.

7. References

GWP Consultants and SOPAC, 2007. Integrated Water Resources Management in Pacific Island Countries: A Synopsis.

Ministry of infrastructure & planning, Cook Islands government, 2012. Cook Islands hydrology trip northern group & Rarotonga. NIWA, 2010. Groundwater scoping report for Rarotonga, Cook Islands. National Institute of Water & Atmospheric Research Ltd, Wellington, New Zealand.

Nicolini E., Karyne R. and Rakowski D., 2016. Baseline geochemical characterisation of a vulnerable tropical karstic aquifer: Lifou, New Caledonia. Journal of Hydrology: Regional Studies 5, 114-130.

SOPAC, 2004. An Overview of Integrated Water Resources Management in Pacific Island Countries: A National and Regional Assessment.

SOPAC, 2007. National integrated water resource management diagnostic report, Niue. Sustainable Integrated Water Resources and Wastewater Management in Pacific Island Countries.

SOPAC, 2007. National integrated water resource management diagnostic report, Samoa. Sustainable Integrated Water Resources and Wastewater Management in Pacific Island Countries.

SOPAC, 2011. An economic assessment of water safety planning: Niue.

Appendix I: workshop agenda

Advancing Groundwater Monitoring in Small Island Developing States in the Pacific

29 August – 2 September 2016, Suva, Fiji

Day 1 – Groundwater in SIDS (Tanoa Plaza)

08:30 – 09:00 Registration
09:00 – 09:15 Welcome addresses, content and objectives of the workshop (WMO)
09:15 – 10:30 Groundwater resources and small islands
Introduction to groundwater resources and sustainable groundwater development on SIDS (Andreas – IGRAC)
Importance of groundwater monitoring in Pacific SIDS (Nienke – IGRAC)
10:30 – 10:50 Break
10:50 – 12:00 Current state of groundwater resources and their monitoring in the Pacific SIDS
Overview of the state of the groundwater resources (Pacific Island Groundwater Vulnerability to Future Climates) (SPC – Peter)
Status and problems linked to groundwater monitoring (SPC – Peter)

12:00 – 13:30 Lunch break

13:30 – 15:00 Current state of groundwater resources and their monitoring in the Pacific SIDS
Presentations by SIDS representatives
Presentations on projects by SPC and SPREP
15:00 – 15:20 Break
15:45 – 17:00 Advancing assessment towards sustainable use of groundwater resources
Reference to past action plans and frameworks (WMO)
Activities required to improve the knowledge of groundwater resources, taking into consideration specifics of individual islands/states (Sustainable Development Goals) (Andreas – IGRAC)

Day 2 – Groundwater monitoring and assessment techniques (Tanoa Plaza)

08:30 – 10:00 Groundwater monitoring and assessment techniques (Andreas/Nienke)
Methods and procedures used in groundwater assessment
10:20 – 10:40 Break
10:40 – 12:00 Groundwater monitoring and assessment techniques (Andreas/Nienke)
Methods and procedures used in groundwater monitoring
Groundwater quality monitoring
Acceptable limits of pollutants according to intended uses
Sources of pollutants and contamination
Attenuation and prevention of pollution
Examples of low-cost equipment that can be used in the Pacific

12:00 – 13:30 Lunch break

13:30 – 14:50 Groundwater data analysis (Andreas/Nienke)
Interpretation of hydrogeological time series and spatial data
14:50 – 15:10 Break
15:10 – 17:00 Groundwater data analysis (Andreas – IGRAC)
Example from Majuro atoll, Republic of Marshall Islands

Day 3 – Field work

08:00 – 17:00 Field visit (Nukulau island) (SPC and Mineral Resources Department)
Participants divided into 3 teams and to rotate through 3 sets of activities on the island
Resistivity – Trainers (Ian Acworth/Peter Sinclair)

EM-34 – Trainer (Amini Loco)
Piezometer installation, water sampling, diver deployment and download, water quality field analysis Trainer (Sandra Galvis Rodriguez, Anesh Kumar, SPC workshop team (4))

Day 4 – Field work and data analysis (Tanoa Plaza)

08:30 – 10:00 Resistivity and Electromagnetic theory (Ian Acworth)
Theory of resistivity
Theory of electromagnetic
10:00 – 10:20 Break
10:20 – 12:00 Data analysis of field measurements
Review of existing reports/imagery, information
Drought analysis – SCOPIC
Geophysical analysis - EM34

12:00 – 13:30 Lunch break

13:30 – 15:30 Data analysis of field measurements
Geophysical analysis - Resistivity
Time series analysis
Tidal lags/efficiencies
Groundwater quality
15:30 – 15:50 Break
15:50 – 17:00 Data Interpretation (all)
Data and groundwater assessment interpretation of Nukulau

Day 5 – Advanced geophysics (Tanoa Plaza)

08:30 – 9:15 The Global Groundwater Monitoring Network programme (Nienke)
09:15 – 10:00 Wrap-up of the training and the way forward (WMO)
10:00 – 10:20 Break
10:00 – 12:00 Advanced geophysics
Resistivity analysis and interpretation (Ian Acworth)
Field investigation techniques – survey preparation
Demonstration or hands on data analysis – case study – Ian Acworth data set

12:00 – 13:30 Lunch break

13:30 – 14:50 Resistivity data analysis and interpretation continued (Ian Acworth/SPC)
Analysis of data sets from Pacific Islands eg Fiji, Tuvalu
14:50 – 15:10 Break
15:10 – 17:00 Case study from Australia (Ian Acworth)
Example resistivity from Hat Head, Australia and future applications

Appendix II: List of workshop participants

State	Name	Email address
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Samoa	Azarel Mariner	azarelm@sprep.org

Groundwater Monitoring in Small Island Developing States in the Pacific

This report is a summary on groundwater monitoring practices in Small Islands Developing States (SIDS) in the Pacific. A brief overview is given for each Pacific SIDS to capture the current groundwater monitoring and assessment practices and their future challenges. This is a compilation of information shared during the workshop "Advancing Groundwater Monitoring in Pacific SIDS". We thank the workshop participants for their active participation and their valuable input. This report would not have been possible without their collaboration and timely contributions.

IGRAC is the UNESCO Global Groundwater Centre, it also works under the auspices of WMO, it is a corporate IAH partner and it is financially supported by the Government of the Netherlands.

WMO provides world leadership and expertise in international cooperation in the delivery and use of high-quality, authoritative weather, climate, hydrological and related environmental services by its Members, for the improvement of the well-being of societies of all nations.

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