Pacific Regional Consultation on
Water in Small Island Countries

Sigatoka, Fiji, 29 July – 3 August 2002

FROM VISION TO ACTION

TOWARDS SUSTAINABLE WATER MANAGEMENT IN THE PACIFIC

Theme 1 Overview Report

Water Resources Management

prepared by

Tony Falkland

Ecowise Environmental

Canberra, Australia

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List of Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AusAID	Australian Agency for International Development
CSC	Commonwealth Science Council
DFID	Department for International Development (UK)
EC	European Community
ENSO	El Niño Southern Oscillation
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organisation
FSM	Federated States of Micronesia
GEF	Global Environment Facility
GWP	Global Water Partnership
ICM	Integrated catchment management
IETC	International Environmental Technology Centre
IHP	International Hydrological Programme (of UNESCO)
IWP	International Waters Programme (abbreviation for Strategic Action Programme for International Waters)
JICA	Japan International Cooperation Agency
kL	kilolitres (= 1,000 litres)
km	kilometre
L	litres
L/p/d	litres per person per day
MSL	mean sea level
NIWA	National Institute of Water and Atmospheric Research
NEMS	National Environment Management Strategy
NGO	Non-governmental organisation
NZODA	New Zealand Overseas Development Agency
OHP	Operational Hydrology Programme (of WMO)
PCM	Participatory catchment management
PIC	Pacific Island Country
PICs	Pacific Island Countries
PNG	Papua New Guinea
PVC	polyvinyl chloride
PWA	Pacific Water Association
PWP	Pacific Water Partnership
RO	Reverse osmosis (a method of desalination)
SAP	Strategic Action Programme for International Waters
SAPHE	Sanitation, Public Health and Environment (ADB funded project in Tarawa)
SIDS	Small Island Developing States
SIWIN	Small Islands Water Information Network
SPaRCE	Schools of the Pacific Rainfall Climate Experiment
SPC	Secretariat for the Pacific Community (formerly South Pacific Commission)
SOPAC	South Pacific Applied Geoscience Commission
SPREP	South Pacific Regional Environment Programme
TNC	The Nature Conservancy
UNDDSMS	United Nations Department for Development Support and Management Services
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Childrens Fund
USGS	United States Geological Survey
WERI	Water and Energy Research Institute (University of Guam)
WHO	World Health Organisation
WMO	World Meteorological Organisation
WRU	Water Resources Unit (of SOPAC)
WSSCC	Water Supply and Sanitation Collaborative Council

Executive Summary

The integrated and sustainable management of water resources in small island countries of the Pacific and other regions is vital for the health and social well being of their people, the protection of their environments and the development of their economies. The very limited nature of water resources, the vulnerability of these islands and their resources, including water, to natural disasters, over-exploitation and pollution combined with increasing demands for freshwater due to expanding populations and, in some cases, tourism, industry and agriculture, makes the sustainable management of water resources a very high priority.

In reality, there are many issues which currently constrain the achievement of the goal of sustainable water resources management. At the national level, there is often fragmentation in the water sector, inadequate water resources legislation, policy and planning. There is often insufficient local human resources capacity to conduct water resources assessment and monitoring. In many islands, there is insufficient hydrological data available for analysis and water resources planning. Other issues include conflicts related to use of water resources and locations of water supply systems on customary land, problems with designs and implementation of projects, and insufficient community education, awareness & participation. In addition, there are some water resources issues which require further applied research and training in order to better understand them and to disseminate results

This report outlines issues, concerns and constraints to sustainable water resources management. Actions taken in recent years to address some of these issues and concerns are then presented. The report proceeds to outline actions that could be taken to move towards a more sustainable water resources management in the small islands countries of the Pacific region.

The focus of the report is not on the whole water sector but rather on a number of important components including assessment of water resources; sustainable development of these resources, especially in rural areas; appropriate technology for rural water supply and sanitation; catchment management to improve water quality; needs for training, capacity building, applied research, information dissemination and networking/partnerships. The needs for participation, education and awareness of communities are also considered in relation to water resources management.

There is no single action that will improve the sustainability of water resources management in small island countries. Rather, an integrated approach is required at all levels in order for this to occur. Commitment and encouragement from national governments is required. This needs to be backed by technical and financial support from bilateral, regional and international donor agencies, and others including NGOs and consultants. The capacity of national water agencies need to be strengthened in many areas including water resources assessment and monitoring capabilities, water planning, appropriate technology in water, sanitation and wastewater. In particular, there is a need for improved sanitation systems on small coral islands where current systems continue to seriously contaminate the groundwater and lead to major human health problems. Regional agencies with interests and responsibilities in water resources management should also be strengthened so that they can provide technical support to water personnel from national agencies. Additional applied research is required in order to better understand some of the fundamental hydrological and water quality processes in small island environments. Communities should be encouraged and enabled to take a greater role in the management of water resources at the local level. This should include participation in the management of their own surface water and groundwater catchments to redress the water quality degradation that has occurred and will continue to occur unless appropriate steps are taken. Concerted efforts in the area of community awareness and education and greater recognition of the importance of both genders in the water sector are also required. Through these integrated actions, the sustainability of water resources in small island countries will improve.

1. Introduction

This report has been prepared for the Pacific Regional Consultation on Water in Small Island Countries, Sigatoka, Fiji, 29th July – 3rd August 2002. The aim of the meeting, organised by the Asian Development Bank (ADB) and the South Pacific Applied Geoscience Commission (SOPAC) is to discuss key water management issues and to develop a regional policy statement and action plan to be considered by donor organisations. A report will be prepared for presentation at the 3rd World Water Forum in Kyoto, Japan in March 2003.

A Planning Meeting held in Vanuatu in February 2002 identified Water Resources Management as one of six major themes to be addressed at the Regional Consultation. The other five themes are Island Vulnerability, Awareness, Technology, Institutional Arrangements and Finance.

The focus in Theme 1 and this report is on the sustainable management of freshwater resources. In the context of this report, sustainability is interpreted to mean the capacity of freshwater resources to sustain the health and social well being of communities (rural and urban) and to provide sufficient water to meet environmental needs (particularly needs of animals and birds). The issue of sustainability therefore relates to a broad range of topics including water availability and quality; the water needs of communities; knowledge of water resources; appropriate technology to develop and manage water supplies; impacts on water resources from climate variability; land use changes and pollution; appropriate means and methods of managing catchments and pollution sources; appropriate institutional arrangements; and vital needs in the area of community information, education and awareness.

As this report is focused on “small islands”, it is appropriate to define a small island. Islands with areas less than 2,000 km^2 or widths less than 10 km have been classified as “small” islands (UNESCO, 1991). The classification is somewhat arbitrary, but is based on a realisation that for areas less than 2,000 km^2, a number of issues, including water resources management issues, become more pronounced than those on larger islands and continents. Other definitions of small islands have been applied in the past (e.g. 10,000 km^2 in Hess (1990) and 5,000 km^2 in CSC (1984)). Most small islands are less than 200 km^2 in area and many fit into a category of "very small islands" which are less than 100 km^2 or have a maximum width of 3 km (Dijon, 1984). In very small islands, surface and groundwater resources are generally limited to the supply of water to island communities and limited other uses. It is noted that many populated islands are less than 10 km^2*while some, especially those on atolls, are less than 1 km^2.

The Water Resources Management Theme (Theme 1) is considered in this report under the following headings:

?? Summary data for participating countries and territories.
?? Water resources of small islands and water use.
?? Major water resources issues, concerns and constraints.
?? Actions taken to improve water resources management.
?? Actions required to move towards sustainable water resources management.
?? Summary of proposed actions.

The main focus under this theme is on the following topics:

?? Freshwater availability.
?? Water quality degradation.
?? Catchment management.
?? Knowledge of island freshwater resources.
?? Appropriate technology and methods, in relation to rural water supplies.

Where appropriate, reference is also made to aspects covered under the other five themes. Given the wide scope of the Water Resources Management theme, there is, inevitably, some overlap with the reports prepared for the other themes.

In addition to this theme report, four case studies dealing with specific aspects of water resources management in small islands, have been prepared by authors from selected small island countries. These case studies are:

?? Water management in Tuvalu with special emphasis on rainwater harvesting (Taulima, 2002).

?? Water management in Kiribati with special emphasis on groundwater development using infiltration galleries (Metutera, 2002.

?? Water management in Maldives with special emphasis on desalination (Ibrahim, Bari and Miles, 2002).

?? Integrated Catchment Management in ‘Eua, Kingdom of Tonga (Fielea, 2002).

2. Summary data for the participating islands

Summary data for each of the island countries and territories participating in the Regional Consultation is shown in Table 1. The data focuses on characteristics which impact on freshwater resources and water use in these island countries and territories.

Table 1 Summary data for island countries and territories

Country or Territory	Sub-Region	Approx. Population (in 2000)	Total Land Area (km^2)	Number of islands or atolls	Island type according to geology
Pacific Island Countries					
Cook Islands	Polynesia	16,000	240	15	Volcanic, volcanic & limestone, atoll
Federated States of Micronesia	Micronesia	114,000	702	607	Volcanic, atoll, mixed
Fiji	Melanesia	785,000	18,300	300 (approx.)	Volcanic, limestone, atoll, mixed
Kiribati	Micronesia	85,000	810	33	32 atolls or coral islands, 1 limestone island
Nauru	Micronesia	11,000	21	1	Limestone
Niue	Polynesia	1,700	260	1	Limestone
Palau	Micronesia	22,000	487	200 (approx.)	Volcanic, some with limestone
Papua New Guinea	Melanesia	4,400,000	462,000	?	Volcanic, limestone, coral islands and atolls
Republic of Marshall Islands	Micronesia	60,000	181	29	Atolls and coral islands
Samoa	Polynesia	175,000	2,930	9	Volcanic
Solomon Islands	Melanesia	417,000	28,000	347	Volcanic, limestone, atolls
Tonga	Polynesia	99,000	747	171	Volcanic, limestone, limestone & sand, mixed
Tuvalu	Polynesia	11,000	26	9	Atoll
Vanuatu	Melanesia	182,000	12,190	80	Predominantly volcanic with coastal sands and limestone
Other Pacific islands (Territories of USA and France)					
American Samoa	Polynesia	67,000	199	7	5 volcanic and 2 atolls
French Polynesia	Polynesia	254,000	3,660	130	Volcanic, volcanic & limestone, atolls
Guam (USA)	Micronesia	158,000	549	1	Volcanic (south) and limestone (north)
New Caledonia (France)	Melanesia	205,000	18,600	7	Volcanic, limestone
Island countries in other regions					
East Timor	SE Asia	800,000	24,000	1 main island	Volcanic
Maldives	Indian Ocean	270,100	300	26 atolls	Approx. 1,900 islands

Notes:

?? Populations and areas from Case Studies and Country Briefing Reports for the Regional Consultation (where available) and SOPAC (2002). Actual population data maybe different than shown, as some of the data is from 1998.

?? Number of islands from: UNDTCD (1983), UNEP (1999), UNEP (2000), various National Environment Management Strategies (NEMS) for PICs.

?? Some numerical differences were noted between data sources.

Represented are 14 Pacific Island Countries (PICs), 4 Pacific Territories (of USA and France) and two countries (East Timor and Maldives) outside the Pacific region.

Most of the islands belonging to the nations and territories represented at the Regional Consultation can be considered as small islands, according to the above definition. In fact, many fall into the very small island category. Exceptions are the larger islands in the Melanesian countries and East Timor.

Table 1 shows that four of the 14 PICs are in Melanesia, five are in Polynesia and five are in Micronesia. Large variations in demographic and selected physical characteristics (total area, number and geology of islands) are evident. Often the conditions within PICs vary considerably, with conditions on outer islands being significantly different from those on main islands.

Most of the population in the PICs live in rural villages and towns (ESCAP, 2000) and the peri-urban areas on the fringes of the main centres. In many cases, living conditions in the peri-urban areas (fringes of urban areas) are poor and normal urban utility services (including water supply) are sparse, inadequate or non-existent.

3. Water resources and water use in small islands

3.1 Types of water resources

While the topic of Theme 1 is Water Resources Management, emphasis is placed on freshwater resources. Freshwater resources in small islands can be classified in two main categories as follows:

- Naturally occurring water resources requiring a relatively low level of technology in order to develop them. This category, which is sometimes referred to as 'conventional' water resources, includes:
  - Surface water
  - Groundwater
  - Rainwater.
- Water resources involving a higher level of technology (sometimes referred to as "non-conventional" water resources). This category includes:
  - Desalination
  - Importation
  - Wastewater reuse.

Other "non-conventional" water resources include:

- Use of seawater or brackish water for selected non-potable requirements
- Substitution.

Where available, the naturally occurring water resources are inevitably more economic to develop than the "non-conventional" water resources. The main water resources in both categories are described in more detail below, as well as the major influences on the occurrence and distribution of the naturally occurring water resources.

3.2 Naturally occurring water resources

3.2.1 Surface water

Where conditions are favourable, surface water can occur on small high islands in the form of ephemeral and perennial streams and springs, and as freshwater lagoons, lakes and swamps.

Perennial streams and springs occur mainly in high volcanic islands where the permeability of the rock is low. Many streams are in small steep catchments and are not perennial. Some flow for several hours or days after heavy rainfall while others flow for longer periods but become dry in droughts.

Freshwater lagoons and small lakes are not common but are found on some small islands. These can occur in the craters of extinct volcanoes or depressions in the topography. Low lying coral islands rarely have fresh surface water resources except where rainfall is abundant. Many small island lakes, lagoons and swamps, particularly those at or close to sea level, are brackish.

3.2.2 Groundwater

Groundwater occurs on small islands as either perched (high level) or basal (low level) aquifers.

Perched aquifers commonly occur over horizontal confining layers (aquicludes). Dyke-confined aquifers are a less common form of perched aquifer and are formed when vertical volcanic dykes trap water in the intervening compartments (e.g. some of the islands of Hawaii and French Polynesia).

Basal aquifers consist of unconfined, partially confined or confined freshwater bodies which form at or below sea level. On many small coral and limestone islands, the basal aquifer takes the form of a 'freshwater lens' (or 'groundwater lens') which underlies the whole island.

Basal aquifers tend to be more important than perched aquifers because they are more common and generally have larger storage volumes. Basal aquifers are, however, vulnerable to saline intrusion owing to the freshwater-seawater interaction, and must be carefully managed to avoid over-exploitation and consequent seawater intrusion.

The term 'freshwater lens' can be misleading as it implies a distinct freshwater aquifer. In reality, there is no distinct boundary between freshwater and seawater but rather a transition zone (refer Figure 1). The base of the freshwater zone can be defined on the basis of a salinity criterion such as chloride ion concentration or electrical conductivity.

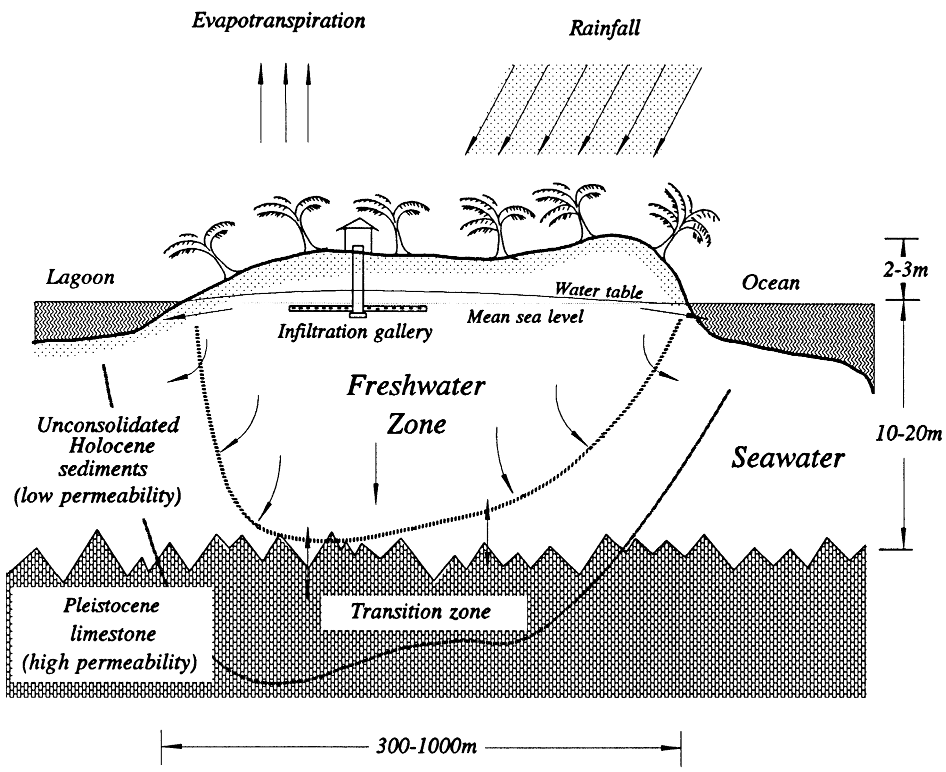

Figure 1 Cross section through a small coral island showing main features of a freshwater lens (exaggerated vertical scale) and location of an infiltration gallery.

Freshwater lenses often have asymmetric shapes with the deepest portions displaced towards the lagoon side of the island, as shown in Figure 1. Typically, the freshwater zone of a thick freshwater lens on a small coral island is about 10-20 m thick, with a transition zone of a similar thickness. Where the freshwater zone is less than about 5 m thick, the transition zone is often thicker than the freshwater zone. The freshwater and transition zone thicknesses are not static but vary according to fluctuations in recharge and possibly, abstraction of groundwater.

3.2.3 Rainwater

Rainwater collection systems are common on many islands. In small islands with high rainfall (e.g. the islands of Tuvalu), rainwater catchments using the roofs of individual houses and some community buildings, are the primary source of freshwater (refer Tuvalu Case Study: Taulima, 2002).

In other small islands, rainwater is used as a source for essential water needs (e.g. drinking and cooking). In drought periods, when rainfall can be very little, or nil for many months, household rainwater storages are susceptible to being severely depleted unless very strict rationing is imposed. Common materials for rainwater tanks are ferrocement, fibreglass and plastic. Steel tanks are generally not used, owing to corrosion problems, unless they are well painted. Ferrocement tanks are commonly used in some Pacific islands (e.g. Tonga, Tuvalu, Kiribati, Federated States of Micronesia) as they can be constructed by local contractors and community groups. In recent years, plastic tanks have become popular for household rainwater collection in many islands of the Pacific and in Maldives.

In addition to roof catchments, rainfall is sometimes collected from specially prepared surfaces. Examples are paved runways (e.g. Majuro, Marshall Islands) and specially prepared surfaces with adjacent storage tanks or artificially lined reservoirs (e.g. some islands in Torres Strait, between Australia and PNG). Simple rainwater collection systems consisting of containers (e.g. plastic barrels) located under the crown of coconut trees where rainfall is concentrated, are still used in some islands (e.g. outer islands of PNG).

3.3 'Non-conventional' water resources

3.3.1 Desalination

Desalination is another less common method of freshwater production. Desalination systems are based on a distillation or a membrane process. Distillation processes include multi-stage flash (MSF), multiple effect (ME) and vapour compression (VC) while the membrane processes include reverse osmosis (RO) and electrodialysis (ED). Descriptions of these processes are provided together with approximate costs and a comprehensive reference list in IETC (1998). The most common method used in small island countries is RO. Further information is provided in UNESCO (1991) and SOPAC (1998).

In the Pacific region, desalination is used for regular water supply to resident populations on Nauru (distillation using waste heat from power station) and on Ebeye, Kwajalein atoll, Marshall Islands (reverse osmosis). On South Tarawa, Kiribati, RO units have been installed at a number of sites including the main hotel, the hospital and one urban centre (Kiribati Case Study, Metutera, 2002). These systems, two of which have failed, supply a small proportion of the total water supply requirements. RO units are also used on some tourist islands for water supply (e.g. Mana Island, Fiji and Akitua island, Aitutaki atoll, Cook Islands). In other regions, desalination is more common on small islands for regular water supply (e.g. Malé' and resort islands in Maldives and a number of Caribbean islands).

RO units have also been supplied and installed as an emergency source of potable water during droughts (e.g. Kiribati, Marshall Islands, Tuvalu and PNG). In non-drought periods, are stored for emergency use (Marshall Islands), are currently operating (Kiribati, Tuvalu) or have failed (examples in Kiribati and PNG).

Desalination is a relatively expensive and complex method of obtaining freshwater for small islands (UNESCO, 1991). The cost of producing desalinated water is almost invariably higher than 'conventional' options (e.g. pumping of groundwater) due to the high energy costs and other operating costs.

The use of desalination in small islands is further discussed in sections 4.6 and 5.5,.

3.3.2 Importation

Water importation has been used for a number of islands, especially as an emergency measure during severe drought situations. Water has been imported by sea transport (boats, or barges) during droughts, for instance, to outer islands of Fiji and Tonga. Sometimes people on islands with a water shortage will travel by boat or canoe to nearby islands with more plentiful water sources.

Water can also be piped to islands close to large land masses. Water is piped, for instance, to Manono Island, from Upolo in Samoa.

In many small islands, bottled water had become an alternative source of drinking water (either imported or made locally by desalination plants). Invariably, its cost is higher than water supplied by local water authorities.

3.3.3 Non-potable water sources

Non-potable water sources include seawater, brackish groundwater and treated wastewater.

There are many examples of the use of seawater and brackish waters in order to conserve valuable freshwater resources on small islands. For example, reticulated seawater is used for toilet flushing and as a source for fire-fighting in densely populated parts of Tarawa and Majuro. Dual pipe systems are used to distribute water to houses and other connections – one for freshwater supply and the other for seawater. Seawater or brackish well water is often used for bathing and some washing purposes on small islands. Seawater is also used on some islands for cooling of electric power generation plants, for ice making and in swimming pools.

Treated wastewater is not a common non-potable source in small islands, but is sometimes reused for irrigation of garden and recreational areas at tourist resorts and hotels on some small islands (e.g. Fiji, Maldives).

3.3.4 Substitution

During severe drought conditions, or after natural disasters, coconut water has been used as a substitute for fresh drinking water. People on some of the smaller outer islands in Fiji, Kiribati, Marshall Islands and PNG, for instance, have survived on coconuts during drought periods. The coconut tree is very salt-tolerant and can continue to produce coconuts once groundwater has turned brackish.

3.4 Major influences on island surface water and groundwater

Major influences on the occurrence of surface water and groundwater resources are considered in this section while further detailed information is contained in UNESCO (1991). These influences include the physical characteristics of islands, climate and human impacts.

3.4.1 Size

The water resource management issues of scarcity and vulnerability to drought and other natural disasters increase considerably as island size decreases. Islands can be classified as large, small or very small, according to the definitions outlined in section 1.

Examples of very small islands are the sand cays, coral atoll islands and small limestone islands, typically less than 1 km^2 in area, where surface water resources are non-existent and fresh groundwater resources are very limited. On these islands, freshwater sources are limited to groundwater and rainwater. Other examples are very small volcanic islands where fresh groundwater is very limited or non-existent, and geological conditions are not favourable for surface water storages. On some very small limestone islands, the only freshwater source is rainwater which may need to be supplemented in severe droughts by water imported by boats or barges (e.g. in some islands in Tonga) or desalination units (e.g. Funafuti in Tuvalu).

The width of islands is also important. Long then islands generally have lower water resources potential than near circular islands. Width is especially important for small coral islands, which rarely have a permanent freshwater lens if the island width is less than about 250m.

3.4.2 Geology and topography

Geological conditions are one of the primary determining characteristics of the type and occurrence of freshwater resources. The structure of small oceanic islands is generally formed from volcanic, carbonate (limestone or coral sand) or mixed geology.

Small islands are often classified according to topography as either 'high' or 'low'. Depending on geological conditions, high islands have potential for surface water resources as well as groundwater resources, while low islands generally have only groundwater resources.

High volcanic islands often have perennial streams or rivers (e.g. many islands in Fiji, Papua New Guinea, Samoa, Solomon Islands and Vanuatu). In the smaller islands and small catchments of larger islands, stream flows may becomes very low or cease during extended droughts. Volcanic islands frequently have springs, both in elevated and coastal areas.

While raised coral limestone islands are topographically high, they generally have no surface water owing to the high permeability of the rock. Nauru, for example, is a limestone island which has an interior brackish lake near sea level. Surface water on low islands, if present, is likely to be in the form of shallow, brackish lakes unless the rainfall is very high where it may be fresh (e.g. Teraina island in Kiribati).

Coral sand and limestone islands generally have only groundwater resources (e.g. the atolls of the northern Cook Islands, Kiribati, Marshall Islands and Maldives; coral and limestone islands in most of Tonga, parts of the Federated States of Micronesia and some islands in almost all PICs). In coral and limestone islands, topography does not have a significant influence on groundwater resources (freshwater lenses) which occur at and below sea level. By contrast, the topography and detailed geology of volcanic islands has a significant effect on the distribution of groundwater.

3.4.3 Climate and hydrology

The climate of small islands within tropical regions is quite variable, depending on geographical location, island size and topography. The climate of small oceanic islands is governed by the regional climate while small islands closer to continents or large islands may also be influenced by local climatic conditions.

Average annual rainfall on small islands varies considerably between islands in the tropical Pacific Ocean (e.g. Taylor, 1973 show variations between rainfalls in excess of 4,000 mm to less than 500 mm). In high volcanic islands, orographic effects can cause much higher rainfall at altitude than in low-lying areas, while long-term rainfall does not usually vary much over low islands.

Two of the most important climatic influences on small islands in the Pacific region are tropical storms and El Niño Southern Oscillation (ENSO) episodes.

ENSO and anti-ENSO (also referred to as La Niña) episodes have a significant impact on the climate of many small islands and can produce extensive wet and dry cycles. On many Pacific Ocean islands there is a strong relationship between rainfall and ENSO. During ENSO episodes, most Pacific islands experience extensive droughts while some others (e.g. the islands of Kiribati) experience extensive wet periods.

Many small islands are affected by random cyclonic events which are a major problem for communities, often causing significant storm damage and flooding. Storm surges have inundated land, caused loss of life and severely damaged infrastructure in some small islands, for example, atolls in Tuvalu, the Marshall Islands, Federated States of Micronesia and the northern Cook Islands. During these events, freshwater lenses may receive considerable inputs of seawater, and many months may pass before they return to a potable condition.

The impact of current climate variability in PICs, especially in relation to droughts, has been a major focus in recent years (e.g. SOPAC, 1999a). This topic has attracted considerable attention in the scientific community (e.g. Terry, 1998), the popular media, and by funding agencies (e.g. World Bank, 2000).

In addition to current climatic variability, there is the possibility of climate change and sea level rise due to the enhanced greenhouse effect resulting from worldwide emissions of greenhouse gases.

Climate change scenarios for PICs vary according to location and the models used. Most models predict an increase in frequency of El Niño episodes and increased intensity of cyclones (World Bank, 2000). There is less certainty about changes to rainfall, which could impact on the availability of island freshwater resources. Current scenarios indicate a small rise in sea level over the next few decades (approx. 0.2-0.4 m).

The impact of current sea level rise scenarios on freshwater resources is likely to be relatively minor, compared with other influences (e.g. present climate variability, human impacts). The main potential impact would be inundation on the edges of low-lying islands and coastal zones of high islands. Tarawa, Kiribati has been the focus of impact studies under possible sea level rise and climate change scenarios. Results of groundwater modelling studies to assess the impacts on a freshwater lens under the combined effects of pumping, climate change and sea level rise show that impacts of sea level rise on freshwater lenses are not detrimental provided that land is not permanently lost by inundation at the margins (World Bank, 2000).

Further aspects of the influence of climate variability and climate change scenarios on small island water resources are presented in the Theme 2 (Vulnerability) report and in a recent publication (Burns, 2002). These aspects will also be considered in the Dialogue on Water and Climate at the Regional Consultation.

3.4.4 Soils and vegetation

Soils play an important role in the hydrological cycle and may significantly influence water resources through their influence on evapotranspiration, surface runoff and groundwater recharge. Important properties are type and thickness, infiltration capacity, and susceptibility to erosion. Soil properties also influence the potential for contamination of groundwater, particularly on small coral islands, and in sandy coastal areas of larger islands. In these situations, the highly permeable, thin soils allow water and contaminants to move easily to the water table and into the groundwater.

The type and density of vegetation has important effects on the hydrological cycle and available water resources. Vegetation intercepts part of rainfall, causes transpiration to occur and, on high islands, may slow surface runoff and reduces erosion. Interception and transpiration by vegetation decrease recharge. On many small islands, the native vegetation has been partially or largely cleared for agriculture, urban development or tourism, and significant erosion of the landscape may have occurred.

Depending on the depth to water table and type of vegetation, direct transpiration losses from a freshwater lens may be promoted. For example, coconut trees on low coral islands act as phreatophytes (i.e. they draw water directly from the water table) and can lead to a reduction in groundwater resources in relatively dry periods.

3.4.5 Human impacts

Major impacts on water resources are caused by the pattern and density of human settlements (rural, urban, peri-urban) and the location and type of activities (e.g. agriculture, forestry, mining, industry, tourism). Impacts are most severe in sensitive water catchment areas (e.g. streams, springs and groundwater systems which are used for town or village water supplies).

Human activities impact on both the quantity and quality of surface and groundwater resources. Over-exploitation and various pollution sources have led to the depletion and/or contamination of available water resources, particularly groundwater resources, on a number of small islands.

Land use changes can be significant. These may involve removal of trees and other vegetation leading to increased problems of erosion and sedimentation; compaction and sealing of surfaces leading to increased surface runoff, and sometimes flooding, and loss of potential recharge; alteration of coastlines and construction of channels, leading to changes in groundwater storage.

Biological and chemical pollution of surface water and groundwater, caused by inappropriate sanitation and inadequate solid waste disposal, is evident on many small islands. Other sources of pollution are industrial discharges, hydrocarbon spills and leaks, and agricultural chemicals.

Further details of these impacts are presented in section 4.

3.5 Water supply and use

As part of water resources management in small islands, it is important to understand the amount and pattern of water use. The main uses of freshwater in small islands of the Pacific are:

- Water supply for human settlements, both urban and rural.
- Industrial (mainly in larger urban centres) and mining.
- Agriculture and forestry.
- Tourism.
- Environmental needs.

Additional non-consumptive uses are hydropower generation (e.g. Fiji, Samoa), navigation and recreation.

The primary use for freshwater on small islands is water supply to urban and rural communities. Additional freshwater supplies are required in some islands to support tourist facilities, limited industry and for farm and domestic animals. Overall, there is only minor utilisation of freshwater for industrial purposes, including mining, on small islands. Irrigated agriculture is not common on most small islands due to the limited water resources.

Further details of some of the more important water uses are outlined below.

3.5.1 Water supply and usage for human settlements

Potable fresh water is used for drinking and cooking and may also be used for bathing, washing and cleaning. Other applications may include toilet flushing, cooling, heating, freezing, drinking water for animals and garden watering.

The types of water supplies and associated management systems vary from centralised water supply systems in urban areas to village and household systems in rural areas. The centralised systems most commonly consist of source works (groundwater pumping areas and/or surface water collection and storage), transmission pipelines and networks of distribution pipe systems to consumers. These water supplies are sometimes metered so that water usage can be monitored. Urban water supply systems are considered in detail in Theme 4 (Technology) while rural systems are considered in this Theme.

At the village level on many small islands, freshwater is generally obtained in traditional ways and water usage tends to be reasonably low, on a per capita basis. Methods of obtaining freshwater include rainwater collection at the household level, groundwater withdrawal from privately owned wells and, on high islands, collection of water from small streams and springs. In addition to fresh (potable) water, non-potable water (brackish water and seawater) is utilised on some islands in order to conserve valuable freshwater reserves. During droughts, private wells that normally supply fresh groundwater may become brackish. This water continues to be used for some purposes, for example clothes washing and bathing. In some islands, where residents have no access to freshwater, seawater is used for bathing.

Typical rural water supply systems consist of communal systems and/or individual household systems. Communal systems have a distribution pipe network based on either surface or groundwater sources. Surface water systems normally use gravity flow pipelines from streams or springs to tanks or standpipes in the village. Groundwater systems generally consist of a pump, which is operated for a number of hours each day supplying water to an overhead tank feeding standpipes within the village. Individual household water supply systems typically consist of a well, a rainwater catchment or collection from a spring or stream source near the village. In some cases, water is extracted from shallow wells dug at low tide on the beach.

Communal water supply systems are often managed by village or community 'water committees'. This may include collection of revenue to provide for operating costs (e.g. in Tonga, most rural water supplies use groundwater, and village water committees raise revenue to pay for pump operation and maintenance costs). Village water committees are also the basis of rural water supply implementation and operation in the Melanesian countries.

In other PICs, communal water supplies are operated by island councils (e.g. Kiribati) or municipal administrations (e.g. Federated States of Micronesia). This may or may not include the collection of revenue from households benefiting from the water supply.

On Funafuti, the main island of Tuvalu, rainwater is collected in both household and communal tanks. Where shortages are experienced at household tanks during extended dry periods, water is delivered by small tanker from the communal tanks. This service is provided by government and a fee is charged.

Per capita freshwater usage varies considerably between islands and within islands depending on availability, quality, type and age of water distribution systems, cultural and socio-economic factors and administrative procedures. Water usage varies from low values of approximately 20-50 litres per person per day (L/p/d), where water is very limited, to more than 1,000 L/p/d on some islands where water resources are plentiful. Water usage can be high where piped water supply systems are not kept in a good state of repair (leading to high leakage rates). Typical water usage in well-managed pipe systems is in the order of 50-150 L/p/d.

Water usage tends to be higher in urban than in rural areas for a number of reasons, including the use of water consuming devices (e.g. washing machines) and the inevitable leakage and wastage from distribution systems.

3.5.2 Tourism

Water supply to tourist resorts may represent a reasonably high proportion of total water consumption in some small islands, or parts of these islands. Water usage rates of 500 L/p/d are not uncommon (UNESCO, 1991).

3.5.3 Irrigation

Irrigated agriculture schemes on small islands, where they exist, tend to be on a relatively minor scale, although there are exceptions. Many small islands, particularly coral atolls and small limestone islands, generally do not have either sufficient water resources or suitable soil conditions for irrigated agriculture. Irrigation is possible and is practised on a relatively small scale, however, in some of the high volcanic islands where water is more prevalent and soils are suitable for agriculture.

Cultivation of root and tuber crops is practised in many Pacific Ocean, islands. One important example is the cultivation of swamp taro on some coral atolls by digging pits to the water table. The production of cash crops, such as sugar cane, involves high water use. These crops are commercially grown with irrigation schemes on some islands. In Fiji, for instance, the greatest use of water is for agriculture, primarily sugar cane cultivation.

3.5.4 Hydro-power generation

There are a number of small high islands where hydroelectric power generation schemes have been implemented (e.g. French Polynesia and Pohnpei). Some larger islands have extensive hydroelectric power generation schemes (e.g. Viti Levu, Fiji). Many other high islands have the potential for hydroelectric power generation.

3.6 Freshwater resources and use in the participating islands

A summary of the main freshwater resources and uses for each of the island countries and territories participating in the Regional Consultation is shown in Table 2.

Table 2 Summary of freshwater resources in participating islands

Country or Territory	Main freshwater resources[1]	Main freshwater uses[2]
Pacific Island Countries		
Cook Islands	SW, GW, RW	WS, T
Federated States of Micronesia	SW, GW, RW	
Fiji	SW, GW, RW, D (tourist resort only)	WS, T, H, I
Kiribati	GW, RW, D (limited)	WS
Marshall Islands	RW (from airport catchment and buildings), GW, D (emergency)	WS
Nauru	D (regular use), RW, GW (limited)	WS
Niue	GW, RW	WS
Palau	SW, GW, RW	WS
Papua New Guinea	SW, GW, RW	WS, M
Samoa	SW, GW, RW	WS
Solomon Islands	SW, GW, RW	WS
Tonga	GW, RW, SW (limited)	WS
Tuvalu	RW (primary), GW (limited), D (emergency)	WS
Vanuatu	SW, GW, RW	WS
Other Pacific islands (Territories of USA and France)		
American Samoa	SW, GW, RW	WS
French Polynesia	SW, GW, RW	WS, T
Guam	SW, GW, RW, D	WS
New Caledonia	SW, GW, RW	WS
Island countries in other regions		
East Timor	SW, GW, RW	WS, I
Maldives	D (main island of Malé); GW, RW (outer islands)	WS

Notes:
1. SW = Surface water, GW = groundwater, RW = rainwater; D = desalination.
2. WS = water supply to communities, T = tourism, H = hydroelectricity, M = mining.

4. Major water resources issues, concerns and constraints

4.1 Overview

This section summarises major issues and concerns about, and current constraints to, sustainable management of water resources in small island countries of the Pacific region. Many of these also apply to small and larger islands in other regions. As mentioned in section 1, sustainability is interpreted to mean the capacity of freshwater resources to sustain the health and social well being of communities (rural and urban) and to provide sufficient water to meet environmental needs (particularly needs of animals and birds). The issue of sustainable water resources management therefore relates to a broad range of topics, some of which are considered in detail in Theme 1, while others are considered in the five other themes.

Key issues, concerns and constraints, which are considered in this section within the scope of Theme 1, are:

?? Freshwater availability issues including increasing demands for water.

?? Water quality degradation in surface water and groundwater catchments, with consequent downstream impacts on human health and the environment.

?? Insufficient knowledge of island freshwater resources.

?? Insufficient education, training and capacity in water resources.

?? Inappropriate technology and methods, in relation to rural water supplies.

?? Catchment management issues.

?? Other issues and constraints.

Other key water resource management issues and concerns, as listed below, are considered in detail in the overview reports for the other five themes. These issues and concerns are also briefly mentioned, as appropriate, in this section.

?? Vulnerability of water resources to natural hazards and climate variability and change (Theme 2, Vulnerability).

?? Insufficient community education, awareness and participation (Theme 3, Awareness).

?? Water leakage and other losses including wastage in distribution systems (Theme 4, Technology).

?? Legislation, policy, planning and administrative issues (Theme 5, Institutional Arrangements).

?? Role of donor agencies and other financing organisations in water resources projects (Theme 6, Finance).

Much of the material in this section is based on a synopsis of information on freshwater and watershed management issues in the Pacific region, which was prepared for SPREP as part of their International Waters Programme (Falkland, 2002).

4.2 Freshwater availability and demand for water

Sustainability of freshwater resources is dependent on both their availability and on the demand for these resources. The issue of sustainability becomes more critical for islands of small size where population densities are high, for example some of the more densely populated islands of atolls (e.g. Tarawa, Kiribati; Majuro, Marshall Islands, Funafuti, Tuvalu and Malé, Maldives). In such islands, the fresh groundwater resources are (or have been in the case of Malé) under stress to supply even basic human needs. In the case of Malé, the groundwater resources have been depleted to the extent where desalination of seawater is now required to supply most of the water needs of the population (refer Maldives Case Study: Bari, Ibrahim, Bari and Miles, 2002).

4.2.1 Availability of water resources

Major influences and constraints on the availability of water resources on small islands are:

?? Physical characteristics and climatic conditions, as outlined in section 3.4. In particular, the area and geology of islands have major influences on available naturally occurring water resources.

?? Climatic variability. Surface water resources are often severely depleted, and sometimes exhausted, during extended droughts. Groundwater resources also become depleted in drought periods, and may under natural (no pumping) conditions become brackish on small islands or near coastal zones of larger islands. During moderate to severe droughts, rainwater storages may become very low or empty, and insufficient even for the most basic of needs (e.g. drinking and cooking). In many small islands with low average rainfall and a high variability (e.g. Kiritimati Island in Kiribati), rainwater catchments do not offer a sustainable water supply and other sources are required (e.g. groundwater). Very small islands with highly permeable geological conditions (e.g. small limestone islands) are particularly vulnerable to droughts. These islands have no potential for surface water and very little, if any, potential for fresh groundwater. During droughts when rainwater catchments are no longer able to supply freshwater, other measures have been implemented such as importation by boat (e.g. outer islands of Tonga and Fiji) or installation of desalination units (e.g. Marshall Islands, Kiribati, PNG, Tuvalu). These measures are expensive and only partially successful.

?? Water resources development methods. For example, in otherwise favourable conditions, inappropriate groundwater pumping systems can readily induce saltwater intrusion if care is not taken in their design and operation. Systems are sometimes designed and implemented without the necessary investigations and monitoring arrangements required to ensure sustainable pumping rates (i.e. rates which do not induce saline intrusion) are applied.

?? Land management practices. On high islands, inappropriate clearing of native forest for timber, agricultural land and other activities, can easily cause erosion problems with consequent downstream water quality deterioration. Clearing of native vegetation and conversion to open land for grazing of animals or planting of crops increases peak stream flows after heavy rainfall. This is due to decreased interception and retention of water by the vegetation and leaf litter and decreased infiltration into the soil. Clearing can also lead to decreased baseflow (low flow) in streams causing lower yields for other purposes (e.g. potable water supply).

?? Biological and chemical pollution. These have major impacts on the quality of fresh surface water and groundwater resources with ensuing impacts on human health, as outlined in section 4.3.

4.2.2 Water demand

Demands on available water resources are increasing, sometimes rapidly, in many small islands in the Pacific and other regions, due to the following factors:

?? Increasing populations and urbanisation. Populations are increasing, sometimes rapidly, in many PICs, especially on main islands. Urban water supplies have difficulty keeping pace with urban expansion in some cases. In others, water supplies are not capable of delivering water on a 24-hour basis owing to the additional demand, but also due to high leakage and sometimes wastage. A current example is urban Tarawa, Kiribati, where the piped water supply system is available for a few hours only each day.

?? Growing expectations for water supply by urban populations is increasing the water demand per capita. Past estimates of reasonable per capita water usage (say 50 litres/person/day or L/p/d) are now not capable of meeting normal expectations of reasonable consumption levels. Recent design estimates, based on analysis of usage in larger villages and small towns, suggest demands of about 100-150 L/p/d (e.g. TWB, 1997; Goodwin, 2000; AusAID, 2000). Per capita water usage in principal regional towns with continuous water supplies can be of the order of 250-330 L/p/d, according to a finding from an ADB funded benchmarking survey of PIC water utilities in 2000-2001 (information supplied by SOPAC).

?? On islands where flush toilets are installed (normally only in urban areas), significant quantities of water (30- 40% of total demand) may be used for flushing. Hence, the use of flush toilets may have a large impact on water resources. This was taken into consideration for the design of reticulated sewerage systems in Tarawa and Majuro with seawater being used as the flushing water.

?? Increasing demands for water in other sectors, for example, tourism, agriculture, industry and mining. The growth of tourism on some very small islands puts considerable pressure on available water resources and, in many cases, requires the use of other solutions (e.g. desalination, wastewater reuse).

?? Leakage and other losses from piped distribution systems act to increase the demand for freshwater. Such losses in urban centres and larger rural villages of many PICs are recognised as a major issue by the Pacific Water Association (PWA) and SOPAC (e.g. SOPAC, 1999b). Where metering data is available, it is often found that over 50% of the water diverted or pumped from sources is lost through leakage from pipelines. Increased abstractions to supply leakages may lead to over-exploitation of available water sources. In many cases, water shortages during droughts (and often in more normal rainfall periods) could be averted or at least minimised, if regular and systematic leakage control and other demand management measures (education and awareness) were implemented. In addition, infrastructure costs to develop additional sources to supply future demands could be delayed.

4.3 Water quality degradation

Degradation of water quality is a major problem and an increasing threat to surface water and groundwater resources and potable water supply systems in many small islands of the Pacific and other regions. Contamination can originate from point source discharges of pollutants and diffuse pollution sources.

The small size and steep slopes of many surface water catchments on many high islands enable water and pollutants to move quickly to downstream areas. Also, the highly permeable soils and shallow water tables on many small coral islands enable pollutants to easily migrate to fresh groundwater. While the timeframe is rapid for the impacts of pollution to occur, the reversal of impacts is difficult and time consuming.

The issue of water quality degradation in PICs has been highlighted in reports over many years, for example, Brodie et al (1984), Lau and Mink (1987), Detay et al (1989), Miller et al (1991), UNESCO (1991), Dillon (1997), UNEP (2000), Crennan (2001), Falkland (2002) and Crennan and Berry (2002).

4.3.1 Pollution sources

Surface water and groundwater quality has been degraded in many small islands by a variety of pollution sources as follows.

- ?? Discharges of untreated or partially treated wastewater (from sanitation and greywater systems) with associated pathogenic organisms into streams, rivers and groundwater aquifers. The rapid urbanisation in some islands has put great pressure on both surface water supply catchments used for urban and nearby rural water supplies (e.g. Apia, Samoa). The dominant source of serious faecal contamination in the Ba River and estuary, Fiji was found to be the nearby urban area (Anderson et al, 1999). Groundwater underlying settlements, both urban and rural, is highly vulnerable to contamination, especially on low-lying coral islands. Further details of this major issue are provided in section 4.3.3.
- ?? Direct faecal contamination from animals (e.g. cattle, pigs). Waste matter runoff from commercial piggeries and from less formalised urban and village pigpens is a major source of stream pollution in many small Pacific islands (UNEP, 2000). On some islands including those with vulnerable groundwater resources, animals are allowed to wander freely through village areas with defecation occurring at random and sometimes close to wells. Human defecation in the ‘bush’ (often in urban areas) or on the beach is a necessary sanitation practice in some crowded urban communities on atolls, where sanitation systems are not available for all to use. Wells utilised for potable and other purposes are not always covered, and often have inadequate protection around the base, enabling pollutants to wash in after heavy rainfall.
- ?? Inadequate solid waste disposal sites (e.g. close to streams; above groundwater systems; in or above water catchment areas). This is especially serious where solid waste, containing toxic chemicals and hydrocarbon residues, is dumped over, or close to, fresh groundwater areas. Locating landfill sites on the edges of an island (as in some very small islands with limited options for land disposal of solid waste), acts to keep pollution away from freshwater resources but can have major impact on near-shore water quality and marine resources. On some islands, there is also a threat of groundwater pollution from cemeteries and burial sites.
- ?? Increased sediment discharges, high turbidity and colour problems in streams due to soil erosion on high islands. Serious erosion is often caused by extensive or inappropriate logging of native forests, poorly designed or constructed roads and unplanned development activities. Another issue is the use of fire to clear undesired weeds in farming and forestry areas, which exposes the soil and destroys the structure of the upper soil layer (Baisyet, 1994). The risk of erosion in small ‘high’ tropical islands is very significant due to high intensity rainfall, destructive forces from cyclones and other major natural disasters, steep island topography and often unstable soils if vegetation is removed.

?? Chemical contamination of surface water and groundwater resources, caused by uncontrolled use of agricultural chemicals (fertilisers, and often toxic insecticides and pesticides). The extent of the problem is not always known, owing to little or no monitoring.

?? Leakage of hydrocarbons (e.g. from poorly maintained fuel storages, power stations and pumping stations) and untreated industrial effluent discharges. On the island of Betio, Tarawa atoll, Kiribati, the disposal of waste oil on the ground adjacent to the power station is a source of contamination for groundwater. Detailed water quality tests at special pollution holes near power stations on another atoll, namely, South Keeling atoll in the Cocos (Keeling) Islands have revealed heavy hydrocarbon, lead and arsenic contamination (Barratt & Falkland, 1999). Similar contaminants are likely to be present in polluted groundwater near power stations on other small islands, especially small coral islands.

?? Persistent organic pollutants (POPs). These are a threat in some Pacific islands due to their high toxicity, persistence in the environment, and ability to be transported long distances (Aalbersberg & Thaman, 2000). In PICs, there is only limited data on the levels of the 12 UNEP-designated POPs.

?? Discharges and accidental spillages of toxic chemicals from mining sites into streams and rivers (e.g. from some of the gold mining sites in PNG).

In addition to the pollution sources, groundwater systems on small islands and in the coastal margins of larger islands can be contaminated by seawater intrusion resulting from inappropriate pumping systems. This has led to the depletion of groundwater resources on a number of small islands, as mentioned previously.

4.3.2 Major impacts of pollution

Impacts of pollution sources on both surface water and groundwater are often severe for communities and the environment, as summarised below:

?? Impacts on human health due to microbiological contamination and elevated nitrate levels in water supplies. Case studies prepared for this Regional Consultation highlight this problem (e.g. Metutera, 2002; Ibrahim, Bari and Miles, 2002) although this issue has been recognised for many years. For example, Baisyet, (1994) stated that "the pollution of drinking water and the resulting health hazard may be one of the biggest watershed issues in island countries of the South Pacific." Also, this major issue of water pollution in the Pacific region (and other regions) and the linkages with waterborne diseases has been raised in the past (e.g. Detay et al (1989), Miller et al (1991) and UNESCO (1991)) and reiterated in more recent reports including ADB (1999), SOPAC et al (2001), Falkland (2002), Crennan and Berry (2002). The high incidence of diarrhoeal diseases and other infectious diseases (e.g. hepatitis, typhoid and sometimes cholera) on some small islands is often caused by poor quality groundwater used as a source of drinking water (e.g. Micronesian Source Water Protection Coalition, 2001; FSM, 2002, Metutera, 2002). Outbreaks of cholera in PICs have been linked to contaminated water (e.g. Tarawa in 1977, and Federated States of Micronesia (e.g. Chuuk in 1982-83 and Pohnpei in 2000). The incidence of diarrhoeal diseases in PICs has been found to vary with water availability and climate. High incidences tend to be associated with low water availability and higher temperatures (Singh et al, 2001)

?? Impacts on human health from chemical pollution, either directly from the water or through the food chain.

?? Impacts on physical quality of water supplies making the water unusable for days to months. On the island of 'Eua in Tonga, high turbidity and suspended solids are experienced by consumers after periods of heavy rainfall. The water becomes unusable for a day or more. The water quality problems on 'Eua are at least partly due to tree clearing and cattle grazing within the formerly forested catchment above the water supply intakes. Further details are provided in the Case Study for 'Eua, Tonga (Fielea, 2002).

?? The effectiveness of water supply intakes and treatment systems is compromised by high suspended sediment loads, leading to higher costs of providing clean, safe water supplies. For instance, Apia's water supply, which is fed from a number of catchments above the town, requires filtration (roughing filter and slow sand filter) and disinfection (chlorination) to achieve adequate water quality for the consumers. After very heavy rainfall, treatment plants have been overtopped by floods and covered in sediment from contributing catchment areas, causing disruption to water supplies for months (e.g. water supply for Apia was severely disrupted after a major flood in April 2001). This sort of event is most likely unavoidable, but the frequency of major flooding which can cause such problems is increased by catchment clearing, leading to higher and more rapidly rising flows than under uncleared conditions.

?? Sedimentation in water supply reservoirs and rivers is a problem in some islands due to disturbances in upstream catchments (e.g. islands of Melanesia impacted by logging and mining operations).

?? Adverse impacts from sediments, nutrients, chemicals and bacteria on riverine and coastal environments (including aquatic life, fish resources, inner reef lagoons, mangrove areas and coral communities).

4.3.3 Major issue of pollution from sanitation systems

Pollution from sanitation systems, as outlined above, is a priority issue since it severely impacts on water resources and the health of populations in many small islands. Especially affected are those islands with high population densities such as the main population centres in atolls. This problem is a major one for many small island communities, as alternatives, while available, are not necessarily affordable or acceptable to all people. Unless urgent action is taken, the problem is likely to get worse as populations increase. Without appropriate, affordable sanitation systems in many small communities on islands, there will not be any significant reduction in microbiological pollution of groundwater or surface water resources currently impacted by unsatisfactory sanitation systems.

The pollution problems are generally greater in urban and peri-urban areas with high population densities where the sanitation systems are principally pit toilets (either latrine or pour flush) and septic tanks. Many smaller villages however, also exhibit high bacterial levels in groundwater or have the potential for such pollution. This problem is endemic in many small low-lying coral islands of the Pacific and other regions and is a major constraint to improvements in water quality.

Pit toilets, which are normally dug to the water table, allow direct contamination of the freshwater lens. Where septic tanks are used, the situation is better as long as they are well constructed and maintained. However, this is often not the case, with raw sewage leaking from septic tanks due to poor construction or overflowing due to blockages caused by lack of de-sludging.

On islands with thin highly permeable soils and shallow water tables (e.g. atoll islands and other small coral islands), contamination can occur readily (e.g. a high level of contamination was found in village wells on Lifuka, Tonga: UNESCO, 2001). Similar high levels of contamination were noted in extensive surveys as part of the implementation of a reticulated sewerage project on Tarawa in the early 1980s (TSP, undated) and continue to be a major problem (Kiribati Case Study; Metutera, 2002). Detay et al (1989) and Miller et al (1991) report extensive bacterial contamination of wells in islands in the Federated States of Micronesia. Dillon (1997) found the thickness of the unsaturated zone (i.e. zone between ground surface and water table) is the most significant influencing factor on groundwater contamination. Hence islands with sandy unsaturated zones with thickness of 1 to 2 m are probably the most vulnerable of all. Limestone islands also offer little protection to groundwater contamination unless they are overlain by thick soil sequences.

Sanitation facilities are often sited without concern for the direction of groundwater flow, and possibly according to guidelines which are not applicable to island environments (UNESCO, 1991; Falkland, 1999a). The normally accepted minimum distance between a sanitation facility and a well is about 15 m (50 feet). This is based on studies in hydrogeological environments quite different from those found on many small islands. In many small coral islands such conditions do not apply. Travel times through the groundwater between sanitation facilities (where wastewater is injected into the groundwater), and groundwater wells can be short in such environments. This has been clearly demonstrated in an applied research and training project on the island of Lifuka in Tonga where tracers (dye and bromide) were used to measure the travel times between injection points and measuring points several metres away (Crennan et al, 1998; UNESCO, 2001; Crennan and Berry, 2002).

The density of household sanitation systems is also a problem, especially in the small coral islands. Acceptable densities and separation distances outlined from studies relevant to tropical islands (Dillon, 1997) are well exceeded in many PICs, especially in urban areas.

The problem of extensive groundwater pollution is prevalent not only in coral islands in the Pacific, but also impacts on many other small islands (e.g. coral islands in the Maldives). Pollution is widespread and, as there are very few animals compared with the Pacific (e.g. no pigs, dogs), the major proportion of this pollution is of human origin. As septic tanks are not always well constructed and often dug to the water table and have soak pits near the water table, direct contamination of the groundwater occurs (Falkland, 2000; Ibrahim, Bari and Miles, 2002).

4.4 Insufficient knowledge of island freshwater resources

4.4.1 Overview of issues and constraints

Insufficient knowledge of water resources, especially freshwater resources is a major constraint to the sustainable water resources development and management on many small islands.

In many small islands, the knowledge of the type, extent and sustainable yields of surface and groundwater resources is very limited. This is the case, even on some islands where water shortages occur due to the exiting water resources being inadequate to supply demands in drought periods.

Contributing factors to insufficient knowledge of island water resources are:

- ?? Inadequate baseline water resources assessments.
- ?? Insufficient regular monitoring of water resources.
- ?? Limited analysis and interpretation of water resources data for planning and design of water resources development projects, and for water resources management of catchments.
- ?? Knowledge gaps requiring new or further applied research in a range of island environments.

These issues have been raised at many regional workshops and meetings over the past 20 or so years (e.g. CSC, 1984; UNDTCD, 1989; UNESCO/SOPAC/UNDDSMS, 1994; WMO, 1999) but the issues still remain. A summary of key issues is contained in specific publications (e.g., UNESCO, 1991; IETC (1998). Similar concerns are expressed for small islands in other regions (e.g. Maldives: refer Case Study by Ibrahim, Bari and Miles, 2002). National agencies concerned with water resources monitoring have indicated their problems and needs at these workshops and meetings. Major problems cited are shortages of trained staff and training opportunities, limited budgets and problems of co-ordination between internal agencies and with external stakeholders (donor agencies, consultants). Further difficulties are presented by large travel distances, access to remote sites, equipment failures due to exposure to harsh environmental conditions (humid tropical environment, sea spray) and natural disasters (e.g. cyclones, flood damage).

The WMO meeting in 1999 reported that the most important reasons for undertaking water resources assessment in small islands countries were:

- ?? Water resources development
  - o Databases for future planning and development;
  - o Master Plans for water supply development and water allocation to existing and potential users;
  - o Knowledge of availability of water (for example, averages and extremes (droughts and floods));
  - o Baseline data (hydrological and environmental) prior to future development;
  - o Identification of potential water supply for specific purposes (for example, hydropower, mining, etc.); and
  - o Integrated water resources management (for example, taking account of the interactions amongst land, water and environment)

- Sustainable management of water resources
  - Sustainability of ecosystems
- Hazard mitigation
  - Flood forecasting and flood risk assessment; and
  - Drought risk management
- Development of water related infrastructure (for example, dams, bridges, culverts, etc)
  - Island design standards based on local data for optimal design of future projects

The concerns about the inadequate capacity to collect good quality hydrological data and undertake water resources assessments in PICs have been reiterated in two recent review/proposals (Mosley, 2000; SOPAC/WMO/UNESCO, 2001). These are considered in section 4.4.3 and elsewhere in this report.

Further details of some of the key issues are provided below.

4.4.2 Inadequate water resources assessment

While adequate baseline water resource assessments have been undertaken for some islands, particularly for some of the major urban centres on the main islands in PICs, this is often not the case for smaller towns and villages on main islands and for outer (rural) islands.

In some cases, unsatisfactory water supply and water management solutions have been implemented due to inadequate water resources assessments having being undertaken. Examples of problems include:

- Inadequate assessment of groundwater resources on small coral islands and selection of inappropriate pumping technology leading to saline water intrusion and hence saline water in water supply systems.
- Inadequate assessment of surface water resources leading to installation of groundwater pumping systems in the coastal area of a high island where a surface water source could have been used, with lower operational costs, to provide supply to nearby villages.
- Allowing settlement to occur in areas which once had good potential for freshwater resource development but have become polluted to such an extent that they are unusable, or require expensive treatment.
- Installation of desalination plants on small islands as a "quick-fix" response to water shortage problems in droughts, rather than a structured approach to assessing all water management options and implementing appropriate water resources and water supply solutions.

Major causes of these problems include:

- Insufficient and sometimes no hydrological data on which to base the assessments (e.g. insufficient rainfall and climate data).
- Insufficient emphasis given to water resources assessment in the planning phase of water supply and water resources development projects.
- Short-term consultants undertaking water resources assessments without a thorough knowledge of island hydrology and water resources. Most water resource assessment projects in small islands are implemented by external consultants, most commonly through bilateral or multilateral funding agencies, and sometimes in partnership with local staff of water supply or water resources agencies. The quality of the assessments therefore depends largely on the expertise and knowledge of the consultant(s). As external consultants are selected according to criteria used by donor agencies, which do not generally involve procedures for vetting the knowledge and experience of the consultants. Hence, the quality of the work can be compromised. There are many examples in the PICs where water resources assessments have been inadequately performed with the inevitable result that poor management decisions follow.

4.4.3 Inadequate monitoring data

"If you do not measure it, you cannot manage it" is a very relevant statement in relation to water resources management. Water resources monitoring (also known as "hydrological monitoring" or "water resources data collection") should be a regular and ongoing activity, in order to assess the long-term behaviour of water resources due to climate variability and change and the impacts of various developments and land management practices. There is, however, often a shortage of good quality meteorological, hydrological, hydrogeological and water quality data on many PICs.

From a review of issues faced by national hydrological services (Mosley, 2000), the following were identified as priority items.

?? Real-time rainfall and streamflow information for flood forecasting.

?? A drought forecasting capability

?? Baseline information on the water resource in waterways having hydropower potential, most of which would be at the micro- or mini-hydro scale.

?? Baseline information on surface waters likely to be affected by mining or forestry development, and subsequent monitoring.

?? Water resource information, including streams, springs, and aquifers, at a reconnaissance scale, in support of rural water supply projects

?? Baseline and ongoing monitoring information on the quality of groundwater, particularly in the low islands and atolls where aquifers are subject to contamination by human and animal wastes: about ten countries.

It is noted that these priorities were based on visits by two consultants (Rishi Raj, Fiji and Paul Mosley, New Zealand) to 7 PICs (Cook Islands, Fiji, PNG, Solomon Islands, Tonga and Vanuatu) and 2 territories (French Polynesia and New Caledonia). In addition, two other countries, Niue and Samoa attended the WMO Meeting of Experts on Hydrological Needs of Small Islands (WMO, 1999) prior to the consultant' visits. The needs tend to reflect those of the larger high islands in Polynesia and Melanesia.

A similar, but not identical, list of needs was presented in a review of hydrological needs and proposal "A Programme to meet Hydrological Training Needs of Small Island Countries in the Pacific"), jointly prepared by SOPAC, WMO and UNESCO (SOPAC/WMO/UNESCO, 2001). This review considered a wider scope of countries including those mentioned above as well as the Micronesian countries, Kiribati, Marshall Islands and Nauru. In SOPAC/WMO/UNESO (2001), the main water-related issues and water monitoring needs were identified as:

?? Domestic, industrial / commercial water supplies.

?? Hydropower development - including mini and micro projects.

?? Irrigation.

?? Flood forecasting and river training.

?? Drought forecasting and resource management.

?? Saline intrusion into unconfined freshwater aquifers (lenses).

From the above mentioned reports, and the various meetings preceding these (section 4.4.1), the causes of inadequate data are multiple, but include:

?? Inadequate and often declining commitment and funding from governments.

?? Insufficient institutional capacity to carry out water resource assessments including inadequately trained or even no water resources staff.

?? Outdated or faulty water resources monitoring equipment.

?? Lack of logistical support items such as transport to travel to monitoring sites.

Government's are often reluctant to invest in water resources monitoring. It is often seen as a non-essential activity, which can be delayed or cut until funding becomes available. This issue is not only a problem in small island developing countries but affects developed and developing countries alike. At a time when it could be argued that water resources monitoring is even more crucial then before (due to increasing stresses on water resources expanding populations, increasing pollution, uncertainty over climate change and even climate variability), it appears that the level of commitment to water resources monitoring is static or declining.

At present, the agencies with the most potential for water monitoring are the water supply authorities, whose budgets and income maybe more adequate than other government agencies involved with natural resources management

In some islands, monitoring is often only conducted over short periods in some islands in association with specific projects, mainly donor funded and often aimed at water supply improvements. The issues become greater in the smaller island countries, particularly in the outer islands. Once the project is completed, the local staff, however willing to continue, inevitably incur problems including equipment failures, no funding for maintenance and repairs of equipment, work schedules which do not cater for such activity, lack of transport and other logistical factors.

Some specific issues and concerns related to water resources monitoring are as follows:

?? Good rainfall records are essential ingredients for long-term water resources assessment. In some small islands, there appears to be a decline in recent years in the quality of rainfall and climate data. Recent gaps in data in previously continuous records, often over decades, are a symptom of the problem. The causes are not always evident but point to a general lower commitment to data collection at all levels.

?? Higher technology solutions have been implemented to overcome staff shortages due to budget cuts but these have led to inadequate data being collected. An example is the replacement of manually read raingauges in outer islands with automatic raingauges connected via radio or other communications links to main islands. In theory, this enables rainfall to be captured on a central office computer. In practice, valuable data is often lost due to (a) malfunctions with the automatic raingauges e.g. blockages which are not cleared and (b) communications problems meaning that data is not transmitted.

?? In some islands, school-based raingauge readings (under the Schools of the Pacific Rainfall Climate Experiment or SPaRCE program) are used as substitutes for former meteorological stations with paid observers. While this is a commendable move to fill an ‘institutional gap’ with a community-based initiative, there are concerns about the quality and continuity of the record. Monitoring of these (non-standard) raingauges serve as a very useful educational tool for young people and the collected data is a useful supplementary source of data. However, it should not be seen as a long-term substitute for records obtained from standard raingauges by trained observers.

?? Insufficient streamflow monitoring stations for water resources assessment and other needs (e.g. flash flood forecasting). Basic hydrological monitoring networks do not exist in nearly all PICs. Most streamflow stations have been established for specific projects (Mosley, 2000)

?? There is generally very little, and sometimes no baseline water quality data. Water quality testing, particularly for pathogenic organisms, is also not commonly conducted, especially in outer islands. Testing is often conducted only after major health problems are detected.

?? There is also insufficient data available about the physical, chemical and other biological processes that take place in island watersheds, including soil erosion and loss of biodiversity as a result of land conversion due to logging and other practices. Quantitative evidence of microbiological and chemical water quality deterioration in streams is largely unavailable despite much anecdotal and visual evidence of physical deterioration.

?? Regular groundwater monitoring is not a common practice in some PICs. Very few islands have monitoring boreholes specifically for the purpose of monitoring the status of groundwater resources in response to climatic and pumping impacts, despite recognition of this issue. For example, FSM (2002) recognises the need to undertake groundwater monitoring for aquifer protection but mentions that this not being done.

?? Metering of groundwater pumps and surface water flow diversions, required for assessment of water usage, is not always done. Where meters installed as part of water development projects, they are often not maintained and sometimes not read. Valuable data is thus lost.

?? Damage due to direct damage or flash flooding from cyclones and storms can cause destruction to water resources monitoring equipment. Streamflow recorders established in water supply catchments in Apia, Samoa were damaged by flash floods after very heavy rainfall occurred in early 2001. The recent cyclone in the northern Pacific (Typhoon Chata'an, July 2002 which devastated parts of Federated States of Micronesia and Guam) caused very extensive damage and destruction to a network of 11 stream gauging stations on Guam.

?? Vandalism and/or theft of monitoring equipment by landowners are another concern in some islands. Vandalism of groundwater monitoring boreholes has occurred over many years on the island of Bonriki, Tarawa due to disputes between the landowners and government. Vandalism and theft of surface water resource monitoring equipment has occurred in an number of countries. Solar panels used for charging of batteries at remote sites are often a target of theft.

4.4.4 Limited analysis and interpretation of data

?? In many PICS, routine data processing, quality assurance checks and storage of the data require improvements. Databases are usually limited to water quantity data in the form of water levels, discharge measurements, and rainfall data, but few include water quality data. Databases with partial datasets are sometimes distributed over several agencies involved in water resources (e.g. Ministries responsible for water supply, natural resources, environment and health). In some cases data has been lost due to computer problems (e.g. hard drive failures and lack of back-up facilities).

?? There is often very little or no analysis, interpretation and use made of the hydrological data by water personnel within PICs, as they are often too busy on other tasks or lack the necessary training. Where analysis of available data for water resources planning, development and management purposes is done, it is normally done by external consultants. An example is the review of groundwater sustainable yields for the islands of Bonriki and Buota, Tarawa using groundwater and other data and groundwater models (e.g. Alam et al, 2002).

4.4.5 Insufficient applied research

There has been insufficient research into some key hydrological issues in small island environments. The need for further applied research in small island countries was raised in a major review of water resources of small islands including PICs (UNESCO, 1991) and reiterated at the Pacific Water Sector Planning, Research and Training Workshop in Honiara, 1994 (UNESCO/SOPAC/UNDDSMS, 1994). It has been noted that the results of hydrological research and investigations from large islands or continents are not directly applicable to small islands, owing to the different scales and response times. For instance, groundwater pollution, saline intrusion caused by over-pumping, and the impacts of activities in surface water catchments can occur very rapidly in small islands.

The Honiara workshop recognised that the need extended not only to technical and scientific areas but also required an emphasis on social science and community-based issues. It was also emphasised that training of personnel involved in water resources and freshwater supply systems was a major need in PICs.

Despite some progress in certain applied research areas, knowledge gaps and the need for further applied research and training remain. More recent workshops and meetings have again reiterated priority lists of projects for funding (e.g. Sankey et al, 1997 and White et al, 2000). Falkland (1999b) identifies current knowledge of island water resources and future needs for applied research.

National governments have also recognised this need. For instance, the “Water for All'' draft national water policy for Samoa (Samoa Government, 2000) states that ongoing research and measurement of all aspects of water resources in Samoa is an essential step towards protection and enhancement of water resources. National governments are also keen to be involved with such projects, as demonstrated by the level of interest in two applied research projects undertaken in Kiribati and Tonga in the late 1990s.

Further details of applied research projects, either undertaken or imminent, are contained in section 5.7 and recommended applied research needs are presented in section 6.8.

4.5 Insufficient education, training and capacity in water resources

4.5.1 Identification of needs

The issues raised in section 4.4 are to a large degree a symptom of insufficient capacity within PICs to conduct adequate water resources assessments, to collect adequate hydrological data and to analyse such data, and to carry out applied research into areas requiring further understanding.

The need for appropriate water resources and hydrological training and education for water sector professional and technical staff continues to be raised by representatives of PICs as a key concern and constraint to water resources development and management in their countries. Regional workshops and meetings in recent years where these concerns have been raised include:

- ?? Water Sector Planning, Research and Training Workshop, Honiara, Solomon Islands, June 1994 (UNESCO/SOPAC/UNDDSMS, 1994).
- ?? Water Resources Workshop, Suva, Fiji, July 1997; (Sankey et al, 1994).
- ?? Meeting of Experts on Hydrological Needs of Small Islands, Nadi, Fiji, October 1999 (WMO, 1999).

Based on the concerns expressed at the meetings mentioned above, a review/proposal ("A Programme to Meet Hydrological Training Needs of Small Island Countries in the Pacific") was developed by SOPAC, WMO and UNESCO summarising the hydrological training needs of PICs and recommending steps to address these needs (SOPAC/WMO/UNESCO, 2001).

SOPAC/WMO/UNESCO (2001) state that the most fundamental need arising from various needs analyses was that of human resources development in association with wider institutional or capacity building. As mentioned in section 4.4, a constraint raised in the report to developing effective water resources assessment and management capability is the fragmented responsibility for water resources.

The issue of training needs and overall capacity building has also been reiterated in a needs analysis in a report on the implementation of a Hydrological Cycle Observing System for the Pacific Island Countries or "Pacific-HYCOS" (Mosley, 2000). The "Pacific HYCOS" concept is further considered in section 6.4 and in the Theme 2 report.

Again the need for training of water technicians was viewed as the highest priority at a recent meeting of the Working Group on Hydrology of the WMO Regional Association V (South-West Pacific) in January 2002 (WMO, 2002). PICs represented at the meeting (members of WMO) were Cook Islands, Fiji, Niue, PNG, Solomon Islands, Samoa and Vanuatu.

One of the constraints to current bilateral assistance projects aimed at strengthening water resources assessment capacity is the low number of staff involved in hydrology and water resources at both technical and professional level in many PICs (SOPAC/WMO/UNESCO, 2001). Often there may be only one or two people involved in these matters, and generally on a part time basis, as they usually have other responsibilities. Bilateral and multi-lateral donors have, in the past, placed water resources specialists into PICs to assist in training and development of local personnel. These specialists have found themselves on occasions with few or even no personnel to train as the limited relevant staff are away (e.g. training course elsewhere, leave, etc).

An additional issue in relation to education and training is staff retention, as sometimes staff, once trained, move on to other government agencies, the private sector or move away (Mosley, 2000).

Current education and training initiatives, presented in section 5.9 while discussion of actions required to address training and education needs are presented in sections 6.4 and 6.9.

4.6 Inappropriate technology and methods

Numerous water supply technologies and methods have been trialled in small island countries. While many have been successful, there are also examples of water supply technology that have not been appropriate for either the natural environment or the socio-economic conditions. Generally, systems requiring a high degree of operation and maintenance have led to problems. Simple systems using tried and tested technology are the most enduring.

Some examples of inappropriate technology are mentioned below.

4.6.1 Inappropriate groundwater pumping systems

Inappropriate groundwater pumping systems have caused saline water intrusion and hence a brackish water supply in a number of small islands. Problems have arisen where pumping rates have been set too high, the wrong type of pumping system has been installed, or insufficient consideration has being given to the sustainable yield of the groundwater system. This issue is particularly important for freshwater lenses on small coral islands, where conventional wells or vertical boreholes (tubewells) are not necessarily the most suitable groundwater pumping solution.

4.6.2 Desalination in some applications

While desalination technology itself is proven, the application of this technology in small island countries presents a number of problems, which have often led to the failure of such systems. Desalination is a relatively expensive and complex technology for obtaining freshwater in small islands. The cost of producing desalinated water is invariably higher than ‘conventional’ options (e.g. pumping of groundwater) due to the high energy costs and other operating costs. In the Maldives, desalination is considered as an expensive alternative, but one that is necessary in some islands (Ibrahim, Bari and Miles, 2002). In addition, trained operators and a reliable source of supply for chemicals and spare parts are essential for reliable operation.

The unit cost of supplying desalinated water from a reverse osmosis system installed on the island of Betio, Tarawa is A$5.40/m3, compared with A$2.40/m3 for groundwater (refer Kiribati Case Study: Metutera, 2002). In terms of energy (electricity) costs, desalinated water is about 16 times more expensive than groundwater (A$2.81 compared with A$0.71).

Emergency water supply shortages due to the impact of droughts have led to the introduction of desalination systems in some small islands. However, operational problems (e.g. inadequate filtering of feed water or insufficiently trained operators) and high operating costs have resulted in many of these units being shut down and, in some cases, stored for future emergency use.

Desalination units were installed in two of the Lihir islands of PNG as an emergency drought measure in late 2000. These units only operated for short periods before the intakes were damaged by high seas. Other problems were the high expense for fuel costs and lack of suitably trained operators.

Similar negative experiences have been witnessed in the past on other small Pacific Islands where this type of technology has been introduced in small islands in the Pacific (e.g. Kiribati, Tonga and Tuvalu). A number of lessons have been learnt from these experiences and the application of this technology should be carefully managed in future. Further comments are provided in section 5.5.6.

4.6.3 Inappropriate sanitation systems

While sanitation is not a specific aspect of this theme, it is necessary to make mention of inappropriate sanitation systems, as these often adversely impact on the microbiological and chemical quality of freshwater resources. As mentioned in section 4.3.3, pit toilets and poorly maintained septic tanks are two examples. Because of their high pollution potential, particularly in island environments where soils are very permeable and water tables are shallow (e.g. small coral islands), pit toilets are often very inappropriate. Septic tank systems, while in theory a reasonable wastewater treatment option, are often unsuitable due to poor construction and lack of maintenance. In the past, these sanitation practices have been introduced by well-meaning donor agencies without a full consideration or appreciation of the groundwater conditions on small islands.

4.7 Catchment management issues

The major issue for both surface water and groundwater catchments (watersheds) is water quality degradation caused by human activity. Examples of activities and impacts on water quality are provided in section 4.3. Problems have arisen on many small islands because people are living above or very close to the water resources they use for water supply, including potable water.

Catchment management concerns the rational use and management of land and resources, including water, with minimum impact on the environment within and downstream or under of the catchment. Catchment management necessarily involves the people who own, reside on and use the land and water resources. In many PICs, land (often called 'customary' or 'traditional' land) is owned by customary landowners and decisions about the land are community-based. The issue of customary land and its relationship to water resources and catchment management is a special and important one in many PICs. Customary land tenure systems are not readily compatible with areas designated by governments for water supply or water resources protection, especially where restrictions have been imposed rather than agreed upon. Also, water rights are often not clear. Legislation may claim that water resources are vested in the government yet customary land ownership encompasses land and other resources, including water (e.g. Samoa Government, 2000).

In some PICs, conflicts have arisen due to the actual or attempted imposition or regulation by governments of land uses for public purposes on customary land. In cases where mutual agreement over land use has not occurred, conflicts, uncertainty and protracted delays in achieving effective land and water management have resulted. Such conflicts affect both surface water catchments and groundwater catchments where the main water resources issues are the use of the water, building of water supply infrastructure and protection of the water resources from pollution.

Catchment management issues related to the clearing of customary land to cultivate kava (or *sakau*) in surface water catchments of Pohnpei, Federated States of Micronesia to resolve these issues are well documented in Dahl and Raynor (1996) and Raynor and Kostka, (2001). Cultivations of kava on steep slopes in upland areas led to soil erosion and sedimentation in downstream mangroves, lagoons and coral reefs and adverse effects on water supplies. The need for catchment management in Pohnpei was recognised since the late 1970s but initial catchment management procedures were focused on a regulatory approach. Enforcement of legislation failed as it did not recognise customary land tenure and resource use, and there was very little community awareness and support for it. Measures taken since the late 1980s to resolve these issue have focused on participatory catchment management (refer section 5.4.1).

An example of groundwater catchment issues on a designated water reserve in Tarawa, Kiribati is documented in White et al (1999), and the Kiribati Case Study (Metutera, 2002). Bonriki Island in Tarawa, Kiribati has an international airport and a declared water reserve (i.e. a groundwater protection zone) above the main part of a large freshwater lens. Groundwater is pumped from the lens for water supply for South Tarawa. Legislation from the 1970s has place restrictions over land use within the water reserve to protect the quality of the groundwater which have been a source of friction over many years between the landowners and the government. The establishment of water reserves have failed to appreciate local community needs, culture, land tenure and land use requirements (White et al, 1999). In addition, the legislation for the water reserves shows a lack of identified roles and responsibilities due to the absence of overarching water resources legislation. In the past 10-15 years, some landowners and tenants have moved onto parts of the water reserve and established dwellings and associated gardens, presenting a threat to the groundwater quality. At the same time, the condition of coconut trees and other vegetation within the reserve has deteriorated. Further details are presented in White et al (1999). Recent measures taken to resolve this issue, including the establishment of a Water Resources Protection Committee to enable the local community and landowners in participate in measures to protect the groundwater resource are outlined in section 5.4.2.

Issues of water quality degradation in catchments are not confined to customary land. The Tonga Case Study (Fielea, 2002) provides an example of catchment management problems in a surface water supply catchment on the island of 'Eua in Tonga. There the land is owned by the government. Other parcels of land in Tonga which are used for groundwater extraction are owned by either the monarchy, the nobility or the government, as there is no private or customary and ownership under the unique land tenure system in Tonga.

4.8 Other issues and constraints

There are many other issues and constraints to sustainable water resources management. Many of these are not specifically identified as aspects to be covered under Theme 1, but rather will be addressed in detail in reports of the other five themes. However, as some issues and constraints are very important in the overall context of water resources management and impinge on aspects already covered in this Theme, a summary of the most important aspects is presented below.

These water resources management issues cover the following areas:

- Government policy.
- Water legislation.
- Institutional arrangements.
- Community awareness and participation.
- Customary land and catchment management.

Many of these issues are identified in a number of key sources (e.g. UNESCO, 1991; UNESCO/SOPAC/UNDDSMS, 1994; and ADB 1996) as well as other specific reports (e.g. White et al, 1999; Crennan, 2001). A brief summary of some of the major issues is provided below.

4.8.1 National government policy

Based on the results of a recent study (Mosley, 2000), water resources management has, in general, a low profile in many South Pacific Island countries. This is a major constraint to achieving sustainable and effective water resources management. Governments generally see other issues as having a much higher priority than water resources management issues. Concerns about water resources management issues tend to be focused during droughts due to water shortages, and shortly after floods, especially where there is loss of life and major damage to housing and infrastructure. At other times, however, activities such as long-term water resources monitoring tend not to be viewed as important and receive a corresponding level of support and funding.

In general, there is a need for greater and ongoing commitment and support from national governments in the area of water resources management and, indeed, in the wider water sector. The Tuvalu Case Study (Taulima, 2002) provides an example of this issue.

4.8.2 Legislation

Important issues related to water legislation are:

- There is often inadequate or no legislation to protect and conserve water resources and to manage surface water and groundwater catchments (watersheds). Sometimes there is legislation related to forest management or environmental conservation, but no specific watershed management legislation.
- Water rights are often unclear. Legislation may claim that water resources are vested in the government, yet customary land ownership encompasses land and other resources, including water (e.g. Samoa Government, 2000).
- There is often insufficient political will and/or institutional capacity to enforce legislation.

4.8.3 Institutional arrangements

- In some island countries, there is effectively no national water resources agency or 'national hydrological service' (Mosley, 2000). There is generally a meteorological service with a prime function of collecting, storing and disseminating climate data. However, surface water and groundwater resources data is often not collected, especially in outer islands.

- Where water resources data is collected, it may be by the water supply authority or by some form of national hydrological service located in a ministry for the environment, public works, or natural resources (Mosley, 2002). Such 'services' are often under-resourced reducing their capacity .
- Roles and responsibilities of agencies involved in water matters are sometimes unclear, fragmented and un-coordinated. For instance, there may be a lack of clear distinction between agencies involved in the provision of water supply and the regulation and protection of water resources.
- Competition for funding between government agencies involved in water management.
- Environmental impact assessment is almost non-existent in some PICs, and is in its infancy in others. This may encourage the development of projects that are not sound from a catchment management perspective.
- National water quality standards and water supply guidelines are sometimes non-existent.

4.8.4 Community awareness and participation

Important issues related to the involvement and participation of communities in water resources planning and management are:

- Insufficient emphasis placed on community education and awareness.
- Insufficient consultation with communities and opportunities for participation in decisions affecting water resource development, management and protection in many PICs.
- Insufficient recognition of the important role of women in the provision of water and sanitation, particularly in rural communities within PICs.
- Insufficient use of local knowledge in relation to the assessment of water resources potential in some islands.

Measures taken since the late 1980s to resolve this issue and promote participatory watershed management are outlined in section 6.2.2.

5. Actions taken to improve water resources management

5.1 Overview

This section presents an overview of actions taken in recent years to address the issues and concerns raised in section 4. The focus is on the PICs but many of these measures apply to small island countries in other regions.

The information presented in this section within the defined scope of Theme 1, is organised under the following headings:

- Water resources assessment and monitoring
- Water resources planning and development strategies
- Participatory catchment management
- Appropriate technology for water supply
- Appropriate technology for sanitation and wastewater
- Applied research projects
- Knowledge and information transfer
- Education, training and capacity building
- Inputs by regional and international agencies and NGOs.
- Other relevant initiatives.

Measures taken to address other aspects of water resources management, as raised in section 4.8 (government water policy, legislation, institutional arrangements and community awareness and participation), are covered in other theme reports for the Regional Consultation and in Falkland (2002).

5.2 Water resources assessment and monitoring

This section examines some of the steps taken to address these issues and concerns, presented in section 4.4. Actions required to improve water resources assessment and monitoring, including recommendations from recent detailed needs analyses (WMO, 1999; Mosley, 2000 and SOPAC/WMO/UNESCO (2001), are outlined in section 6.4.

The actions taken to improve water resources monitoring are considered at regional, national or institutional level and community or local level.

5.2.1 Regional level

SOPAC has provide assistance to water resources assessment projects in some PICs. Examples include a groundwater potential assessment of Rarotonga coastal plain, Cook Islands (SOPAC, 1998b) and a water resources assessment on Banaba Island (SOPAC, 2000b).

Further inputs by SOPAC are provided in Annex B.

5.2.2 National level

Surface and groundwater monitoring programmes are being implemented in most PICs but to varying levels of effectiveness. There have been a number of projects in individual PICs in recent years, funded by either bilateral development assistance agencies, multilateral agencies and private companies, which have been targeted directly at, or have included elements which have assisted with, water resources assessment and monitoring. Examples include:

?? Installation of raingauges and stream gauging stations in Samoa and Rarotonga, Cook Islands. These gauging stations and related water resources and database training for Ministry of Works staff are part of a 5 year NZODA funded project.

?? Drilling of replacement and some new groundwater monitoring boreholes on Tarawa atoll, Kiribati. These are to be used for investigation and monitoring of the freshwater lenses used for public water supply on the islands of Bonriki and Buota (part of the ADB funded SAPHE Project).

?? Drilling of groundwater monitoring boreholes, water resources monitoring training, database installation in conjunction with groundwater development projects on 3 islands, Tongatapu, Lifuka and Vava'u in Tonga for the Tonga Water Board (AusAID and EC funded projects).

?? Installation of streamflow monitoring weirs and groundwater investigations for a community village water management project as part of a wider community development program in the Lihir Islands, PNG (funded by Lihir Management Company, a gold mining company).

5.2.3 Community level

Initiatives to involve communities, particularly schools, in water resources monitoring programs have been implemented in a number of PICs. One of the most widely implemented projects is the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) which is a co-operative field project involving local meteorological services and schools. There are over 160 schools from approximately 22 different countries involved in this program. Data from SPaRCE stations is normally rainfall but in some cases includes additional climatic information (e.g. temperature and humidity). This program is co-ordinated through the University of Oklahoma in the USA and sponsored by a number of agencies. Further information is available at the SPaRCE website (http://www.evac.ou.edu/sparce).

Live & Learn Environmental Education have developed a 'River Care' project for implementation through schools and their local communities. Based on the Streamwatch programme in Australia, River Care is a water quality monitoring and education project designed to help raise community awareness of pollution in rivers (Live & Learn; 2000, 2002). It is not intended to be a solution in itself but is designed to raise awareness in students through river monitoring. Initially, it is intended to introduce it to schools and communities in the four most polluted river catchments in Fiji including the Rewa River catchment.

To overcome the shortage of staff to undertake routine water resource monitoring in Vanuatu, a proposal has been written which would utilise school students in streamflow and water quality assessments (Vanuatu Hydrology Section, 2001). Students would receive training in appropriate water resources monitoring and would be expected to undertake regular visits to selected sites to undertake this work.

Specific projects have also been undertaken in conjunction with schools. An example was the conducting of part of an applied research project at a secondary school on the island of Lifuka. The purposes of the project was to study groundwater movement of pollutants in a small coral island environment. The project was a practical example of groundwater quality monitoring and dye tracing used to educate and raise awareness of water resources management issues (Crennan et al, 1998, Crennan, 2001).

A number potential community based pilot projects focusing on specific freshwater management issues have been identified in a recent report for SPREP under their International Waters Programme (Falkland, 2002). These potential projects include the following

?? 'Stream Health' (similar to 'River Care') which involves monitoring of stream water quality and demonstrating the linkage between upstream catchment uses and downstream water quality impacts,

?? 'Groundwater Health' focusing on groundwater monitoring to demonstrate linkages between groundwater pollution from sanitation systems and water quality impacts in nearby wells.

?? 'Leakage Watch' which involves flow monitoring at schools and other institutions to demonstrate patterns of water consumption and promote water conservation.

In each proposed pilot project, the key elements are:

?? Community education and awareness raising of the issue.

?? Improvement of understanding of catchment (watershed) processes and impacts on freshwater quantity and quality through appropriate data collection and monitoring.

?? Examination of factors which are impacting on sustainability and water quality of the freshwater resources.

?? Demonstration of methods or technologies that can be used to resolve or improve current conditions.

?? Discussion with communities and other stakeholders and preparation of future management options and preferred approaches.

?? Local and wider dissemination of results through appropriate media.

In addition, community based projects related to sanitation, wastewater and solid waste management are presented in a parallel report for SPREP under their International Waters Programme on waste management (Crennan and Berry, 2002). These are also relevant to the water resources management theme as many current waste disposal methods have a direct on freshwater pollution and degradation.

5.3 Water resources planning and development strategies

This section examines activities taken in small island countries to improve the sustainability of freshwater resources through effective and appropriate water resources planning and development strategies. It is not possible to present a comprehensive overview of activities but rather some specific examples are provided.

These strategies, which form part of an integrated approach to water resources management, include:

?? Effective, long-term planning of water resources development.

?? Drought management strategies.

?? Conjunctive use of water sources.

?? Protection of water sources and supplies.

?? Water demand management and conservation.

Related topics dealing with appropriate water supply and sanitation technologies, primarily for rural water supplies are considered in sections 5.5 and 5.

5.3.1 Planning of water resources development

Effective, long-term planning of water resources development needs to take account of many factors including the nature and extent of naturally occurring water resources, climatic and other impacts on these resources, economic conditions, type and location of water demand centres, and community attitudes and practices through consultation. Crucial to effective planning is the assessment of water resources potential and water demands. Initially, surface water, groundwater and rainwater resources need to be adequately assessed and sustainable yields estimated. 'Non-conventional' options, including desalination and importation and use of other water (e.g. seawater) should only be considered in special circumstances (e.g. where freshwater resources are very limited under normal conditions or during drought) but not before other simpler and less expensive options have been thoroughly investigated.

Planning for water resources development has, in general, occurred to a satisfactory degree for larger urban centres in PICs. Planning for water supplies in outer or rural islands receives generally less attention. In some cases, solutions that are adopted are non-sustainable leading to shortages in droughts or salinisation or pollution of water supplies. Water planning is generally undertaken on an intermittent rather than continuous basis, often with external technical assistance from consultants and funding from bilateral or multi-lateral development aid projects. In many cases, there is limited local staff with sufficient training and often limited water resources data on which to base the long-term plans, and hence the decisions, which are made may require review in the future.

An example of current water resources planning for the long-term future is the current Sanitation, Public Health, and Environment (SAPHE) project in Tarawa, Kiribati. The ADB loan funded project aims to improve the development potential of Kiribati and the health and well-being of the people through a improvements in water supply, sanitation, solid waste disposal and environmental awareness and conservation. The water supply component involves a planning element to look at long term water supply options for South (urban) Tarawa. Options include increased groundwater extraction from the current water sources (Bonriki and Buota freshwater lenses) and other islands in north (rural) Tarawa, additional rainwater collection and desalination. Key planning components of this project have been a review of the sustainable yields of the Bonriki and Buota freshwater lenses including additional water resources assessments, trials of constant flow systems to households to control water demands and economic appraisals of the available water development options. Additional assessments of groundwater resources potential in north Tarawa are planned. Further details of this project and other water planning and management issues in Kiribati are presented in the Kiribati Case Study (Metutera, 2002).

The water resources development for South Tarawa is an interesting example of water resources management in a small island context where naturally occurring freshwater resources are very scarce. For many years, it has been recognised that the freshwater resources need to be conserved as much as possible. For this reason, water supply planning has been based on relatively low per capita consumption rates (40 litres per person per day) and reticulation sewerage systems in the main centres, built 20 years ago, have used seawater as the flushing water. Currently, other sanitation options including dry composting toilets are being trialled for less densely populated parts of South Tarawa. Further discussions of this technology, is presented in section 5.6.1.

5.3.2 Drought management strategies

Drought management strategies should be part of the long term planning for water supplies. While this is primarily an issue for the smaller islands with limited water resources, particularly those susceptible to long droughts, it is also important for islands with larger landmasses or where rainfall has a high variability. Examples of drought management strategies have included:

?? Water restrictions. Such measures were taken in the 1997-1998 El Niño drought in several countries including PNG, Solomon Islands and Fiji (SOPAC, 1999a). Radio programs have been used as a means of raising public awareness to reduce water consumption in some countries (e.g. Marshall islands, Kiribati, Tonga and Samoa).

?? Leakage control measures. On the main island of Rarotonga in the Cook Islands, where surface water flows were less than half of normal flows at water intakes, the water supply agency used leakage control measures to reduce the loss of water (SOPAC, 2000b).

?? Groundwater pumping strategies. To ensure sustainability of groundwater for public water supply during droughts, some island water supply agencies have adopted the philosophy that pumping rates should be set at a minimum constant rate, which has been designed to cope with worst historical drought periods. This approach is used for groundwater pumping from the islands of Bonriki and Buota in Tarawa. Another strategy is to pump at low rates once water salinity levels reach a threshold level but allow higher pumping rates when condition are favourable. This involves a detailed knowledge of the impacts of climate and pumping on freshwater lenses that can be done only after sufficient monitoring data has been collected and assessed. An example of an island where such a strategy is in place is Home Island, Cocos (Keeling) Islands in the Indian Ocean (Falkland, 1999c).

?? Water conservation. An important part of the drought management process is to recognise the effectiveness of rainwater catchments in supplying basic needs throughout droughts. In the Ha'apai group of Tonga, where significant droughts can occur, many households recognise that rainwater should be conserved for only potable purposes when regular rainfall ceases. In other islands where the impacts of droughts are very severe (e.g. Kiritimati, Kiribati), normal rainwater catchment systems cannot supply sufficient freshwater for even basic demands.

?? Larger domestic rainwater storages. In the northern atolls of the Cook Islands, the main current water supply source is rainwater although groundwater is used as a supplementary source during drought, especially for 'second class' water requirements. Following major destruction of houses and community facilities on Manihiki atoll, northern Cook Islands, by over-washing waves due to Cyclone Martin in 1997, rainwater tank improvements were implemented. These included the installation of large in-ground rainwater storage tanks as integral parts of new household cyclone shelters, as part of a move to more effective drought management.

?? Rainwater tanks for communal use. In Tuvalu, rainwater collection is the primary source of water as rainfall is generally high and drought periods tend to be of relatively short duration compared with other parts of the Pacific. When water shortages occur, communal tank water, is used to supplement private rainwater catchment systems. This water is rationed. As a further step towards improving the overall capacity of rainwater storage for the urban area on Funafuti atoll, public housing designs have incorporated separate underground cisterns for private household use and for communal use in times of drought (refer Tuvalu Case Study: Taulima, 2002).

?? Importation. Some small islands with limited or no fresh surface and groundwater, and limited rainwater capacity are reliant on freshwater imported from larger islands. This can involve local people canoeing to other nearby islands or, in larger emergencies, government funded boats or barges supplying water to the islands (e.g. in some outer islands of Tonga and Fiji).

?? Desalination: In some islands, desalination systems have been provided and installed as a response to severe droughts, and stored for emergency purposes when rainfall conditions have improved (e.g. Marshall Islands, Tuvalu). In the case of Kiribati, a desalination unit was installed during the long and severe drought in the late 1990's and was kept operational following the drought. The use of desalination systems to supplement potable water supplies in droughts is an appropriate response, provided that it is not a substitute for more effective and economical long- term water supply strategies.

?? Other sources. Communities on small islands have long known methods appropriate for dealing with droughts. These have included collection of water from sustainable springs, digging shallow wells on beaches to extract groundwater and travelling by boats to nearby islands to collect water from more permanent sources. Other measures include the use of coconuts as a substitute for drinking water and using brackish or seawater for non-potable uses. It is probably true to say that very few communities will be totally devoid of freshwater or substitutes (e.g. coconuts). Potential exceptions are islands reliant solely on rainwater or where population pressure is extremely high and available water resources are scare (e.g. Ebeye, Marshall Islands).

5.3.3 Conjunctive use of water sources

The conjunctive use of water from different sources for different purposes can provide an effective means of water resources management at the household and community levels. Conjunctive use of water from different sources enables consumers to exercise some control over the sustainability of the water supply and water quality.

Conjunctive use schemes on small low-lying islands typically involve using rainwater for 'first class' needs (e.g. drinking, cooking) and groundwater from wells for 'second class' needs (e.g. bathing and washing). There are many examples of this type of conjunctive use in PICs (e.g. for islands in the Federated States of Micronesia, examples are provided Winter; 1995a, 1995b; Federated States of Micronesia, 2002). The conjunctive use of surface water and rainwater is practised in a number of high islands. Rainwater tanks adjacent to houses provide a convenient means of supplying drinking water and water for bathing and washing can be obtained from nearby streams (often used at the site). Sometimes three classes of water are present in urban or peri-urban areas. For example, many houses in urban Tarawa where some houses have access to local wells, rainwater and piped, chlorinated water).

Other forms of conjunctive use are evident in islands with limited freshwater resources in order to maximise the use of these resources for potable purposes. As mentioned, previously seawater or brackish well water may be used for bathing in some islands where freshwater resources are limited. Seawater is also used for flushing water in reticulated sewerage systems in densely populated areas of Tarawa and in Majuro, Marshall Islands.

5.3.4 Protection of water sources and supplies

Measures to more effectively manage and protect water sources from (further) water quality degradation have been taken in some islands and are planned in others. These measures include a combination of catchment management measures, application of appropriate technology and procedures, and administrative arrangements.

?? Measures to control land uses in surface water catchments that cause erosion, sedimentation and contamination from sanitation and solid waste disposal. For instance, controls on the cultivation of steep slopes, clearing of forests and construction and use of tracks and roads in sensitive water supply catchments are necessary.

?? Siting of groundwater supply sources well away from potential pollution sources. This may include using certain islands on atolls or parts of islands reserved for freshwater extraction (e.g. Tarawa). Where this is not possible, large open spaces (e.g. playing fields) provide reasonable areas for the development of groundwater. A project was implemented on Lifuka, Tonga to install infiltration galleries on sports fields within the urban area (the only area which has a freshwater lens under it). The galleries were sited as far from human habitations and pollution sources as possible in order to minimise the threat of biological contamination.

?? Disinfection of water supplies that are impacted by bacteriological contamination. Chlorination plants are present in most urban water supply systems in PICs, with some using powder (calcium hypochlorite) and others using gas chlorination systems. They are rarely used in rural water supply systems.

?? Filtration systems have been built and maintained to remove suspended solids and hence clarify the water. Examples are the roughing and slow sand filters used for the Apia water supply in Samoa. These require maintenance (e.g. replacements of sand) at more frequent intervals as catchment water quality becomes worse.

?? Improved methods of sanitation to prevent ground and surface water pollution from wastewater. This could involve waterless (dry composting) toilets (e.g. Kiribati, Tonga). In the Maldives, other measures to protect groundwater quality on very small islands through improved sewage treatment and disposal of wastewater are planned (e.g. low gradient "small bore" pipe systems to gravel bed hydroponics or constructed wetlands for sewage treatment: Ibrahim, Bari and Miles, 2002).

?? Controls on areas where animals can be kept and/or methods to deal with animal waste.

?? Adequate bunding around fuel and other storage tanks.

?? Impermeable membranes and effective leachate control and disposal systems at landfill sites and pollution monitoring boreholes to monitor impacts.

?? Siting and selection of appropriate methods of groundwater pumping systems that do not cause saline intrusion. Siting of pumping systems in the central parts of coral islands will ensure more sustainable freshwater supplies than those near the edge.

?? National guidelines or site-specific guidelines, with similar measures have been prepared in some PICs in relation to groundwater protection, sometimes as part of draft or enacted national water resources (or water supply) legislation. These have been implemented to various degrees depending on local circumstances. In Tonga, for instance, legislation enables the Tonga Water Board to establish groundwater protection zones over freshwater lens areas used for water supply.

?? To maximise groundwater availability, it may be prudent to selectively clear vegetation, particularly coconut trees, in designated areas, to reduce transpiration. Coconut trees on low coral islands act as phreatophytes (i.e. draw water directly from the water table) and may cause a reduction in available groundwater resources, especially during relatively dry periods. However, this suggestion should be treated very cautiously, as coconut trees are often a source of food and drink, shade and materials for building and other purposes. In some islands, areas that have been already cleared for other land uses, such as airfields, offer good opportunities for groundwater development, especially on low lying coral islands (e.g. Tarawa in Kiribati, Aitutaki in the Cook Islands, Kwajalein in the Marshall islands).

?? Develop contingency plans for occasions when surface or ground water does not meet the required quality (e.g. use rainwater for potable water). This is a sound measure whereby water is used conjunctively and is typical of approaches on some atolls where other options are not available.

Examples and further details are provided in other parts of section 5 and in the Case Studies for Kiribati, Tonga and Maldives. In addition, community-based measures to cope with water supply quality degradation in islands of Chuuk in the Federated States of Micronesia are outlined in the Micronesian Source Water Protection Coalition (2001).

5.3.5 Water demand management and conservation

Water utilities in urban and some rural centres in PICs utilise a range of demand management measures including metering and charging for water on user pays basis, leakage control, water saving devices and education and awareness about water conservation.

Metering and charging on the basis of water usage is an effective demand management tool and has been implemented in a number of PIC urban areas (e.g. PNG, Solomon Islands, Vanuatu, Marshall Islands, Tonga, Samoa and parts of the Federated States of Micronesia). In some PICs, metering and charging has been previously implemented but temporarily stopped due to operational problems (e.g. Kiribati) or has not yet been implemented (e.g. Cook Islands). Water usage reductions have been noted following the introduction of these measures. An example is Apia, Samoa, where the consumption fell from an estimated 825 litres/person/day to 325 litres/person/day following the introduction of metering (Samoan Government, 2000).

In rural areas where water charging is applied, it is normally done on a flat fee basis and collected by the village water committees (e.g. Tonga).

Where pipe networks are used to distribute water, active leakage control can greatly assist in reducing losses. In recent years, a number of urban water authorities have instituted leakage control programs (e.g. Fiji, Tonga and Samoa). The Pacific Water Association (PWA) is also involved in leakage detection promotion, as it is recognised as one of the main issues facing its members. SOPAC has been instrumental at raising awareness and dialogue on this topic through a regional workshop (SOPAC, 1999b) and has conducted in-country investigations and associated pipe network modelling and training of local personnel, for example, Cook Islands, Fiji, Kiribati, Niue, Samoa, Solomon Islands, Tonga and Vanuatu (various SOPAC reports).

Measures to improve leakage in plumbing systems in houses and other buildings (e.g. offices, schools) can have a beneficial impact on operational costs for pumped systems. In Niue, it was estimated that a 55% reduction of water usage was achieved by conducting a survey of every house in each village and repairing leaks in taps, showers and toilet cisterns. This measure nearly halved operational costs for groundwater pumping (SOPAC, 2000a).

Water saving devices, such as spring loaded taps for standpipes and improved household plumbing fixtures (low and dual flush toilet cisterns, low flow taps and shower heads) can assist in water conservation and have been installed in some islands. In recent water supply designs in Kiribati for villages on Kiritimati (AusAID funded water and sanitation project) and urban areas of Tarawa (ADB SAPHE Project), constant flow systems have been included for each household so as to restrict the total daily flow to a selected volume.

Education and awareness about water conservation is a most important part of overall demand management and is presented in Theme 3.

5.4 Participatory catchment management

Catchments management issues were briefly outlined in section 4.7. While government agencies are generally aware of the measures required to achieve effective catchment management, the problem in the past in many countries, including PICs, has been insufficient attention to the 'human activity system' or social dimension of catchments. In PICs, this means the recognition of traditional systems and values including land tenure systems and social structures (Falkland, 2002).

'Integrated catchment management' (ICM) has been introduced over the past decade to recognise the importance of the social dimension and to integrate it with the physical dimension in the process of catchment management. ICM has been defined as the 'process of formulating and implementing a course of action involving natural and human resources in a catchment, taking account of the social, political, economic and institutional factors operating within the catchment to achieve specific objectives' (Hufschmidt and Tejwani, 1993). ICM is effectively a component of integrated water resources management (IWRM) applies at the catchment, watershed or basin scale. IWRM is further discussed in the small island context in section 5.11.1.

'Participatory watershed management' (PCM) emphasises people's participation and action as the central element of ICM. PCM has often been recognised as a more effective means of achieving sustainable resource management, including protection of water resources, than the more commonly applied 'top down' approach (Hinchcliff et al, 1999).

PCM is not well developed in PICs. Worthwhile results have been achieved where it has applied (e.g. Pohnpei and Tarawa, as outlined below). In other PICs, steps have and are being taken to enable the participation of communities in catchment management and the rational use and protection of water resources (e.g. "Water for All" national water policy in Samoa: Samoa Government, 2000). Another example is provided in the Tonga Case Study of the island of 'Eua (Fielea, 2002).

5.4.1 Surface water catchment management in Pohnpei

Early failed attempts at catchment management in the 1980s were introduced in section 5.7. Starting in the late 1980s, a number of measures were taken to rectify water quality degradation problems through participatory watershed management. This management process evolved over several years in Pohnpei with support from various agencies including US Forest Service, ADB, SPREP and The Nature Conservancy (TNC). A multi-agency Watershed Steering Committee (WSC) was established in 1989, with government and NGO representatives. Which conducted an island-wide watershed education and consultation program, visiting all local communities. An Integrated Watershed Management Strategy (WMS) was developed by TNC with assistance from SPREP and ADB, and approved in 1996 (Raynor and Kostka, 2001). The WMS was based on participation of community members, traditional and civil leaders and the private sector. It recognised the authority of local villagers to manage their own forest and marine resources. One of the main objectives of the WMS was to develop a practical cost-effective monitoring program to measure the status and trends of Pohnpei's watershed resources and to be used as a guide to community-based resource management. A monitoring program was developed in 1997 (Crocker et al, 1997). TNC has assisted its local partner, the Conservation Society of Pohnpei (CSP), and others in community-based conservation monitoring and enforcement throughout Pohnpei. They have also assisted farmers to plant kava (*sakau*) in the lowlands, under the shade of commercial fruit trees ("Grow Low" campaign).

During this period, the Pohnpei Watershed Conservation Area Project under the South Pacific Biodiversity Conservation Programme (SPBCP) was also established. Its main objective was to protect and conserve the ecological functions and processes of the upland forest within the Pohnpei Island Watershed Forest Reserve area and the mangrove forests (SPREP, 2001). Over time, this project has evolved from a defined watershed area to the island-wide conservation effort involving nearly 200 villages in the five municipalities, relying mainly on the work of the TNC and CSP. The project has been generally successful in raising awareness on the need for conservation of the upland watershed. Numerous posters in the local language have been printed and distributed, and project staff have worked very closely with local communities. While not all aspects of this initiative have been successful (refer SPREP, 2001), the overall process of developing the participatory approach to catchment management has been successful.

5.4.2 Groundwater catchment management in Tarawa

White et al (1999) presented a list of recommendations aimed at both the institutional and the community level, which could assist in longer-term resolution of potentially ongoing issues. One concept advanced to the government, was to establish village-based committees for the continued protection and management of activities on the freshwater lenses (P. Jones, pers. comm., 2001), representing a step towards participatory catchment management.

Recent attempts to achieve better management of the Bonriki and nearby Buota freshwater reserves, Tarawa (refer section 5.7) have included the establishment of a Water Resources Protection Committee to enable the local community and landowners in participate in measures to protect the groundwater resource (Metutera, 2002). Landowners and others who are living in the freshwater reserve are being encouraged to move voluntarily. A compromise solution was found where most could be resettled along a 50m wide strip on the ocean side of Bonriki island, and effectively on the edge of the freshwater lens. After a series of land boundary adjustments, some of the people have moved. This solution was reached after consultation between the Bonriki landowners and government, recognising that the water reserve was a necessary long- term water supply for urban Tarawa.

5.5 Appropriate technology for water supply

5.5.1 Overview

Appropriate technologies for application in small island developing states to achieve sustainable development and management of water resources has been the focus of a major initiative in the past few years. UNEP and the International Environmental Technology Centre (IETC) sponsored a series of surveys, workshops and publications to evaluate and present a number of appropriate or alternative technologies for 'freshwater augmentation' in small island developing states. In the Pacific region, this work was undertaken largely by SOPAC with inputs from individuals in the Pacific, Indian Ocean and South China Sea regions. A workshop was held at SOPAC in February 1996 (SOPAC, 1996), which was followed by preparation and publication of a Source Book on Alternative Technologies for Freshwater Augmentation in Small Island Developing States (IETC, 1998). The purpose of the book is to provide information to water and environmental managers and planners about available methods for sustainable development of freshwater resources on small islands.

There have been other projects and reports aimed at providing useful methods, approaches and designs for sustainable water resources development and management. SOPAC has been a key agency in many of these initiatives, particularly in its role as a regional co-ordinator of workshops on relevant topics (e.g. hand pumps, solar pumps, demand management and appropriate sanitation for the management, conservation and protection of freshwater resources). A number of bilateral agencies including NZODA and AusAID have funded projects with a focus on providing sustainable solutions to water management.

As mentioned previously, the focus in this report on rural water supply systems and hence consideration of appropriate technologies applying to these systems are considered. Urban water supply technology and approaches are considered in Theme 4.

5.5.2 Rainwater harvesting

In general, household rainwater tanks are one of the most appropriate solutions to improving potable water supplies and they also increase the level of community involvement and self-reliance in rural water supply schemes.

The vital importance of rainwater is evident in many islands and may in fact be the primary, and in some cases only, source of freshwater (e.g. many atolls in Tuvalu, and some very small islands in Cook Islands, Fiji, PNG and Tonga). In other islands, where average rainfall is moderate and where droughts can last for many months, rainwater can be considered only as a useful supplementary water source. The cost of building sufficiently large catchments areas and storage tanks to supply rainwater as a main source of supply in such islands would be prohibitive.

Household rainwater harvesting systems involving rainfall collection from all or part of the roof and storing it in a small to medium sized tank are common. There are many examples of such systems on small islands in the Pacific and other regions. Such schemes are and should continue to be implemented. There have been many examples of communal projects to build ferrocement rainwater tanks throughout PICs. A variety of aid donors, NGOs and other groups have been involved in this work. In some cases, the projects aim at individual household tanks while others have built communal tanks near public buildings. Examples are provided in Annex B (Water resources management in the 14 participating countries) of a recent report under the International Waters Programme of SPREP (Falkland, 2002).

Methods for the design of rainwater catchment systems are the focus of a number of reports in proceedings of a series of international conferences on this subject and other specific references (e.g. Gould, 1991; Nissen-Peterson and Gould, 1999). Specific design guidelines for particular countries have been developed including Tuvalu (Chapman, 1986; SOPAC, 2001c) and Federated States of Micronesia (Heitz and Winter, 1996).

Rainwater catchment construction programmes in rural areas have been the focus of many aid projects in PICs. These programmes have been implemented with funding from a large number of international and bilateral donors and NGOs. Many involve the construction of ferrocement tanks which can be implemented in community based construction schemes. In some cases, this may involve local contractors (e.g. Tonga) while in others, whole villages have been involved in the process. Various guidelines have been written, often in the local language, to assist in the training of persons to carry out construction work, examples of which are presented in IETC (1998). In some island countries (e.g. Cook Islands, Tuvalu, Maldives), plastic tanks are becoming more popular than previous ferrocement, or fibreglass tanks.

In Tarawa, Kiribati, recent building regulations require that new buildings include gutters and minimum rainwater storage of 5,000 L. This measure will assist in the longer term in relieving the water demand on the public groundwater supply system (Kiribati Case Study: Metutera, 2002). Similar measures have been previously taken in other islands. In Tuvalu, regulations regarding rainwater harvesting have been in place since 1990. Revision to the regulations based on recent analysis of rainfall data have been suggested (SOPAC, 2001c).

One issue that is not commonly considered in the planning process for rainwater harvesting systems is a means of preventing or minimising runoff of leaf matter, animal and bird faeces and other debris from roofs and gutters into storage tanks. This is an important consideration as often the levels of bacteria in rainwater tanks can become quite high if no action is taken to prevent entry of potential pollutants. Most important is some means of “first flush” device as most of the pollutants wash off roofs and gutters debris shortly after the first heavy rainfall for some time. Simple “first flush” measures are adopted by householders in some islands by removing the downpipe from gutters to tanks during long periods of no rain (e.g. rural areas of Tonga). This is very effective although more convenient approaches using a bypass pipe, T-junction and two valves are used for rainwater collection in some islands (e.g. Maldives). The main pipe to the tank can be closed while the bypass pipe diverts dirty water to waste during the 'first flush'. Under normal condition the valve to the tank is opened while the bypass valve is closed. Materials are quite inexpensive.

Recognising the scarcity and vulnerability of water resources on atolls islands, a project proposal has been developed by UNEP and SOPAC to promote rainwater harvesting in atolls (UNEP/SOPAC, 2001; SOPAC Water Resources Unit website). The proposed project, entitled Empowering Women in Rainwater Harvesting in Pacific Atoll Islands, has the goals of (a) increasing the quantity and quality of water available on vulnerable atoll islands, and (b) increase women's participation in the implementation of rainwater harvesting systems.

Proposed outputs from the project are:

?? Rainwater harvesting scheme installed in one urban community and one rural community

?? Draft policy for promoting water harvesting in the project area

?? Committees on water management established at the local level

?? Training manuals and guidelines for rainwater harvesting projects

?? Report on water harvesting technologies and pilot study results

?? Video entitled "Empowering Women in Water Resources Management focussing on Rain Water Harvesting" and distribution of materials produced to other countries.

The island of Vava'u in Tonga had been selected for the project Tonga and Tuvalu. Funding will be provided by UNEP and the project will be managed by SOPAC in association with a local NGO, the Tonga Community Development Trust.

A community-based rainwater harvesting project was also rated as a possible project to be funded under the International Waters Programme of SPREP (Falkland, 2002).

5.5.3 Surface water development

Surface water resources development methods on small islands are generally stream intake structures, dams and other storages, or spring cappings. Examples of the application of these methods are provided in UNESCO (1991) and IETC (1998).

Stream intake structures generally consist of in-stream weirs or buried collector pipe systems laid in or near the stream bed. In-stream weirs are often used in high islands with volcanic rock channels. There are many local designs which generally consist of a small concrete weir to impound streamflow from the base of which a pipe diverts water to a village. Screens are often used to remove medium to large floating objects. The largest issue is the entry of dirty (turbid) water following heavy rain and high flows. Water treatment systems are required to remove the small particulate matter and turbidity, but are not used except in some of the larger water supply systems. A simpler method is to lay a network of PVC pipes in a sand filter bed behind the weir (AusAID, 2000). This method can remove fine particulate matter and turbidity but has the disadvantage of being subject to damage during floods or becoming clogged requiring regular maintenance. In practice, water supplies affected by high turbidity require a day or more for the water quality to return to normal. During these times, it is very useful to use supplementary rainwater.

Buried porous concrete collector pipes within streams have also been used on some islands (e.g. the Cook islands: Waterhouse & Petty, 1986).

Water retaining structures can be constructed as dams within the stream or as off-channel storages. Neither is very common on small islands due to unsuitable topography or geology and high costs. Sometimes dams have been constructed in unsuitable geological conditions leading to leakage problems (e.g. dam constructed for hydropower project on Upolo, Samoa).

Spring cappings, common in many small high islands, typically consist of an open or covered containment structure, generally constructed from concrete or masonry. Spring flows are contained by the structure and diverted to an intake pipe.

5.5.4 Groundwater extraction using infiltration galleries

Groundwater abstraction methods on small islands are generally bailing or pumping from dug wells or pumping from boreholes (or drilled wells). Dug wells are common in villages and towns in low-lying islands and the coastal areas of high islands. Where extraction rates are small, this method of groundwater withdrawal is highly appropriate. Pumping from boreholes is also a common method on high islands and moderately high limestone islands. This method is used for supplying water to many villages in volcanic and limestone islands in Samoa and Tonga, and to a number of urban centres (e.g. Port Vial in Vanuatu and Tongatapu in Tonga).

For freshwater lenses on small low-lying coral islands, moderate to high pumping from wells and boreholes using can lead, and has led, to upconing of brackish water causing the pumped water to become saline. The reason for this is that the impact of the pumping is localised near the point of extraction.

A much more appropriate method of pumping from small coral islands is to from infiltration galleries (also called “horizontal wells” or "skimming wells"). Infiltration galleries avoid the problems of saline intrusion because they spread the impact of pumping over a wider area of the freshwater lens than wells or boreholes

Infiltration galleries generally consist of buried horizontal conduit systems which are permeable to water (e.g. PVC slotted pipes), laid in trenches dug at or close to mean sea level thus allowing water to be drawn towards a central pump. The trenches are dug by hand or with the aid of mechanical digger. Once the gallery pipes are laid, the area is backfilled and the only structure seen above ground level is a pump well and pumping system.

Infiltration galleries are successfully operating in a number of PICs including Tarawa, Kiribati (Falkland & Woodroffe, 1997), Kwajalein in the Marshall Islands (Hunt, 1996) and Lifuka, Tonga (TWB, 2000). On the island of Bonriki, Tarawa, a yield of about 1 million litres/day is obtained from 17 galleries, each 300 m long (White et al, 1999). There are other examples in PICs in the Marshall Islands (Majuro and Kwajalein) and the Cook Islands (Aitutaki). Open trenches, as previously used on Kiritimati atoll in Kiribati, prior to recent construction of new galleries, are not recommended as these are subject to surface pollution.

On the island of Lifuka in Tonga, where groundwater pumped to the residents of the village of Pangai-Hihifo had traditionally been quite saline, improvements using infiltration galleries have significantly lowered the level of salinity of the water supply (TWB, 2000). The community has been acutely aware of previous attempts to improve the water supply by using wells and boreholes. They were also made aware of the infiltration gallery project, partly through public information sessions but also through involvement of local workers in constructing the galleries, fitting the solar and electric pumps, building a new tankstand and tank and finally experiencing the results of the improvements in reduced water salinity from the day the new system was commissioned.

Further consideration of infiltration galleries on Tarawa are provided in the Kiribati Case Study (Metutera, 2002).

5.5.5 Energy for pumping

Most groundwater pumping systems use fossil fuel, predominantly diesel fuel, for energy sources. However, the use of alternatives is being considered more often for rural pumping systems, particularly solar pumping systems.

Solar pumping for groundwater supplies has been found very useful in rural villages where the pumping heads are not too high. Solar pumping is used for many village water supplies in the rural islands of Kiribati, and in Tonga solar pumps have been used in tandem with electric pumps at galleries on the island of Lifuka.. A recent water supply and sanitation project in Kiritimati island, Kiribati has installed infiltration galleries with a solar and a wind pump at each gallery.

In general, the use of solar pumping systems has been more successful than wind pumping systems. This is due to the lower maintenance requirements (less moving parts).

5.5.6 Desalination – appropriate or not?

Desalination can be an appropriate solution for small island countries where options for further use of naturally occurring freshwater resources are exhausted due to over use or major contamination, or as an emergency measure during droughts. However, desalination should only be considered when more conventional water sources are non-existent, fully utilised or more expensive to develop

In all cases, however, it is necessary to analyse the options based on a good knowledge of the other water resources options and the economics of supplying water from each source. In the case of Nauru, for instance, there is potential for use of groundwater instead of desalinated water for some uses. Despite some previous groundwater investigations, there is a need for a more comprehensive assessment of groundwater potential on the island (e.g. WHO, 2001).

It could be argued that desalination is the only option for Malé' in the Maldives and for Ebeye in the Marshall Islands, owing to the high population densities and the limited and polluted groundwater. Even in these islands, other options are available for supplementary water (e.g. rainwater and use of brackish groundwater for some uses). In the case of Malé', all three sources are used.

It is worth noting that the only operational desalination units for regular water supply in Pacific Islands are in limited urban areas (e.g. Nauru, Ebeye and part of Tarawa), tourist resorts or military facilities. In these cases, funding and technical expertise to operate and maintain such units is generally available. Even then, major problems can and do occur (e.g. blockages of intake in Nauru in 2002).

In addition to desalination systems requiring the use of energy from diesel powered pumps or power stations, solar stills offer a "low technology" solution in certain applications. They systems, using solar energy, have been used, generally on a temporary or research basis, for the production of small quantities of freshwater from seawater. With typical daily solar radiation values in the humid tropics, freshwater yields of about 3 L/ m^2/day can be produced. While solar stills have major advantages in that they use readily available energy and produce high quality water, there are some significant problems for large-scale production of freshwater by this method. They can, however, be employed for emergency purposes. This technology has not been utilised in small islands, except at the experimental level. There is, however, scope for greater use of this technology at the community level. It can for instance be used to supply small quantities of drinking water in droughts.

5.6 Appropriate technology for sanitation and wastewater

Improvements in sanitation systems are important from a water resources management perspective for two major reasons. Firstly, the type of sanitation system may impact on availability of water resources for other needs. In particular, flush toilets require water as the flushing medium and if freshwater is used, this may lead to shortages for other, including potable water needs. Secondly, sanitation systems can be a major source of biological and chemical pollution of water resources, as outlined in sections 4.3.

This section is primarily concerned with rural water supply systems but some reference is made to sanitation options which are relevant to urban systems.

5.6.1 Compost (waterless) toilets

Recognising the need for sanitation improvements in small island countries, there have been many bilateral and regional projects attempting to redress the situation. Some of these are aimed at improvements to centralised sewerage systems while others are aimed at appropriate on-site sanitation systems. It is the latter that is the subject of this theme.

As outlined in section 4, major pollution can occur from septic tanks and pit toilets especially in islands with permeable soils and shallow water tables. These types of sanitation systems are therefore considered inappropriate in many island situations.

One sanitation alternative that has great potential for use in rural and in fact urban areas in PICs is the dry composting or 'waterless' toilet. There are significant advantages of waterless toilets as follows (Crennan and Berry, 2002):

?? They do not use water and hence conserve water resources.

?? They prevent pollution of groundwater and surface water resources.

?? They can provide more effective destruction of disease causing organisms than common waterborne sewage treatment.

?? They can be constructed cheaply from local materials.

?? They can produce a useful soil improver.

Trials of dry composting toilets have been conducted under AusAID projects in Tonga (on the island of Lifuka) and in Kiribati (on Kiritimati) and more recently as part of an ADB project in Tarawa. The trial in Tonga, involved 15 units at 13 households and two schools. Overall, the trial, which was completed in 1999 (Crennan, 1999), was successful and the Government of Tonga has indicated that they wish to see a greater use of this form of sanitation. A large component of the trial project was community education, awareness raising and training. The largest impediments to the introduction of this technology are social rather than technical (e.g. initial scepticism about the viability of this sanitation approach, fears of bad odours and important issues related to handling human waste, even after decomposition). However, these issues can be resolved with appropriate community education delivered before and throughout the course of a properly designed and conducted trial.

A composting toilet pilot project is included as one of the potential community-based project activities under the waste management theme for the International Waters Programme of SPREP (Crennan and Berry, 2002).

There is an urgent need for greater use of technologies such as water less toilets in small islands to assist in the process of managing water demand and reducing the degradation of water quality. Further consideration of this technology is considered in section 6.6.

5.6.2 Regional meetings and publications

In recent years, at the regional level there have been a number of important meetings and workshops to raise awareness and examine alternative approaches to sanitation. These include:

?? Workshop on Appropriate and Affordable Sanitation for Small Islands, Tarawa, Kiribati, September 1996. Further work based on the workshop findings led to the publication "Sanitation for small islands. Guidelines for selection and development" published by SOPAC in conjunction with UNDP and WHO (Depledge, 1997).

?? Regional Meeting of Stakeholders in Wastewater Management. Majuro, Marshall Islands, 10-15 October 2001, SOPAC (2001). This was an initiative under the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and followed two planning meetings held in February and March 2001. The objective of the Majuro meeting was to discuss a draft policy statement on 'waste' water and to develop a regional framework for action. The program included presentations covering a range of public health and conservation issues related to waste water management. The major outcomes of the meeting were the Pacific Wastewater, Policy Statement and Pacific Wastewater, Framework for Action (SOPAC/SPREP/PWA/UNEP; 2001a; 2001b).

?? Workshop on 'Environmentally Sound Technologies (EST) for Integrated Waste Management in Pacific SIDS' which followed the above-mentioned meeting in Majuro, Marshall Islands. The participants discussed suggested technologies and practices (IETC, 1999) for management of liquid, solid, and hazardous 'wastes' for a regional EST Directory.

SOPAC in collaboration with other agencies have published a number of guidelines and other reports on aspects of sanitation in the PICs. These include:

?? SOPAC. (1997). Sanitation for Small Islands: Guidelines for Selection and Development, Compiled by Derrick Depledge, SOPAC Miscellaneous Report 250.

?? SOPAC. (1999). Small Scale Wastewater Treatment Plant Project; Report on Project Inception. Bower, R. and Scholzel, H., SOPAC Preliminary Report 113.

?? SOPAC. (1999). Small Scale Wastewater Treatment Plant Project; Report on Project Criteria, Guidelines and Technologies. R Bower and H Scholzel, SOPAC Technical Report 288.

?? SOPAC. (2000). Environmentally Sound Technologies for Wastewater and Stormwater Management in Small Developing States in the Pacific, Compiled by Ed Burke, SOPAC Technical Report 321.

5.6.3 Regional wastewater management policy

The Pacific Wastewater, Policy Statement (SOPAC/SPREP/PWA/UNEP, 2001a) and the accompanying Pacific Wastewater, Framework for Action are significant as they present a regional policy and strategy for wastewater management in PICs. This policy is relevant to the water resources management theme through impacts the impacts that sanitation and wastewater systems has on water quality and water use.

Within the wastewater management policy, there are five guiding principles which incorporate an overall objective leading to policies and actions. These guiding principles are:

?? National wastewater management policies and regulations will be appropriate and acceptable to the people and cultures of the Pacific Islands.

?? Appropriate national institutions, infrastructure and Information will support sustainable wastewater management.

?? Better access to funding will improve service delivery and develop the private sector.

?? Community participation in wastewater management and sanitation will ensure equitable benefit with recognition of socio-cultural sensitivities.

?? Viable and sustainable levels of skilled and knowledgeable people within the wastewater sector and communities will improve wastewater management.

Much of the content of the wastewater policy/framework for action are relevant to the wider water sector and there is scope for it to be widened so as to incorporate other elements including those pertaining to Theme 1, water resources management.

5.6.4 Bacteriological testing

Bacteriological testing of water supplies (to test for faecal contamination) is generally difficult in PICs and often to the extent that it is not done regularly if at all. Current testing methods generally involve collection of samples in sterile bottles and sending to a central laboratory on the main islands, generally at the main hospital. The procedures required for sampling and transporting samples are not easily undertaken, especially in remote islands where flights are either irregular or not available.

Alternative, simpler methods for bacteriological testing are now available. Rather than using the more common membrane filtration test, a colour change indicator method has been developed (several types) which can indicate the presence or absence of bacteria (total and faecal coliforms). This test is good for rural and even urban water supplies as it is simple to use, does not require a laboratory or expensive equipment and provides sufficient information to show if water supplies are fit or unfit for potable use (according to WHO guidelines for drinking water: WHO, 1993). A cheaper presence/absence method is the use of hydrogen sulphide report strip tests to detect hydrogen sulphide producers that inhabit the intestinal tracts of warm-blooded animals, rather than direct evidence of total or faecal coliforms. Correlations with more conventional tests have shown good results (D. Sharp, pers. comm., 2001).

5.7 Applied research projects

This section provides a summary of recent and current applied research projects. Future research needs are presented in section 6.8.

5.7.1 'UNESCO-SOPAC' projects

Three priority applied research projects were recommended at the Pacific Water Sector Planning, Research and Training Workshop in Honiara, 1994 (UNESCO/SOPAC/UNDDSMS, 1994). These were:

?? A groundwater recharge project with the aim of quantifying the key hydrological processes affecting the amount of water which recharges groundwater (freshwater lenses) on small coral islands. The island of Bonriki, Tarawa atoll, Kiribati was the selected project site.

?? A groundwater pollution study with the aim of analysing the linkage between sanitation systems and groundwater pollution in nearby wells. The island of Lifuka in the Kingdom of Tonga was the selected project site.

?? A 'catchment and communities' project on a small 'high' island, aiming to study the impacts of upstream activities (e.g., deforestation, mining) on downstream communities. An island in Melanesia was the preferred target area but no site was selected.

In each case, it was recognised that community consultation, participation, education and awareness are as important as the scientific and technical issues. Other key elements to be addressed were the training of water professional and technical staff, and the discussion of test results with the local communities during and following monitoring projects.

UNESCO provided a pivotal role and the initial funding to support the first two projects with additional funding and logistical support provided by SOPAC, the Commonwealth Science Council and a number of institutions in Australia. Literature surveys were completed in the early stages of both projects (White, 1996; Dillon, 1997). Reports with the findings of the research have been completed for both projects. Findings from the recharge project in Tarawa are presented in White et al (1999, 2002) with additional aspects, covering the integration of social and technical science components, in Crennan (2001). For the groundwater pollution project in Tonga, findings are presented on Crennan et al (1998) and Crennan (2001).

The third mentioned 'Catchment and Communities" project has not yet been implemented. The project scope and location has been revised on a number of occasions, since it was originally suggested in 1994. An updated project proposal is provided in White et al (2000). The project is now proposed for Vanuatu where sites are being selected and a project document is being prepared jointly by the Department of Geology, Mines and Water Resources and NIWA, New Zealand for consideration by UNESCO for funding.

5.7.2 Groundwater and agriculture research project

Recently, another major research project entitled "Equitable Groundwater Management for the Development of Atolls and Small Islands" has commenced (ACIAR, 2002). This project, funded by the Australian Centre for International Agricultural Research (ACIAR), will study the impacts of cropping on groundwater and of groundwater management on cropping and groundwater resources in Tonga and Kiribati. The project concentrates on groundwater as it is the major source of fresh water in many atolls and small islands and its availability, quality, management and allocation are central to their sustainable development. The main research organisation is the Centre for Resource and Environmental Studies of the Australian National University. Collaborating institutions are SOPAC and government agencies and the water authorities in Tonga and Kiribati. The project team aim to integrate hydrogeological, agronomic, social, economic and cultural information, to assist in setting broadly accepted, long-term goals for groundwater management and allocation and to reduce conflict.

5.7.3 Other selected research projects and publications

Research into the impacts of droughts on different water resources (e.g. groundwater and rainwater) on small coral islands has led to the development of a broadly applicable 'drought index' (White, Falkland and Scott, 1999). This drought index approach, developed for Tarawa, but applicable to other drought-prone island countries, uses a relatively simple analysis of monthly rainfall data to identify the severity of various drought periods. Using this information, critical drought indices can be used to trigger various water conservation or relief strategies, as appropriate.

At the ENSO Impact on Water Resources in the Pacific Region Workshop in Nadi, Fiji, in September 1999 (SOPAC, 1999a) an additional priority project of drought assessment in small island nations was proposed. A project proposal is also provided in White et al (2000).

Further discussion of this topic of drought assessment is presented in the Theme 2 report.

In addition to the research mentioned above, which has involved largely 'South Pacific' countries, applied research has been conducted in the former US Trust Territory islands (i.e. Federated States of Micronesia, Marshall Islands and Palau) by US agencies including the US Geological Survey, the Water Resources Research Centre of the University of Hawaii and the Water and Energy Research Institute of the University of Guam. This has led to a wide range of water resources studies on many of the islands in these countries. Examples include Mink (1986), Miller et al (1991) Spengler et al (1992), Hunt (1996), Peterson (1997) and Buddemeier and Oberdorfer (1997).

Other publications which have extensive summaries of past research into island hydrology, hydrogeology and water resources in the Pacific and other regions are contained in a number of specific publications including UNESCO (1991) and Vacher and Quinn (1997).

5.8 Knowledge and information transfer

5.8.1 Previous meetings and workshops

A number of important regional meetings and workshops, specifically concerned with freshwater resources, water supply and related issues on islands have been held in the Pacific Region over the past 20 years. These were organised in response to the water resource management concerns and needs of PICs. Major events since 1983 are listed below and citations to proceedings of these meetings and workshops are shown in brackets:

- Meeting on Water Resources Development in the South Pacific, Suva, Fiji, 1983 (ESCAP, 1983).
- Regional Workshop on Water Resources of Small Islands, Suva, Fiji, 1984. (CSC, 1984).
- Interregional Seminar on Water Resources Management Techniques for Small Islands, Suva, Fiji, 1989 (UNDTCD, 1989).
- Workshop on Water Sector Planning, Research and Training, Honiara, Solomon Islands, 1994 (UNESCO/SOPAC/UNDDSMS, 1994).
- Workshop on Technologies for Maximising and Augmenting Freshwater Resources in Small Islands, Suva, Fiji, 1996 (SOPAC, 1996 and IETC, 1998).
- Small Islands Developing States Working Group Meeting on Water, Suva, Fiji, 1997 (SOPAC, 1997b).
- Small Islands Water Information Network (SIWIN) Workshop, Suva, Fiji, 1997 (SOPAC, 1997c).
- UNESCO Water Resources Workshop, Suva, Fiji, 1997 (Sankey et al, 1997).
- Workshop on Water Demand Management Workshop, 1999 (SOPAC, 1999b).
- Meeting of Experts on Hydrological Needs of Small Islands, Nadi, Fiji, 1999 (WMO, 1999).
- Workshop ENSO Impact on Water Resources in the Pacific Region, 1999 (SOPAC, 1999a).
- Meeting of Pacific Focal Group for Water Resources, Priority Issues in Water Resources, Christchurch, New Zealand, November 2000 (White et al, 2000).

Annual meetings of the Science, Technology and Resources (STAR) network are held at SOPAC Annual Sessions which often review water resources issues. In addition, annual meetings of the Pacific Water Association (PWA) have a strong focus on water supply in the urban sector and also consider wider water management issues.

5.8.2 Relevant publications

Publications which cover aspects of island hydrology and water resources management in the Pacific and other regions include:

?? Pacific Island water resources (Dale, 1981).

?? Groundwater in the Pacific Region (UNDTCD, 1983).

?? Coral island hydrology: a training guide for field practice (Dale et al, 1986).

?? Hydrology and water resources of small islands, a practical guide (UNESCO, 1991).

?? Small Tropical Islands, water resources of paradises lost (UNESCO, 1992).

?? Geology and hydrogeology of carbonate Islands (Vacher & Quinn, 1997).

?? Source book of alternative technologies for freshwater augmentation in small island developing states (IETC, 1998).

?? Tropical island hydrology and water resources: current knowledge and future needs (Falkland, 1999b).

?? Synopsis of information on freshwater and watershed management issues in the Pacific Region (SPREP-IWP, 2002).

While some of the above references are somewhat dated, they contain useful background information about the water resources of PICs.

In addition, there are numerous reports on Pacific regional water activities, which also refer to specific PICs. These include reports by, or prepared for:

?? Regional organisations (e.g. SOPAC, SPREP).

?? International organisations (e.g. UNESCO, WHO).

?? Donor and loan agencies (ADB, EC and various bilateral donors).

?? NGOs and individuals about community-based water related projects in PICs.

?? Educational and research organisations within the Pacific Region. These are too numerous to be listed but many are contained in the reference list.

5.8.3 PIC water working groups

In recent years, from PICs involved in the water sector have met at various workshops and formed ad-hoc working groups on water resources. These have generally only lasted for the duration of the meeting and shortly thereafter. They have provided opportunities for useful dialogue between individuals about shared issues and potential solutions. Depending on availability, funding and other reasons, individuals from PICs and other agencies and individuals within the Pacific region may attend. A summary of these water working and 'focus' groups is provided below.

At Science, Technology and Resources (STAR) Network meetings, which are held in conjunction with SOPAC Annual Sessions, an ad-hoc group called the STAR Water Working Group (or Technical Advisory Group on Water is convened from delegates attending with an interest in water issues. This group normally review the recommendations of the previous year's group, reviews the work program of SOPAC's Water Resources Unit (WRU) and other initiatives, and makes recommendations to the STAR chairman to take to the SOPAC Council.

For instance, at the October 2001 STAR/SOPAC meeting in Majuro, the Water Working Group reviewed the Water Working Group recommendations from the 2000 meeting, and the Pacific Wastewater Policy Statement and the Pacific Wastewater Framework for Action from the Regional Wastewater Meeting (also held in Majuro in October 2001). Amongst the recommendations, the 2001 Water Working Group, endorsed the following recommendations emanating from the Regional Wastewater Meeting:

?? a Pacific Wastewater Focal Group be established to continue the dialogue on wastewater in the region; and

?? Pacific Island Countries develop National Frameworks for Action and establish National Wastewater Focal Groups.

The 2001 Water Working Group also recommended that SOPAC:

?? take a lead in collaboration with SPREP and the Pacific Wastewater Focal Group to mobilise funds that through the Global Programme for Action (GPA) to implement demonstration projects on wastewater in the region.

?? initiate further activities in the Pacific region on Environmentally Sound Technologies, including research and dissemination of information (emanating from a UNEP-funded workshop on Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for Small Island Developing States in the Pacific, also held in Majuro in October 2001).

A "UNESCO-IHP Working Group on Water Resources" was convened at the UNESCO Water Resources Workshop in 1997. This group reviewed the progress on two applied research projects in PICs and developed a revised list of research activities and priorities (refer Sankey et al, 1997 and section 5.7.1)

Another focal group for water resources was inaugurated at a meeting held in Christchurch, New Zealand in November 2000 (White et al, 2000). This meeting was held in conjunction with a wider Regional Steering Committee (RSC) Meeting of the UNESCO International Hydrological Programme (IHP) in the Asia-Pacific Region. It was attended by PIC delegates from Cook Islands, Kiribati, Niue, PNG, Tonga and Vanuatu, as well as Australia, New Zealand, UNESCO and SOPAC. The delegates recognised that many small island nations, although members of UNESCO, do not have their own national International Hydrological Programme (IHP) committees and therefore are not formally part of the RSC network. It was proposed that an alternative group called the 'Pacific Focal Group for Water Resources' be established. This could meet as part of or in conjunction with STAR Water Working Group meetings, possibly every 2 years. The main purpose would be to review water resources activities including applied research, develop priorities and make recommendations for action. Recommendations could be taken to RSC meetings by a UNESCO or SOPAC representative. Details of the workings of the Pacific Focal Group for Water Resources have not been finalised.

At the Christchurch meeting, the applied research projects were again reviewed (refer White et al, 2000 and section 5.7.1).

For the 9 member countries of the World Meteorological Organisation, there is also the WMO Regional Association 5 (RA V) Working Group on Hydrology. This group with membership predominantly from the national Meteorological Services meets at regular intervals. One of the most relevant meetings from the viewpoint of this theme was the Meeting of Experts on Hydrological Needs of Small Islands in 1999 which identified deficiencies in current water resources assessment and monitoring programs in PICs.

In addition to the above groups, there are many other avenues for networking and information dissemination/gathering available to water personnel in PICs. One of these is through the Pacific Water Association (PWA). Another avenue is the Small Islands Water Information Network (SIWIN) which has a website.

From the above discussion, it is evident that there are many current mechanisms and proposals for interaction and networking between delegates from PICs on water resources and wider aspects of water and wastewater. The main issue is the effective use of such groups for discussion of issues and priorities and for the development of recommendations for action. There is scope for some rationalisation of the various groups to provide and effective, coherent voice, as discussed in section 6.11.

5.9 Education, training and capacity building

This section briefly considers current education, training and capacity building for personnel and institutions in involved water resources assessment and monitoring. These current opportunities partially satisfy the needs as expressed in section 4.5.

Possible future actions to more adequately address these needs are presented in section 6.4 and 6.9.

5.9.1 Regional level

SOPAC's Water Resources Unit has provided and continues to provide technical support and training through a number of channels, including:

?? Training workshops on specific water resources management topics (e.g. hand pumps, solar pumps, demand management and appropriate sanitation for the management, conservation and protection of freshwater resources). These are normally held at SOPAC headquarters but have been held elsewhere.

?? Direct technical support to technical and professional staff from PICs both at SOPAC headquarters and in-country.

?? Assistance through provision of lecturers at the Hydrogeology course at the University of South Pacific to water technicians within PICs. This course forms part of the 3-year Certificate Course in Earth Science and Geology which has been undertaken by significant numbers of geoscience and water resources personnel from PICs.

The extent of the current training is limited by the resources within the WRU of SOPAC.

In addition, training programmes to water supply technicians and professional staff have been co-ordinated by the Pacific Water Association. Further detail of water supply training for utilities is the subject of Theme 4.

5.9.2 National level

Training in water resources assessment and monitoring have been given to national agencies involved in water supply or water resource management. This tends to be project based and may involve only limited staff. The most successful projects in this regard are those that have had long duration to enable training to occur over longer time periods and for a number of staff to be involved in the training. An example of such a project was an AusAID funded institutional strengthening project of the Tonga Water Board from 1995 to 1999 in which one major component was the implementation of a technical training program in groundwater resources monitoring and associated data processing. Other examples include training of surface water resources technicians in Vanuatu, the Solomon Islands, Samoa and the Cook Islands by NIWA staff under NZODA funded projects.

Educational opportunities at university level for water professionals are provided through scholarships provided by donors. For instance, AusAID has funded university education placements for engineers and hydrogeologists at universities in Australia. More recently, distance learning schemes for master's level courses in water and other related disciplines have become available.

5.10 Inputs by regional and international agencies and NGOs

There are a number of regional and international agencies involved in the water sector within the Pacific region. The main agencies are as follows:

?? Regional agencies:
  - o South Pacific Applied Geoscience Commission (SOPAC)
  - o South Pacific Regional Environment Programme (SPREP)
  - o Secretariat for the Pacific Community (formerly South Pacific Commission) (SPC)
  - o Asian Development Bank (ADB)

?? International agencies:
  - o United Nations Educational, Scientific and Cultural Organisation (UNESCO)
  - o United Nations Environment Programme (UNEP)
  - o United Nations Development Programme (UNDP)
  - o United Nations Children's Fund (UNICEF)
  - o World Health Organisation (WHO)
  - o World Meteorological Organisation (WMO)

- o Food and Agriculture Organisation (FAO)
- o Commonwealth Science Council (CSC)
- o Water Supply and Sanitation Collaborative Council (WSSCC)

The Pacific Water Association (PWA) is a regional association of Pacific Island water supply organisations, mainly in urban areas, operating in Pacific Island countries

In the addition to the agencies above, there are many NGOs who have considerable input at community level into predominantly rural water supply schemes (e.g. household rainwater harvesting schemes), sanitation systems and associated education and community awareness programs. Some of the relevant NGOs and their activities are presented in the Theme 3 report and also in Crennan and Berry (2002) and Falkland (2002).

It is beyond the scope of this report to present an overview of the involvement of all these agencies in the water sector. Rather, Annex B presents a summary of major contributors in recent years within the scope of Theme 1 as defined for the Regional Consultation process.

5.11 Other relevant initiatives

There are a number of water resources management initiatives that have occurred outside the Pacific region which are of relevant to Theme 1. These are briefly discussed below.

5.11.1 IWRM and the Global Water Partnership

Much has been written about integrated water resources management (IWRM) in recent years. IWRM views water resources management from a holistic perspective to ensure that social, technical, economic and environmental factors are taken into account with the aim of sustainably developing and managing the water resources. IWRM has been defined by the Global Water Partnership (GWP) as a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWPTAC, 2000).

Typically, IWRM is undertaken at the level of a river basin (watershed or surface water catchment) or groundwater basin (groundwater catchment) as these are natural units for managing water resources. In the island context, IWRM can be applied at whole island scale especially for low-lying islands or for those high islands with multiple small surface water catchments.

At present, there is a large amount of knowledge and a wealth of experience worldwide in the field of integrated water resources management but less so in developing countries including the PICs. The Global Water Partnership (GWP) has integrated much of this knowledge and experience into an “IWRM Toolbox” to enable water policy makers, water agencies, and other groups and individuals in the water sector benefit from experience elsewhere and assist in implementation of IWRM principles and practices. The aim of the IWRM Toolbox is to offer easy access to practical, non-prescriptive advice, information and guidance on how to establish IWRM in real situations. GWP consider that the IWRM Toolbox (available on the web at www.gwpforum.org/iwrmtoolbox) will become a vital aid to the successful implementation of sustainable water resources management world-wide.

It is noted that other agencies have an active interest in IWRM including the ADB, WMO and UNESCO-IHP.

This concept is further considered in section 6.3.

5.11.2 Bonn Conference on Freshwater

In December 2002, an International Conference on Freshwater was held in Bonn, Germany. This was a preparatory meeting on freshwater issues for the World Summit on Sustainable Development (Johannesburg, South Africa, September 2002) and the Third World Water Forum (Kyoto, Japan, March 2003). Outcomes of the conference included a Ministerial Declaration (endorsed by Ministers for water, environment and development from 46 countries), Recommendations for Action and ‘The Bonn Keys’ (a synopsis of the main findings). These documents form useful background information for consideration at the Regional Consultation.

6. Actions towards sustainable water resources management

6.1 Overview

This section presents an overview of actions that could be taken to move towards a more sustainable water resources management in the small islands countries of the Pacific region. These are based on the issues, concerns and constraints raised in section 4 and the activities already undertaken, as presented in section 5.

At this stage it is worth reiterating the aim of the Regional Consultation on Water in Small Island Countries (Information Note to participants, May 2002 is to "to help international, regional and country practitioners strengthen their policies, institutional arrangements and projects through: enhancing public awareness of the need for better water and wastewater management; exchanging views and experiences, and developing a shared understanding about policies, institutional frameworks and approaches to sustainable sector development".

It is also recognised that further necessary input is required from other sources including the Country Briefing Papers to be presented at the Regional Consultation and the discussion that will take place at the Consultation. Thus, the list of possible actions presented in this section should be viewed as a preliminary list and is open for discussion and amendment.

There is no single action that will improve the sustainability of water resources management in small island countries. Rather, an integrated approach to improving a range of factors is required at all levels in order for this to occur. Commitment and encouragement from national governments is required. This needs to be backed by technical and financial support from bilateral, regional and international donor agencies, and others including NGOs and consultants. The capacity of national water agencies need to be strengthened in many areas including water resources assessment and monitoring capabilities, water planning, appropriate technology in water, sanitation and wastewater. Regional agencies with interests and responsibilities in water resources management should also be strengthened so that they can provide technical support to water personnel from national agencies. Additional applied research is required in order to better understand some of the fundamental hydrological and water quality processes in small island environments. Communities should be encouraged and enabled to take a greater role in the management of water resources at the local level. This should include participation in the management of their own surface water and groundwater catchments to redress the water quality degradation that has occurred and will continue to occur unless appropriate steps are taken. This will require concerted efforts in the area of community awareness and education and greater recognition of the importance of both genders in the water sector.

The information presented in this section within the defined scope of Theme 1, is organised under the following headings:

?? Commitment and support from national governments.

?? Integrated water resources management.

?? Water resources assessment and monitoring, and associated training and capacity building.

?? Appropriate water supply and sanitation.

?? Participatory catchment management.

?? Applied research projects.

?? Education and professional training.

?? Knowledge and information dissemination.

?? Networking and partnerships.

It is noted that some aspects of water resources management will be considered in more depth within the scopes of the other five themes for the Regional Consultation process.

6.2 Commitment and support from national governments

There is a need for greater and ongoing commitment and support from national governments in the area of water resources management and, indeed, in the wider water sector. As sustainable and effective water resources management is fundamental to the health and social well being of the people, the economic development and environmental protection, it should be afforded a high priority in national policies, strategies.

Many of the requirements for more sustainable and effective water resources management such as water resources assessment, appropriate technology, effective institutions arrangements, committed and well trained personnel, effective community participation (and others) will not be achieved unless there is the political will and support for these to occur.

This is a priority issue and impacts on all themes within the scope of the Regional Consultation and it is suggested that this topic be given due consideration.

6.3 Integrated water resources management

From the issues and concerns raised in section 4, there is a need in PICs for greater integration of effort within the water sector and a wider view taken on sustainable management of water resources. As mentioned in section 5, this requires that water resources management be viewed from a wide (or holistic) perspective to ensure that social, technical, economic and environmental factors are taken into account. In other words, there is a need for greater emphasis on integrated water resources management (IWRM) principle and practices

To assist in the implementation of IWRM principles and practices, one method is the IWRM ‘Toolbox’ developed by the Global Water Partnership (GWP). The Toolbox is based on the large amount of knowledge and a wealth of experience worldwide. It has been developed, and continues to be developed, to assist water policy makers, water agencies, and other groups and individuals in the water sector to assist in implementation of IWRM principles and practices. The Toolbox is divided in three categories in a similar fashion as our regional meeting and include:

?? Enabling Environment (policy, legislation, finance)

?? Institutional Roles (organizational framework, institutional capacity building)

?? Management Instruments (water resources assessment, IWRM plans, demand management, social change, conflict resolution, regulatory instruments, economic instruments, information management and exchange)

All aspects of the IWRM Toolbox have application within the various themes for the Regional Consultation. Specific to the defined scope of Theme 1 are a number of items including water resources assessment and IWRM plans under the ‘Managing Instruments’ category.

To assist in implementation of IWRM principles and practices in PICs, one proposal is to establish a Pacific Water Partnership (PWP) Technical Advisory Committee. Membership would be open to all organisations with a common interest in the Pacific water sector for the promotion of IWRM.

At the Regional Consultation, it is intended that the IWRM Toolbox, the Pacific Water Partnership Technical Advisory Committee and wider concept of the PWP will be further explained by GWP, SOPAC and others.

In addition to the IWM Toolbox, recent information provided by SOPAC has indicated that a year-long (250 hour) training curriculum on IWRM is to be developed under a new United Nations project. One of the first components will be established in the Pacific, and a coordinator will work with the University of South Pacific (USP) in establishing the IWRM Curriculum in the Pacific.. This will be an internet-based "Virtual Learning Center for Water" providing distance learning opportunities and information for practicing professionals in the water sector wishing to upgrade their knowledge of modern water management concepts and practices. It is intended that the curriculum will be disseminated through a global electronic network of regional and national training institutions.

It is suggested that the implementation of IWRM principles and practices in PICs with appropriate support from relevant agencies and using relevant methods be considered as a priority matter

6.4 Water resources assessment and monitoring

There is a need for a much greater emphasis on water resources assessment and monitoring in small island countries in the Pacific region. A detailed list of concerns and issues, and areas which require training and capacity building in these areas, are outlined in sections 4.4 and 4.5.

This can only occur through a commitment at national government level, supported by appropriate training, education and capacity building efforts at national and regional level.

This section outlines a number of suggested actions for consideration at the Regional Consultation. In order to review these suggested actions, it is proposed that a **Water Resources Assessment and Monitoring Working Group** be formed to consider these and other suggestions and make recommendations for possible endorsement by delegates. It is noted that some of these topics overlap with other Themes, so that the Working Group would not only be relevant to Theme 1.

6.4.1 Pacific HYCOS project proposal for capacity building

Recently, two major reports which highlight the inadequate capacity in PICs to collect good quality hydrological data and undertake water resources assessments have been prepared:

- Hydrological Cycle Observing System for the Pacific Island Countries (Pacific-HYCOS), Project document, prepared by a WMO consultant (Mosley, 2000)
- A Programme to meet Hydrological Training Needs of Small Island Countries in the Pacific; jointly prepared by SOPAC, WMO and UNESCO (SOPAC/WMO/UNESCO, 2001).

Mosley (2000) emphasised the need for long-term water resources monitoring information in all PICs. Mosley (2000) recommends a project called Pacific HYCOS (Hydrological Cycle Observing System) which emphasises capacity building and training through a regionally co-ordinated approach. The stated goal of the project is that participating PICs will:

- Attain a common capacity to assess and monitor the status and trend of their water resources, and to provide the water-related information and hazard warnings needed to support national social and economic development and environmental management.
- Have established databases and information archives, maintained to acceptable standards, that form the basis for sustained future data capture and information processing and dissemination.

To achieve the goal, the project has 3 stated purposes:

- To assist the participating countries to establish the human and institutional capacity to assess the status and trend of national water resources and to provide adequate warnings of water-related hazards.
- To establish basic hydrological monitoring and data capture systems, using technology that balances modernity, economy, robustness, and suitability for Pacific Island circumstances.
- To establish hydrological databases and information systems that provide users with the information they require, to the standards (including accuracy, timeliness, usability, etc.) they need, and that provide a secure repository of information for the indefinite future.

The project proposes to deliver six distinct 'technical' components and a project management component designed to meet the needs of PICs, as follows:

- Flood forecasting capability,
- Water resources assessment in major rivers,
- Water resources databases,
- Drought forecasting,
- Groundwater monitoring and assessment, and
- Water quality monitoring and assessment.

The project proposes investment in data acquisition systems, field equipment, communication systems, spare parts, databases, development of procedures and training.

It is noted that this project proposal was strongly supported by members of the Working Group on Hydrology of the WMO Regional Association V (South-West Pacific) at their meeting in Wellington in January 2002 (WMO, 2002). PIC members of the working group, represented at the meeting, were Cook Islands, Fiji, Niue, PNG, Solomon Islands, Samoa and Vanuatu.

Many of these components are directly linked to Theme 1 of this Regional Consultation while others link to Theme 2.

6.4.2 Hydrological training needs at regional level

A proposal to meet the hydrological (water resources) training needs of PICs (SOPAC/WMO/UNESCO, 2001) outlines a training programme implemented through a regional body. The stated goal of the proposed training programme is:

?? To provide, through a targeted course of training, a corps of technical staff in the National Hydrological Services of participating PICs who are competent to assemble, maintain and apply data and information on national water resources, and are able to pass on their knowledge and skills to others.

The stated objectives of the programme are:

?? To have available a body of training material that is suitable for use by technical staff in the National Hydrological Services of PICs.

?? To encourage representation from all small island countries to enable the development of staff competent in the essentials of operational hydrology, and able to pass on their competencies to other staff.

?? To ensure the long term sustainability of the programme through implementation by an existing regional body (SOPAC) with an existing training framework.

It is noted in SOPAC/WMO/UNESCO (2001) that the 'National Hydrological Services' (NHSs) are at various levels of development, with different requirements, and training needs. In many PICs, NHSs do not exist at present and water monitoring if done at all is normally carries out by various agencies, normally water supply utilities or agencies. The proposal recognises that training will need to be tailored to the individual situations and requirements for each PIC.

The training programme proposes a series of courses initially over 3 years and these would be held at the University of South Pacific facilities. The first and second year courses would be held over 4 week periods and involve classroom instruction, laboratory exercises and fieldwork. Further details on the requirements for participants, possible venues and costs are identified in the proposal. SOPAC/WMO/UNESCO (2001) proposes that the training would eventually be incorporated into the Pacific HYCOS programme.

6.4.3 Capacity building and training through bilateral projects

It is recognised that bilateral donors have been and are likely to continue involvement in capacity building or "institutional strengthening" projects for water agencies, normally those responsible for urban water supplies but also involving rural water supplies. This contribution to the water management in PICs is valuable through the supply of equipment, installation of monitoring stations, database development and the training of staff.

It is important that water resources training components of such projects are co-ordinated with any future regional efforts to avoid duplication of effort and funding. At the same time, specific training and professional development components that go beyond regional training are encouraged (refer section 6.9). Examples would be scholarships to universities for water engineers, hydrogeologists and other water related disciplines, on-site training in specific areas (e.g. groundwater modelling for sustainable yield and climate vulnerability assessments, design of water supply systems, etc).

In addition, it is suggested that donor funded projects in water resources development and water supply and sanitation projects increase their level of finding for water resources assessment programs for water resources assessment components. This can be achieved through supply of monitoring equipment, installation of monitoring facilities and training

6.4.4 Special needs of very small islands

There is a need for special attention to monitoring needs of 'outer islands' where there is often no water related staff other than selected village people who may operate groundwater pumps, maintain surface intakes and use rainwater tanks.

In these often remote islands, there remains a need to monitor water resources used for water supply purposes, in order to assess their sustainability during droughts. Simple measuring equipment (e.g. salinity meters to text groundwater condition, flow measuring weirs (or pipes) in streams and simple bacteriological test kits) can be used with effectiveness. However, training and support are vital for sustainability of such operations. The support and funding from national governments for such operations to outer island councils is a necessity.

6.4.5 Guidelines for water assessment and monitoring

The WMO has published operational guidelines for water resources assessment/monitoring in many different environments (e.g. WMO: 1987, 1994). Much of these are relevant to continental and larger island conditions, where large rives and aquifers prevail. In addition, there have been some specific guidelines prepared for water resources assessments in small islands (e.g. Hydrology and water resources of small islands, a practical guide: UNESCO, 1991) and very small coral islands (e.g. Coral island hydrology: a training guide for field practice: Dale et al, 1986).

There is scope for developing updated practical guidelines for surface and groundwater resources and assessment in very small islands by synthesising and updating previous guidelines. Experiences with different methods in different environments (including lessons learned) in the form of case studies would be useful for small island water resources personnel.

6.4.6 Community based monitoring

Initiatives to involve communities, particularly schools, in water resources monitoring programs were outlined in section 5.2.3. Such programs serve a very useful community awareness role. There is further scope for cooperation between local communities and supporting NGOs with water agencies and national hydrological or meteorological services in this regard. It is important, however, that such programs are not seen as a substitute for, rather the complementary to, regular water resources monitoring by trained technicians.

6.4.7 Bacteriological testing

The testing of water supplies for indicator bacteria to assess the quality of water for potable purposes was considered in section 5.6.4. Current methods are often difficult to implement and often not done regularly if at all. Simpler methods are available and it is suggested that such methods be considered for use in small islands, particularly in remote outer islands where access to main islands with laboratory facilities is difficult.

6.5 Appropriate water supply and sanitation

This section considers appropriate water resources development, particularly in relation to rural water supplies, while Theme 4 focuses on urban water supply systems. This section also considers appropriate sanitation systems for rural and some urban applications. A number of suggestions and recommendations are made, for consideration by the Regional Consultation. It may be useful to form an <u>**Appropriate Technology Working Group** to consider these and other suggestions and make recommendations for possible endorsement by delegates</u>. Depending on the level of interest, it may be useful to have two sub-groups one to review water technology issues and the other to review sanitation technology issues.

6.5.1 Water supply strategies

?? Water resources development should utilise naturally occurring freshwater resources before other options such as desalination and importation.

?? Water resources development options should take account of all factors: technical, economic, social and cultural, environmental, before decisions are made.

?? The conjunctive use of water from different sources (e.g. rainwater and groundwater) is recognised as a most appropriate approach to water resources management in islands with scare water resources or where water quality has degraded.

?? Strategies for water supply operations need to take account of 'normal' and drought periods. These procedures should be developed as part of long-term plans.

6.5.2 Rainwater harvesting

?? Rainwater harvesting, particularly at the household level should be seen as a high priority. Although in most islands, rainwater harvesting could not be viewed as a main or sole source of water, it is an excellent supplementary source for 'first class' water for potable purposes. The efforts of NGOs and some donors to support such programs within community development projects is a valuable contribution to sustainable water resources management. Such systems enable households to take responsibility and have control over water availability and water quality. There is considerable scope for a greater support for rainwater harvesting programs in PICs and for encouragement of households to maintain their own gutters, roofs and tanks.

?? Rainwater systems should be designed according to the prevailing rainfall patterns. Analysis methods used in previous studies of rainwater harvesting systems (considering roof area, tank volume, demand and risk of tank becoming dry) should be used to develop guidelines for each PIC. Assistance should be made available from agencies with expertise in this type of analysis where required.

?? Building regulations should be considered for introduction requiring new houses and buildings to be equipped with rainwater collection and storage facilities with required volume based on roof area.

?? Financial support through subsidised materials (e.g. tanks, gutters, roofing) should be considered as incentive. Community education and awareness programs should also be commenced, continued or enhanced.

?? To improve water quality in tanks, simple 'first flush' systems have been found effective and should be implemented. A technical guideline for the design and implementation of such systems would be useful for households with rainwater tanks.

?? Consideration should be given to additional projects for community-based rainwater harvesting.

6.5.3 Groundwater

?? Groundwater pumping systems in small low-lying islands and the coastal zones of high islands should be designed carefully to avoid saline intrusion. Pumping from vertical boreholes is not be an appropriate measure in small islands with thin freshwater lenses and alternative methods such as infiltration galleries should be considered.

?? The use of alternative energy sources such as solar and wind have been found as to be useful in a number of islands. This type of technology is useful for rural villages and should be encouraged where possible

?? Groundwater monitoring systems to monitor the impacts of climate variability and pumping effects should be installed, especially where groundwater development is extensive on small islands. Appropriate systems should be installed for different applications. For instance, open boreholes should not be used for monitoring in small low lying islands as they tend to induce saline intrusion and yield incorrect results.

?? There is scope for the development of guidelines for the appropriate use of pumping systems, energy sources and monitoring systems in different islands environments. These should be based on existing information and updated according to recent trends. Such guidelines would be enhanced with the addition of case studies, showing appropriate and poor application of pumping technology.

6.5.4 Surface water

?? The design and implementation of simple, inexpensive filtration systems to improve the water quality of small streams affected by high turbidity and suspended solids after heavy rain is a high priority item for water supplies in many small volcanic islands. It is suggested that a review of technology that could be utilised in such applications be undertaken and guidelines developed.

?? Careful development and management of perennial springs should be encouraged for use in droughts when other streams have ceased to flow. Adequate spring cappings should be designed, built and maintained for such applications.

6.5.5 Desalination

?? With the current focus on desalination as a technology to resolve water supply issues in small islands, there needs to be careful appraisal of all factors before investing in this technology. Such factors include costs (primarily pumping costs), ability of community to pay, operation and maintenance requirements, design of intakes to prevent fouling, availability of spare parts and chemicals, remoteness of island and transport routes, availability of skilled operators and training opportunities. It needs to be emphasised that there have been a number of ‘classic’ failures of desalination technology because some of these factors have not been taken into account.

?? The lessons of the past where desalination systems have been installed in PICs and have failed should be documented together with the examples of sustainable systems. This would be a useful guide for governments considering the introduction of such technology wither for regular use or for emergency use in droughts.

?? There is scope for the use of simple ‘solar still’ technology for emergency use in rural communities particularly in remote outer islands. Such systems are not difficult nor expensive to construct and could be used for basic potable water needs of households during droughts. Such systems have been used before, and it is suggested that efforts should be made to examine available current systems and consider these for use.

6.5.6 Demand management and conservation

?? There is an ongoing need for demand management programs to ensure that the water from existing water sources is used wisely.

?? Water supply flow and leakage monitoring is an essential tool even in simple rural water supply distribution systems. Local personnel should be provided with basic training in monitoring methods.

?? Community education and awareness about water conservation and wise use of water is an essential part of sustainable water resources management (refer Theme 3).

6.5.7 Sanitation and wastewater

The introduction in PICs of non-polluting sanitation systems particularly in highly vulnerable coral island environments, is considered to be one of the highest priority issues for achieving sustainable water resources management. Major problems and issues associated with current predominantly poor sanitation systems are highlighted in sections 4.3.3 and 4.6.3. As mentioned previously, current sanitation approaches using pit latrines, septic tanks are definitely not appropriate in coral islands and many coastal areas of high islands.

It is recommended that steps be taken towards a “zero water pollution” policy especially in the smaller islands where water resources are limited and highly susceptible to contamination. In order to achieve this, possible solutions include low-technology and low-cost compost (waterless) toilets and relatively high-technology and high-cost reticulated sewerage systems with treatment and ocean outfalls. For rural and many urban communities in PICs, properly constructed sewerage systems that pump sewage (either raw or preferably treated) to sea, are not a realistic option, due to the financial and operational needs. This means that simpler yet non-polluting, on site systems are the most appropriate solution.

The following actions are presented for consideration:

?? Ongoing support for projects that are currently implementing appropriate solutions (e.g. compost toilets in Kiribati and Tonga and the proposed trial under the International Water Programme of SPREP: Crennan and Berry, 2002).

?? Further carefully designed and monitored trials of compost toilets in PICs where such systems have not been trialled or where previous attempt have been unsuccessful. Consideration of local cultural values are especially important and adequate community education, awareness and training must accompany trial and implementation projects (Crennan and Berry, 2002).

- ?? Dissemination of information from past compost toilets trials (reports, videos).
- ?? Community education and awareness programs regarding this type of sanitation.
- ?? Development and periodic development of guidelines for this type of technology.
- ?? Consideration and possible and other alternatives that may be appropriate in certain situations (e.g. low gradient "small bore" pipe systems to gravel bed hydroponics or constructed wetlands for sewage treatment as planned in Maldives).
- ?? Implementation and possible extension of relevant components of the Pacific Wastewater, Framework for Action (refer section 5.6.3).

It is noted that part of the above recommended approaches overlap with the scope of Theme 3, Awareness.

6.6 Participatory catchment management

The principles of participatory catchment (watershed) management were introduced in section 5.4. The advantages of these approaches involving local communities in the management of surface and groundwater catchments are evident from a number of case studies. In some PICs, steps have and are being taken to enable the participation of communities in catchment management and the rational use and protection of water resources within the catchments.

It is suggested that:

- ?? The participatory water catchment management approach be endorsed for use in PICs.
- ?? Steps be taken to establish catchment management committees (alternatively called watershed management committees or water resources protection committees) with representatives from key stakeholders including local owners, local communities, water supply agencies, government regulatory agencies, farmers (if present) and others as appropriate.
- ?? Catchment plans be developed to provide for the rational allocation, use and protection of water resources and downstream environments (e.g. coastal fisheries, reefs and mangroves).
- ?? Community education and awareness programs should be implemented to encourage local communities to be involved in the process.
- ?? Assistance and support to such committees should be provided in the initial stages by governments and, if required, donors.

It is noted that part of the above recommended approaches overlap with the scope of Theme 3, Awareness.

6.7 Applied research projects

While there has been significant commitment to island hydrological research in recent years (refer section 5.7), there is still a need for further commitment in this area. Such commitment to applied research and associated training and dissemination of results can provide great benefit to small islands in offering solutions to some of the fundamental hydrological issues (e.g. sustainability of water resources, impacts of droughts, pollution, etc.).

At a 1997 UNESCO Water Resources Workshop (Sankey et al, 1997) and again at the Pacific Focal Group for Water Resources meeting in 2000 (White et al, 2000), progress was noted on the groundwater recharge and groundwater pollution projects in Kiribati and Tonga, respectively (refer section 5.7.1). Delegates from Cook Islands, Kiribati, Niue, PNG, Tonga and Vanuatu, as well as Australia, New Zealand, UNESCO and SOPAC attended the meeting in 2000.

Further work on the first two projects, particularly in other PICs and commencement of work on other projects was recommended at both meetings. In order of priority, the projects for which additional funding was recommended were as follows (White et al, 2000):

- ?? Catchment and communities project on a high volcanic island.

?? Groundwater recharge and modelling (further work in initial and other sites).

?? Groundwater pollution due to sanitation systems (further work in initial and other sites).

?? Integrated island water resources study.

?? Groundwater and surface water pollution due to chemicals.

?? Rainwater catchment study.

?? Appropriate groundwater extraction systems.

Project proposals for these are provided in White et al (2000). For all projects, the workshop recommended that:

?? Projects should have a regional application, achievable in terms of publications, training of locals, etc.

?? Projects should be carried out through close liaison between the organisations: UNESCO, SOPAC, SPREP, WMO, and others.

As mentioned in section 5.7,

At the ENSO Impact on Water Resources in the Pacific Region Workshop in Nadi, Fiji, in September 1999 (SOPAC, 1999a) an additional priority project of drought assessment in small island nations was proposed. A project proposal is also provided in White et al (2000).

This list is recommended as the basis for discussion regarding priority listing and funding for future applied research projects. Additional potential applied research projects from other delegates should also be tables and considered.

It is suggested that an **Applied Research Working Group** be formed to consider these and other suggestions and make recommendations for possible endorsement by delegates.

6.8 Education and professional training

Training needs in relation to water resources assessment and monitoring are outlined in section 6.4.3. In addition, specific training and professional development components were mentioned including scholarships to universities for water engineers, hydrogeologists and other water related disciplines.

Additional training and professional development opportunities should be encouraged, including the following:

?? In-country training workshops.

?? Regional or in-country training workshops on specific topics related to water resources assessment, monitoring and management, and (rural) water supply & sanitation. Agencies including but not limited to SOPAC, UNESCO and WMO have greatly assisted with appropriate workshops on island water resources management.

?? Postgraduate courses in specific water resources areas by distance learning.

?? Possible twinning or interchange of professional and technical staff between different islands.

?? Active involvement of island personnel in appropriate research and implementation projects undertaken in-country or in similar island environments.

?? Pilot projects of regional significance.

6.9 Knowledge and information dissemination

There is ongoing need for information dissemination in the water sector. It is recognised that there have been significant advances in this area in recent years with greater access to regional libraries such as the SOPAC library, email, and the ongoing developments of useful websites. The establishment of a ‘virtual library’ of technical reports and access to this information through the Internet is a welcome addition. However, not all personnel have access to electronic mail facilities and websites, and those that do have access suffer inevitable communications problems.

Areas where improvements are suggested are:

- The results of studies and research into water resources issues should be effectively communicated by the researchers and funding agencies to island governments, relevant agencies and local communities in order that the potential benefits of research work is realised. Where research results have a wider regional application, this information should be disseminated through regional agencies and appropriate institutions. The results of research which is published only through scientific or technical journals is of limited practical value and may not reach the wider community.
- Bilateral and other donors working in water sector should be encouraged to submit relevant consultant reports on water resources management topics to the regional library (at SOPAC).
- Periodic regional and inter-regional workshops/seminars should be convened to summarise/evaluate progress and continue to seek new solutions (as per past practice). There should be a balance between being too frequent or too seldom. An interval of about 4 to 5 years is probably appropriate.
- Specific publications on small island water resource and water supply issues (e.g. Hydrology and water resources of small islands, a practical guide (UNESCO, 1991) and Source book of alternative technologies for freshwater augmentation in Small Island Developing States (IETC, 1998)) have provided valuable information. Where publications are out of print (e.g. UNESCO, 1991) steps should be taken to make such information available through alternative channels. Consideration should be given to updating such publications with updated methods, approaches and technologies.
- Newsletters on current and forthcoming activities can also be a useful means of transferring information (e.g. SOPAC WRU and UNESCO-IHP newsletters) and are encouraged .

6.10 Networking and partnerships

6.10.1 Within countries

There is scope for greater co-ordination between agencies involved in the water sector in each PIC, as identified previously. This issue is part of Theme 5 of the Regional Consultation.

There is also duplication of effort in the water related activities of several regional and international agencies. In WMO (2002), it was recommended that National Committees should be established to co-ordinate water related activities of these organisations and to provide guidance in providing national input to regional programmes. The National Committee concept has been found to work well in other countries (and stemmed from a need to coordinate UNESCO-IHP and WMO-OHP activities).

It is noted that such co-ordination is a worthwhile objective and should be considered at the Regional Consultation. It is noted that in some of the very small islands such a committee may not be appropriate given the very small number of personnel involved in the sector.

6.10.2 Within the Pacific region

From section 5.8.3, it is evident that there are many current mechanisms and proposals for interaction and networking between delegates from PICs on water resources and wider aspects of water and wastewater. In summary these are:

- UNESCO-IHP Pacific Focal Group on Water Resources (7 PICs)
- UNEP/GPA/SOPAC Pacific Wastewater Focal Group (7 PICs)
- WMO RA V Working Group on Hydrology (9 PICs)
- SOPAC Science, Technology and Research (STAR) Water Working Group (16 PICs)

The number of groups and the membership of each indicates an interest and a need for information exchange on a variety of water related topics. However there is an obvious duplication of effort between at least some of these groups. The main issue is the need for effective use of such groups for discussion of issues and priorities and for the development of recommendations for action. There is obviously scope for some rationalisation of the various groups to provide and effective, coherent voice.

One possibility to achieve greater co-ordination is the concept of a Pacific Water Partnership (PWP), with the aim of facilitating greater and effective interaction between the various agencies and groups involved in the water sector. Details of the PWP concept are to be presented in session at the Regional Consultation. Preliminary objectives for a PWP are as follows

?? Introduce Integrated Water Resources Management concepts in Pacific island countries through:

?? Strengthen collaboration on international and regional initiatives, through sharing information between relevant agencies and focal groups (including those mentioned above).

?? Exchange information with and between donor agencies including consultation on water policies, strategies and development programmes (AusAID, NZAID, ADB, World Bank, EU, JICA, France, USDOI, etc).

?? Involvement and exchange of information with water utilities and water associations (AWA, NZWWA, PWA) and the private sector.

6.10.3 Inter-regional

Inter-regional networking between relevant agencies with an interest in small island hydrology and water resources management such as those mentioned above and others, for instance, in the Caribbean and Latin America region and in the Indian Ocean can assist with this important process. A recommendation from the small islands working group at the Second International Colloquium on Hydrology and Water Management in the Humid Tropics (Panama City, March 1999) was that regional focal points should assist small island nations in the co-ordination of applied hydrological research, training and information dissemination. In the Pacific Ocean region, for instance, SOPAC in conjunction with UNESCO and WMO acts in this capacity to a large degree and provides an archive and clearing house of water resources information for the Pacific Islands.

Given that delegates from other regions are attending the Regional Consultation it is appropriate that inter-regional networking opportunities be further explored.

7. Summary of proposed actions

The following summary of proposed actions is based on the suggested and recommendation actions presented in section 6. It is submitted for consideration by delegates to the Pacific Regional Consultation on Water in Small Island Countries.

Summary of Proposed Actions for consideration by delegates at Pacific Regional Consultation

No	Section	Item / Issue	Proposed Actions	Documents/Comment
1	6.2	Commitment and support from national governments	?? For Governments to consider and decide	??This is a priority issue and impacts on all themes within the scope of the Regional Consultation
2	6.3	Integrated water resources management	?? Consider implementation of IWRM principles and practices in PICs with appropriate support from relevant agencies and using relevant methods as a priority matter	?? IWRM Toolbox, Global Water Partnership ?? Other information presented at the Regional Consultation
?? 3	6.4	Water resources assessment ?? Pacific HYCOS project proposal for capacity building ?? Hydrological training needs at regional level ?? Capacity building and training through bilateral projects ?? Special needs of very small islands ?? Guidelines for water assessment and monitoring ?? Community based monitoring ?? Bacteriological testing	?? **Water Resources Assessment and Monitoring Working Group** be formed to consider these and other suggestions for possible endorsement by the delegates	?? WMO (1999) ?? Mosley (2000) ?? SOPAC/WMO/UNESCO(2001) ?? WMO (2002) ?? UNESCO (1991) ?? Dale et al (1986) ?? Other information presented at the Regional Consultation ?? Overlaps with Theme 2 and 5
4	6.5	Appropriate water supply and sanitation ?? Water supply strategies ?? Rainwater harvesting ?? Groundwater ?? Surface water ?? Desalination ?? Demand management and conservation ?? Sanitation and wastewater	?? **Appropriate Technology Working Group** be formed to consider these and other suggestions and make recommendations for possible endorsement by the delegates	?? Theme 1 Case studies for Kiribati, Tuvalu, and Maldives ?? Crennan and Berry (2002) ?? Other information presented at the Regional Consultation ?? Overlaps with Theme 3 and 4
5	6.6	Participatory catchment management	?? Consider for endorsement the items in section 6.6.	?? Theme 1 Case studies for Tonga ?? Other information presented at the Regional Consultation
6	6.7	Applied research projects	?? **Applied Research Working Group** be formed to consider these and other suggestions and make recommendations for possible endorsement by the delegates	?? White et al (2000) ?? Sankey et al (1997) ?? Other information presented at the Regional Consultation
7	6.8	Education and professional training	?? Consider for endorsement the items in section 6.8.	?? Other information presented at the Regional Consultation
8	6.9	Knowledge and information dissemination	?? Consider for endorsement the items in section 6.9.	?? Other information presented at the Regional Consultation
9	6.10	Networking and partnerships	?? Consider for endorsement the items in section 6.10.	?? Other information presented at the Regional Consultation

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