Mwoakilloa Atoll

FRESHWATER RESOURCES AND THEIR USAGE, STATE, AND INFRASTRUCTURE

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October, 2010

Island Research & Education Initiative

Water and Environmental Research Institute of the Western Pacific

Dedicated to the people of Micronesia.

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Contents

List of figures

List of maps

List of tables

List of appendices

Background

Introduction

This study is a fact-finding operation to document the current state of freshwater resources on Mwoakilloa Atoll.

This document is the result of a comprehensive baseline survey of the current condition, infrastructure, and use of freshwater resources on Mwoakilloa Atoll, in the Federated States of Micronesia. Using a combined hydrologic and sociological fieldwork approach, we have evaluated all hydrologically significant infrastructure; described practices of water production, distribution, and consumption; and recorded people's perceptions and concerns related to freshwater resources on their island. The infrastructure survey component included the inventory of all collection and storage elements of rainwater catchment systems, all wells utilizing groundwater supply, and all other relevant features. People-oriented component was based on direct observations and interviews of residents and leaders regarding the lifestyle practices, notions, and opinions pertaining to freshwater resources. The purpose of the project has been to collect up-to-date information in order to understand availability of and threats to fresh water resources on the island, support their future sustainable management, and avoid crises.

Federated States of Micronesia

There are 38 low islands – coral atolls and lone coral islets – in the Federated States of Micronesia.

The Federated States of Micronesia (FSM) is a small island developing state (SIDS) in the Western Pacific. It consists of 4 high island units (Yap, Chuuk, Pohnpei, and Kosrae) and 38 low island units. High islands are of volcanic origin and have relatively large land areas. They are centers of socioeconomic and political life of the country and home to the majority of its population. Low islands are of carbonate origin and include atolls and solitary coral isles, all of which have extremely limited land area and reach only a few meters above the sea level. They are collectively known as the "Outer Islands," and have relatively small populations.

Outer Islands and limited resources

Except for Kosrae, each high island in the FSM has its own constellation of "Outer Islands." Mwoakilloa Atoll - the subject of this study - is one of the "Outer Islands of Pohnpei". The appellation 'outer' is somewhat of a misnomer considering the fact that low islands are not mere adjuncts of high islands – they are homes to distinct societies with unique histories, traditions, cultures, and languages. The cultural background and identity of "outer" islanders are clearly differentiated from those indigenous to high islands. Their lifestyle remains largely traditional and based on time-honored agroforestry and fishing methods. Such a way of life is shaped by unique geography of restricted low island environments and is defined principally by two attributes: extreme scarcity of natural resources and utmost dependence on natural conditions.

Fig 1
Scene on lagoon-side of Mwoakilloa.

Climate and rainfall

Micronesia is tropical, its islands having a fairly uniform annual temperature range (26~27°C / 79~81°F) and relative humidity over 80%. Rainfall varies with geographic position and island size (from 180 cm / 70 in. in the driest islands to 960 cm / 380 in. in the mountains of the wettest island of Pohnpei). Most of the rainfall falls within the wet season (June to October), but this seasonal variation is less pronounced on Pohnpei, which is wet throughout the year and sees only a slight reduction in rainfall from January through March. According to the National Weather Service, Mwoakilloa receives 400 cm / 160 in. of annual rainfall on the average. Total rainfall recorded on the atoll in 2010 was 353 cm / 139 in.

Micronesian climate is characterized by occasional typhoons and droughts, which can be severe and very damaging to quality of life and infrastructure. Being located at Micronesia's eastern end, Mwoakilloa is generally out of the path of most cyclonic storms.

Fig 2
Main road on Mwoakilloa.

Fresh water needs and issues

Despite the small numbers of residents, the pressure on resources in the low islands can be quite high due to their extremely limited land areas. The FSM is the fourth most densely populated Pacific island nation based on the national average, and population densities of individual low islets are some of the highest in the world. Their residents have access only to the most basic amenities and infrastructure. Availability of fresh water is a major problem.

Availability of fresh water is a major problem in low islands.

Thanks to their traditional lifestyle and subsistence economy, the residents of Mwoakilloa exert no unreasonable demands on their water resources. They have no technology-related demands for water and forgo many forms of water usage that are commonplace in communities accustomed to municipal water and power supplies and relatively lavish lifestyle. There are no conveniences that require plumbing and pressurization. The islanders' demand for water, therefore, does not extend beyond the basic needs for drinking, cooking, dishwashing, laundry, and showering. Table 1 outlines the basic needs in order of relative importance.

Water usage	Importance	Notes
Cooking	High	Necessity
Drinking	High	Coconuts are alternate source
Washing dishes	High	Health related need
Washing clothes	Medium	Health related need
Watering pigs	Medium	Agricultural need
Rinsing after bathing	Medium	Health related need
Showering / bathing	Low	Ocean is alternate source

Table 1
Overview of water usage on Mwoakilloa.

However, the fact that the islanders' requirements are relatively low also means that they are based on fundamental needs. Therefore, any restriction or interruption of water supply immediately affects comfort and quality of life. If unmitigated, it can result in threats to well-being and health, and necessitates emergency intervention from outside sources.

Residents of low islands catch and store rain for their potable water needs.

Residents of Mwoakilloa and other low islands in Micronesia rely almost exclusively on catchment of rainwater to meet their potable water needs. Such water is more often than not unsafe for drinking due to a number of factors, including the prolific microbial growth in a tropical climate, limited possibilities for hygienic conditions, ease of contamination, lack of physical and chemical treatment of water, and imperfect service and upkeep. Estimates made in the neighboring Republic of the Marshall Islands state that less than 2% of low island population have access to safe drinking water.

Droughts and typhoons disrupt supply and cause water shortages.

Difficult weather conditions are a major threat. The use of rainwater for all potable water needs is a precarious arrangement characterized by a tight relationship between supply and demand. The system tends to break down during natural disasters, when emergency assistance from the outside becomes a matter of survival. During prolonged droughts, especially following El Niño events, catchment systems generally fail to collect and store sufficient water to meet even basic needs. They are also quite vulnerable to typhoons and other severe storms, which can render them inoperable for extended periods of time. Gutters and any associated hardware can be blown away by strong winds. Roofs can also be damaged by gusts of wind, and plastic tanks can be broken by flying debris. That reduces an island's total catchment and storage capacity in the aftermath and creates shortages that profoundly affect the local people's health and quality of life.

Waterborne contagious diseases also represent a major concern. Health surveys in the FSM have shown that at least a third of disease outbreaks in the nation are a direct result of the lack of safe water supplies. In one of the more dramatic recent incidents, contaminated water was the identified as the source of the 2000 cholera epidemic in Pohnpei when 21 person died and more than 3000 were treated.

At least a third of disease outbreaks in Micronesia result from the lack of safe water supplies.

Availability of safe and ample fresh water remains one of the greatest challenges of life in the low islands, and a priority for sustainable development in Micronesia. It depends on numerous factors, including sufficient and appropriate catchment and storage infrastructure, backup systems, appropriate maintenance and periodic rehabilitation, and preparedness for emergencies. The critical tool necessary for planning of such sustainable development strategies is, of course, accurate and up-to-date information. We have carried out this research and prepared this publication in order to help with fulfilling that need. Part of a series dealing individually with select low islands in Micronesia, this report focuses on Mwoakilloa Atoll and provides baseline data regarding the current state of its freshwater resources. The information contained within is based on extensive fieldwork and comprehensive inventorying of features and facts relevant to the usage, state, and infrastructure of freshwater resources on Mwoakilloa Atoll.

We hope that it will become a useful reference for resource managers, planners, government authorities, and researchers who wish to improve the well-being of people in Mwoakilloa and other low islands in Micronesia.

Key concepts

Low islands are small carbonate bodies unable to support surface water flow and accumulation. For all practical purposes, their freshwater resources belong in two categories only: rainwater and groundwater.

Rainwater

Water vapor contained in the atmosphere precipitates and falls as rain. In the low islands, small total area and permeable coral rock mean that the little water that does fall on the land surface there is quickly lost into the ground and the surrounding ocean. People must capture and store the rainwater in order to use it. Typically, that is achieved using catchment systems consisting of an impermeable area that receives the rain (ie., roof), a series of conduits that transfer it (ie., gutter), and a storage component (ie., water tank) that keeps the water until it is used.

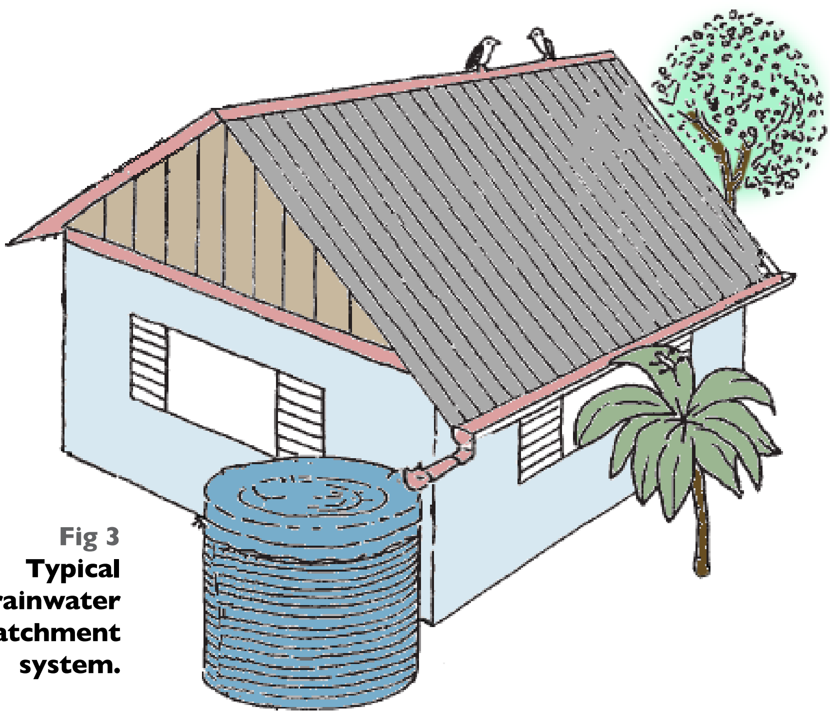

Fig 3
Typical rainwater catchment system.

Groundwater

Rain that falls on an island quickly sinks into the ground and continues to percolate downward through porous coral rock. It reaches the water table, below which rocks are saturated with fresh groundwater. All that water originated as rain and is contained within the island because it is slightly less dense than seawater -- which also percolates into the porous island rocks and provides a base on which the fresh water rests. The fresh groundwater body is the thickest in the island's interior and thinnest around the perimeter, which gives it an overall shape reminiscent of a biconvex lens. The thickness of a groundwater lens and the amount of fresh water within it depend on island's size, amount of rainfall, and properties of rock that holds it.

Fresh and salty groundwaters do not blend because of their density differences (much like oil floating on top of water in a glass). They mix somewhat along the zone where they are in contact. Such mixed water is known as brackish - neither very salty nor sufficiently fresh.

Freshwater wells are excavated by people in order to allow extraction of water from the freshwater lens.

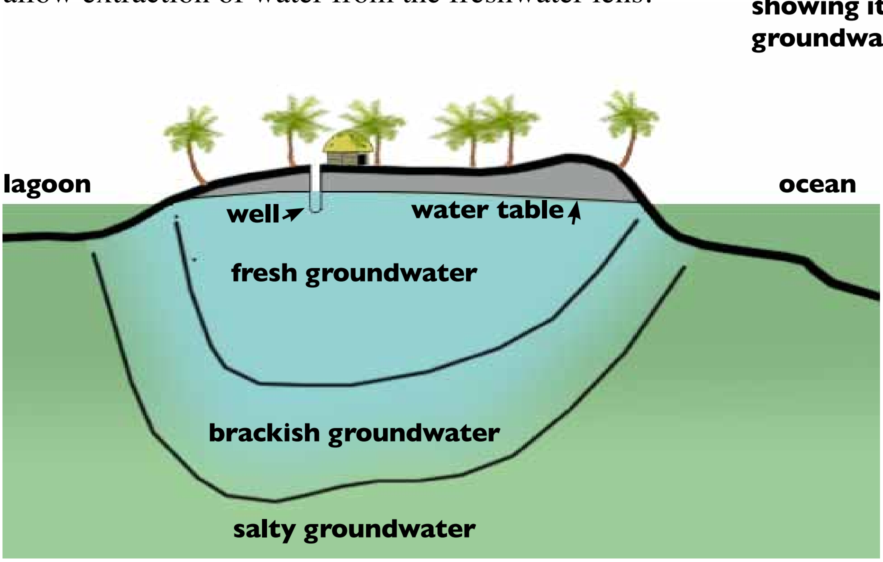

Fig 4
Cross-section of a low island showing its groundwater.

Rationale

Freshwater resources on coral atolls and other low islands in the Federated States of Micronesia (FSM) are under threat of overuse due to changing lifestyles and increasing population pressures, damage by pollution and unsustainable development, and obliteration by the global climate change. The extent of specific problems are different on various islands, but cannot be evaluated at present due to the lack of most basic field data. Despite the rapid socioeconomic and environmental changes being experienced by the low islands in the FSM, there has been no comprehensive study to examine the current condition, infrastructure, and utilization patterns of their freshwater resources. The lack of such information represents a huge obstacle to government planners, resource managers, engineers, educators, environmental scientists, and others dedicated to the sustainable development and use of freshwater resources in Micronesia.

Freshwater resources on low islands are under threat by unsustainable practices.

Historically, people on low islands have coped with the enormous restrictions of their natural environment by means of cultural and technological adaptations such as traditional conservation practices and resource management, specialized agriculture and distinctive land use systems, advanced fishing and navigational methods, etc. In the second half of the 20th century, however, as these societies gradually changed from those based on subsistence economy and traditional authority to those based on cash economy and individual freedoms, and improved transportation and communication links reduced their levels of self-reliance, much of the balance they had previously enjoyed with their environment has been lost. As a consequence, their limited natural resources have come under threat. For example, acquired desires for consumer goods are causing unprecedented amounts of non-biodegradable materials to be imported to the islands, which creates ever increasing solid waste disposal problems; abandonment of indigenous religion has meant the replacement of traditional sea burials with interment practices that threaten the quality of atoll islets' exceedingly small groundwater bodies; the use of diesel, motor oil, soap, bleach, detergents, and other fuels and chemicals has introduced the threat of pollution; and more frequent travel and movement of goods between the islands pose new risks of introduction of plant diseases, agricultural pests, and other invasive species. In addition, the reduction of chiefly authority has lessened the strength of traditional regulations and taboos aimed at controlling population growth, which has lead to very high birth rates and extreme population densities. The increases in population are reflected in greater amounts of human and animal waste, greater pressure on the islands' limited resources, and greater likelihoods of environmental and health problems.

Similarly, the dichotomy between "old" and "new" can also be extended to the atolls' vulnerability to changing natural conditions. Over the centuries, people indigenous to atolls and low islands have developed response mechanisms and complex strategies to survive natural disasters, including destructive typhoons, giant swells, saltwater intrusion, and rapid erosion, as well as famines and epidemics that come with them. However, it is possible that the global climate change, irrespective of its actual cause, intensity and pace, is triggering events that have previously not been experienced by the atolls' current populations. If extreme weather conditions are striking with increased frequency and intensity, they could overwhelm the islands' vegetation and populations and even the islands themselves. The most terrifying threat, of course, is the possibility of a global sea level rise, which would obliterate the low islands' thin groundwater lenses and end the human ability to inhabit atolls at all.

Problems are exacerbated by erosion, saltwater intrusion, and extreme weather.

This report provides baseline data to support resource management, sustainable development, and emergency preparedness.

Considering how the changing socioeconomic and environmental circumstances described above are threatening atoll populations with resource shortages and reduced environmental quality, it is critical to evaluate the local people's current relationship with their most precious and sensitive resource of all: fresh water. Regrettably, up-to-date and detailed information on the state and usage of fresh water on low islands of Pohnpei State and other parts of the FSM is not easily accessible. This includes the data on water resources' current condition (e.g., salinity of groundwater and its suitability for an emergency supply of drinking water), infrastructure (e.g., size of rainwater catchment and storage facilities available on different islands), and lifestyle practices (e.g., water utilization patterns, solid and human waste disposal, animal husbandry, etc.).

We have attempted to alleviate this problem in Pohnpei State by carrying out a comprehensive study of its atolls to document the current condition of their freshwater resources and related infrastructure, as well as the local people's relationship with those resources. Such information needs to be available not only to improve our understanding of the water resources in the low islands, but also to support their sustained use.

Finally, data collected as part of this project will help avoid or better respond to fresh water emergencies, agricultural difficulties, food shortages, health problems and other environmental crises that may arise due to lack of knowledge, awareness or preparation.

Fig 5
Church building overlooking the village in Mwoakilloa.


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Objectives

The fundamental objective of research behind this project is to obtain baseline data on the freshwater resources on Mwoakilloa Atoll. The purpose of this report itself if to provide a comprehensive description of those resources and relevant information regarding their current state, usage, and associated infrastructure.

Specific tasks carried out include the following:

- Describe the atoll's physical and human environment (e.g., depict geographic, social, and cultural characteristics; highlight significant natural and man-made features; provide relevant maps; list major points of contact; etc.)

- Inventory, assess, and map hydrologically significant infrastructure (e.g., rainwater catchment systems, storage tanks, shallow wells, etc.)

- Examine the state of freshwater resources and their usage patterns on each island (e.g., relate specific water sources and infrastructure to daily water use for drinking, bathing, washing, etc.)

- Investigate other relevant lifestyle features (e.g., waste disposal, burial practices, animal husbandry and agroforestry patterns, etc.)

- Record island residents' attitudes and relevant cultural norms, perceptions, behavior and opinions related to freshwater resources (e.g., people's habits, concerns, and beliefs about their water, etc.)

- Identify and report any critical problems related to freshwater resources (e.g., historical or current shortages, health problems, agricultural problems, etc.)

The research objectives were identified as to fill data gaps in knowledge of the current situation in Micronesian low islands and their freshwater resources. They were pursued in order to provide information that is vital for improved usage, monitoring, management, and protection of the freshwater resources in Mwoakilloa Atoll.

In addition, it is hoped that research and data presented here will provide not only specific information relevant to Mwoakilloa Atoll, but also criteria for similar surveys on other low islands in Micronesia and small island developing states elsewhere, as well as provide a basis for systematic comparisons.

Fig 6
Researchers surveying infrastructure on Mwoakilloa.

Methods

The work presented here was carried out by Micronesia-based non-governmental organization Island Research & Education Initiative (IREI), with funding from the United States Geological Survey (GIS) received from the Water and Environmental Research Institute of the Western Pacific (WERI). Methodology employed has incorporated hydrogeological fieldwork, engineering studies, and sociological inquiry.

Project structure

Prior to project implementation, we have gathered and examined all extant relevant information in the form of scientific papers, maps, on-line resources, etc. about the island to be surveyed. We have conveyed our plans to the local points of contact, requested feedback from elected leaders and community members, and modified the research plan according to received input.

After thorough preparatory work, we undertook intensive data collection trips to the atoll. We met with island leaders and elders to explain the nature of our visit project and its objectives. We visually examined the island and coastal areas, performed comprehensive surveys of infrastructure, interviewed local leaders and residents, carried out GPS and GIS mapping, acquired numerous photographs, and finally worked on data processing and dissemination.

Fieldwork

Fieldwork comprised of three separate research trips to the atoll. Each trip included a hydrogeologic component comprising of field observations and mapping; an engineering component comprising of infrastructure measurements and evaluations; and "people-oriented" component comprising of standardized surveys and freeform interviews of local residents. The data produced encompasses 1) hydrogeologic observations (e.g., descriptions of coastal discharge, taro patches, etc.), 2) technical particulars (e.g., size and shape of rainwater catchment tanks, condition of wells, etc.); 3) GIS data (e.g., locations of wells and water catchment systems); 4) lifestyle and sociological information (e.g., usage patterns of groundwater, perceptions of its quality, etc.); 5) images (e.g., photographs of infrastructure and daily life); and 6) other relevant data.

During the first visit to the atoll, we carried out an informal inspection and photographing of the island, its settlement, vegetation, buildings and other infrastructure, and any other distinguishing features. During the second visit, we carried out a systematic survey by visiting individual households and public facilities and assessing rainwater catchment systems, wells, and other relevant features. The third visit was used to verify previously collected data and fill in any information that may have been missing.

For data collection, researchers used sets of checklists to help them note all information previously identified as significant (or deemed so at the time of surveying). See Appendix 1 for the detailed list of information, attributes, and topics that were sought, examined, and recorded by researchers in the field.

Survey of infrastructure

The core of this project is a comprehensive survey of rainwater catchment systems and groundwater wells. Households were visited systematically and each had all of its water-related infrastructure examined. We recorded the size and state of repair of each component of existing rainwater catchment systems. We measured dimensions of all individual catchment systems, storage tanks, and groundwater wells using a tape measure, noted their engineering characteristics, and recorded geographic coordinates by a hand-held GPS unit. See Appendices 2 and 3 for data collection sheets used by researchers during interviews.

In addition, we examined and documented other relevant features, such as solid and human waste disposal sites, weather data collecting stations, cemeteries and other burial sites, etc. Finally, we made observations of agricultural and coastal areas, paying special attention to anomalies such as saltwater damage to vegetation or unusual erosion features.

GPS and GIS

This study is the first to represent Mwoakilloa using GIS datasets and layered maps. We began by scanning and georeferencing the only available large scale map of Mwoakilloa (1946, US Army Corps of Engineers, 1:25,000, series W856, sheet 6141 I). Vector data were derived by digitizing individual features off the scanned image. The information was updated using remote sensing imagery and corrected by ground control points collected in the field (by making GPS placemarks of prominent features visible in remote sensing imagery). Following base map preparation, we proceeded to build original data relevant to the project. We used a GPS-based mobile mapping unit (Thales MobileMapper CE) capable of creating GIS shapefiles to map important linear, areal, and point features on site. In addition to recording the locations of all water-related infrastructure, we mapped household sites, municipal and public buildings, main pathways, seawalls, taro patches, and other prominent features. GIS coverages generated in field were exported into ArcGIS® software and processed to create detailed maps.

Throughout the fieldwork, we used a secondary GPS unit (Qstarz BT-Q1200) capable of automatic logging to record researchers' position in 10 second intervals. That data was used to digitially geotag photographs taken by cameras whose internal clocks were previously synchronized with the GPS logger.

Interviews

Key aspects of the project were to evaluate the state of freshwater resources on a given island as perceived by local residents and to record their usage patterns of those resources. We made concerted efforts to have as many as possible informal conversations and formal interviews with local officials, community leaders, and average residents. We asked a range of questions designed to (1) record exact information (e.g. regarding specifics of catchment systems and wells), (2) determine customary behavior (e.g., regarding common and uncommon use of well water), (3) note people's impressions and perceptions (e.g., opinion of water quality and overall fresh water situation on the island), and (4) document past incidents (e.g., cases of water shortages or food shortages, epidemics, and weather-related crises in the island's past). The information was noted on previously prepared standardized interview data sheets, which were referred to during conversations in order not to omit any important questions, and used to note down responses until they could be transcribed and organized. An Olympus digital voice recorder was also used to record everything as an audio backup and for future reference.

In addition, over the course of our stay on the island we nearly continuously interacted with local people and made informal observations regarding drinking of water, cooking, dish washing, laundry washing, bathing, waste disposal, and other day-to-day activities.

Photography and geotagging

As many as possible features, landscapes, and photographs of people and their daily life were made using high-resolution digital SLR cameras and saved as uncompressed JPG files. The cameras' clocks were synchronized with the GPS logger used in the field, thus allowing straightforward geotagging (georeferencing) of acquired images.

GPS data was saved in GPX file format and imported into Houdah Geo software for Mac OS X operating system. That software was used to process photographs taken by camera and combine them with the GPX file, so that coordinates where the camera-coupled GPS logger was located at the moment when each photo was taken became embedded within each particular image JPG file.

Viewable in GoogleEarth® and other geospatial applications, geotagged images are a unique ground truth evidence and and a useful reference tool.

Data processing and dissemination

Upon completion of data acquiry portion of the project, we processed all information and prepared final reports and products. Results of work are presented in this report (and comparable ones for other islands), which contain most data and metadata acquired and observations made on each island, including technical information, geographic coordinates, informers' names, interview dates, photodocumentation, etc. The reports are available to government agencies, resource managers, engineers, educators, and others interested in natural resources in FSM's low islands.

In addition, digital media version of the report (PDF file) is made available for free download from IREI and

WERI websites, along with photographic collection labeled and organized by topic and location, GIS shapefiles generated as part of the project, audio files of interviews, and other supporting files. This approach ensures quick and easy information dissemination and access to raw data useful to various interested parties.

Fig 7
Screenshot of WERI's homepage.

Fig 8
Screenshot of this project's main page.


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Mwoakilloa Atoll

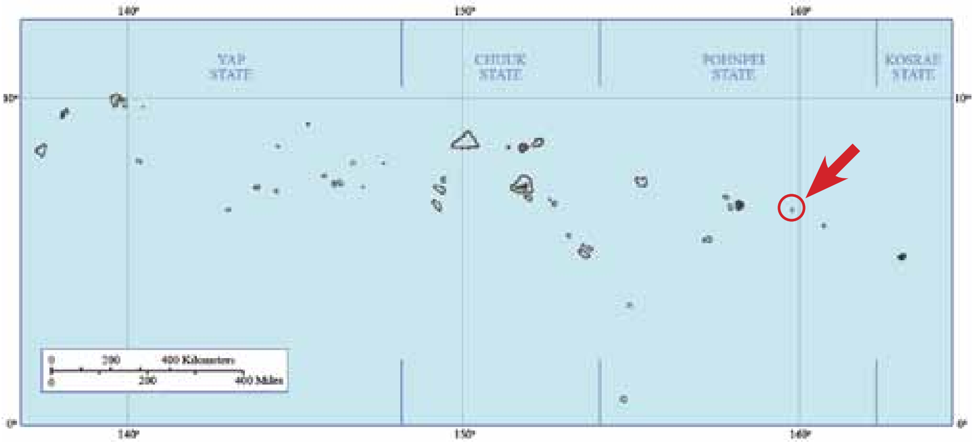
Geography and history

Mwoakilloa is one of the smallest inhabited atolls in the FSM.

Mwoakilloa is a small coral atoll located in the eastern Caroline Islands. It is one of the "Outer Islands" of Pohnpei State, of the Federated States of Micronesia (see Map 1). It is located ~100 miles east of Pohnpei and ~200 miles northwest of Kosrae. Mwoakilloa is one of the smallest inhabited atolls in the FSM and consists of three closely packed islets surrounded by a reef. The small lagoon is divided by a linear patch reef into deep and shallow parts (see Map 2). Mwoakilloa was known as Mokil until recently and the adjective Mokilese is still commonly used for local ethnicity and language.

The people of Mwoakilloa reside along the leeward side of the main islet known as Kahlap. The remaining two islets, Mwandohn and Uhrek, are not inhabited. Total population of the atoll was reported to us as <100 people [in 2009] people, which is about half of what is usually cited, including by the last FSM population census [174 people, 2000]. The population was about four times larger some 50 years ago. The actual number of people at any time fluctuates widely due to circular migration patterns between the atoll and the main island of Pohnpei, whose Mwoakilloa community is tenfold that on the home island. The last population census recorded 1,015 Mokilese people living in Pohnpei State. Mwoakilloa is one of municipalities of Pohnpei and has a representative in the State Legislature.

Fig 9
An aerial view of Mwoakilloa Atoll, as seen from the southwest. [Photo by Nashy Christine]



Map 1
Location of Mwoakilloa Atoll in the Federated States of Micronesia.

The present inhabitants of Mwoakilloa and the entire Mokilese diaspora in Pohnpei and elsewhere are all descendants of 25 to 30 individuals who survived a devastating typhoon that occurred around 1775. Genealogies also indicate a few immigrants from other islands and countries among the ancestors. Western whalers began visiting the island in 1830s and became numerous by 1850s. The *Nahnmwarki* (paramount chief) of Mwoakilloa converted to Christianity in 1862 and by the end of the 19th century the island was firmly integrated into commerce patterns that have formed regionally and involved trade of local produce and especially copra for tools, tobacco, and alcohol. Trade brought unprecedented transportation links with Pohnpei and the wider region and caused profound socioeconomic changes on the atoll. During German administration (1899-1919), many atoll residents emigrated to work in copra trade, phosphate mining, and other labor. Main destination for the people leaving Mwoakilloa was the island of Pohnpei. The Germans encouraged settlement there as a way of releasing pressure on atoll resources following a bad 1905 typhoon. When the Sokehs Rebellion (1910-1911) again German rule on Pohnpei failed, the colonial authorities confiscated all the rebels' land and awarded it to settlers from Mwoakilloa and the other "Outer Islands." Today, Mwoakilloa community on

People of Mwoakilloa are a separate ethnic group, related to, but distinct from Pohnpeians.

Pohnpei is still concentrated in Sokehs, though many live in other areas, notably Madolenihmw. The people of Mwoakilloa engage in taro farming, agroforestry, copra harvesting, and fishing on a subsistence level. Children attend elementary school on Mwoakilloa. After graduating, most move to Pohnpei to continue education.

Nearly all residences on the atoll are made of concrete.

Somewhat surprisingly, nearly all residences on Mwoakilloa are made of concrete. This makes the atoll (along with Pingelap, its neighbor 70 miles to the southeast) a prominent exception among FSM's "Outer Islands," where local-style thatched roof houses are still the norm. Until about the 1960s, houses in Mwoakilloa were still traditional. Each seaside house is said to have had its own rock wall, artificial fish pond, cookhouse, canoe house, and a canoe. This traditional pattern changed with time and today's house in Mwoakilloa integrates previously separate structures so that dwelling room, kitchen, shower area, etc. are all found within the same building. A few households retain outdoor cooking areas, which mostly coincide with the *naj* [pronounced 'nash'], unwalled, roofed traditional structure that was originally the canoe house, but now a general meeting place for the family, still very important in social life, built near the water, and separate from the main house.

Mwoakilloa and Pohnpei are connected by ship and small airplane service.

Residences are concentrated on the lagoon-side of the northern half of Kahlap, whose central area of closely packed buildings resembles a small-town neighborhood rather than an atoll village. The settlement is surrounded by taro patches, coconut groves, and agroforest. The southern end of the island used to have a few lone dwellings, but these have now been abandoned. It is still regularly visited because of the airstrip located there. The native vegetation consists of atoll forest, with *Pisonia*, coconut palms, *Pandanus*, and other trees, which transition to *Scaevola* and saltwater-resistant scrub on the island's ocean-facing side.

All land on Mwoakilloa is privately owned. The major divisions run from lagoon side to ocean side and split the island into elongate land sections. They may be divided into numerous smaller parcels belonging to different families. The main sections are shown in table 2, in the order from the northwestern tip of the island toward the south (see table 2).

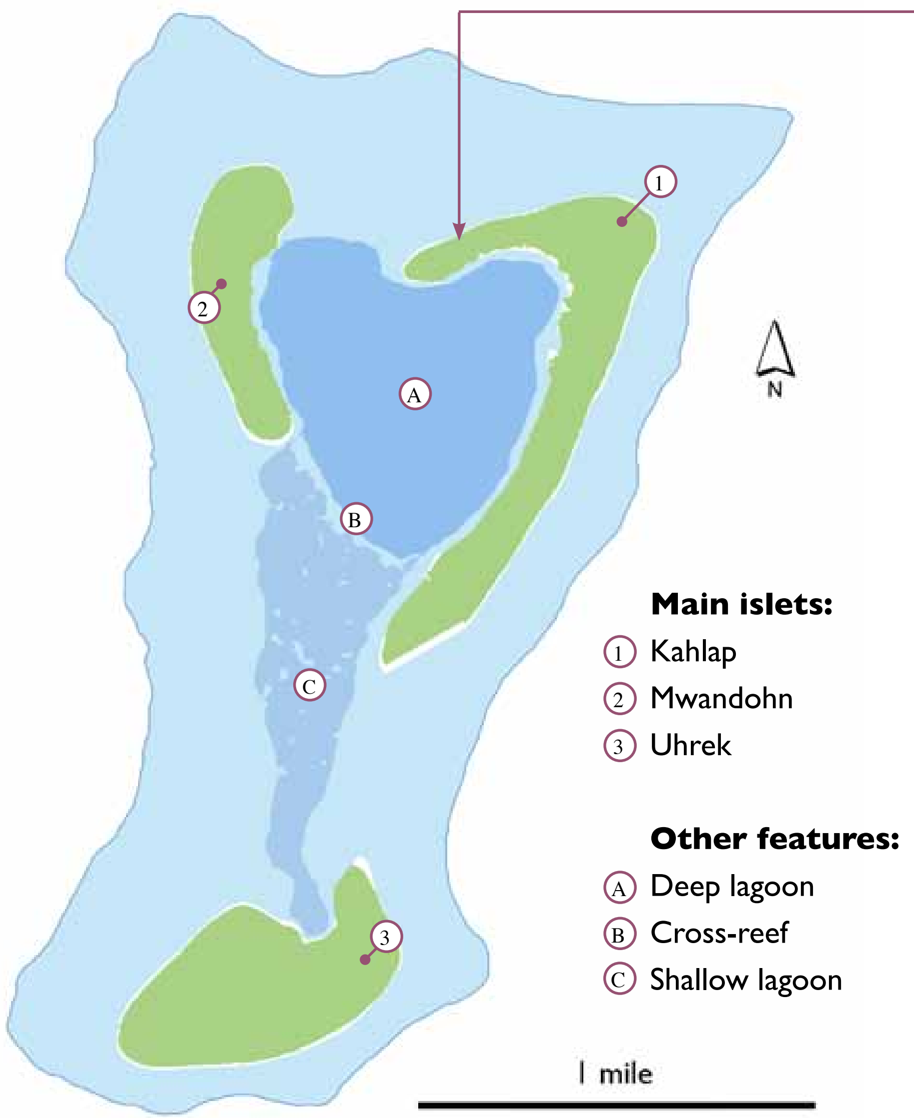
Table 2
Major land sections on Kahlap islet.
1~37 are located along the coast in the order from north to south. The remainder are inland above the taro patch.

1.	Jokojkoa	24.	Donmaj
2.	Miniko	25.	Anelok
3.	Kielek	26.	Likinkaj
4.	Jakarsik	27.	Injapoad
5.	Lillo	28.	Insipilong
6.	Langarkapw	29.	Joaponmokil
7.	Imwinoajor	30.	Koapinmeido
8.	Imwinpweleng	31.	Kasan
9.	Poaidi	32.	Joawoik
10.	Ililinno	33.	Mijenwio
11.	Poaidi	34.	Lojapw
12.	Lokpaj	35.	Joaponjilel
13.	Mwododow	36.	Wakad
14.	Koapinlong	37.	Iminpiko
15.	Rongonpalaro	38.	Mijenpeio
16.	Imroj	39.	Likinjapw japwkapw
17.	Loamej	40.	Indiadio
18.	Kajpaia	41.	Japwkapw
19.	Alok	42.	Longojleng
20.	Loapingping	43.	Inmoadol
21.	Woanoap	44.	Pwokonso
22.	Likinwena	45.	Jopoananij
23.	Piken	46.	Kakalia

Travel between Mwoakilloa and Pohnpei is not feasible by small boats. In addition to the vast distance, the small lagoon lacks a channel and cannot be entered by most vessels. Transportation links with Pohnpei are maintained by government ship Caroline Voyager, calling at the atoll once every few months, and Caroline Islands Aviation, which runs a scheduled but not always reliable service by small plane several times a month.

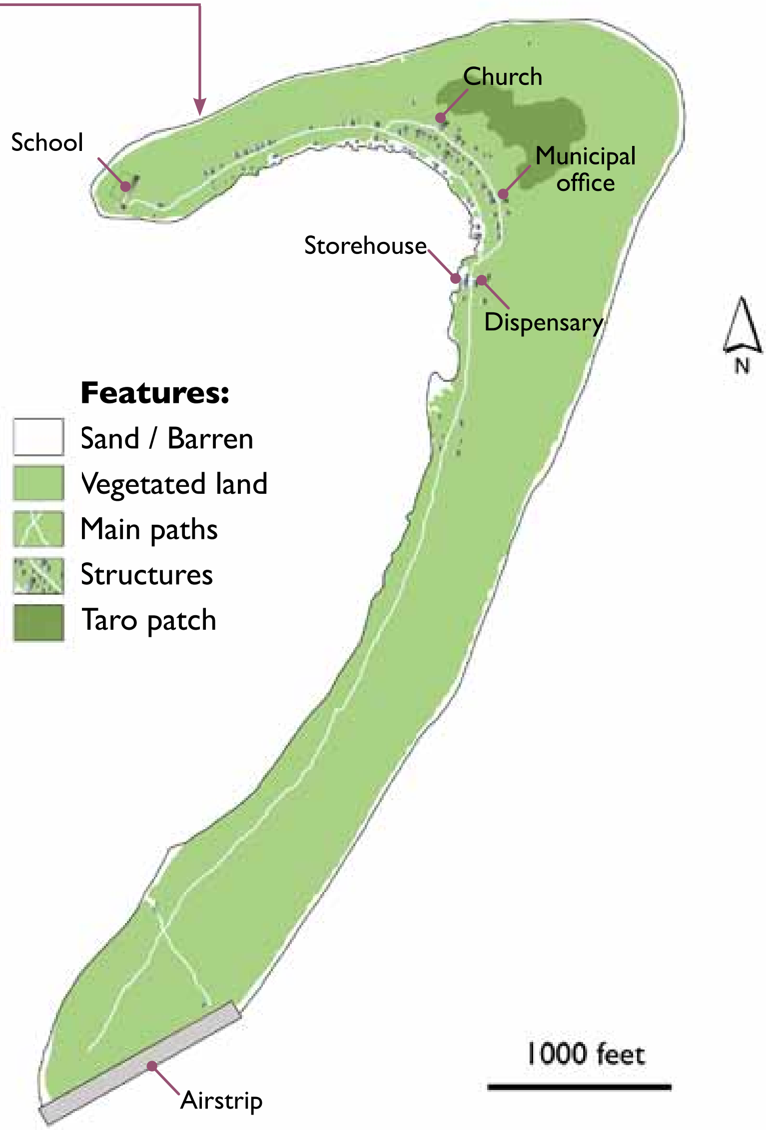
General maps

Map of Mwoakilloa Atoll



Map 2 Mwoakilloa Atoll. Map based on a US Army Corps of Engineers map. Place names were recorded in interviews with residents and are spelled here in Mokilese orthography.

Map of Kahlap islet



Map 3 Kahlap, Mwoakilloa's main islet. Map based on field mapping completed in 2009 by D. Taborosi and M. Sánchez Collazo.

Basic facts

Table 3 Geography

Standard name:	Mwoakilloa
Other spellings:	Mokil
Historical names:	Wellington Island, Duperrey Island
Location:	E of Pohnpei
Coordinates:	6° 40' N, 159° 47' E
Island type:	atoll
State:	Pohnpei State
Political status:	Municipality within Pohnpei State
Ownership:	All land is privately owned by families residing on Mwoakilloa and Pohnpei
Closest high island:	Pohnpei
Distance to Pohnpei:	~100 miles
Closest low island:	Pingelap Atoll
Number of islets:	3
Total land area:	1.46 km^2
Reef area:	4.82 km^2
Reef outer perimeter:	13.5 km
Reef inner perimeter:	7.54 km
Reef passes:	none
Lagoon area:	1.63 km^2
Lagoon max. depth:	60 m
Distinctive features:	lagoon split into separate deep and shallow parts
Rainfall:	400 cm/yr

Table 4 Population

Population:	~100 people, about 60 adults and 40 children
Inhabited islets:	one
Inhabited islet name:	Kahlap
Uninhabited islets:	Mwandohn, Uhrek
Ethnic group:	Mokilese [based on the former, less-cumbersome spelling of atoll name]
Language:	Mokilese
Population origin:	Indigenous population for at least 1,000 years.

Table 5 **Infrastructure**

Atoll accessibility:	by sea only and by air
Lagoon accessibility:	to small boats only, difficult at low tide
Lagoon entry points:	none, only across reef at high tide
Concrete buildings:	numerous, including all private residences among which are five two-story houses
Public buildings:	municipal office, municipal storage building, dispensary, school, airport terminal, church, three chapels (*jinakoke*), and one privately owned store
School:	N 6.69200° E 159.75943°
Dispensary:	N 6.69053° E 159.76510°
Church:	N 6.69303° E 159.76455°
Traditional buildings:	few, only *naj* (boathouses) and a few cookhouses and copra-drying houses
School:	elementary, <40 students [2009], 3-4 teachers [2009]
Clinic:	there is a dispensary on island
Commercial activities:	copra production
Ongoing research:	none known
Conservation projects:	municipal turtle sanctuary on Uhrek islet
Coastal engineering:	seawalls, rock platforms, fish pools on Kahlap islet
Electric power:	sporadic (solar power and generator)
Internet access:	none
Cell phone reception:	none
Weather station:	yes

Table 6 **Points of contact**

Chief Magistrate:	Ruly Neth [2009]
Senior pastor, UCCP:	John Ichiro [former Chief Magistrate]
School principal:	Romeo Joel
CIA [airline] agent:	Don Allen [in charge of all Caroline Islands Aviation flights]
Speaker of the Council:	Higgin Hedson
Postmaster	Molvina Ludah
Recent PCV:	Kate Fosdick [Peace Corps volunteer, M76, 2009-2011] Zachary Stepan [Peace Corps volunteer, M73, 2006-2008] Collin Shields [Peace Corps volunteer, M71, 2004-2005] Christina Caros [Peace Corps volunteer, M70, 2003-205]
Traditional leaders:	Unlike municipalities in Pohnpei and Pingelap, Mwoakilloa lacks a *nahnmwarki*, the highest traditional authority.

Lifestyle

Mwoakilloa has a largely subsistence economy and almost no public infrastructure. Its residents are actively engaged in gardening, agroforestry, and fishing in order to produce food for themselves and their families. For everything that they cannot produce, they depend on imports from the main island of Pohnpei. In recent decades, this has come to include even food items, including the new staple food -- rice.

Everyone on Mwoakilloa lives on the main islet of Kahlap, with residences concentrated on the lagoon-facing side of the northern half of the islet. Much of the waterfront in the settlement has been reinforced by seawalls, behind which coral rocks were piled up to create horizontal and flat platforms, occasionally with empty space left to act as fish pond. The seaside of the village area is thus not defined by a natural beach slope as elsewhere, but by the step-like arrangement of platform-wall-lagoon floor. The platforms are the main landing points for arriving boats and building

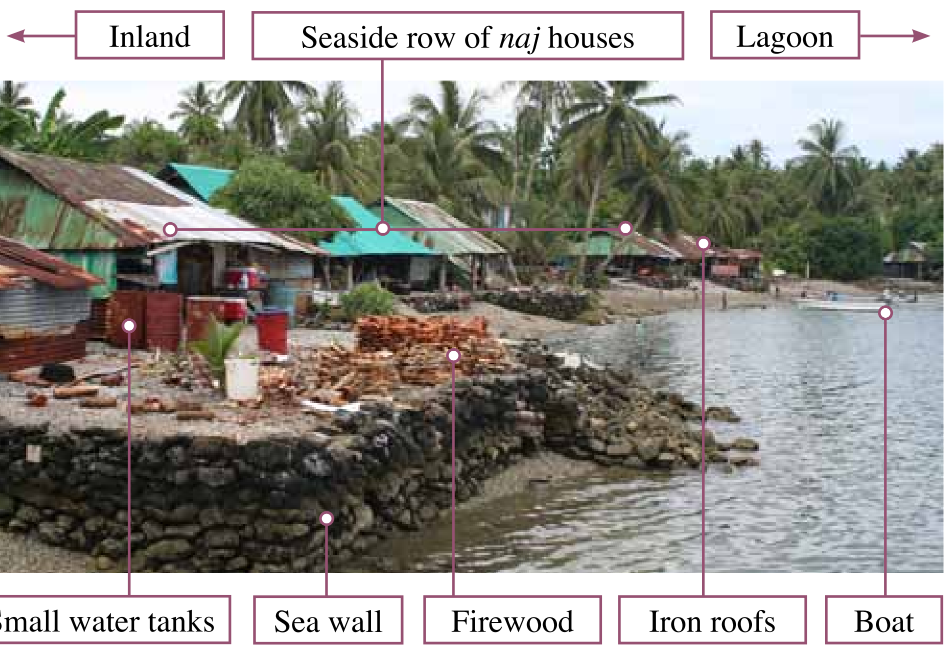


Fig 10
Area of *naj* houses by the lagoon shore.

sites for the *naj*, roofed, unwalled cabins that act as boathouses, family meeting places, and traditional centers of much social life (but not as dwelling places). Actual homes are located on firmer ground a bit inland. A well-maintained, paved path parallels the shore throughout much of the village. It was built using coral rock covered with cement and has cement curbs. The waterfront side of the path is lined with the *naj*, whereas residences are rather closely lined up along the inland side. There is also a parallel path on higher ground in the village and it is lined with houses on both sides, including the large church building and the municipal office. The settlement is divided into three sections (I, II, and III), each with its own chapel known as *jinakuke* [synagogue]. Belonging to a section is important in daily life, holiday celebrations, and especially church-related events. That encompasses much of the activity on this island. The airstrip and a small office house that serves it are located at the southern tip of the island and are reached from the settlement by a well maintained forest path that extends from the paved village path. A couple of households used to be located in the vicinity of the airstrip but

Mwoakilloa lacks any municipal water and energy facilities

Fig 11
Main road and one of the three section chapels.

this is no longer the case. One site is still maintained as a *naj*, the rest have been abandoned. Elementary school is on the opposite end of the island. It is a complex consisting of administrative buildings and three classroom buildings, and a central area used as volleyball/basketball court and playground. Enrollment is about 2-3 dozen students taught by 3-4 teachers.

House construction no longer reflects traditional architecture. Only the *naj* are still made of local materials (wood and thatch) but increasingly include corrugated iron (for roofs). Floors of the *naj* and general surroundings of houses are veneered with dried and fragmented coral gravel. This gives them a clean and often strikingly white appearance, which is maintained by replacing the gravel once a year (usually around Christmas time). The houses where people sleep are all made of concrete, with plywood and corrugated iron used for many roofs and various add-ons. Unlike most outer islands, households rarely have separate outdoor kitchens, cookhouses, or bathing sites. In Mwoakilloa, all is integrated into

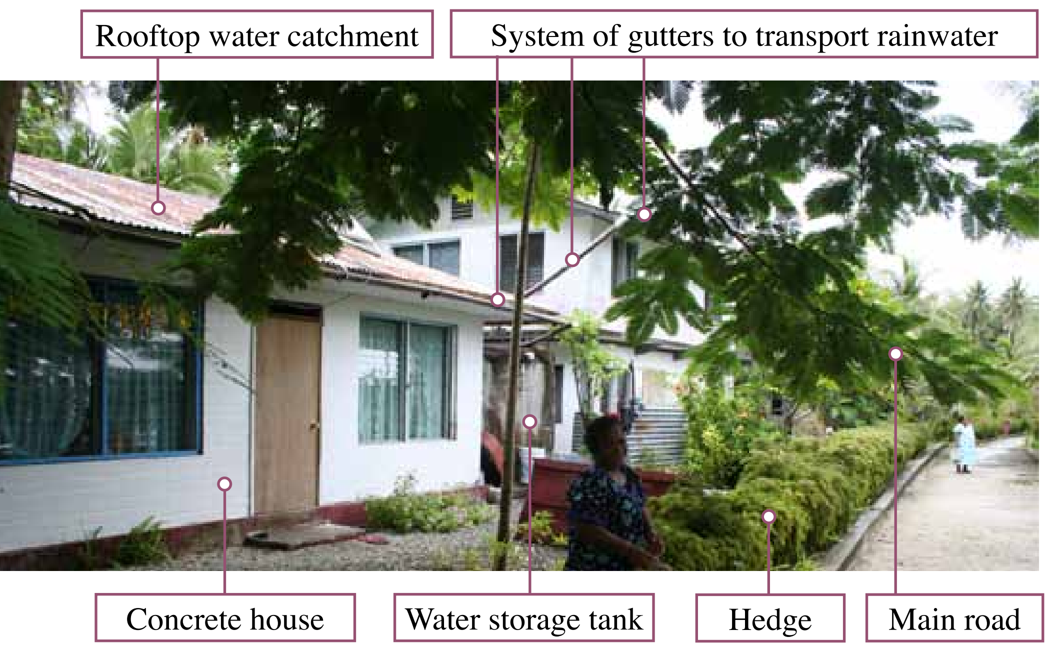


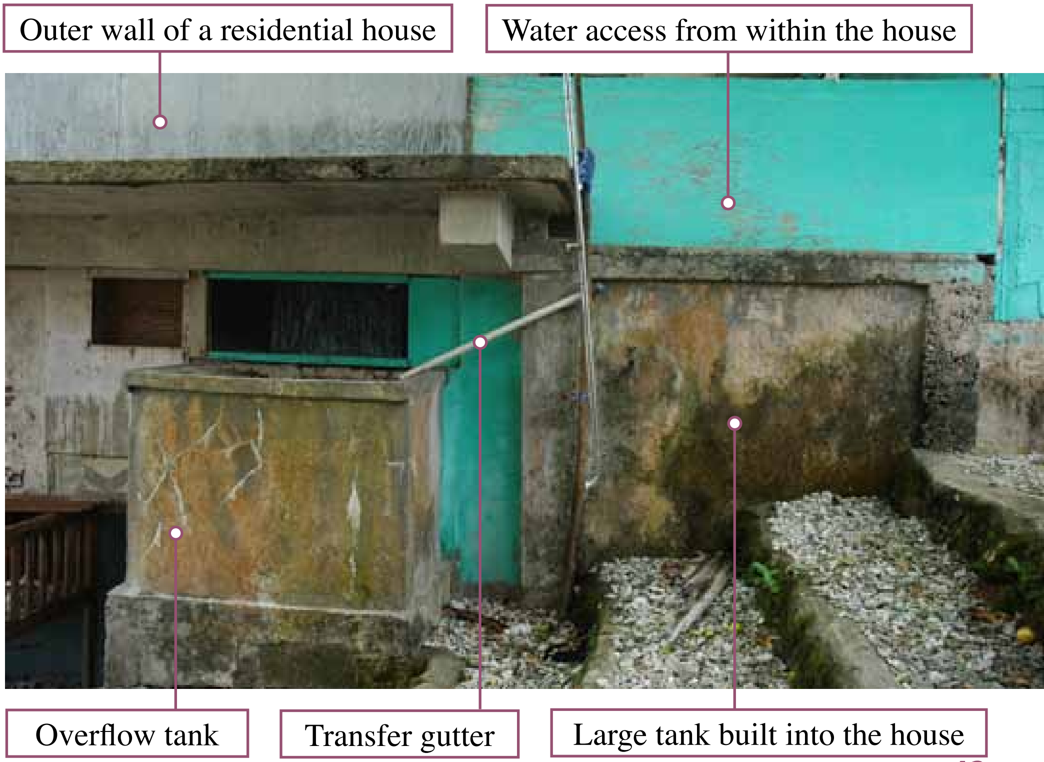
Fig 12
View of a Mwoakilloa household.

new concrete houses. Even rainwater collection tanks, which are in most islands clearly separate concrete or plastic cylinders placed next to a house, are in many cases in Mwoakilloa rectangular pools built into house foundations.

Other than the *jinakuke* in each village section, the center of life in Mwoakilloa is the imposing church built on a slight hill. It overlooks the settlement and is very prominent due to its all-white color and large size (for an atoll islet). The village is clean, though the all-concrete houses and their unusually compact arrangement give impression of an out-of-place town neighborhood rather than an atoll village.

The surroundings of the village are covered by agroforest of coconut palms, breadfruit, and other useful trees. The interior of the northern part of the island has been excavated over the centuries and hosts

Fig 13
Built-in water storage tanks.



the island's main food source: taro pits, divided into numerous patches owned and maintained by individual families.

With no municipal facilities available on island, the people of Mwoakilloa solve water and energy needs on their own. Water for drinking, cooking, dishwashing, washing laundry, showering, and bathing is all usually obtained from the rain, which is captured by rooftop catchment systems and stored in concrete or fiberglass water tanks, mostly rectangular or cylindrical (thereon called 'round') in shape. Water for watering domestic animals often comes from shallow hand-dug wells, which are available to the large households. When rainwater is lacking, groundwater is used to wash laundry and other non-essential purposes to conserve water, but is practically never consumed.

Transport and fishing trips around the lagoon are made by fiberglass boats with outboard engines. There are no more sailing canoes left on the island and even the paddling canoes are very few. Knowledge of building a sailing canoe is lost, though the elderly still know how to construct paddling canoes. In recent years, there were talks about starting paddling canoe project on island. This idea was prompted by a major gasoline shortage on island but was abandoned as soon as gasoline became available again. It is possible that rising prices of gasoline will cause further shortages and difficulties in the future. People of Mwoakilloa have a very limited number of options to earn money. Production and export of copra, previously the main economic activity, is no longer done due to exceedingly low price of copra ($4/sack in 2009). Lemons are collected with much less effort and can be solid for about $1/pound. However, the viability of this trade is threatened by the agricultural pest that attacks lemons on Mokil, Pingelap, and Kosrae.

Fig 14 (top)
Family relaxing inside a *naj*.

Fig 15 (bottom)
Man-made fishpond and coral rock walls.

Inventory of households

Infrastructure by household

This section presents data from the comprehensive inventory of households and associated water-related infrastructure on Mwoakilloa. The survey was carried out over the course of two work-intensive visits in 2009. Households are listed here in the approximate geographic order starting from section I and moving toward section III. Houses and their water-related infrastructure are described in the following manner: an arbitrarily assigned ID number, general description, number of residents, number and characteristics of water tanks, description of groundwater wells, and miscellanea. For privacy reasons, names of individual households have been deleted from the following text. IREI and WERI maintain an unaltered version of this document in confidentiality.

Section I

43. Mwoakilloa Elementary School

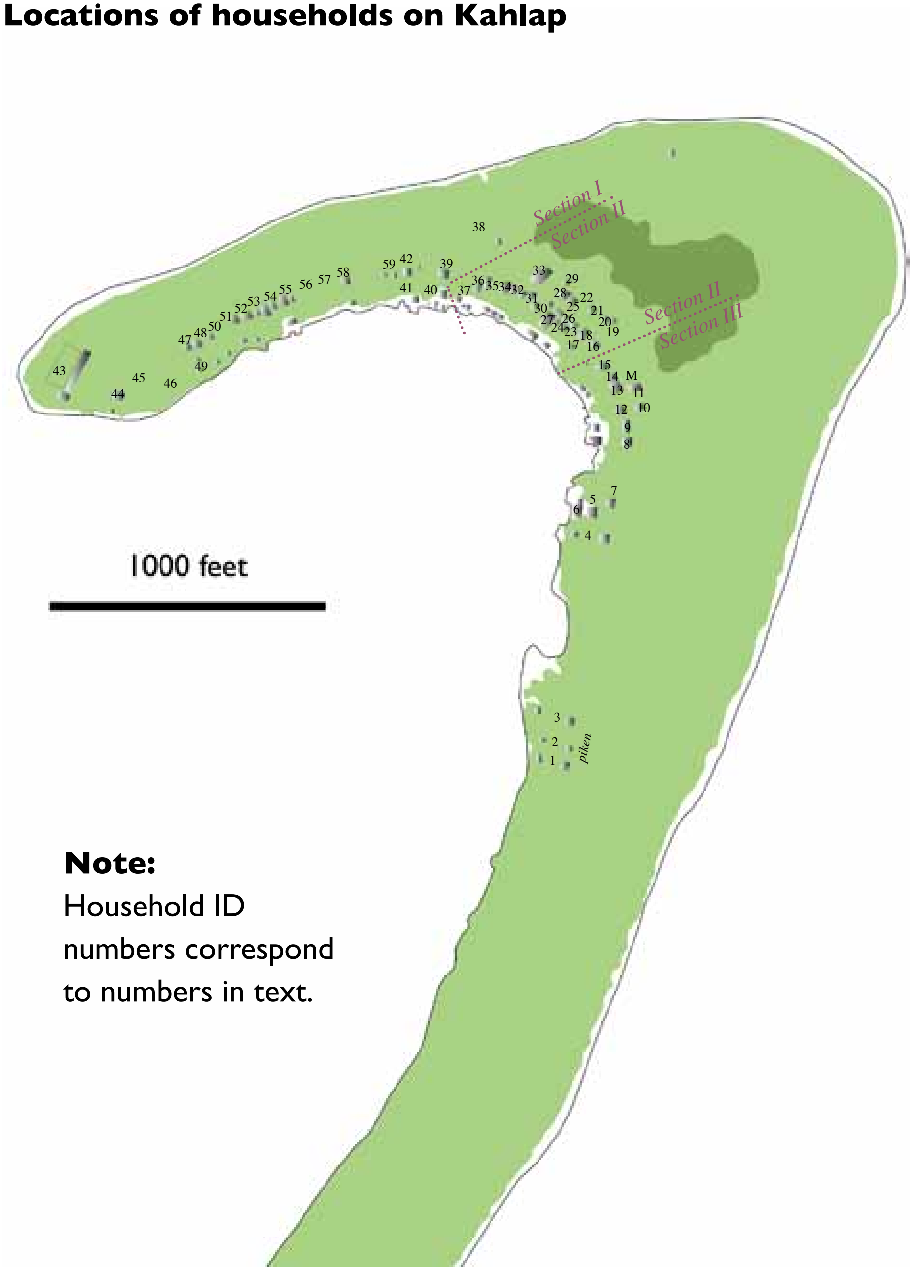
photodocumentation: M1041-1048; D0700-0715

Division of Mwoakilloa settlement into three section plays important role in daily life

Four concrete buildings, volleyball/basketball court, large antenna and solar power.

- one large rectangular cement tank, with cement top connected to the toilet (~3m x 4m x 2m tall), catches water from school roof, good metal gutter
- toward the ocean side, one round black plastic PVC tank, plastic cap (~1.5m tall, 1.5m diam.) catches from the roof, good metal gutter, used for drinking
- one large cement tank, cement top (~220 cm in diameter, 170 cm height), roof catchment
- blue fiberglass 700 gallon tank, school roof catchment (potential is shared with previous tank)
- two bathrooms: one outhouse and one within southeasternmost building, connected to tanks
- public toilet, separate male and female, not in use, and is used instead as a shed and storage area

Locations of households on Kahlap



Map 4 Locations of households on Kahlap, Mwoakilloa's main islet. Map is based on a survey completed in 2009. ID numbers are assigned arbitrarily to each household or a separate living area.

Fig 16
A typical concrete house with a tin roof.

- concrete 3,500 gallon tank, with top, no catchment, unused, always empty
- drilled well, concrete lining, with pump, unused
- a set of solar panels, mounted on aluminum poles; dedicated for use with the well pump, but currently unused because the pump is broken
- no shallow wells in the vicinity
- white fiberglass 150 gallon tank, elevated, connected to the well, should be fed by pump and used to flush public toilet; but is currently unused, as the toilet itself

44. //Name removed for reasons of privacy//

photodocumentation: M1049-1057; D0716-0722

Concrete house with corrugated iron roof and a *naj* across the path. Most of the times no one stays here. At the time of our visit there were two adults, three children. No well.

- front area of the house has two large cement tanks with cement tops (~220 cm diam., 180 cm tall), receiving catchment from the roof via metal gutter; one of them connects to the bathroom
- one outhouse toilet connected to a small cement round tank (~110 cm, diam., 100 cm tall) for flushing, not covered
- one medium cement round tank, cement cap (~170 cm diam., 170 cm tall), unused, no catchment

45. //Name removed for reasons of privacy//
photodocumentation: M1058-1063; D0723-0728

Abandoned house, right next to house #44, destroyed cement and iron roof. House is used by the neighbors to dry their laundry.

- medium cement round tank (~170 cm diam., 170 cm tall), no cover/catchment, unused
- one big cement (~200 cm diam, 170 cm tall), cement top partially broken, no catchment, completely dry with some trash on it
- another small cement round tank connected to the toilet (~85 cm diam., 80 cm tall), covered with corrugated iron, not in use (toilet house used as a storage room)
- a small round cement tank, turned over, broken, no top nor bottom

46. Abandoned copra house

Copra house, just a concrete foundation with nothing on it, at the ocean side of the path. Across the path inland, there is a rectangular cement tank owned by house #28 from section II.

47. //Name removed for reasons of privacy//
photodocumentation: M1065-1073; D0732-0741

Concrete house, iron roof. Vacant at time of survey, but usually four adults, three children. Family on island is taking care of the house. Five tanks, one well.

- medium cement round tank, no cover, (~170 cm diam., 170 cm tall), roof catchment
- big cement round tank (~220 cm diam., 170 cm tall), cement top, roof catchment
- another big round cement tank in the front of the house (~240 cm diam, 200 cm tall), cement top, roof catchment, mostly new gutter
- one small cement round tank connected to the toilet (~85 cm diam., 80 cm tall) for flushing, iron cover, toilet roof catchment
- another tank, same type and size as previous, by the toilet, iron cover, unused
- one relatively deep well, 150 cm to the water level, made of coral rocks and cement top, the water is reported as a bit salty, sometimes used for the pigs

48. //Name removed for reasons of privacy//
photodocumentation: M1074-1075; D0747-0750

Two-story cement and iron roof. Five adults, one child. Five tanks, no well.

- big cement round tank (~220 cm diam, 170 cm tall), cement top, roof catchment
- square cement tank (~1.8 x 1.8 x 1 m deep), covered with iron sheet, used for washing
- small cement round tank connected to the toilet (~85 cm diam., 80 cm tall) for flushing, iron cover, toilet roof catchment
- unusual rusty metal tank (~3.1m diam., 3m tall), metal top, it has a ladder, catching from the roof, used for showering
- medium cement round tank, (~170 cm diam., 170 cm tall), roof catchment, iron cover

49. //Name removed for reasons of privacy//

photodocumentation: D0742-0746

Concrete house. Four adults, no children. The family shares the well with house #47.

- one big cement round tank (~210 cm diam, 170 cm tall), cement top, roof catchment, PVC gutter
- one turned over small toilet cement tank, no top nor bottom

50. //Name removed for reasons of privacy//

photodocumentation: M1076-1086; D0751-0758, 0761

Abandoned house. Ruined, cement walls left, no roof. Tanks behind the house.

- one small cement round tank connected to the toilet (~diam.85 cm, 80 cm tall) for flushing, iron cover, toilet roof catchment
- one big square cement tank (~1.8 m x 1.8 m x 2m deep), roof catchment, used by neighbors sometimes
- one medium cement round tank, no cover, (~170 cm diam., 170 cm tall), no catchment
- another medium cement tank, cement top, different shape as usual (~150 cm diam, 170 cm tall), roof catchment, rusty gutter

51. //Name removed for reasons of privacy//

photodocumentation: M1091/D0787 (by *naj*); D0774-0785

Two-story concrete house and a *naj* across the path. Three adults, no children.

- One small cement round tank connected to the toilet (~85 cm diam., 80 cm tall) for flushing, no cover, toilet roof catchment
- ne big cement round tank (~250 cm diam, 200 cm tall), cement top, PVC tube connected to it receiving water from the roof
- another big cement round tank (~220 cm diam, 170 cm tall), cement top, roof catchment
- the well is right under the house, made of cement blocks on the top border, 90 cm to the water for washing clothes and dishes, water is clear but has some trash in it
- the family has another tank next to the *naj* of house #52, medium round cement tank (~1.5m tall, 1.3 diam), no cover, no catchment, unused

52. //Name removed for reasons of privacy//

photodocumentation: M1090, 1092-1094 ; D0786, 0788-0796

Concrete house, iron roof and a *naj* across the path. Two adults, two children.

- around the *naj* one cement round tank (1m diam., ~1.1m tall), no cover
- one big square cement tank (~1.5 m x 1.5 m x 2m deep) behind the house, full of trash
- one big cement round tank (~220 cm diam., 170 cm tall), no cover, roof catchment
- another big cement round tank connected to the washing area (~200 cm diam, 170 cm tall), cement top, roof catchment
- one small cement round tank connected to the toilet (~diam. 85 cm, 80 cm tall) for

flushing, no cover, toilet roof catchment

- one well lined with coral rock walls, top part reinforced with cement, 1 m to the water, covered with plywood board, moss growth

53. //Name removed for reasons of privacy//

photodocumentation: D0797-0801

Concrete house, iron roof. Four adults, two children. No well.

- one medium cement round tank (~170 cm diam., 170 cm tall) behind the house, no cover, roof catchment
- another medium cement round tank that feeds into the house (~170 cm diam., 170 cm tall), roof catchment
- one big cement round tank (~220 cm diam, 170 cm tall), cement top, roof catchment

54. *Jinakoke* I

photodocumentation: D0802

This is the chapel for section I residents. No tanks, no wells.

55. //Name removed for reasons of privacy//

photodocumentation: M1095-1110; D0803-0814

Two-story concrete house, next to the *Jinakoke* I. Iron roof, second floor is empty. Concrete house next door belongs to this household. Four adults, three children. In the summer there are more people staying. Nine tanks, one well.

- one cement round tank connected to the toilet (90 cm diam., ~110 cm tall), cement top, toilet roof catchment, rusty metal gutter.
- another toilet flushing tank, little bit different from the previous one (~85 cm tall, 110 cm diam), cement top, no catchment
- one medium cement round tank connected to the toilet, cement cap (~170 cm diam., 170 cm tall), roof catchment
- additional two medium cement round tanks, cement top (~170 cm diam., 170 cm tall), one receiving catchment from the roof, the other one not catching water
- two big cement round tanks, cement top (~220 cm diam, 170 cm tall), roof catchment
- one square cement tank (~1.5 m x 1.5m, 2m deep), under the roof, roof catchment, clean water
- across the path, next to their *naj*, one small round tank, cement cap, *naj* roof catchment
- one well with three pipes sticking out of it, used to have a pump but it's been broken, 90 cm deep to the water, covered with corrugated iron, made of coral rocks and cement border on top, bit salty; said to be part of USGS research

56. //Name removed for reasons of privacy//

photodocumentation: M1111-1115 ; D0815-0823

Abandoned house, two-story with just the framework. No well.

- one medium cement round tank (~170 cm diam., 170 cm tall) with plants in it

- another medium tank of same size, the outside is just corrugated iron but in the inside they lined it with cement, no catchment, not in use, full of dirty water

57. //Name removed for reasons of privacy//
photodocumentation: M1116-1119 ; D0824-0829

Empty lot. No well.

- one cement square cistern (2 m x 2 m, 1m deep), actually looks like a house, with its own roof catchment
- one abandoned small round tank (~diam. 85 cm, 80 cm tall), unused
- one medium cement round tank (~170 cm diam.,170 cm tall), unused

58. //Name removed for reasons of privacy//
photodocumentation: M1150-1165 ; D0832-0847

Abandoned house. Cement and corrugated iron and a *naj* across the path.

- behind the house, built into one corner of the house, a square cement tank (~2 m x 2 m x 2m) receiving catchment from the roof, rusty gutter
- one small round tank connected to the toilet (~diam. 85 cm, 80 cm tall), toilet roof catchment
- one medium cement round tank, cement cap (~180cm tall, 110cm diam), roof catchment, very leaky gutter
- another medium tank, cement cap (~180cm tall, 120 cm diam.), no catchment, towards the jungle, behind the house
- one broken medium tank (~1m diam., 1.8m tall) cement cap, surrounded by trees
- at the *naj* site, there are three tanks: one square cement tank (~1.8m tall, 2x2m) receives overflow catchment from next tank, covered with corrugated iron; one big cement round tank, cement top (~220 cm diam, 180 cm tall), no catchment (disassembled now, so neither of the two tanks is catching); and one abandoned medium tank (~170 cm diam., 150 cm tall), no cover, no catchment, full of trash
- well has a concrete rim, made of mostly cement, coral rock in the bottom, very clean, 150 cm to the water level

Fig 17
One of surprising number of two-story houses.

59. //Name removed for reasons of privacy//
photodocumentation: M1166-1169 ; D0848-0852, 0857

Empty lot. Some graves, many pigs. Little bit further inland there is a ruined house, with just concrete walls left, no roof.

- one broken well, no longer maintained and full of trash

38. **//Name removed for reasons of privacy//**
photodocumentation: M1228-1229; D0956-0963

Concrete house, corrugated iron roof, right at the edge of the taro patch. Three adults, two children. A lot of trash and rotten food around the house, bad smell. No well.

- one big cement round tank, cement top (~220 cm diam, 180 cm tall), roof catchment
- small round cement tank connected to toilet, iron cover, toilet roof catch., rusty gutter
- medium round cement tank (~150 cm diam.,170 cm tall), cement cap, roof catchment
- unused tall cement round tank (~110 cm diam., 220 cm tall), cement cap, no catchment

39. **//Name removed for reasons of privacy//**
photodocumentation: M1236-1240, 1242;
D0977-0986, 0990

Two-story cement and corrugated iron roof. Two adults, no children.

- two big cement round tanks, cement tops with pipes running underground to showering room on the opposite side of the road (~220 cm diam, 180 cm tall), own roof for catchment
- one small round tank connected to the toilet (~85 cm diam., 80 cm tall), toilet roof catchment, no cover
- one medium round cement tank (~150 cm diam.,170 cm tall), cement cap, roof catchment
- at the *naj* across the road, by the lagoon: one small round tank connected to the toilet (~85 cm diam., 80 cm tall), toilet roof catchment, corrugated iron cover and one round cement tank (~110 cm tall, 110 cm diam.), iron cover, roof catchment
-

40. //Name removed for reasons of privacy//
photodocumentation: D1088-1105;
0533-34 [well in section III]

Two cement houses, facing each other across the main path. Three adults, no children. Access to two wells, one pump-operated next to the house, and one in section III of the village. Fish pond built into the platform and seawall by the water.

- one big cement round tank, cement top (~220 cm diam, 180 cm tall), roof catchment, PVC gutter
- one medium round cement tank, cement top (~170 cm diam., 170 cm tall), roof catchment, PVC gutter
- three medium cement round tanks, cement top (~170 cm diam., 170 cm tall), roof catchment, PVC gutter
- one small round cement tank connected to toilet (~85 cm diam., 80 cm tall), roof catchment
- square cement tank, 3m x 2 m x 3m tall, roof catchment
- two big cement round tanks, cement top (~220 cm diam, 180 cm tall), roof catchment, PVC gutter: one is connected to kitchen, one is connected to shower room by PVC tubes
- next to the fish pond one small round cement tank (~90 tall, 120 cm diam), not covered, roof catchment, PVC gutter, used for cleaning
- well located behind the inland house, clean water, no bad smell, not salty, used for cleaning the pigs' area and sometimes used for washing clothes; walled by coral rocks and cement lining near the top; this well is closed so depth cannot be observed; pump is used to extract the water -- one of only two such wells on the island
- also own well in section III, behind house #8, coral rocks and cement wall, partially covered with a piece of plywood, 110 cm to the water level

41. //Name removed for reasons of privacy//
photodocumentation: D1106-1129

Concrete house and *naj*. Six adults, two children. No well.

- one 500 L orange plastic tank in the *naj* area, no cap, roof catchment, PVC gutter, used for washing dishes
- two 1200 L orange plastic tanks in the *naj* area, plastic cap, roof catchment, one used for the washing machine (which runs when generator is running), the other is connected to toilet across the path by the weather station
- across the path by the house, two big cement round tanks, cement top (~220 cm diam, 180 cm tall), roof catchment, PVC gutter, used for drinking
- also by the house, one medium round cement tank (~150 cm diam., 170 cm tall), unused, plants growing out of it
- two round cement tanks (~110 cm diam, 120 cm tall),, cement top, connected to toilet, toilet roof catchment; one 55 gal, no cover, roof catchment, PVC gutter

42. //Name removed for reasons of privacy//
photodocumentation: D1130-1132

Cement and iron roof house. Vacant. No well.

- cement round tank (~220 cm diam, 180 cm tall), cement top, no catchment, unused
- cement square tank, 2m x 2m x 1.5 tall, not covered, full of nasty garbage, dirty water

Section II

16. //Name removed for reasons of privacy// and HFS store

photodocumentation: D0594-0599

Two-story concrete house and the island's only small store (HFS, including a billiard room) across the road. One adult, no children. Four tanks, no well.

- two big cement round tanks, cement top (~200 cm in diameter, 180 cm tall), roof catchment
- one small cement round tank connected to the toilet (~85 cm diameter, 80 cm tall), catching from toilet roof, iron cover
- one medium cement round tank, not covered, no catchment, unused (~170 cm diameter, 170 cm tall)

17. //Name removed for reasons of privacy//

photodocumentation: D0600-0604

Vacant house. Concrete house with corrugated iron roof. Two tanks, no well.

- one medium cement round tank (~170 cm diameter, 170 cm tall), not covered, roof catchment, full of water
- one small cement round tank connected to toilet (~85 cm diameter, 80 cm tall), no catchment, no cover

18. //Name removed for reasons of privacy//

photodocumentation: D0605-0609

Right behind house #18. Concrete house with corrugated iron roof. One adult, no children. Five tanks, no well.

- one big cement round tank in the back of the house, cement top (~220 cm in diameter, 180 cm tall), roof catchment that goes by a PVC tube into the washing area
- one big square cement tank behind the house, open cistern, like a pool (~2.5 m x 1.5m, 0.7m tall), has its own catchment, corrugated iron roof house, part of the washing area
- one small cement round tank in front of thr house, cement cap (~85 cm diameter, 80 cm tall, used for toilet
- one medium cement round tank (~170 cm diameter, 170 cm tall), covered with corrugated iron
- abandoned small round cement toilet tank found across the path

19. //Name removed for reasons of privacy//

photodocumentation: D0610-0618

Concrete house, corrugated iron roof. Three adults, one child. Three tanks, one well.

- one small cement round tank connected to the toilet (~85 cm diameter, 80 cm tall), catching from toilet roof, rusty gutter, not covered
- one medium cement round tank (~170 cm diameter, 170 cm tall), covered with corrugated iron, roof catchment
- one square cement tank, unusual design, built half outside of the house (covered with a metal sheet), half inside the house in the bathroom area (~40 cm tall, 1 m x 1m)
- one old well further away behind the house, right at the beginning of the taro patch, made of cement walls and coral rocks, 1m to the water level, unused, very dirty, full of vegetation

20. //Name removed for reasons of privacy//

photodocumentation: D0619-0623

Vacant house. Concrete house with corrugated iron roof. Three tanks, no well.

- one medium cement round tank (~170 cm diameter, 170 cm tall), not covered, no catchment, completely dry
- one square cement tank (1 m x 1 m x 1m), not covered, dirty water, some trash
- one small cement round tank connected to toilet (~85 cm diameter, 80 cm tall), toilet roof catchment, metal sheet cover

21. //Name removed for reasons of privacy//

photodocumentation: D0624-0630

Abandoned house, completely ruined, no roof, right next to a destroyed building of the church. No well.

- two big cement round tanks, completely destroyed, dry, no top, no catchment
- one small cement round tank connected to the toilet (~85 cm diameter, 80 cm tall), no catchment, not covered, full of dirty water

22. Old destroyed church

photodocumentation: D0631

Ruined building. No tanks, no wells.

23. //Name removed for reasons of privacy//

photodocumentation: D0632-0635

Abandoned house.

- one big square tank, (~160 cm tall, 2 m x 2m), plants growing out of it

24. //Name removed for reasons of privacy//

photodocumentation: D0636-0641

Abandoned concrete house, no windows. Four old tanks, unused. No well.

- big cement round tank, cement top (~220 cm in diameter, 170 cm tall), no catchment
- one small cement round tank connected to the toilet (~85 cm diameter, 80 cm tall), no catchment, not covered
- one cement cube-like tank (~1.5 m x 1.5m, 1m tall), no cover, full of dirty water wth floating algal scum
- one medium cement round tank (~170 cm diameter,170 cm tall), covered with corrugated iron, catching from the house roof

25. //Name removed for reasons of privacy//

photodocumentation: D0642-0646

Concrete house with corrugated iron roof. Four adults, one child. Four tanks, no well.

- one big cement tank (~220 cm in diameter, 180 cm tall), cement top, roof catchment, located in front of the house
- small cement round tank (~85 cm diameter, 80 cm tall), covered with corrugated iron, full of clean water, located in the back of the house, like both of the following tanks
- one abandoned big square tank with plants growing inside (2 m x 2 m x 1.6m tall)
- big cement tank, cement top (~220 cm in diameter, 180 cm tall), roof catchment

26. //Name removed for reasons of privacy//

photodocumentation: D0647-0653

Concrete house with corrugated iron roof. Located on the opposite, inland side of the path from house #25. Two adults, one child. No well.

- One big cement tank, cement top (~220 cm in diameter, 180 cm tall), no catchment (with a strange metal ball decoration on top)
- at the side of the house, one medium cement round tank (~170 cm diameter, 170 cm tall), not covered, catching from the house roof
- one square cement tank attached to the house (~2 m x 2m, 1.2m tall) half outside, half inside the house, getting filled up from the roof
- another big cement tank, cement top (~220 cm in diameter, 180 cm tall), no catchment, unused

27. //Name removed for reasons of privacy//

photodocumentation: D0654-0663, 0973-75; M1087-89 and D0759-60 (tank in section I), M1231-4 and 0677-0680 (well); 1147-49 (*naj* near airport)

Big two-story concrete house and a *naj* across the road. Six adults, three children. Three tanks, one well.

- two rectangular cement tanks next to each other built into the house (~1.5 m tall, x 1.5

m x 1.5 m in the middle of the house, ~4 m x 1.5 m x 1.5m tall used jointly between two houses), both catching from the roof

- there is a small cement square tank (~1 m x 1 m x 1m), receiving water from the first mentioned tank by a PVC tube connected to it (right next to it), open top
- well is right in the middle of the taro patch, concrete platform with coral rocks walls, at the ground level, full of muddy water
- this household also has one big cement round tank (~200 cm diam, 180 cm tall), cement top, own roof catchment, at the *naj* next to house #50 in section I
- the *naj* next to the airport is on this owner's land, there are one small cement round tank connected to the toilet (~85 cm diameter, 80 cm tall), roof catchment, not covered and another big cement round tank (~220 cm diam, 180 cm tall), cement top, no catchment, unused

28. //Name removed for reasons of privacy//

photodocumentation: M1064+D0729-0731 (sect. 1 tank); D 0664-0668, 0670

Concrete house, built on land right behind the *Jinakoke* II. Three adults, no children.

- across the road from the house, there is one big cement tank, cement top connected to the shower room (~220 cm in diameter, 180 cm tall), roof catchment
- in front of the house there is a big cement tank, cement top (~220 cm in diameter, 180 cm tall), roof catchment
- in the back of the house another big cement tank, cement top (~220 cm in diameter, 180 cm tall), roof catchment
- behind the *Jinakoke* II, next to house #27 is the well belonging to this household, very deep, with concrete lining, clean water, bit salty, depth 190 cm

28b. *Jinakoke* II

Chapel for residents of section II. No tank, no well.

29. //Name removed for reasons of privacy//

photodocumentation: D0669, 0671-0676, 312, 0971-72 (well)

Concrete house. Two adults, one child.

- one big cement tank, cement top (~220 cm in diameter, 180 cm tall), roof catchment, metal gutter
- one small cement round tank (~85 cm diameter, 80 cm tall), not covered, full of water, used for the pigs
- well is behind the house, by the taro patch, made of coral rocks and cement foundation at the top, water level is the same as ground level, moss growth, dirty water (during dry season they use it for the pigs and for cleaning after working in the taro patch

30. //Name removed for reasons of privacy//

photodocumentation: M1178-1182; D0866-0871

Concrete and corrugated iron roof house, next to *Jinakoke* II. Two adults, two children. No well.

- two medium cement round tanks (~170 cm diameter,170 cm tall), roof catchment, metal gutter (one of the two is cracked, metal underneath is visible), not covered
- cement round tank (1.1m diameter, (~1m tall), roof catchment, metal gutter, no cover

31. //Name removed for reasons of privacy//

photodocumentation: M1183-1190;1241; D0872-0881; 0987 (tank by #39)

Concrete and corrugated iron roof house. Two adults, one child.

- one big cement round tank, cement top (~220 cm diam, 180 cm tall), roof catchment, rusty metal gutter
- another cement round tank, cement top (~220 cm diam, 180 cm tall), but no catchment
- one small round tank, cement cap, connected to the toilet (~120 cm diameter, 80 cm tall), toilet roof catchment
- one big square cement cistern (~1.5 m x 2 m x 1.5m deep) connected to the washing area, half of it inside the room, the other half open but covered with corrugated iron, roof catchment, very rusty gutter
- one medium cement tank next to *naj* of house #39 (~150 cm diameter,170 cm tall), iron cover, boat roof catchment

32. //Name removed for reasons of privacy//

photodocumentation: M1191-1193; D0882-0888

Vacant house. Cement and corrugated iron roof house, with a grave in the front.

- two cement round tanks (~120 cm diam, 170 cm tall), one of them catching from the roof with a very rusty gutter, the other one has no catchment
- one small round tank connected to the toilet (~85 cm diameter, 80 cm tall), toilet roof catchment, rusty gutter, no cover
- one square cement tank (1.5 x 1.5 x 1.5 m), covered with iron, no catchment

33. **UCCP Church** (Congregation of the United Church of Christ, Pohnpei)

photodocumentation: M 1194; D0889-0897

Two two-story cement building. No well.

- big square cement tank (~1.8 m x 1.8 m x 1.8m), roof catchment, rusty metal gutter
- one big round cement tank (~220 cm diam, 180 cm tall) getting catchment from the roof of the building attached to the church

34. //Name removed for reasons of privacy//

photodocumentation: M1195-1211; D0898-0916, 0964-65 (well)

Two-story cement and corrugated iron roof house. Detached cooking house across the path, next to the church. Two adults, four children. Two wells.

- one medium round cement tank (~170 cm diameter, 150 cm tall) in the back of the house, cement cover, roof catchment

- big cement round tank in the back of the house, cement top (~200 cm diam, 170 cm tall), roof catchment
- one small round toilet tank, iron cover, no catchment, not in use
- another two small round tanks, (~85 cm diameter, 80 cm tall), iron cover, toilet roof catchment, rusty metal gutter
- two big cement round tanks, cement top (~200 cm diam, 170 cm tall), one of them catching from the roof (used for cooking) but the other is unused, with no catchment
- well is made of coral rocks with cement blocks on top (border), cement cover, 200 cm deep, clean water
- an additional well is in the taro patch area and does not look like a well, but a hole in the ground with water level same as the level of mud in the surroundings

35. //Name removed for reasons of privacy//

photodocumentation: M1212-1217; D: 0917-0931

Concrete house, corrugated iron roof. Detached cooking house across the road. Three adults, three children.

- one big cement round tank connected to the shower, cement top (~240 cm diameter, 180 cm tall), roof catchment
- one medium round cement tank (~170 cm diameter, 170 cm tall), cement cover, roof catchment
- well built into the shower room, metal cover, very clean water, extract the water with a pump (they use it for drinking during emergencies), 170 cm deep to the water level
- the cooking house is across the upper path, church road
- another big cement round tank, cement top (~240 cm diam, 180 cm tall), catching from cook house roof
- one small round cement tank connected to the toilet, no cover, toilet roof catchment, metal rusty gutter
- two small round tanks connected to toilets (~85 cm diameter, 80 cm tall), iron cover, toilet roof catchment, rusty metal gutter

36. //Name removed for reasons of privacy//

photodocumentation: M1225 (well); D0932-0933, 0949-0953 (well)

Empty lot between houses #35 and #37.

- one big cement round tank, cement top (~240 cm diam, 180 cm tall)
- one medium round cement tank (~150 cm diameter,170 cm tall), no cover
- well behind house #37, walled by coral rocks (like blocks) and cement near top, with three long pipes (used for research, same as wells at school and by house #55), corrugated iron cover, dirty water, full of trash, unused

37. //Name removed for reasons of privacy//

photodocumentation: M1218-1224; D0934-0948;
M1243-5 and D0988-9 (tanks next to #39 *naj*)

Two abandoned concrete houses.

- one big square cement tank, 2.2m tall, 2.2 x 2.2m, metal cover, dirty water, no catchment, unused
- one medium round cement tank (~150 cm diameter,170 cm tall), no cover, no catchment, unused
- one big cement round tank, no cover (~220 cm diam, 180 cm tall), no catchment
- one medium round cement tank connected to toilet (~100 cm diameter, 170 cm tall), no cover, no catchment, unused
- same owner has two tanks next to *naj* at house #39: one big cement round tank, cement top (~220 cm diam, 180 cm tall), roof catchment and one small square cement tank, 1.2 m x 1.2 m, not covered, no catchment, full of dirty water

Section III

0. Airstrip

photodocumentation: D1150

Small office house next to the runway. A public toilet nearby.

- 1200L orange plastic tank, plastic cap, roof catchment, PVC gutter -- connected to the public toilet

1. //Name removed for reasons of privacy//

photodocumentation: M95, 0993-0994; D114-117, 0486-0496

Concrete house with corrugated iron roof. *Naj* across the road. Two adults, three children. Four tanks, one well.

- one round cement tank, 580 cm circumference, 170 cm tall, covered with corrugated iron, roof catchment, used for drinking, showering and dishes
- one big round cement tank, cement top, 700 cm circumference, 180 cm tall, roof catchment, used for drinking, showering and dishes
- one small round cement tank used for the animals, circumference 180 cm, 85 cm tall, no cover, no catchment
- one small round cement tank connected to toilet (circumference 150 cm, 85 cmm tall), no cover, catching from toilet roof, corrugated iron sheet as gutter
- well is not covered, made of coral and cement, clean, no bad smell, 140 cm depth, primarily used for laundry and dishes

2. //Name removed for reasons of privacy//

photodocumentation: M0995-1005; D0497-0505

Two houses in the same household, sharing the same water. One concrete house with corrugated iron roof and one thatched roof house across the road by the lagoon. Four adults and four children. Five tanks and two wells.

- one big round cement tank (circumference 960 cm, 180 cm tall) with cement top, roof catchment, mostly new gutter
- one small round cement tank (circumference 180 cm, 85 cm tall) connected to toilet,

receiving catchment from toilet roof, iron cover

- two same size round cement tanks (circumference 660 cm, 170 cm tall), both used for showering and drinking, catch water from house roof, rusty corrugated iron cover, leaky gutter
- one small round cement tank, connected to toilet, no cover, catching from toilet house roof (circumference 152 cm, 90 cm tall), rusty and leaky gutter
- both wells are used just for the animals; one is made of coral rocks and cement, 50 cm depth, not covered, moss growth, good condition, pretty clean and a bit salty; the other well is made of coral rocks, 140 cm deep, not covered, moss growth, surrounded by grass, also a bit salty, it looks less clean than the first one

3. //Name removed for reasons of privacy//

photodocumentation: M1006-1023; D0506-0523

Two houses in the same household, sharing the same water. Both houses are made of cement with corrugated iron roof and there is a *naj* across the road by the lagoon. Two adults and three children, all live in the first house. The second house is vacant. Eleven tanks and one well.

- one small cement round tank (150 cm circumference, 85 cm tall), corrugated iron cover, connected to toilet, catching from toilet house roof, very rusty and leaky gutter
- another small round cement tank located right next to the vacant house (150 cm circumference, 85 cm tall), not covered, connected to toilet, receiving catchment from toilet roof, leaky gutter
- round cement tank, with cement top used for shower and drinking (circumference 500 cm, 180 cm tall), catches water from house roof, gutter is mostly new
- one round cement tank used for shower, drinking and dishes (circumference 470 cm, 180 tall), cement top, house roof catchment, mostly new gutter
- one big cement round tank mainly used for drinking (circumference 1000 cm, 180 cm tall), cement top, house roof catchment, mostly new gutter
- another small cement round tank connected to the toilet (circumference 150 cm, 90 cm tall), no covered, toilet roof catchment, leaky gutter
- two more big concrete round tanks of 1000 cm in circumference, 180 cm tall), both have cement tops, no catchment, not in use
- one square cement tank (130 cm x130 cm x 100 cm tall), used mainly for the washing machine, has its own roof which is used for catchment
- one rubber drum (circumference 270 cm, 110 cm tall), not covered, no catchment, dirty water, used for the pigs
- one square cement tank used for drinking and cooking (150 cm x 150 cm, 200 cm tall), built inside of a wood and corrugated iron roof house, catching from boat house roof, OK gutter
- well is located very near behind the house, made of coral rocks and cement blocks edge, good condition, clean, not salty, mainly used for the animals, depth 80 cm

4. *Jinakoke* III

photodocumentation: M1024-1026

Chapel for residents of section III. One tank, no well.

- Big cement round tank, cement top (270 cm diameter, 180 cm tall), no catchment, not in use

5. Dispensary

photodocumentation: D####-####

Concrete house used as clinic for the island residents. One tank, no well.

- Big cement round tank, cement top (320 cm diameter, 180 cm tall), roof catchment, mostly new gutter

6. Municipal storage building

photodocumentation: M1027-1029; D0525

Storehouse on the edge of the water. One tank, no wells.

- large cement round tank, cement top (280 cm diameter, 180 cm tall), roof catchment, mostly new PVC gutter

7. //Name removed for reasons of privacy//

photodocumentation: M1030-1032

Two-story cement, corrugated iron roof house. Three adults, two children. Three tanks, no well.

- one big cement round tank, cement top (~280 cm in diameter, 180 cm tall) roof catchment, PVC gutter supported by a wooden stick
- one small cement round tank, (85 cm diameter, 80 cm tall), connected to toilet, catching from toilet house roof
- one big cement round tank, no catchment, no cover

8. //Name removed for reasons of privacy//

photodocumentation: M1033; D0526-0532

Concrete house with corrugated iron roof, boat house across the road. Three adults, one child. Four tanks, one dry well.

- one big cement round tank, cement top (~280 cm in diameter, 180 cm tall) roof catchment, metal gutter supported by a wooden stick
- one medium cement round tank, rusty corrugated iron cover, ~140 diameter, 170 tall, roof catchment, metal gutter
- one small cement round tank, (diameter 85 cm, 80 cm tall), no catchment, no cover
- one square cement tank (~1 m x 1 m x 1m) with plants growing out of it
- well is completely dry, with some garbage, covered with rusty corrugated iron, 110 cm deep

9. //Name removed for reasons of privacy//
photodocumentation: D0535-0540

Concrete house with corrugated iron roof. Two adults, two children. Three tanks, no well.

- one big cement round tank, cement top (~250 cm in diameter, 180 cm tall) roof catchment, rusty metal gutter
- one small cement round tank (85 cm diameter, 80 cm tall) connected to toilet, toilet house roof catchment, metal gutter
- another small cement round tank (85 cm diameter, 80 cm tall), no catchment, no cover, plants growing out of it

10. //Name removed for reasons of privacy//
photodocumentation: D0541-0544, 0547-0548

Vacant house. Concrete house with corrugated iron roof. Four tanks, no well.

- one medium cement round tank, no cover, no catchment (~150 cm diameter, 170 cm tall)
- another medium cement round tank, no cover, no catchment (~150 cm diameter, 180 cm tall
- one small cement round tank (85 cm diameter, 80 cm tall) connected to toilet, no catchment, full of water
- one orange plastic tank, plastic cap, 1200L volume, roof catchment, OK gutter

11. //Name removed for reasons of privacy//
photodocumentation: D0545-0546

Vacant house. Concrete house, cement roof. Two tanks, no well.

- one big cement round tank, (~200 cm in diameter, 170 cm tall), no cover, no catchment
- one medium cement round tank, no cover, no catchment (~130 cm diameter, 160 cm tall)

M. Municipal office

Two-story concrete building. One tank.

- Large pool-shaped cement tank on the second floor (6 m x 3 m x 1 m)

12. //Name removed for reasons of privacy//
photodocumentation: D0549-0556

Vacant house. Concrete house with corrugated iron roof. Three tanks, no well.

- Two medium cement round tanks (~150 cm in diameter, 160 cm tall), no cover, no

catchment
- one small cement round tank (85 cm diameter, 80 cm tall) connected to toilet, no catchment, full of dirty water

13. //Name removed for reasons of privacy//

photodocumentation: M1034-1035; D0562-0569

Concrete house with corrugated iron roof. Five adults, one child. Six tanks, one well.

- one small cement round tank connected to toilet (~85 cm diameter, 80 cm tall), no catchment, no cover
- two big cement round tanks, cement top (~220 cm in diameter, 170 cm tall) roof catchment, metal gutter
- one medium cement round tank, not covered, (~110 diameter, 150 tall), roof catchment
- one medium cement round tank, not covered, no catchment (~150 cm diameter, 170 cm tall)
- one big cement round tank, (~200 cm in diameter, 170 cm tall), no cover, roof catchment
- well is made of coral rocks with a block border, dirty, moss growth, 120 cm deep

14. //Name removed for reasons of privacy//

photodocumentation: D0570-0576

Abandoned cement and corrugated iron roof house. Three tanks, no well.

- one medium cement round tank, not covered, roof catchment (~150 cm diameter, 170 cm tall
- one square cement tank, 2 m x 2m, 2m tall, has its own roof, extremely dirty water, lot of trash
- one small cement round tank connected to toilet (~85 cm diameter, 80 cm tall), no catchment, iron cover

15. //Name removed for reasons of privacy//

photodocumentation: M1039; D0577-0593

Concrete house. Three adults, no children. Five tanks, one well.

- two big cement round tanks, cement top (~200 cm in diameter, 180 cm tall), roof catchment, new gutter
- one medium cement round tank (~150 cm in diameter, 170 cm tall), cement cap, receiving water by a PVC tube connected to one of the previous big round tanks
- one small cement round tank connected to toilet (~85 cm diameter, 80 cm tall), no catchment, no cover
- one square cement tank, 240 cm x 480 cm, 180 cm tall, roof catchment
- well is walled by cement, corrugated iron cover, a bit dirty

Rainwater catchments

Summary of conditions

Catchment

Rain is typically captured by corrugated iron rooftops. The size of catchment areas vary widely. Their upper limit is defined by the total roof area of a house and availability of suitable material. Areas can be as small as a few square meters, as is the case with rooftops of outdoor toilets. This is deemed sufficient as they collect water only for toilet-flushing purpose. In some cases, where minor quantities of water are required, small isolated metal sheets are positioned to catch water.

During the survey, we have observed that only limited portions of available areas (roofs, etc.) are guttered, which diminishes their effectiveness to capture water.

Transfer

From the roof (or other metal sheet), water flows down slope across the surface and reaches metal or plastic gutters at the lower edge. It enters the gutters and continues to flow down gradient within them. The gutters transfer the water into storage tanks. The condition of gutters varies, but most are quite leaky and rusty and prone to water loss. For that reason, tanks are placed as close to the catchment area to minimize water loss due to gutter leakage and to save on materials.

Storage

Fig 18 (opp.) **Examples of water catchment systems on Mwoakilloa.**

Traditional cisterns made of coral rocks and quicklime (heated pulverized coral mixed with water and resembling cement) used to exist on Mwoakilloa in the past. We did not see remnants of such structures but were told by many people that their 'grandparents used to make them'. They must have appeared similar to rectangular tanks made of concrete that we have

a

b

c

d

e

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h

observed built-in into many houses. Not all, but a substantial number of households have such tanks. Some of them have open top surface and look like pools, accessible from within the house. These tanks were custom-made by the owners at the time houses were built. They occur in various dimensions and volumes and represent unique type of water storage tanks rarely seen on FSM atolls. The authors have considerable experience in the Outer Islands and have observed this type of tanks only on Mwoakilloa and Pingelap.

Some of the earliest imported containers were brought from Nauru, by Mokilese who were originally recruited to work in phosphate mines there. Since that time, a variety of water storage tanks were brought to Mwoakilloa by individual families and include those made of fiberglass, PVC, and stainless steel. The most commonly observed units, however, are cylindrical (mostly called 'round' in this document) tanks made of ferro-concrete (mostly called 'concrete' in this document). The majority of them were created via project by governmental agency CAA (Community Action Agency), which supplied material (metal sheets, cement, piping, etc.) needed to build tanks. CAA also provided toilet seats. People on the island performed the labor and built a large number of medium and small tanks, many of which became toilet-flushing tanks. This was most likely done following the drought in 1983. In addition, Pohnpei State Government entity TNI (Office of Transportation and Infrastructure) provided many large round tanks, which are mostly used for storing drinking water. Before so many round tanks appeared on the island, households that did not have the older rectangular tanks had to share drinking water with family or neighbors with appropriate tanks and had to rely on well groundwater for most of their non-drinking water needs.

Today, many families still prefer rectangular tanks built into homes, accessible from within and unobserved from the outside. They are found only in the older houses. Round tanks, usually more than one, are possessed by all households and are readily visible around individual compounds. The capacities of rectangular tanks vary between 250 gallons and 3000 gallons. Round tanks come in three broad size categories, of 130-150, 500-900, and 1700-2500 gallons, but also include a few larger units and many 55 gallon drums, which are the smallest meaningful containers.

Cleaning

Large tanks are cleaned annually or biannually, usually when people start feeling a strange flavor to the water or when water level is low and the rainy season is coming. Round tanks are drained and are entered by a person through a small opening at the top. The person washes the interior with bleach, scrubs the inner walls, and rinses the tank with clean water. The work takes and entire day. Square tanks do not have drains so they must be emptied using buckets in order to be cleaned. This is also said to be very difficult work. Smaller tanks are generally not cleaned because they are not used for storage of drinking water.

Summary of sites

Public rainwater catchment sites

The only public water sources on the island are at the elementary school and municipal office, both of which have own rainwater catchment systems. The school has possibly the largest water tank on the island, holding over 6000 gallons when full. The municipal office has a tank holding 4800 gallons and the dispensary has another very large tank, holding 3800 gallons. Several other tanks are available at the school and the church building. These tanks normally satisfy the needs of people working in and visiting public buildings and children during school time, but can also provide water for any residents in need.

Other major rainwater catchment sites

Individual households maintain their own water tanks. On the main island, Kahlap, there are over a dozen significant private rainwater storage sites with large-volume tanks; and there numerous smaller sites. The largest tanks are rectangular tanks built into individual homes and containing up to 3000 gallons of water. This volume is approached by the largest cylindrical ferro-concrete tanks. Families with major tanks are expected to assist their relatives and neighbors by sharing water with them during drought episodes.

Minor rainwater catchment sites

In addition to permanent rainwater catchment sites, residents of Mwoakilloa rely on numerous small containers to make impromptu catchments as they are needed. These utilize 55-gallon drums, PVC containers and smaller vessels for storage.

Abandoned sites

During our household survey it quickly became evident that a large number of homes on Mwoakilloa are not inhabited. Some appear to have been vacant for relatively short periods of time -- from a few months to a few years -- but others are clearly abandoned and have not been kept up for many years. By extension, the water storage tanks possessed by such households are also abandoned and left to decay. Many such tanks could be cleaned, repaired, and put to good use.

Fig 18 (opp.) **Continued. Examples of water catchment systems on Mwoakilloa.**

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Abandoned households

One third of households in Mwoakilloa were vacant or abandoned during the survey.

Considering that all households on the island include a concrete house and one or, more commonly, several water tanks, this means that a huge amount of living space and water storage potential is wasted. In addition, the lack of maintenance at various sites, including some that have been neglected for very long periods (many years), means that they have become hazardous to the surrounding community. They are physically risky locations for children and youngsters to frequent, they are visually detrimental to the island and psychologically harmful to the community, and -- what is most relevant to the topic of this report -- they represent serious health hazards through accumulation of organic and solid waste and stagnant polluted water.

We have observed tanks filled with cesspools of polluted water, floating scum, and various organic waste. They enable completion of the life cycle of mosquitoes and possibly other vectors of contagious diseases.

In addition to numerous tanks in abandoned households, there are also many tanks that have fallen into disuse for no apparent reason. Some inhabited houses have tanks located in immediate vicinity but unconnected to any catchment area, opened at the top and allowed to accumulate rainfall that is never used.

One third of households on the island are vacant or abandoned.

Fig 19
Examples of cesspools in water tanks of abandoned households.

Wells and groundwater

Summary of conditions

Residents of Mwoakilloa use captured and stored rain water for all their daily needs. In general, groundwater sees regular use only for watering domestic animals and for washing laundry in a few households. As a result, the island has relatively few groundwater wells and the majority of households lacks them altogether. In addition, the wells are poorly maintained overall. People tend to clean them only when water volumes stored in tanks decrease during droughts. At such times, they turn to groundwater for doing laundry, showering, and washing the dishes until ample rainfall resumes.

Summary of conditions

a) Appearance

We recorded two dozen wells on Kahlap islet. Most of them are shallow and similarly constructed, having been dug up by hands and stabilized by coral rock walls. Nevertheless, they are quite variable in appearance due to different maintenance history. They may or may not be covered. If covered, it is by wood or metal sheets. This is done to prevent debris and small animals from falling in. Some well openings are surrounded by a concrete platform for ease of access.

Water level in all hand dug wells changes with tides. In wells around the taro patch, it also changes visibly as a result of annual cycles and is higher in the rainy season.

Fig 20 (opp.) **Investigating wells on Mwoakilloa.**

There is a driven well not far from the school site. Two additional driven wells were discovered. Residents do not have much information regarding these wells and do not use them. They are actually a remnant of work by Stephen Anthony, from the United States Geological Survey (USGS), who installed them in 1988. Each well has three metal pipes sticking out of the bottom

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d

-- essentially a cluster of three separate wells bracketing the freshwater lens at different depths. They used to be operated using pumps, which were later broken and removed, so the wells currently see no use. We could not locate the other driven wells made by USGS. Six were supposed to have been drilled around the taro patch. Residents report that this had some effect on the taro patch and interpret the wilting of the taro around the patch perimeter to be a consequence of well drilling.

b) Lining

Hand-dug wells are all similarly constructed. The walls are generally lined by piles of small coral heads. Some of them are better fitted than the others and make for a more stable structure. In a few wells, we could see that the rocks were cut and fitted to create tight and stable walls. In addition, cement is added to the walls of the well to strengthen the structure, especially in the topmost parts. Two wells were seen to have fully concrete linings down to the water level.

c) Extraction

Water is taken from wells by buckets tied to a rope and pulled by hand. Only two wells are equipped with working electric pumps. Three additional wells were built for pump extraction, but are no longer operable.

d) Cleanliness and water quality

Residents consider the groundwater to be of bad quality. It is said to taste salty, especially in wells near the shore, and less so in the wells near the taro patch. Well water is practically never consumed, with only a few people occasionally taking sips when they are very thirsty while working outdoors. We have seen that many wells have water of bad smell and obvious microbial contamination. This is likely a reflection of lack of cleaning and maintenance at specific well sites rather than the general state of groundwater.

Summary of sites

a) Public wells

The only well built on public property is a drilled well found on the premises of Mwoakilloa elementary school. It has an inoperative pump, previously attached to solar panels (still standing). The well is not used.

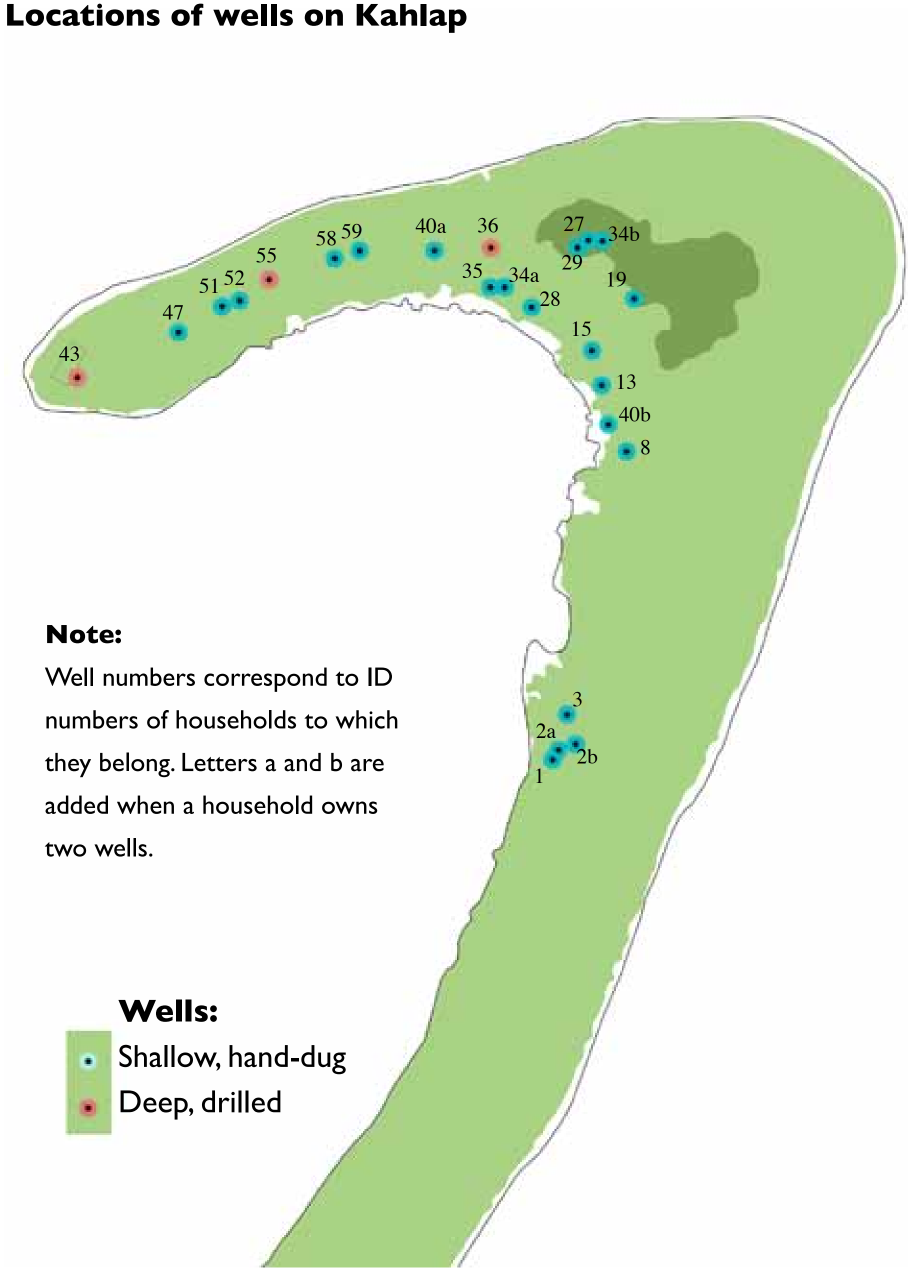
b) Private wells

We located 23 private wells on Kahlap, of which very few experience regular use (see Map 5 and Table 8).

c) Abandoned wells

Several collapsed, filled in, and abandoned wells were documented (see Table 8).

Locations of wells on Kahlap



Map 5 Locations of wells on Kahlap, Mwoakilloa's main islet. Map is based on a survey completed in May 2008.

Household	Ownership	Use	Type	Depth to water
1	private	washing clothes, dishes	SHD	~ 140 cm
2a	private	for animals only	SHD	~50 cm
2b	private	for animals only	SHD	~140 cm
3	private	for animals only	SHD	~80 cm
8	private	none, abandoned, dry, full of garbage	SHD	~110 cm
13	private	infrequent, dirty	SHD	~120 cm
15	private	occasional, clean	SHD	~100 cm
19	private	none, abandoned, plants growing inside	SHD	~100 cm

Table 7 Summary and specifications of wells on Mwoakilloa, in the order of ID number of household to which they belong.

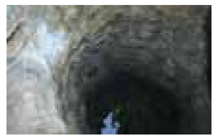
Type key:
SHD-shallow hand-dug well
DR-drilled well.

Wall lining	Cover	Extraction	Condition	Photo
cemented coral rocks	none	hand-pulled bucket	VG	
cemented coral rocks	none	hand-pulled bucket	VG	
coral rocks	none	hand-pulled bucket	G	
coral rocks, cement blocks	none	hand-pulled bucket	G	
coral pile	iron sheet	none	B	
coral rocks, cement blocks	none	hand-pulled bucket	B	
all cement wall	iron sheet	hand-pulled bucket	G	
cemented coral rocks	none	none	B	

Condition key:
VG-very good, quality lining, maintained, clean, no or little debris; G-good, reasonable lining, maintained, usable water, some debris; B-bad, unsuitable or decaying well lining, not maintained, water not usable, filled with debris and/or sand.

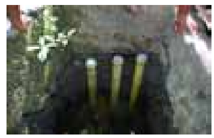
Household	Ownership	Use	Type	Depth to water
27	private	washing in taro patch	SHD	~10 cm
28	private	occasional, clean	SHD	~190 cm
29	private	washing in taro patch	SHD	~10 cm
34a	private	occasional, clean	SHD	~200 cm
34b	private	washing in taro patch	SHD	~0 cm
35	private	regular, all but drinking and even drinking in emergency	SHD	~170 cm
36	private	none, full of trash	DR	
40a	private	fairly regular, for washing pigs' area and clothes sometimes	SHD	
40b	private	occasional	SHD	~ 110 cm
43	public	none	DR	

Table 7 Continued

Wall lining	Cover	Extraction	Condition	Photo
coral, concrete foundation	none	at ground level	G	
cement wall	none	hand-pulled bucket	G	
coral, concrete foundation	none	at ground level	G	
coral rocks, cement blocks	concrete cap	hand-pulled bucket	G	
coral pile, mud	none	at ground level	B	
concrete, built inside house	indoors	pump (working)	G	
fitted blocks, cement	iron sheet	pump (broken)	B	
could not be observed	plywood	pump (working)		
coral rocks, cement at top	plywood	hand-pulled bucket	G	
		pump (broken)		

Household	Ownership	Use	Type	Depth to water
47	private	for animals only	SHD	~150 cm
51	private	washing clothes, dishes	SHD	~90 cm
52	private	occasional	SHD	~100 cm
55	private	none	DR	~ 90 cm
58	private	occasional	SHD	~150 cm
59	private	none	SHD	full of trash

Table 7 Continued

Wall lining	Cover	Extraction	Condition	Photo
coral rocks, cement at top	none	hand-pulled bucket	B	
coral rocks, cement blocks	indoors	hand-pulled bucket	VG	
coral rocks, cement at top	plywood	hand-pulled bucket	G	
fitted blocks, cement	iron sheet	pump (broken)	B	
cement, coral at the bottom	none	hand-pulled bucket	VG	
coral rocks, cement blocks	none	none	B	

Natural discharge

We have not observed natural freshwater discharge on the main islet. Nevertheless, coastal springs are a familiar concept on Mwoakilloa. The residents call it *pil kujkuda* and report that one exists on Urak islet. This is unusual, as atoll beaches in Micronesia generally lack visible freshwater discharge.

Surface water

Surface water is regularly seen only within taro patches. They are excavated and maintained as to have water accumulations required for cultivation of wetland taro (*Cyrtosperma* and *Colocasia*). Other than the taro patches, there are no real surface water bodies.

Ephemeral puddles form during heavy rainfall. This is commonly observed on the paved going through the village. It is partly cemented and generally well trodden throughout, making the surface there less permeable. It is also largely lined with concrete curbs on both sides which contains pooled water.

Fig 21 (opp.)
Part of the taro patch in the interior of Kahlap islet.

Water and way of life

Water usage patterns

Drinking and cooking

Captured rain is almost exclusive source of water for drinking, cooking, and dishwashing. Groundwater is never used for these purposes. Residents consider it to be unfit even as an emergency drinking water source during droughts. They report that it has been boiled and consumed in the past but has a salty taste.

People drink water directly from storage tanks and do not treat it in any way. Cooking typically takes place in a kitchen built as part of a house or an outdoor kitchen that is part of the *naj* complex. The same area or an adjacent place is also used for washing dishes. Minor cooking, such as rice or coffee is done using kerosene. Larger things are prepared on open fire or in a ground oven (*uhm*) by burning wood.

Other sources of hydration

Water content of fruits used in the local diet are an additional source of hydration. Juicy fruits, such as papayas and citrus, provide water and nutrients when regularly consumed. Coconuts, however, are by far the most important. They grow year-round, bear abundant fruit, and contain around 300 ml (10 fl. oz.) of liquid that is an excellent source of water and electrolytes. Ample supply of coconuts can sustain proper hydration even if no other sources are available.

Coconuts are plentiful on Mwoakilloa and are regularly but not intensively used for drinking. There are different cultivars (varieties). Some are sweeter than others, and some grow on shorter trees. Residents report consuming less than one coconuts per individual on an average day and perhaps 4-5 per week. The actual number depends on personal preference and also ability to climb trees. In the words of one of our informants, "There is no limited amount of coconuts, it's just that it's hard to get them." Coconuts are, therefore, not conserved and palms are said to produce just as many nuts as in the past. Children may consume more coconuts than adults. In general, everyone drinks far more water than coconut juice. In addition, water-based powdered drinks such as instant coffee and Tang® are the most popular, but rarely available. More common is a drink called *limpoak*, also known as the 'local coffee' and made of breadfruit seeds (*maipah*).

Coconuts are used a lot in celebrations and meetings, and are readily brought to visitors. Nevertheless, although coconuts can be an important component of usual hydration and even coooking needs of islanders, it cannot be considered an alternative to safe drinking water and definitely not a reliable emergency source. This is because water shortages are typically caused by droughts and storms, which also affect coconuts.

Fig 22 *(opp.)* **Sink next to a roofed storage tank.**

Prolonged droughts are known to gradually reduce quantity or quality of nuts. Major storms can virtually eliminate standing crop of coconuts in an instant. Residents report that major storms damage almost every coconut palm and drinking nuts cannot be found for several months afterward.

Showering and laundry

Water for showering, bathing and washing laundry is generally taken from rainwater storage tanks. It is used directly and is not treated in any physical or chemical way. In most cases, tanks that provide water for these purposes are different from those used for drinking water. They tend to be cleaned less often and may have more decayed catchment and transfer components.

Showering and bathing is usually done in a bathroom that is fully enclosed as part of a house, or attached to a house as a separate but well enclosed shower room located next to its source water tank. In general, these bath areas are constructed of concrete blocks and/or metal sheeting. Elevated tanks are rare, so most bathing is done using buckets of water. The same area is typically used for washing of laundry, which is then dried on lines strung adjacent to homes.

Washing off after work in the taro patch is usually done using water from one of the wells located around the taro patch perimeter.

Water for animals

Animals are watered using either rain or groundwater. In fact, groundwater on Mwoakilloa sees regular use only as water source for animals. Pigs also utilize ephemeral ponds after heavy rains as wallows.

Fig 23 (opp.) **Illustrations of lifestyle and water use by Mwoakilloa residents.**

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g

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Fig 23 Continued.
Illustrations of lifestyle and water use by Mwoakilloa residents.

Water issues

Residents report that they sense a risk of fresh water shortage when the level of water in their tanks drops to one-half full. At that time, residents respond to the situation by modifying certain daily water consumption practices. They reserve the stored rain water only for high priority needs: drinking and cooking. Lower priority needs are relegated to groundwater sources. Washing of laundry and showers are performed using water from the wells. Families with no wells access well water available at their neighbors or relatives. It is generally only at such times of water shortages that the wells are cleaned of vegetation and other accumulated waste.

Modified water consumption behavior allows water crisis to be delayed somewhat, but not averted if absence of rainfall continues. If crisis level is reached, sharing of water between the compounds is increased, part of demand is transferred to public sources, and usage minimized to vital purposes only. Despite change of behavior, individual households have been known to run out of water completely.

Perceptions

With exception of a few households that have a lot of water tanks, the residents have expressed feelings that there is not enough fresh water on the island. They agree that water should be carefully used and not wasted. On the other hand, the fact that so many available storage tanks are not cleaned and used -- at least as emergency supplies -- seems to indicate that there is ample water most of the time. Therefore, it appears that island residents are not worried about water quantity overall and at normal times, accept unreliable supply as inevitable, and are not properly prepared for severe shortages.

Shortages

Individuals we interviewed stated that most drinking water tanks will be reduced from full to half-full if there is no rain for about one month. At that point, water is conserved in previously described fashion and part of the demand is shifted to public sources (tanks at the municipal office and school) and wells.

Thanks to conservation measures, the second half of water in tanks lasts longer than the first half of the total volume. Nevertheless, if drought continues households do run out of potable water completely. Drinking water needs cannot be shifted to groundwater because of its generally perceived poor quality. Everyone on the island agrees that well water cannot be used for drinking, even in emergencies and even if boiled.

It is important to note that there is a large difference in storage capacity between individual households. Some large families have no more than two functioning tanks, whereas in other households smaller families have access to seven or eight tanks. Therefore, some families must begin to conserve water after only two weeks without rain, whereas others do not need to modify their water usage until no less than a month without rain.

During severe droughts, Pohnpei State has to bring fresh water to the atoll by ship. This has occurred several times but two specific events are generally recalled: one in 1983 and one during the past decade. At such times, residents go out in their own outboard-equipped fiberglass boats to the supply ship outside the lagoon and receive water. In general, there are 17 to 18 private boats and 2 to 3 municipal boats available. Water is received from the main ship, decanted into small containers, and ferried back to the island. This is said to be very difficult work.

Interestingly, during the most recent crisis, a very large rectangular tanks from an abandoned household was left in good shape and still filled with potable water. The residents used water from that tank during the drought. That supply outlasted the drought so that the relief water delivered by ship never was never actually used. This anecdote confirms our observations that the current rainwater catchment system is sufficient to collect and store enough water to meet the needs of the local people during most of the time. During periods of droughts, individually owned supplies may and do become exhausted, but public and abandoned or unclaimed sources could provide the needed relief. This is only possible if such sources are cleaned, maintained, and conserved as contingency reserves.

Quality

Drinking water quality is not perceived as problematic. People drink water only from the tanks that are properly covered by screens to avoid leaves and other contaminants from entering. Quality of water also depends on the cleanliness of roof catchment area. Many roofs are very rusty and impart a metallic taste to water. Water from properly fitted and well maintained tanks is not treated in any way before consumption and is said to be of fine quality.

Health problems

No water-related health problems were reported to us, other than occasional stomachaches and diarrhea when water is consumed from a tank that needs to be cleaned. Cholera epidemics were known in the past, but such island-wide crises did not occur in the past 20-30 years. Individual health issues are generally not linked to water. Minor problems are handled by local dispensary, whose staff occasionally calls doctors in Pohnpei for advice. Serious personal health issues are cause for evacuations to Pohnpei hospital by CIA flight or FSM patrol boat.

Agriculture, animal husbandry, and fishing

Residents of Mwoakilloa engage in agriculture and keep animals for subsistence. Agriculture is not intensive and is based on sustained modification and maintenance of parts of the natural ecosystem. The key source of plant foods are 1) agroforest, which is a maintained garden of trees and useful plants in the vicinity of households; and 2) taro patches, which are natural or man-made depressions where wetland conditions allow cultivation of taro*. The rest of the island is covered by atoll forest and coastal scrub vegetation. Main sources of animal foods are fish and other edible marine organisms and domestic animals.

Agroforestry

Areas in the vicinity of households is covered with agroforest. It contains coconut, breadfruit, banana, papaya, lemon, pandanus, and other useful plants.

Trees are highly susceptible to storms. Typhoons regularly break down large trees. Residents lament that large breadfruit trees were plentiful in the past but are relatively few nowadays. The estimate is that there are more than 10 but fewer than 100 truly large breadfruit trees on Kahlap. Coconut trees are quite numerous on both lagoon and ocean-facing shores and also interspersed with other trees in the island's interior.

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* Taro is one of the few crops in the world (others being rice and lotus) that is grown in flooded conditions. Large air spaces in the petiole permit the submerged parts to maintain gaseous exchange with the atmosphere. However, surrounding water must have enough dissolved oxygen. If the water is too stagnant and warm, the high temperature and resultant low oxygen content can cause the basal rotting and wilting of the taro.

The land is divided between individual families. Separate pieces of agroforest are maintained by owners, who take care of the land, clean it, cut bushes, etc. Now that many landowners no longer reside on the island, many sections of agroforest have been neglected.

Taro patches

The inner part of Kahlap contains a large taro pit divided into a many smaller patches maintained by individual families. These water-filled depressions are excavated and maintained by people in order to cultivate wetland taro, which requires ample water supply. In the past, smaller pits have been dug in the interior of the other two islets. They do not appear to be regularly maintained nowadays but residents indicate that some people still use them.

Agricultural problems

The leaves of some large taro plants turn yellow and brown. At the same time, the root is observed to become rotten, described as *perrer* in Mokilese language. This is happening more in the part of the taro patch that faces the ocean and the residents feel that it is caused by intrusion of salty water into the patch.

Trees, mostly coconut, banana and lemons, are attacked by a pest. The problem started about 10 years ago. The

a b

Fig 24 Lemon fruits from a healthy (a) and diseased tree (b).

residents indicate that this is caused by a small flying white insect. Undersides of leaves may be covered by white powder and fruits develop dark blotches. Such fruits are not consumed. Affected plant may die.

Fishing

Fish are caught predominantly on the reefs and in the lagoon, to a smaller extent in the open ocean. A number of techniques are used, but spearfishing, bottomfishing, and trolling are most popular. Kahlap shores being overfished, the main fishing spots are around Mwandohn and Uhrek. Sea turtles make one or two nests annually on Uhrek islet and are now under protection of a recently declared municipal turtle preserve.

Domestic animals

The only domestic animals on Mwoakilloa are chickens and pigs. Every family has freely-roaming chickens. Their toes are cut in specific combinations to mark them as belonging to specific owners.

Pigs are also kept by every family have pigs. Larger households have over 20 animals. According to municipal ordinance, they are not to be kept near homes, on shore, or allowed to roam freely. Instead, animals are kept mostly on the ocean side of the islet, scattered at many different sites and tied to trees. Animals are moved when too much waste accumulates at one site. In the past, pigs were kept entirely on the two uninhabited islets but none are found there now.

Cats are present on the island and are mostly feral. All dogs were eliminated by collective choice after incidents where people got bitten by them. Mice are common on Kahlap but do not represent a problem. People are used to them and ensure that they cannot access places with foodstuffs. Uhrek is said to have large rats.

Energy and waste

The individual residents of Mwoakilloa resolve their own energy and waste disposal needs. The municipal and state governments provide periodic or emergency assistance, but no regular service of any type.

Energy

Each residence on Kahlap is equipped with solar panels for electric power. The solar facilities were donated by the European Union (EU) about ten years ago. There was a delivery ceremony on the island and it was attended by the French ambassador. At that time, two panels and two batteries were provided for each house. Three island residents were trained and designated as technicians. The capacity possessed by each house us not sufficient to power appliances but is said to be enough to run several light sources for four hours or one light source throughout the night. At the time of survey, all solar panels were reported as working, though some batteries were no longer usable.

In the past few years, the EU delivered additional solar equipment for the school and dispensary. These public facilities are very large and can support the running of numerous appliances, including refrigerators. They are in working order and are expected to last 20 years.

Fig 25
Solar panels and gasoline are Mwoakilloa's energy sources.

a

b

Many families own gasoline/diesel-powered generators. These are occasionally used to power freezer units to preserve meat. This is kept to a minimum because the fuel on the island is expensive and sometimes unavailable.

No gasoline, no fish

The most recent fuel shortage was in 2008 when the island was not served by a supply ship for unusually long time. This was a serious issue because fishing on Mwoakilloa requires the use of motor boats. Nearshore areas of Kahlap are poor in fish and there are no canoes on island to permit travel around the lagoon. The islanders resorted to extending a very long string from Jokojkoa at the northwestern tip of Kahlap all the way to Mwandohn islet and using it to pull their boats when going against the wind and current. Trips across the lagoon also needed to be made to collect wood for cooking, because there was no kerosene. This state of affairs continued for about a month. The string used was fishing line patched up from many pieces provided by individual fishermen. The municipal council actually considered requesting a rope from Pohnpei so that it can be used instead of fishing line.

At that time, the community started a canoe building project. Everyone was very enthusiastic about the idea and many people got involved. The project was well under way when the supply ship arrived. As soon as gasoline arrived, the canoe-building idea died.

Communications

At present, the only reliable means of communication between Mwoakilloa and other islands is HF radio. There are five units on the island, one each at the municipal office, airstrip office, dispensary, elementary school, and the weather station. Radio is also used to send email messages by using wavemail technology. Essentially, messages are aee sent/received via Pohnpei State DOE, where a person manually converts wavemail to email and the other way around. At present, the European Union is engaged in an effort to bring Internet and email access to the island. The FSM Telecom is promising cell phone service in the future. Peace Corps volunteer on island has a satellite phone for emergencies.

Household waste

There is no single locale used for waste disposal. Various types of trash are disposed in several ways, generally in the immediate vicinity of individual households. Organic waste is disposed of in pits dug for that purpose. When the pit gets filled up, the contents are covered with soil. They may or may not be burned prior to that. Often, a banana tree of some other plant is planted at the site, with buried material acting as fertilizer. Similarly, rusty metal is used to fertilize the iron-limited atoll soil. Unfortunately, some unconscientious residents allow all kinds of waste to accumulate around their homes and do not properly separate, burn, or bury it. This produces truly appalling piles of waste in certain areas and represents a health hazard and possible point-source of pollution of groundwater. Also deplorably, larger metal items are sometimes dumped into the ocean, beyond the reef or within the lagoon. Municipal regulations prohibit disposal of any waste into the lagoon.

Plastic waste, such as plastic bags, bottles, packaging foam, etc. may be burned or simply discarded and ignored. Some of these materials are imported by island residents themselves, whereas others arrive as floating debris from distant places. They are common along the shores and are found in large quantities even on the two uninhabited islets.

Batteries thrown away by residents have become a common eyesore. In recent years, an American tourist took an interest in this problem and began to pay island children specific amounts for bringing discarded batteries of all sorts. This has had some effect and three 55-gallon drums worth of collected batteries are currently found in the municipal storage house, awaiting to be picked up and transported to Pohnpei by state EPA.

Fig 26
Garbage pile next to a particularly unkept household.

Human and animal waste

Every house has an outdoors toilet with a septic tank. Septic tanks are constructed by hand-digging a hole and lining the walls with coral rock. The top of the hole is covered with concrete cap, but the walls are not. This was recommended by Pohnpei EPA (Sanitation) in order to allow waste water to penetrate the tank walls and enter the surrounding where it is filtered by soil, sediment, and rock. Tanks made in this fashion rarely get full and some of the older ones have not had to be emptied for over 30 years.

The actual toilets are mostly water-sealed units. They are situated in CAA-donated outhouses with small round concrete tanks. A few people have flushing toilets within their homes.

Burial practices

There is no designated cemetery on Mwoakilloa. Every family buries their dead in wooden caskets somewhere on own land. The decisions are made according to personal preference and the community and municipality do not interfere with such choices. Most graves are found in Mwandohn. Fewer are in Kahlap and there is a very a small number in Uhrek.

Until several decades ago, burials on Kahlap, where people live, were prohibited. This is no longer the case and gravesites have become common on Kahlap. In some cases, however, the initial interment is on Kahlap but the remains are moved to Mwandohn years later. Similarly, Mokilese people who pass away on Pohnpei and are buried there often have their remains moved to Mwoakilloa 10-15 years later. In the very distant past (over a century ago), body of a deceased would be set adrift in the ocean, perhaps in a small canoe. Particulars of such traditional funerals have been lost.

a

b

Fig 27
Interior of a toilet (a). Gravesite adjacent to a house (b).

Shipwrecks

Japanese fishing boat *Kakura Maru*, a steel longliner shipwrecked on the ocean side of Kahlap over 20 years ago. The crew was rescued. The boat got burned by mistake when local people smoked cigarettes during a trip to claim and remove steel ladders and other useful objects from it. The burnt ship sat on the reef for many years until being pushed onto land by typhoon-generated waves. Its disintegrated remains can still be seen in the coastal coconut forest. The island received some financial compensation from the fishing company.

Some 10 years later, a smaller fiberglass longliner from Pohnpei ran on the reef on the ocean side of Uhrek. The wreck was also was pushed onto land by waves and is said to be causing erosion in its immediate vicinity.

Local people believe that the Japanese ship caused poisoning of the fish and the people who ate it. The ship did posses a large freezer for commercial tuna catch and leaked oil, ammonia, and freon. People report that the problem lasted for 5-6 years and there were several incidents where people got terribly sick from eating fish caught in the wreck area. Only certain species, notably barracuda, grouper, and parrotfish, caused the poisoning. It should be noted that all of these species are known to cause sickness and death by ciguatera neurotoxin.

Coastline and climate

During the field surveys on Mwoakilloa, we have made informal observations of coastal areas. Special attention was paid to any distinctive or unusual features, and anything that may indicate problems related to climate change and/or sea level rise.

Meteorologic data

There is a small weather station on Mwoakilloa. It is operated by Galen Joel. The instruments available are barometer, thermometers (one measuring current temperature and the other recording minima and maxima), and a rain gauge. Anemometer was broken and sent to Pohnpei for repairs. Data is recorded every six hours and transmitted by radio to the Weather Service in Pohnpei. While anemometer is not available, wind speed and directions are estimated. This is risky considering that Mwoakilloa is served by small airplane from Pohnpei and accurate picture of the local wind conditions is vital to the pilots.

Fig 28
Meteorological data collection on Mwoakilloa.

a

b

Typhoons and flooding

At least three or four powerful typhoons struck the island in living memory. The worst was in 1993, when practically everyone lost house roof, and all the *naj* (boathouses) were blown away. The runway, originally constructed with money provided by the FSM Congress, was destroyed by typhoon-generated waves. FEMA evaluated the damage and provided financial assistance to rebuild the runway and other damaged structures.

Exceptionally large waves occasionally penetrate significant distances inland. Typhoons disturb lagoon waters sufficiently to generate waves that can enter the settlement area and reach some homes on Kahlap from lagoon-side, where protection by a fringing reef is lacking. Typhoon-generated waves in 2001 or 2002 have entered ~40 m inland at the northwestern tip of the islet and reached up to the school building. Fortunately, saltwater did not enter the taro patches or caused any serious damage. The closest distance from the beach to the taro patch is over 100 m from lagoon shore and approximately 70 m from ocean-facing shore. Despite such distances, seawater does reach the taro patch during particularly strong typhoons. Residents report that this occurred in the 1980s, when, according to anecdotes, dead sharks were found in the taro patch after the storm. More recently, in 2008 there was a high surf event when water coming from the ocean side of Kahlap entered landward part of the way toward the taro patch. Saltwater intrusion into the taro patch is extremely detrimental because it kills the plants and makes recovery difficult for several years.

The residents are warned about impending typhoons by the Weather Service in Pohnpei. At such times, many exposed houses are evacuated and residents gather in the church and other strong buildings at the top of the little hill in Kahlap.

Historically, the worst storm in recent memory struck the island in 1905. At that time, there were no concrete structures on island so the entire population sought shelter on the highest point in the island, which was chiefly land belonging to the then-*Nahnmwarki* Joel Mark. The islet of Kahlap was nearly completely flooded with seawater during the storm, and the entire taro patch was destroyed and filled with water. For a brief period of time people could obtain taro that has not yet rotted away by actually diving down in the taro patch and pulling the roots outs. A famine ensued quickly. This typhoon was the direct cause of massive emigration from the atoll during German administration and the root of the current Pingelapese diaspora in Pohnpei.

Erosion and vegetation loss

No problems were reported or observed on Kahlap. The ocean side of the islet appears to be stable. Lagoon shore of the islet in the settlement area is largely defined by seawall, constructed and re-constructed several times in the past. It is damaged by typhoons and has been neglected lately. Of the previously numerous fishponds contained within sea-wall protected rock platforms on the shore, only one remains today. Residents report localized erosion on the ocean-sides of Mwandohn and Uhrek. In case of the latter, the erosion seems particularly fast and partly associated with the site of the shipwreck there. For both islets, people indicate that sand is eroding at some and accumulating other sites around the perimeter and some elderly residents specifically said that this is nothing new, that they remember the same dynamics when they were children, and that coastal changes are a reflection of island reworking, not island “sinking” (as is increasingly popular belief in the region).

Addenda

Recommendations and conclusions

The availability of fresh water to Mwoakilloa's residents is a currently a function of the amount of rainfall, total catchment area, and total storage capacity. Shortages, therefore, should not be thought of as failures of rain to fall, but as failures to catch and store enough of the rain that did fall. In its current state, the system of rainwater catchments is sufficient to provide enough water to all Mwoakilloa residents for routine use, but may not contain ample supplies for all households during minor droughts and is not appropriate during island-wide emergencies.

Improvement of catchment systems

Rainwater catchment system on Mwoakilloa should be improved to a capacity consistent with past contingencies and likely events in the future. Catchment areas to capture rain could be increased and efficiency of gutters and pipes improved, but most importantly, storage capacity should be adjusted so that reserves can last through extended periods of no rain. Since storage tanks are never connected to each other, setup of each individual household must satisfy such requirements separately in order to be considered appropriate. This would level out the current inequities between households and prevent certain families from reaching water crisis levels well before others. To minimize tank instability due to spillovers, catchments should not be disproportionately high for the size of coupled tanks either.

When we inquired among island leaders and residents regarding what they thing would improve their quality of life and availability of water, many people replied that they need more corrugated iron sheets to make new roofs and more water tanks. The former is certainly a justified request because metal roofs rust quickly in the humid tropical climate and eventually decay enough to affect the quality of water they capture. The request for more tanks stems primarily from the fact that there is a highly unequal distribution of tanks among households. Some houses have sufficient storage capacity to last over a month's drought, whereas other have to conserve water after a mere two weeks without rainfall. On the other hand, the overall number of tanks on the island is very high and it is hard to imagine that bringing more tanks would be a reasonable solution. We have seen that the tanks being used on island are only a portion of all the tanks that are present. In addition to damaged and broken tanks that could possibly be repaired, we have documented a large number of abandoned and unused tanks that are clearly fit for use. Some of those could be restored and put to use. This would provide important emergency supplies and purge many of the present unsanitary water accumulations.

Improved effectiveness of catchment

Our survey has shown that only a small portion of available roof areas are used to catch rain, and the gutters are decayed and leaky. However, regardless of those limitations and loss in collection methods, the patterns of seasonality and amounts of single-episode rainfall are such that available storage tanks get filled anyway during normal weather. That means, that the main limitation to the system is deficiency in storage capacity due to absence of enough actively used tanks.

Technical support and maintenance

Residents of Mwoakilloa are resourceful and hardworking, but could certainly benefit from technical assistance from persons experienced in development and maintenance of water catchment and storage systems. Recommendations should be made regarding the management of all components of rainwater catchment systems. Periodic evaluations should be made to ensure that the island is capable of managing future emergencies. If any outside entity donates new tanks or other parts of the water system, efforts should be made to remove old outdated equipment to prevent accumulations of waste and dirty water.

Worst-case scenario

If a major storm were to occur and severely damage Mwoakilloa's rainwater catchment network, the large concrete tanks, particularly those built into homes, would remain standing. They should provide a water reserve to last until the other components of the system are repaired. However, if a prolonged drought were to follow such an event, water reserves could not be replenished and the island could run out of water. An unusually long drought, even without a preceding storm, would eventually cause the island residents' individual water supplies to be exhausted. Judging from past incidents, at such times the atoll residents' last resort is to request water fresh water to be delivered from Pohnpei. Since the demise of Pohnpei state-owned ship Micro Glory, the only vessel capable of fresh water delivery is the FSM-owned Caroline Voyager. Truly the worst-case scenario would occur if damage to rainwater catchments and a prolonged drought were to coincide with a period when the Caroline Voyager were to be incapacitated.

It would be prudent to prepare for such a contingency by protecting and preparing the groundwater as a viable emergency water supply.

Well maintenance and inspection

The 1991 groundwater study by United States Geological Survey (see references and further reading section) has determined the hydrologic properties and sustainable yield of the aquifer on Kahlap islet. They recommend that deep wells are driven into groundwater lens and water pumped for regular and emergency use. However, we have seen that wells drilled as part of that project have quickly fallen into disuse because water pumps are not properly maintained.

In contrast, shallow hand-dug wells are common on the island and do not require special equipment to be used. They could be promoted as reliable backup sources during severe emergencies. Their ability to provide water during times of need are limited by their water quality, which is largely affected by general behavior of island residents and diligence with which they maintain and clean wells during regular, non-emergency times. As we have seen that on Mwoakilloa the wells are largely ignored during times of ample rainfall, perhaps a recurring well inspection system could be developed and implemented so that each well on the island would be periodically checked and assessed. That would encourage residents to regularly clean and maintain their wells and prevent their abandonment -- making them readily available during emergencies. Of course, overall quality of water in the lens must be protected by preventing point source pollution by waste.

Waste management

The following are specific recommendations designed to minimize pollution risk to the groundwater and facilitate its viability for daily use for washing and showering, and emergency drinking water source.

1) Pig husbandry should continue to be conducted as it is now, with animals located away from wells and households and limited to the ocean-facing side of the island where groundwater is not utilized.

2) Solid waste disposal in pits should not be performed in immediate vicinity of any wells. The pits should never be located up hydraulic gradient from the wells. Specifically, the spatial relationship between a well and waste disposal pit should be such that 1) waste is disposed seaward from wells, or 2) waste is disposed at roughly the same distance from the coast as the location of the well but not close to the well. Such arrangement would ensure that groundwater percolating through any buried waste in the vadose zone recharges the aquifer in a location from where it is unlikely to afterward flow within the phreatic zone to the well.

3) The construction of pit toilets on Mwoakilloa should be designed to enhance filtering of waste water. Septic tanks on the island rarely if ever fill up, even after many decades, because coralline sandy and gravelly soil and sediment typical of low islands are poorly consolidated and have fast percolation rates. Waste liquids entering a pit dug in this material pass through the unlined walls quickly and may seep into groundwater before microorganisms can remove contaminants. To prevent groundwater pollution, walls of the pits should be lined with a layer of absorptive organic material available locally -- for example, a thick mat of old thatch or dry foliage. This material will decompose and become part of the compost pile lining the pit, acting as a filter for percolating liquid. The locations of toilets with respect to wells should be chosen in fashion described in the previous point.

4) People should be informed of the dangerous effects of human burials right within the household compounds and encouraged to create a single cemetery, ideally on a separate islet on the atoll.

References and further reading

Interviews

John Ichiro [former Chief Magistrate, now senior pastor of UCCP on Mwoakilloa], April 11th, 2009.

Galen Joel [Mwoakilloa weather station operator], April 12th, 2009.

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Vacher, L. and Quinn, T., Geology and Hydrology of Carbonate Islands. Developments in Sedimentology, v. 54: Elsevier, New York.

Historical maps

US Army Corps of Engineers (1946) Map of Mwoakilloa Atoll, 1:25,000, series W856, sheet 6141 I NW, edition AMS-1 (Type C)

Appendix 1

Detailed list of information sought by researchers and a guide for researchers during interviews with local leaders and officials

A) Background information: 1) Geographic location and description [island name and location, island type, number and size of islets, land area, lagoon area, coastal perimeter, highest point, description of vegetation, any distinctive features]; 2) Population information [names, size and location of populated islets, population size (adult population, total population), ethnolinguistic affinity, significant demographic events (immigrations, emigrations, evacuations), etc.]; 3) General infrastructure [island accessibility (air/sea), lagoon accessibility (shape, size, and number of channels), major traditional buildings (men's houses, meeting houses, women's houses, menstrual houses, canoe houses, residences), major concrete buildings (mayor's office, church, school, clinic, stores, residences]; 4) Points of contact [name and contact information of the mayor, traditional chief, schoolteachers, municipal officials, Peace Corps volunteers on island]

B) Meteoric water usage and infrastructure: 1) General description of rainwater catchment systems [Rainwater catchment systems present or not, what type (rooftop, dedicated), etc.]; 2) Catchment portion descriptions [material (metal sheet, corrugated iron, plastic), size of catchment area, gutter condition (good, leaky), etc.]; 3) Storage portion description [type of storage tanks, material (concrete, plastic, fiberglass), size (approximate average volumes, maximum volumes]; 4) number of catchment sites [approximate total number of catchments, number per household); 5) locations of catchment sites (approximate locations of catchment site clusters; exact locations of communal/public/major structures]; 6) Ownership [private, communal, or public]; 7) History [origin of rainwater catchment systems (self-made, purchased, donated, FEMA), significant events (destructive typhoons, relief operations, water shortages, other crises]; 8) Meteoric water use [inquire about primary and all other uses of rainwater].

C) Groundwater usage and infrastructure: 1) General description of wells [wells present or not; type of wells]; 2) Well engineering [general depth, walls (reinforced or not), material (rock wall, concrete, plastic, etc.), covering (none, partial, complete]; 3) Well condition [new, damaged, old, destroyed]; 4) Well state [active, partly used, inactive, abandoned]; 5) Number of wells [total number of wells; number per household]; 6) Locations of wells [approximate locations of well clusters; exact locations of significant wells]; 7) Well ownership [private, communal, or public]; 8) Water condition [how do residents perceive groundwater quality (any physical pollution, microbial pollution, bad taste)? Is groundwater fit for drinking or not, fit for cooking or not? Are there any exceptionally good wells, or any exceptionally bad wells?]; 8) Saltwater intrusion [any evidence of saltwater intrusion? What is the water condition like at low tide vs. high tide?]; 9) Groundwater use [what are the primary and other (emergency) uses of groundwater? If ever used for drinking, is the water treated in any way?]; 10) Natural discharge [are there any significant discharge points on the coastline of inhabited islands? Any identifiable springs and seeps? What is their morphology and estimated discharge and quality? Is there any evidence of nutrient-enriched groundwater discharge?]

D) Agriculture and animal husbandry: 1) General description [description and extent of managed vegetation on island, agroforest, taro patches, coconut groves, major crops]; 2) Agroforest [composition of agroforest, major plant species]; 3) Major trees [large breadfruit and/or other trees present or not? Any significant events that destroyed trees? Is lumber harvested on island and what are its uses?]; 4) Taro patches [note extent of taro patches, describe their condition]; 5) Coconut groves [do people perceive that there are enough coconut palms on island? Do they produce enough? Are coconuts casually used for hydration or are they partly or strictly conserved?]; 6) Piggeries [how many pigs are there? Where and how are they kept?]

E) Waste disposal: 1) Solid waste disposal [note any landfill-type areas, contaminated land]; 2) Household waste disposal [is garbage disposed of in piles, pits, burned, buried, thrown to the lagoon, thrown to the ocean?]; 3) Human and animal waste disposal [fixed locations or not? Toilets or outhouses? Any flushing toilets? Any septic tanks? What size, construction and lining of the septic tanks? Any human and animal waste related problems?]; 4) Burials [any designated cemeteries? Any individual graves around households? Are locations of graves and cemeteries in/near village, on same/different island as the village? Any traditional (at sea) burials in living memory?]; 5) Pollution [any evidence of pollution on land? Any evidence of pollution along the coastline? Any evidence of pollution in the lagoon? Any evidence of unusual algal growth or coral decay?]; 6) Shipwrecks [any recent shipwrecks? Any ships still aground on the reef? What state are wrecked vessels in? Any cleanup operations? Any leaks or physical damage to reefs?]

F) Meteorologic data: 1) Meteorologic data collection [are data collected on island? Who is the local person in charge of data collection? What type of data? What instruments are available? Who is the collecting agency? How is the data reported and how often?]

G) Fresh water-related problems: 1) Water availability [do residents perceive that there is enough water on island? Is water use unrestrained or are there some conservation practices in place?]; 2) Water condition [do residents feel there are any specific water-related problems or issues? Is stored rainwater quality suitable for the way it is used? Is groundwater quality suitable for the way it is used?]; 3) Health [has island ever experienced any contagious disease outbreaks? Any unusual health problems? Any community-level health emergencies?]; 4) Water crises [has island ever run out of fresh water? What triggered the crisis? How did the residents respond? How was emergency resolved? Are there any contingency plans for the future?]

H) Sea water-related problems: 1) Flooding [has the island ever been subject to a major flood? What caused it (typhoon, swell, tide)? What was the damage? How did the residents respond? How was the situation remedied?]; 2) Loss of vegetation [are there any formerly well vegetated areas that are now poorly vegetated or barren? Is any natural vegetation or agricultural land damaged by tides, waves, sea-spray, or underground saltwater contamination?]; 3) Erosion [what is the state of coastal vegetation? Is there any evidence of eroded modern beaches, exhumed paleo-beaches, and undercut vegetation? Any evidence of coastal sediment accumulation? Is erosion or accumulation gradual/imperceptible or is it caused by rapid events? Any islets destroyed, created, split, connected, significantly reshaped in living memory?]; 4) Community perceptions [do people perceive any ocean encroachment or loss of land?]

I) Visual information (photographs): 1) Natural features [general landscape; coastal scenery (lagoon-side, oceanward side); inland scenery (natural vegetation, agroforest, taro patches, coconut groves), etc.]; 2) Infrastructure [settlements; households; general infrastructure; water-related infrastructure (rainwater catchment systems, rainwater storage objects, wells, toilets); other relevant sites (waste disposal locations, cemeteries]; 3) Cultural features [water use practices: washing of dishes, washing of clothes, showering, bathing, open fire cooking, outdoor kitchens, etc.]; 4) Problematic features [any features, structures, or areas identified as problematic by investigators or island residents]

Appendix 2

Data collection sheets used by researchers to obtain basic information about individual households (top), their water catchment systems (middle) and wells (bottom)

SECTION	Map #	Household name	GPS waypoint #	# adults	# kids	start photo#	end photo#	# of tanks	# of wells	COMMENT (no tank/well)	>

Map #	Ownership	Use	Purpose	Shape	W cm	L cm	Circ. cm	H cm	Material	Catch w cm	Catch l cm	Potential	Gutter

Map #	Ownership	Use	Purpose	Type	Lining	Cover	Extraction	Condition	Quality	Depth cm	>

Appendix 3

Checklist and interview sheet used by researchers to obtain information from individual households

HOUSEHOLD AND INFRASTRUCTURE SURVEY INVESTIGATOR CHECKLIST
==

Household name: ____________________________

Number of people: ______ adults ______ children

GPS location: ______ N ______ E

Photo numbers: ______ (start) ______ (end)

___ Check water storage tanks: types, size, state, water quality, water use

___ Check catchment area: total used and potential

___ Check wells: type, state, depth, water quality, water use

If no tanks or no wells, ask residents where do they get the water?

Thank the residents for cooperation.

HOUSEHOLD AND INFRASTRUCTURE SURVEY RESIDENT QUESTIONNAIRE
==

0) Household name?

1) What do you drink when you are thirsty? What kind of fruits to you eat regularly?

2) Where do you bathe? Ever bathe in the ocean and just rinse with fresh water?

3) Can you drink water out of any tank, or are there differences in quality between tanks?
What kind of tanks are the best or most popular? Why?

4) How many coconuts do adults and children in your household drink per day?
Can you remember any events in the past when coconut supply was used up?
How long did it take for that to happen?
Do you notice any changes in coconut trees or nuts during droughts?

5) If your tank was full and it stopped raining, how long would it take for the level to drop to half?

6) At what level of water in your tank do you become worried?
At what level of water in your tank would you say that the water is running out?
What did you do in the past when the water level in your tank got that low?
What did you tell your family to do?
How long did it take for the tank to become empty?
Did yours and other households ever run out of water?

7) If your tank was empty, where is the 1st place you would try to get water? And 2nd place?
Are there any rules on how much water can be taken from community tanks?

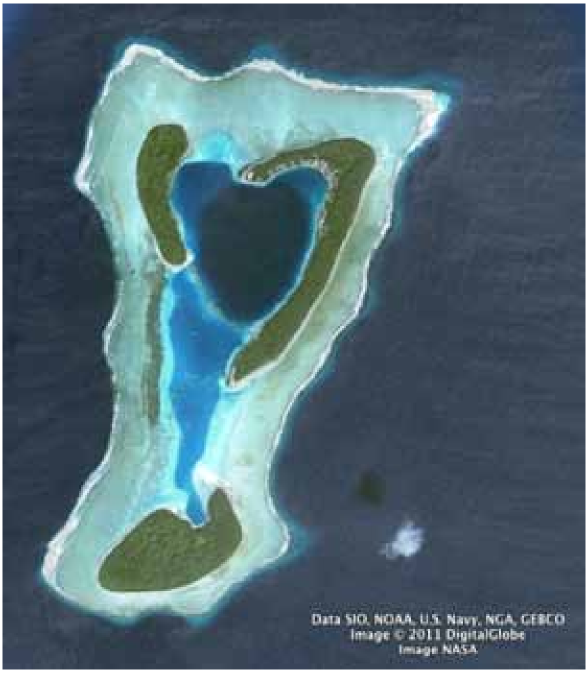
8) Did it ever happen that no tank on the island had water in it? What did you do then?

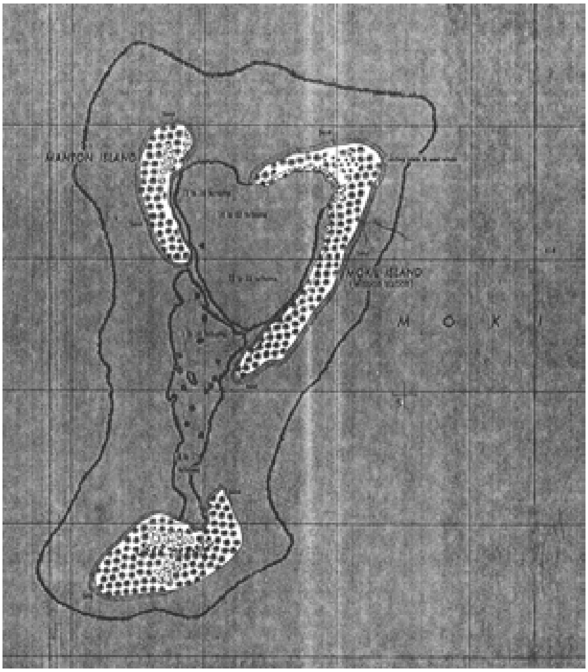
9) Has water on the island ever made anyone sick?

10) Where do you go for human waste disposal?
Where do you throw away your garbage?

Appendix 4

Satellite image (from Google Earth®) and scan of a 1:25,000 paper map (US Army Corps of Engineers, 1946) of Mwoakilloa Atoll.





Appendix 5

Small subset of geotagged photographs taken over the course of this project, each displayed in reduced in size and resolution at exact coordinates where it was taken.