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Inception Workshop and 1st Regional Steering Committee Meeting for the GEF/SPC/UNDP Project Entitled: *“Ridge to Reef – Testing the Integration of Water, Land, Forest & Coastal Management to Preserve Ecosystem Services, Store Carbon, Improve Climate Resilience and Sustain Livelihoods in Pacific Island Countries”*

Nadi, Fiji Islands, 10th– 14th October, 2016

BASELINE SETTING AND ONGOING MONITORING OF THE EFFECTIVENESS OF PROGRAMME ACTIVITIES

Executive Summary

Through Component 1 of the GEF Regional International Waters (IW) Ridge to Reef Projects, National IW Projects will be contributing to stress reduction benefits in five key areas; Municipal Waste Pollution Reduction, Aquifer Pollution Reduction, Habitat Restoration, Catchment Protection and Conserved/Protected Fish Refugia.

The anticipated benefits as a result of the implementation of the identified pilot activities include: municipal waste pollution reduction of 5,775 kg N/yr (6 sites); aquifer pollution reduced by 23 kg N/ha/yr (2 sites); 6,838 ha of restored habitat (4 sites); 290 ha of conserved/protected wetland (2 sites); 25,860 ha of catchment under improved management (7 sites).

GEF minimum standards for monitoring and evaluation include SMART indicators for project implementation and results, and baseline data for the project indicators.

Monitoring Design

Deciding how to sample is often difficult because we must consider trade-offs between costs and benefits of the amount and type of sampling undertaken. Thus, any sampling design represents a balance between the project objectives and the constraints of cost, time, logistics, safety and existing technology. A general monitoring framework is described and presents the three main aspects of the programme; Monitoring Outcomes, Record Keeping and Site Condition. Three main sites will be assessed and monitored. A reference site, a target site and the project intervention site.

Municipal Waste Pollution Reduction

The municipal wastewater pollution reduction results area is concerned with measuring the reduction in *nitrogen, phosphorous and biochemical oxygen demand (BOD) kg.ha.yr* in the receiving environment of the pilot intervention areas. The proposed measures for the IW Pilot Projects include eco-sanitation toilets, wetland systems, on-site wastewater system and dry litter piggeries. There are four countries with this results area, Nauru, Niue, Tonga and Tuvalu.

Proposed methods of analysis are the Hach method 10031 for analysis of ammonia (as N), SM 4500 P-E for orthophosphate (as P) with a portable colorimeter or spectrophotometer. The SM 5210B method using a portable incubator will be used for BOD. Traditional physical and chemical characteristics (T,pH and EC) will be monitored using a handheld multiprobe meter to allow for comparison and detailed analysis.

Aquifer Pollution Reduction

The aquifer pollution reduction results area is concerned with measuring the *volume reduction in pollution to aquifers in kg.ha.yr*. There are two countries with this results area, Niue and Tuvalu, with the reduction occurring due to reductions in municipal wastes discharging to the environment and potentially the groundwater.

For this result area it will be assumed that the reduction in waste comes from the change in human and/or animal waste management practices as a result of the project intervention. It is impractical to directly measure the volume of waste from each house prior to management intervention, therefore a basic calculation will be performed to estimate volume reductions.

Habitat Restoration

The habitat restoration results area is concerned with measuring the extent of restored habitat and is simply defined as *ha restored*. This is a very broad indicator and taken at face value could take many years or even decades to show that habitat has been restored. For the purpose of this guide 'habitat restoration' is defined as those measures necessary to restore, enhance, or create healthy ecosystems, with a focus on the reestablishment of native vegetation and fish and wildlife habitat in degraded or disturbed sites. The proxy indicator is *ha revegetated*. There are three countries with this results area, Nauru, Samoa and Vanuatu.

The Monitoring Revegetation Projects in Rainforest Landscapes Toolkit has developed concise protocols for recording baseline assessment and monitoring details. The protocols include detailed methodology and

the use of proformas that are easy to use and self-explanatory, requiring the project staff to visit the site and describe the current condition. The two recommended protocols to use for baseline assessment and site monitoring are Forest Structure and Plant Species Composition, and include monitoring attributes such as ground cover, canopy height and cover, special life forms and woody debris.

Catchment Protection

The catchment protection results area is not specific about the indicator to be used and simply states *ha under improved management* as the reporting measurement. It is not defined what is meant by 'improved' management. This section describes two main areas of indicators, catchment condition indicators which include native vegetation, threatened species populations, soils, wetlands, groundwater, and rivers and stream and; catchment management indicators which includes voluntary management activities, on-ground operational works, community engagement activities, planning controls implemented and, data collection and control.

It is suggested that one or two of the possible indicators be chosen and used across all countries for comparability. It is also suggested that indicators be chosen that are already being measured in other aspects of the GEF Pacific R2R Programme so as to utilise the equipment, expertise and time involved in monitoring. There are seven countries with this results area, Niue, Cook Islands, Fiji, Solomon Islands, PNG, RMI and FSM.

Conserved/Protected Fish Refugia

The conserved or protected fish refugia results area is concerned with measuring the extent of area that is placed under conservation or protective fish refugia management measures in *ha protected*. This is a basic indicator that could be simply measured as the hectares agreed to protection in writing of the management plans. It is however desirable to understand the current socio-economic and environmental state of the management site and to monitor the activities that contribute to the on-going protection of fish refugia. There are two countries with this results area, Solomon Islands and Tonga.

It is suggested that one or two of the possible indicators be chosen and used across all countries for comparability. These indicators should reflect best practice in the region and be already in use.

Cost Analysis for GEF Indicator Sampling

GEF Pacific R2R Programme monitoring involves many possible costs including paying and training staff, buying equipment, travel expenses, and processing of samples. Funding availability often determines how much sampling is feasible, therefore it is important to evaluate cost as a factor in developing a monitoring program.

This assessment details cost estimates for the following indicators: wastewater chemistry and revegetation. Catchment protection costs can be easily estimated once indicators are chosen. Cost estimates for each indicator include:

- the cost for each item of equipment needed to sample each indicator and whether it is likely to already be owned, if it is shared by several indicators, and if it is consumable
- the length of time it takes each person to sample each site for each indicator
- the cost and time needed to train staff in the protocols for sampling each indicator
- cost estimates for external lab processing of waste/water chemistry

Data Management Systems

While the details will vary, some of the key elements of good data management include data validation and verification (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc). A generic system will be developed by the Regional Program Coordinating Unit and refined after use and comment by the counties.

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1. Introduction

It is recognised that the catchment and coastal environment is heavily influenced, by multiple anthropogenic impacts. These impacts result in physical and chemical changes that ultimately modify the biological processes in freshwater and marine environments, often resulting in environmental degradation. It is because of such situations that the GEF International Waters (IW) and STAR funded Ridge to Reef Project stress reduction activities are essential in areas where anthropogenic activities significantly change an environment.

Establishing a baseline scenario of these areas is important to understand the condition prior to implementation. Intervention monitoring is a key step in the monitoring and evaluation process that seeks to support accountability, good governance and adaptive management, and to generate the knowledge to support future evidence based decisions. Intervention monitoring underpins evaluation, reporting and improved decisions and future monitoring through the adaptive management process.

This document is intended to be used as a foundation for National IW and STAR Projects to plan for and design baseline assessments and monitoring programmes. It is focussed on the stress reduction measures of the Regional and National IW Projects, and does not address the process or governance indicators. The main body of the document makes recommendations for methodologies for each IW results area to determine baseline conditions of the project area and monitoring for GEF IW stress reduction results areas. Many of the recommendations can be applied for monitoring indicators in the STAR Projects and other aspects of the IW Projects.

This document does not provide detailed instructions for monitoring as these are covered in separate protocol documents.

An estimate of start-up and consumable costs associated with monitoring is provided, as well as a brief analysis of the time required to conduct monitoring and training required for project staff. This document is not exhaustive and is open for consideration by RPCU and National project staff and will be updated to reflect recommendations.

The **aim** of the GEF Pacific R2R Monitoring Program is to quantify the outcomes of GEF Pacific R2R Programme stress reduction management interventions over set periods of 1-4 years to underpin reporting requirements and adaptive management. It may also be used to understand changes in the condition of areas where long-term intervention monitoring is occurring. This requires being able to distinguish the responses to IW and STAR management interventions from the myriad of other factors that affect aquatic and terrestrial ecosystems and their associated biota within the management areas.

1.1. Objectives of IW Projects

The first component of the Regional IW Ridge to Reef Project involves national demonstrations to support R2R ICM/IWRM approaches for island resilience and sustainability as detailed below.

Component 1: National demonstrations to support R2R ICM/IWRM approaches for island resilience and sustainability

Outcome 1.1: Successful pilot projects testing innovative solutions involving linking ICM, IWRM and climate change adaptation [linked to national STAR projects via larger Pacific R2R network]

The regional network of national IWRM demonstration projects established and operated as part of the GEF Pacific IWRM Project from 2010-2013: strengthened local and national coordination for IWRM in the water and sanitation sector; enabled the achievement of significant environmental and water resource stress reduction benefits, particularly in vulnerable atoll environments; enhanced catchment management practices for strengthened island resilience to climate variability and disasters; and was effective in engaging and securing participation of local and national stakeholders in the planning, implementation, and monitoring and evaluation of on-the-ground demonstration activities via the application a 'Community to Cabinet' approach to project coordination and management.

The experience and local capacity generated as a result of the GEF Pacific IWRM demonstration projects is recognized both nationally and regionally as an appropriate entry point for the testing of innovative approaches and measures to integrate land, forest, water and coastal management, including climate change adaptation (CCA) via the establishment and operation of national pilot projects at priority locations in the 14 countries. In addition to the role of the pilot projects in generating local and national support for integrated R2R approaches, they will also be used to establish linkages, synergies and mechanisms for learning exchange, particularly between and among community leaders and project stakeholders of the national GEF System for Transparent Allocation of Resources (STAR) projects planned under the broader Ridge to Reef programme. It is also aimed that the pilot activities will develop local experience in linking IWRM to coastal area management and will stimulate cross-sectoral participation in the planning of coordinated investments in land, forest, water and coastal management in the participating countries.

Accordingly, the following three design principles were applied in conceptualizing the national pilot activities: (1) establish and strengthen linkages between IWRM and national STAR projects under the R2R framework; (2) incentivize and foster cross-sectoral and community participation in broader national strategic action planning and institutional strengthening activities planned under project component 3; and (3) demonstrate best practice measures and approaches to guide the planning of replication and scaling-up.

Key water resource and environmental stress reduction benefits anticipated as a result of the implementation of the identified pilot activities include: municipal waste pollution reduction of 5,775 kg N/yr (6 sites); aquifer pollution reduced by 23 kg N/ha/yr (2 sites); 6,838 ha of restored habitat (4 sites); 290 ha of conserved/protected wetland (2 sites); 25,860 ha of catchment under improved management (7 sites). Additionally, mechanisms to monitor the environmental and socioeconomic status of coastal areas will be established at 9 pilot activity locations. Table 1 summarizes planned stress reduction activities and benefits by country.

Table 1: Key water resource and environmental stress reduction benefits anticipated from R2R IW pilot activities

Municipal Waste Pollution Reduction
<ul style="list-style-type: none"> • 749kg/yr (34%) reduction of TN through constructed wetland system serving 15 houses in demonstration area in Nauru • 1623 kg/yr (20%) TN reduction through 200 households septic system upgrades and construction of 15 sand filter on-site wastewater treatment systems in the demonstration area in Niue • 229 kg/yr (5.4%) TN reduction through construction of 8 eco-sanitation toilets in demonstration area in Kiribati • 2,255kg/yr (10%) TN reduction through 40 household on-site wastewater treatment system upgrades and construction of 40 eco-sanitation toilets in the demonstration area in Tonga • 919 kg/yr TN and 503 kg/yr P reduction through conversion of 50 wash-down pigpens to dry-litter systems in Tuvalu
Pollution Reduction to Aquifer
<ul style="list-style-type: none"> • 7.6 kg/ha/yr TN pollution reduction to groundwater system from conversion of 50 piggeries to dry-litter system in Tuvalu • 0.32 kg/ha/yr pollution reduction to groundwater system from on-site sanitation treatment system upgrades in demonstration area in Niue
Restored Habitat
<ul style="list-style-type: none"> • 10 ha of coastal area re-vegetated with salt and drought tolerant species at 10 critical sites in Nauru • 1,200 ha of protected area re-vegetated in Samoa's Apia watershed (above 600m) • 30 ha established and planted with rare endemic species in Vanuatu • 5,598 ha of buffer area re-vegetated at Port villa demonstration site in Vanuatu
Conserved/Protected Wetland
<ul style="list-style-type: none"> • 200 ha of fish refugia and wetland habitat protected through Integrated Coastal Management Plan for Honiara in the Solomon Islands • 90 ha of conserved/protected fish refugia habitat in the development of coastal and fisheries management plans in Tonga
Catchment Protection Measures
<ul style="list-style-type: none"> • 8,018 ha under improved catchment management in Muri Lagoon area of Rarotonga, Cook Islands • 1,905 ha under improved catchment management in Tofol, Kosrae, Federated States of Micronesia

- 4,608 ha under improved catchment management in Alofi North and Alofi South, Niue
- 7,151 ha of conserved/protected coastal area at Bibi in Madang Province, Papua New Guinea
- 544 ha under improved catchment management in the Laura Village, Majuro Atoll, Marshall Islands
- 3,027 ha proposed for improved management under Sustainable Land Use Strategy in Kovi/Kongulai catchment

1.2. GEF Minimum Standards for Monitoring and Evaluation

The GEF requires all projects to design and implement Results-Based Management (RBM) frameworks, and its monitoring and evaluation policy states that all GEF projects must “*adopt monitoring systems, including relevant performance indicators that are SMART*” (specific, measurable, achievable, realistic, timely).

Effort is made during the project design phase and inception period to ensure that the project objectives and intended results are clearly defined, specific, and measurable. This is aimed at providing a suitable platform to monitor and evaluate the project effectively. At the project design and inception stage, baseline data is also required for all of the key indicators for the anticipated results of the project.

The full project implementation stage requires application of project monitoring as a basis for decision-making. At this stage the baselines for the project are expected to be fully established and that data is routinely collected and analysed to fully support adaptive management by the Project Steering Committees and national stakeholders. Information Boxes 2 and 3 summarise the minimum requirements of the GEF with respect to the design and application of monitoring and evaluation.

Information Box 1

Minimum Requirement 1: Project Design of M&E

All projects will include a concrete and fully budgeted monitoring and evaluation plan by the time of work program entry for full-sized projects and CEO approval for medium-sized projects. This monitoring and evaluation plan will contain as a minimum:

- SMART indicators for project implementation, or, if no indicators are identified, an alternative plan for monitoring that will deliver reliable and valid information to management;
- SMART indicators for results (outcomes and, if applicable, impacts), and, where appropriate, indicators identified at the corporate level;
- baseline for the project, with a description of the problem to be addressed, with indicator data, or, if major baseline indicators are not identified, an alternative plan for addressing this within one year of implementation;
- identification of reviews and evaluations that will be undertaken, such as mid-term reviews or evaluations of activities; and
- organisational set-up and budgets for monitoring and evaluation.

Information Box 2

Minimum Requirement 2: Application of Project M&E

- Project monitoring and supervision will include implementation of the M&E plan, comprising:
- SMART indicators for implementation are actively used, or if not, a reasonable explanation is provided;
- SMART indicators for results are actively used, or if not, a reasonable explanation is provided;
- the baseline for the project is fully established and data compiled to review progress, and evaluations are undertaken as planned; and
- the organisational set-up for M&E is operational and budgets are spent as planned.

2. Monitoring Design

2.1. Monitoring Framework

Deciding how to sample is often difficult because we must consider trade-offs between costs and benefits of the amount and type of sampling undertaken. Thus, any sampling design represents a balance between the study objectives and the constraints of cost, time, logistics, safety and existing technology. A general monitoring framework is described below and presents the three main aspects of the program; Record Keeping, Indicator Monitoring and Site Condition Assessments.

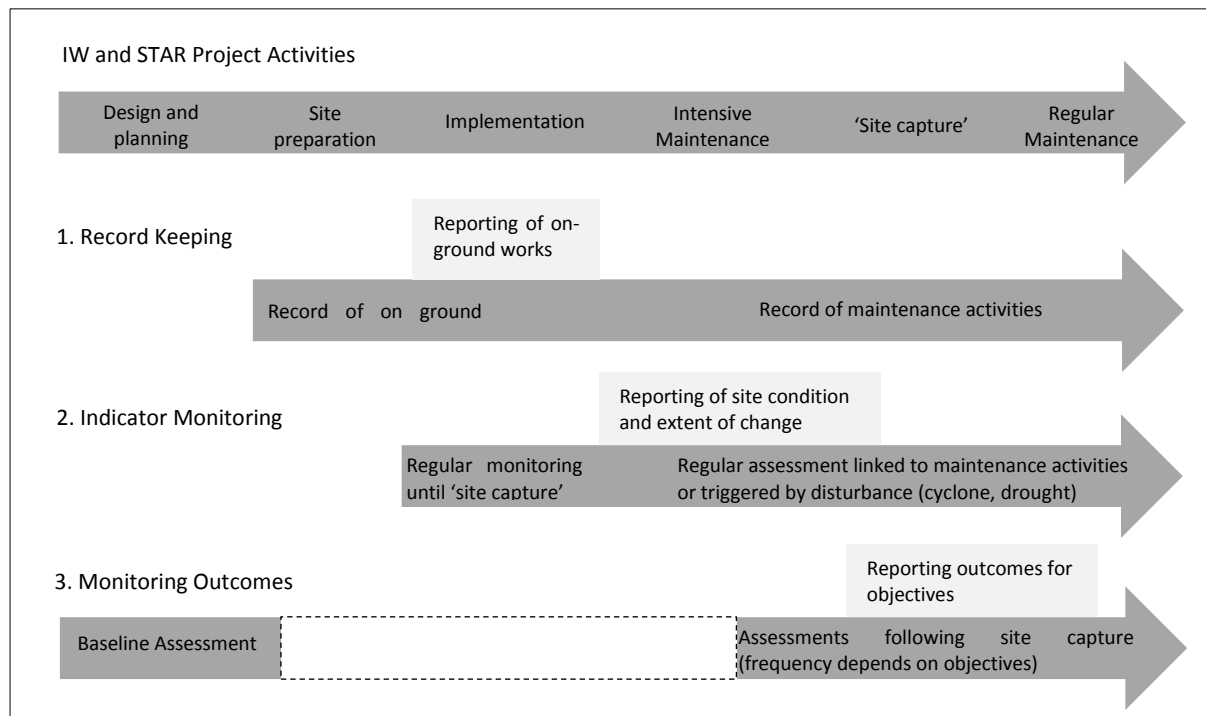


Figure 1: General monitoring framework for GEF R2R Programme interventions

2.1.1. Record Keeping

Basic information about the nature of the IW pilot project and/or STAR project on-ground activities (including location, size, cost, objectives and details of works) needs to be recorded and stored in a properly maintained database. This can be stored nationally with the respective departments as well as regionally with the RPCU. Good record-keeping also requires that national project teams inform their project partners if their on-ground works vary from project proposals. If such variations are not reported, the extent of project interventions in a region is likely to be overestimated. Project details are recorded for every construction event, maintenance activity and monitoring survey.

Though it may seem difficult to keep records accurately over the long term, establishing a user-friendly system to begin with helps to ensure it is maintained. It is critical that as soon as baseline assessments and monitoring surveys are completed that this information is recorded and stored in logical and secure sources for future use and reporting.

2.1.2. Indicator Monitoring

Did attributes and components at the project site change in magnitude as expected over the appropriate timeframe?

Monitoring for effectiveness is used to assess site conditions during or post project and document changes as a result of the project activities. This is done through comparison with pre-project conditions (baseline assessment) to establish trends in the resources at the site. Accordingly, effectiveness monitoring needs to

occur over a sufficient period of time to allow conditions to change as a result of the management interventions. This is a critical time to identify potential threats to project success and adapt management techniques accordingly. It may be that a certain plant species is not thriving, or sanitation system is not operating appropriately and these need to be assessed as they arise.

‘Site capture’ is a term used in reforestation projects and means the point where a site becomes self-sustaining. It is used throughout this guideline to mean the time when the project activities are handed over to the respective government departments or community for monitoring and/or become self-sustaining as in revegetation projects.

2.1.3. Monitoring Outcomes

Baseline Assessment

What are the existing site conditions and what are the reasons for implementing activities at this site?

A baseline assessment defines the pre-project condition at the project site and records indicators or attributes that will be used to assess achievement of the stress reduction objectives defined in the national IW and STAR project’s results framework. When compared with the condition of the same indicators or attributes at some point during implementation (mid-term evaluation) and post-operation implementation (final evaluation), the baseline study forms the foundation for an effectiveness assessment. Without baseline data to establish pre-project conditions for outcome and impact indicators it is difficult to establish whether change at the outcome level has in fact occurred.

Validation Monitoring

Did the natural system (flora, fauna, water, land) at the project site respond to the changes in physical or biological attributes or components brought about by the stress reduction activities?

Validation monitoring determines if the initial activities and recommendations are valid, or are there better ways to meet the goals and objectives of the project. It is used to confirm the cause and effect relationship between the project activities and biotic or physical response. For example this includes the use, presence or abundance of desired species at the project site. Similarly to effectiveness monitoring, validation monitoring needs to occur over a sufficient period of time to allow conditions to change as a result of the management interventions. This is based on the availability and proximity of target species to the project site.

This monitoring will be subject to ongoing funding and resources available in each country but is the natural progression for monitoring once a site has been established.

2.2. Site Selection

The sampling sites are defined as the areas of management interventions in the national IW and STAR Pilot Projects. At these sites thorough documentation in the form of a site description, is required. To give context to changes in the attributes being monitored and any changes in physical or biological attributes of the environment, other sites will be monitored as detailed in the table below. Depending on the purpose of monitoring, data from the management site can be measured against data collected at other sites.

Table 2: Monitoring site definitions

State or type of site	Definition of Site	Purpose of comparison
The baseline state	The state of the site prior to management interventions	to show how the management site has changed since project inception
Reference sites	Sites that are in a similar state, in a similar environmental setting with similar land use to the sampling site that are not subject to management intervention	To scientifically show outcomes of management actions by separating the effects of management from the impact of environmental fluctuations and any other influencing processes.

Target Sites	Sites that are in good ecological condition in similar environmental settings to that of management sites	To show the natural variability in the indicators of interest (e.g. as influenced by environmental factors).
The expected state (of the management site) for a particular stage of development	A hypothetical state that relates to the expected stage of restoration given the time since actions were initiated	To evaluate whether or not management actions are meeting realistic expectations according to a restoration plan schedule.

2.3. Standard Methods

The list of specific questions that can drive a long-term monitoring plan is potentially as diverse as the reasons for establishing a long-term monitoring project. What is evident is that specific questions are necessary to direct the monitoring; otherwise, they become an exercise in data collection with no real purpose. An important component of the long-term monitoring design and implementation phases will be to employ standard methods for indicator measurement, site selection and data management. Continuity, reliability and comparability of information are only assured if monitoring and evaluation plans are implemented to an appropriate standard with consistency and transparency being key elements. As such, standard methods are critical considerations in monitoring design, particularly if trends are to be determined within and between selected areas.

In some instances, standard methods have been developed and recommendations made. In other instances, variation among projects and ecosystems will require agreement on an appropriate standard method to answer the questions posed by the monitoring design. A summary of the major indicators and either the standard method or next step to defining the standard method is summarised in Table 2.

Table 3: Summary of major indicators and associated standard method or the next step required to define the standard method.

Results Area		Indicator	Method	Reference
Municipal Wastewater Pollution Reduction	Nutrients	Nitrogen as ammonia, phosphate as orthophosphate, BOD	Salicylate Method, Ascorbic Acid Method; SM 4500-P-E, SM 5210B	Standard Methods
	Physico-chemical parameters	Salinity, dissolved oxygen, pH, temperature, turbidity, dissolved organic carbon	Standard commercial probes or loggers	(Baldwin, et al., 2005)
Habitat Restoration	Landscape vegetation diversity	Species number and abundance	Species identification within quadrats or along transects.	(Kanowski, et al., 2010)
	Vegetation condition and reproduction	Individual condition		
Protected Fish Refugia	Reduced capture of juveniles	Volume and size of catch	Refer to SPC-Coastal Fisheries Programme	
	Fish larval growth and survival	Abundance of eggs and larvae		
	Fish reproduction	Fish survey		

2.4. Recommendations

For now it is recommended that projects follow the timings and sites described in the table below. The choice of target and reference sites is left up to the professional judgement of the national project teams. Monitoring schedules may change due to cost or personnel constraints however a minimum of baseline monitoring and annual indicator monitoring must be observed.

Table 4: Proposed monitoring schedule and sites

What	When	Where
Baseline assessment	Prior to management intervention start	Project site, Target Site Reference Site
Site description and implementation/maintenance activities	During implementation	Project Site
Indicator Monitoring	<ul style="list-style-type: none"> • Quarterly for municipal waste • Annually for aquifer, restoration and wetlands • Catchment protection will depend on indicators chosen 	Project Site
Record Keeping for maintenance activities	Whenever maintenance or disturbance requires, minimum half yearly	Project Site
Site condition assessment	At close of project	Project Site Target Site Reference Site

3. Municipal Wastewater Pollution Reduction

3.1. Introduction

Many of the R2R Pilot Demonstration sites are faced with similar challenges of inappropriate, poorly constructed/maintained septic systems or no sanitation system at all. Septic systems are recognised as a major source of groundwater contamination and a significant source of nutrient loading in groundwater, coastal and lagoon waters. On small low-lying atolls with shallow groundwater lenses this can become a critical situation as populations become reliant on rainwater harvesting as their major source of freshwater. Regardless of island type, poor sanitation systems are associated with numerous health issues, algal blooms in lagoons and coral reef degradation. Similar problems exist in the extensive use of wash down piggeries where wastewater is often washed directly onto the land or water body carrying with it all the nutrients and pathogens present in animal waste.

The Municipal wastewater pollution reduction results area is concerned with measuring the reduction in *nitrogen, phosphorous and biochemical oxygen demand (BOD) kg.ha.yr* in the receiving environment of the pilot intervention areas. The proposed measures for the IW Pilot Projects include eco-sanitation toilets, wetland systems, on-site wastewater system and dry litter piggeries. The benefits of these measures are that they limit the amount of waste that can directly enter water systems either directly as in wash down piggeries into estuaries or indirectly from aged septic systems seeping into the groundwater and ultimately into river, lagoon or ocean waters.

3.2. Intervention Benefits

There are five countries with this results area, Nauru, Niue, Tonga, Kiribati and Tuvalu. Nauru proposes to reduce pollution by 749kg.ha.yr TN through a constructed wetland system; Niue proposes to reduce pollution by 1623 kg.ha.yr TN through septic system upgrades and improved on-site wastewater treatment systems; Tonga proposes to reduce pollution by 2484kg.ha.yr through improved on-site wastewater treatment systems and eco-sanitation toilets; Kiribati proposes to reduce pollution by 229kg.ha.yr through construction of eco-sanitation toilets and; Tuvalu proposes to reduce pollution by 919kg.ha.yr through conversion to dry-litter piggeries (Table 5).

Table 5: Benefits of municipal wastewater pollution reduction at ProDoc writing

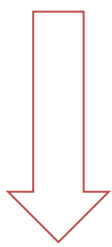

Country	Measure	Benefit at ProDoc
Nauru	Constructed wetland system	749kg.ha.yr TN
Niue	Septic system upgrades and improved on-site wastewater treatment systems	1623kg.ha.yr TN
Tonga	Improved on-site wastewater treatment systems and eco-sanitation toilets	2484kg.ha.yr TN
Kiribati	Eco-sanitation toilets	229kg.ha.yr TN
Tuvalu	Dry-litter piggeries	919kg.ha.yr TN

3.3. Methodology

Options for measuring chemical properties in water range from low cost and subjective, to higher cost and analytical, from lab-based to field ready (Table 6). In choosing a suitable methodology for monitoring nitrogen, phosphorous and BOD the following criteria are used:

- Affordable, portable, light and robust
- methods based on standard methods
- be able to measure a number of substances in various media where applicable
- produce replicable and accurate results
- be able to be used by personnel with little to no analytical training

Table 6: Analysis of methodology for water quality testing

Method	Parameters	General Cost	Use	Accuracy
Water/Soil Quality Test Kits – Manual titration, colour wheel, paper strips	Single parameter	\$500 (+ reagents)		
ISE Meters and Probes	Single parameter	\$1000+		
Pocket Colorimeters	Multiple parameter	\$1000+ (+ reagents)		
Portable Colorimeter	Multiple parameter	\$2400 (+ reagents)		
Portable Spectrophotometer	Multiple parameter	\$5400 (+ reagents)		

There is only one standard method for measuring the amount of BOD in water or wastewater samples and a modified version of this will be used. Nitrogen and phosphorous however can be present in several different forms in the environment and each of these forms requires a different method for extraction and analysis. The different forms are also more or less harmful to the environment and public health. The following criteria were used to select ammonia and orthophosphate as the preferred forms:

- A form likely to cause adverse effects in the coastal environment
- A form with a method of extraction and analysis that meets the overall methods criteria outlined above

Ammonia (NH_3^+) is the preferred nitrogen-containing nutrient for plant growth. Ammonia can be converted to nitrite (NO_2^-) and nitrate (NO_3^-) by bacteria, and then used by plants. Nitrate and ammonia are the most common forms of nitrogen in aquatic systems. However ammonia can be extracted using the salicylate method and analysed with either a colorimeter or spectrophotometer which is a relatively simple procedure and one that has been made portable. These methods are based on standard methods.

Orthophosphates are simple inorganic forms of phosphates, namely PO_4^{3-} , HPO_4^{2-} , H_2PO_4^- , and H_3PO_4 and are the form most readily available for uptake by plants. Orthophosphates can be extracted using the ascorbic acid method and analysed with either a colorimeter or spectrophotometer which is a relatively simple procedure and one that has been made portable. This method has been approved for use by the US EPA, SM 4500-P-E.

Traditional physical and chemical characteristics (T,pH and EC) will be monitored using a handheld multiprobe meter to allow for comparison and detailed analysis. Properly serviced and calibrated meters provide excellent quality data in the field. The use of detailed check-box field data sheets can help ensure that all required measurements are taken and that samples are properly handled and stored during the trip. GPS coordinates for each sampling point should be recorded at the time of collection site by the field crew.

Another option for measuring water quality is to use a Water Quality Test Kit. These are not analytical techniques and may not be suitable for reporting requirements, however they are inexpensive, simple to use and provide a good snapshot of the water conditions in a system. The HACH Surface Water Test Kit tests for ammonia, chlorine, pH, nitrate, dissolved oxygen, phosphorus, and temperature. These will be included in the cost analysis as a first pass option.

The indicator substances and parameters along with their method of analysis are highlighted in Table 7.

Table 7: Parameter, instrumentation and standard method equivalent

Parameter	Instrumentation	Instrument Method	Standard equivalent	Method
pH	HQd MultiProbe	-	-	

temperature (C)			
Conductivity (uS/cm)			
Ammonia (as N mg/L)	DR900 colorimeter OR DR1900 spectrophotometer	Hach Method 10031	Salicylate Method
Orthophosphate (as P mg/l)	DR900 colorimeter OR DR1900 spectrophotometer	Hach Method 8048	Ascorbic Acid Method; SM 4500-P-E
BOD (mg/L)	BD600 Lab System	BOD 5 Day Test	SM 5210B

The Regional Programme Coordinating Unit has developed an Eco-Sanitation and Wastewater Monitoring Protocol that details procedures for conducting in-situ and field lab measurements.

3.3.1. Record Keeping

Identifying a reduction in nutrients and BOD is inherently a long-term activity. It may take several years before consistent reductions are noticeable and even longer for changes to the receiving ecosystems to be observed. Over this time staff may come and go and unless basic records are kept it will become increasingly difficult to monitor and maintain those projects over the long-term.

The Eco-Sanitation and Wastewater Monitoring Protocol provides a series of proformas to assist project teams in recording basic information about waste management projects. To facilitate storage of information in a database (e.g. a regional directory of waste management projects), the proformas include the fields Project ID and Site ID, for unique codes to identify each project and site.

Project details are recorded for every construction event, maintenance activity and monitoring survey.

3.3.2. Baseline Assessment

A thorough baseline survey will define the pre-project conditions at the site and will also serve to define the spatial and temporal variability, and the sampling media to be analysed. This understanding of the sites specific qualities will help in developing project specific monitoring plans. Baseline surveys will be conducted at a target site and reference site. Baseline data will be used to monitor management site conditions against conditions at the target site and assess the progress towards them.

Any existing data pertaining to the results area will be consolidated and where gaps exist the baseline assessment will fill them. Where data is current and complete this will be consolidated and included in the baseline assessment report.

Baseline assessment parameters will be developed to reflect national project objectives and site situations however standards will be used across all to enable comparability of data. Standard physico-chemical characteristics of the receiving environment of the project activities, this may be water, soil, compost or a combination of the three will be surveyed. The three GEF indicator substances will be reported on N, P and BOD. Site observations will be made and photographs taken of the site.

3.3.3. Indicator Monitoring

Monitoring for municipal wastewater pollution reduction can show whether a waste management site is progressing towards the target reduction goal in terms of reduced nitrogen, phosphorous and BOD or other indicator characteristics. Monitoring includes a baseline assessment and several monitoring surveys once the waste management site has been established as shown in the figure below.

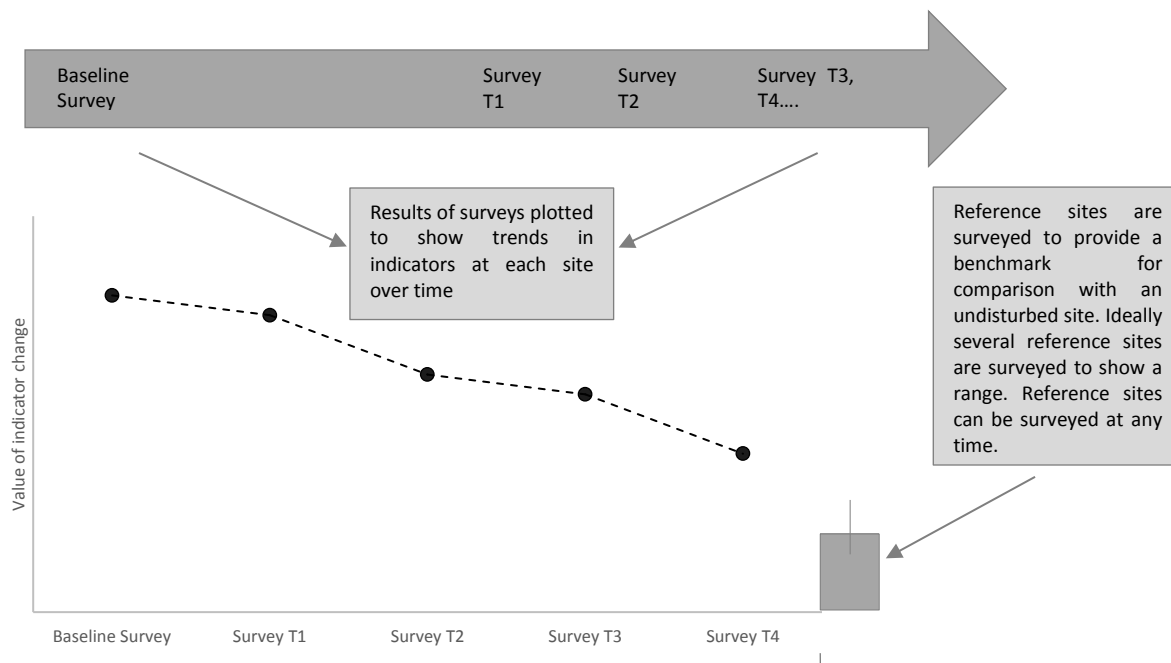


Figure 2: Monitoring program for the waste management sites

The Eco-Sanitation and Wastewater Protocol provides concise protocols for recording baseline assessment and monitoring details including sample collection techniques, quality assurance and data management. The protocols include detailed methodology and the use of proformas that are easy to use and self-explanatory, requiring the project staff to visit the site and describe the current condition. These tools are standardised to ensure a level of comparability across the region for countries with similar projects and will be reviewed and revised after use in country to better reflect the needs of the projects and monitoring objectives. Project staff will visit the site, collect and analyse samples and make observations on the condition of the site.

The portable field colorimeter/spectrophotometer kits come supplied with their own reagents, the multi-probe comes with buffer solutions pre-made. These instruments have their own manuals and it is important that the methods supplied with equipment is followed. Many of the instructions supplied with kits have special tips and general maintenance guides that will need to be followed to ensure the life of the equipment. It is important when testing in the field that methods are followed and equipment is calibrated, clean and in good working order.

3.3.4. Quality Assurance and Control

At all monitoring events quality assurance field blanks, method blanks and rinsate blanks will be taken to measure the accuracy of the sample collection and analysis process. These blanks allows the user to recognise discrepancies in the cleanliness of sampling and storage equipment, collection technique, and sampling process. Keeping accurate records of quality assurance procedures ensures that the methodology is replicable and gives greater confidence in the data being generated from the monitoring program. Detailed description of the process is provided in the Eco-Sanitation and Wastewater Monitoring Protocol. An operational checklist will be developed for monitoring teams to follow and ensures that all monitoring is conducted with the same equipment, in the same order, to the same method and level of cleanliness. Quality control measures will be put in place to verify and validate data through a data management framework also provided in the Eco-Sanitation and Wastewater Monitoring Protocol.

3.3.5. Site Condition Assessment

It is important to regularly assess the condition of waste management infrastructure sites to assess its working condition and identify any problems that the site may be experiencing and adjust maintenance accordingly. Site condition assessments are linked with routine monitoring events to avoid doubling up of

costs and include additional physical and site observations, recorded through standard proformas (provided with Eco-Sanitation and Wastewater Monitoring Protocol).

The main purposes of condition assessment are:

1. To inform practitioners of the condition of sites and to help prioritise maintenance effort;
2. To inform funding bodies of the condition and extent of waste management projects

Site condition assessments may also investigate environmental characteristics such as presence and extent of animal life, as well as community perceptions of the trialled waste management system. This will be developed further by the countries.

3.4. Recommendations

The draft Eco-Sanitation and Wastewater Monitoring Protocol is included in Annex 1 for review and refinement by the Regional Science and Technical Committee. It is recommended that this document be used as the standard protocol for all wastewater monitoring events in the Regional R2R Programme to facilitate collection of comparable data across projects and the region.

A suggested work plan for monitoring progress towards municipal wastewater pollution reduction in waste management sites. Monitoring schedules may change due to cost or personnel constraints however a minimum of baseline monitoring and annual indicator monitoring must be adhered to.

	Year One	Year Two	Year Three	Year Four
Sites	Reference, Target, Management site	Management Site	Management Site	Reference, Target, Management site
Survey Type	Site descriptions, baseline assessment	Monitoring, site condition	Monitoring, site condition	Monitoring, site condition assessment
Record Keeping	Construction, maintenance activities	Maintenance activities, monitoring events	Maintenance activities, monitoring events	Maintenance activities, monitoring events
Timing	Prior to construction	Quarterly or half yearly	Quarterly or half yearly	Quarterly or half yearly
Samples	Observations, N,P,BOD, T pH, EC	Observations, N,P,BOD, T pH, EC	Observations, N,P,BOD, T pH, EC	Observations, N,P,BOD, T pH, EC
Personnel	Two field staff, one week per site	Two field staff, one week per site	Two field staff, one week per site	Two field staff, one week per site
Access	Requires access to sites and a suitable 'lab' space	Requires access to sites and a suitable 'lab' space	Requires access to sites and a suitable 'lab' space	Requires access to sites and a suitable 'lab' space
Cost (indicative only)	Staff salary Equipment start up Consumables	Staff salary Consumables	Staff salary Consumables	Staff salary Consumables
Outputs	Site Assessments, Baseline Report, Construction Report	Monitoring Reports, updated database	Monitoring Reports, updated database	Monitoring Reports, Site Condition Assessments, updated database

4. Aquifer Pollution Reduction

4.1. Introduction

Aquifer pollution from wastewater poses a threat to the health of communities wishing to access water for consumption and irrigation uses, and it poses a threat to the coastal ecosystem when it ultimately meets the sea. This is particularly important in low lying atoll countries that have shallow aquifers that lie directly in contact with the coast. Aquifer contamination occurs when contaminants at the land percolate through the soil and reach the groundwater below. Contaminants can be oil and chemicals from roads, nutrients and pathogens from wastewater or excess fertilisers and pesticides from agriculture. As they flow through the aquifer system nutrient contaminants can ultimately reach the coastal zone where they can contribute to algal bloom and eutrophication of lagoon systems. This in turn can lead to areas where habitats are deprived of the oxygen needed to support life under the sea and along coral reefs. Similarly pathogens from wastewater can travel the same way and is a health risk when the groundwater is used for human consumption.

The aquifer pollution reduction results area is concerned with measuring the volume *reduction in pollution to aquifers in kg.ha.yr.*

For this result area it will be assumed that the reduction in waste comes from the change in human and/or animal waste management practices as a result of the project intervention. It is impractical to directly measure the volume of waste from each house prior to management intervention, therefore a basic calculation will be performed to estimate volume reductions.

4.2. Intervention Benefits

There are two countries with this results area, Niue and Tuvalu. Niue proposes to reduce aquifer pollution by 0.32kg.ha.yr through improved onsite wastewater treatment systems and Tuvalu proposes to reduce aquifer pollution by 7.6kg.ha.yr through conversion of dry-litter piggeries (Table 8).

Table 8: Benefits of aquifer pollution reduction at ProDoc writing

Country	Measure	Benefit at ProDoc
Niue	On-site wastewater treatment systems	0.32kg.ha.yr
Tuvalu	Dry-litter piggeries	7.6kg.ha.yr

4.3. Methodology

Data collected from the municipal wastewater pollution reduction monitoring along with household sanitation survey data will be used to calculate an approximate volume of waste that is no longer being discharged into the environment.

Household sanitation surveys have previously been conducted in both Niue and Tuvalu and data may already exist for the areas of project implementation. Secondary data can then be used where it is deemed still relevant to calculate the average number of people per household and the average volume of waste per produced per person per year.

Household sanitation surveys can be developed for the specific required data or can be included in already planned surveys for the area. The details of the survey will be left to the requirements of the project. The World Health Organisation 'Core Questions on Drinking Water and Sanitation' suggests using a harmonised approach to collecting data so that it can be compared nationally, regionally and globally. Using a harmonised set of survey questions also allows for trends to be established over time. Therefore it is recommended that projects follow these set of core questions when gathering data on sanitation use in the project area. Some examples of relevant questions are:

1. What kind of toilet facility do members of your household usually use?
2. Do you share this facility with other households?
3. How many households use this toilet facility?

4. On average how many people live in this household?
5. What are the age ranges?

4.4. Limitations

As it is impractical to directly measure the volume of waste from each household and assess the reduced load to the aquifer, the calculations will only be an approximate of reduction. This is the start for estimating pollution reduction and will be re-assessed when projects start.

4.5. Recommendations

For now it is suggested that national projects conduct a household sanitation survey of the project area to assess the number and types of sanitation and/or animal waste systems in the area, along with standard population data. The same maintenance and site condition assessments generated for the municipal wastewater pollution reduction results area can also be used to demonstrate the acceptable operation of the improved sanitation and/or animal waste management systems in the area.

The general monitoring framework provided in Annex 1 can be used to guide the aquifer pollution reduction monitoring.

5. Habitat Restoration

5.1. Introduction

In the Pacific region there are many biodiversity hotspots that are increasingly coming under threat from invasive species, the impacts of climate change, and rapid population growth that creates competition for limited natural resources. Habitat degradation can be obvious, such as clearing old-growth forests for timber and draining wetland areas to use the land for raising crops, but it can also be more subtle. Habitat degradation alters the normal abundance and distribution of flora and fauna species in the habitat. All of these types of disturbances require restoration if the land is to be viable in the future.

The habitat restoration results area is concerned with measuring the extent of restored habitat and is simply defined as *ha restored*. This is a very broad indicator and taken at face value could take many years or even decades to show that habitat has been restored. For the purpose of this guide ‘habitat restoration’ is defined as those measures necessary to restore, enhance, or create healthy ecosystems, with a focus on the reestablishment of native vegetation and fish and wildlife habitat in degraded or disturbed sites. The proxy indicator is *ha revegetated*.

To restore habitat implies that there are one or more problems with the current state of a site or system that requires ‘fixing’ for a particular species or group of species. To restore habitat most effectively and monitor success, planners need to clearly identify target species or groups of species that they are restoring habitat for, why they are doing it, and what vegetation is appropriate for that species. Projects seeking to restore terrestrial areas for the benefit of habitat recovery will vary in complexity in accordance with restoration objectives, available resources and site characteristics.

5.2. Intervention Benefits

There are three countries with this results area, Vanuatu, Samoa and Nauru. Vanuatu proposes to restore 6,028ha through revegetation and riparian buffer restoration; Samoa proposes to restore 1,200ha through revegetation of Apia watershed and; Nauru proposes to restore 10ha of coastal area through revegetation with salt and drought tolerant species (Table 9).

Table 9: Benefits of habitat restoration at ProDoc writing

Country	Measure	Benefit at ProDoc
Vanuatu	Revegetation and riparian buffer restoration	6,028ha
Samoa	Watershed revegetation	1,200ha
Nauru	Coastal revegetation	10ha

5.3. Goals and Indicators

Identifying restoration goals and desired habitat states is an iterative process which begins with understanding the past, current and possible future (goal) states of the system being worked on. A baseline assessment should identify the current state of the site and the level of management intervention that is needed to shift the species composition and structure towards the goal state. Goals may need to be redefined if the actions required to meet the goal state are too difficult or require resources beyond those available.

Specifically, national projects will need to consider site level conditions when developing restoration plans. Considerations can include:

- Current and previous conditions of the restoration area
- What is the goal state of the revegetation process?
- Endemic fauna species that require a restored habitat
- Endemic flora species that will accommodate fauna

One obvious goal of habitat restoration monitoring is to detect whether the target species or species group that the habitat is being restored for eventually occupies the site. However it may be many years before a target species group inhabits the target site and not everything of ecological interest can be practically monitored. Therefore key indicators that represent habitat suitability and functioning ecosystems must be chosen.

General habitat attributes that are important factors influencing habitat restoration include:

- plant species diversity
- extent of tree cover
- degree of shrub development
- availability of old trees and associated nesting hollows
- tree regeneration
- amount of coarse woody debris (groundcover) and
- proximity to water or riparian zone vegetation

5.4. Methodology

The overall design of the monitoring program provided highlights the three main aspects; Record Keeping, Site Condition and, Monitoring for Habitat Restoration. We consider the first two in detail below while the monitoring for habitat restoration or biodiversity is a very long term prospect and requires the dedication of funding to resource it.

As a starting point for site assessment and monitoring of revegetated sites the Monitoring Revegetation Projects in Rainforest Landscapes Toolkit (Kanowski, et al., 2010) is recommended. The remainder of this document provides an overview of the key sections of that document. This simple yet comprehensive toolkit includes proformas for recording site details and Excel workbooks for tracking data and has been chosen because it requires no specialist training to be used. The full toolkit and associated proformas and workbooks can be found at [Griffith University - Environmental Futures Research Institute](#).

5.4.1. Record Keeping

Revegetation is inherently a long-term activity. It takes years for a reforested site to achieve 'site capture', and decades to recruit native plants and animals. Over that time, staff, volunteers and institutions will come and go. Unless basic records are kept of revegetation projects, it will be difficult to monitor and maintain those projects over the long-term.

The Monitoring Revegetation Projects in Rainforest Landscapes Toolkit provides a series of proformas to assist project teams in recording basic information about revegetation projects. To facilitate storage of information in a database (e.g. a national or regional directory of revegetation projects), the proformas include the fields Project ID and Site ID, for unique codes to identify each project and site.

5.4.2. Baseline Assessment

The baseline assessment aims to show the current state of the site and any current or future threats that may impact on site condition. The data collected would indicate a site's immediate suitability or its potential suitability for restoration as well as the time period required to direct the desired change. The baseline assessment process also aims to reveal information that will allow predictions of possible outcomes under different management scenarios.

Any existing data pertaining to the results area will be consolidated and where gaps exist the baseline assessment will fill them. Where data is current and complete this will be consolidated and included in the baseline assessment report.

Baseline assessments will use the same methodology as long term monitoring and will include site condition observations, forest structure and plant species composition monitoring. This assessment is to be conducted prior to any revegetation activity being undertaken. Baseline surveys will be conducted at a target site and reference site. Baseline data will be used to monitor management site conditions against conditions at the target site and assess the progress towards them.

5.4.3. Indicator Monitoring

Monitoring for habitat restoration can show whether a revegetated site is progressing towards the target restoration goal in terms of habitat structure, composition or other indicator characteristics.

The Monitoring Revegetation Projects in Rainforest Landscapes Toolkit has developed concise protocols for recording baseline assessment and monitoring details. The protocols include detailed methodology and the use of proformas that are easy to use and self-explanatory, requiring the project staff to visit the site and describe the current condition. The two recommended protocols to use for baseline assessment and site monitoring are Forest Structure and Plant Species Composition, the attributes and associated monitoring methods are outlined in table

Table 10: Monitoring attributes and methods

Forest Structure Attributes	Monitoring Method
<ul style="list-style-type: none"> Location and project details 	observation
<ul style="list-style-type: none"> Ground cover 	Line intercept method (transect and quadrat)
<ul style="list-style-type: none"> Canopy height 	Clinometer or stick method
<ul style="list-style-type: none"> Canopy cover 	Vertical photo imaging
<ul style="list-style-type: none"> Special life forms 	observation
<ul style="list-style-type: none"> Woody debris 	Line intercept method
<ul style="list-style-type: none"> General comments 	observation
Plant Species Composition Proformas	Monitoring Method
<ul style="list-style-type: none"> Location and project details 	observation
<ul style="list-style-type: none"> Seedlings 	Line intercept method (transect and quadrat)
<ul style="list-style-type: none"> Trees and shrubs 	
<ul style="list-style-type: none"> Stags 	
<ul style="list-style-type: none"> Other life forms 	observation

Forest structure is surveyed on two 50m x 20m plots per site, the same basic plot layout is used to monitor floristic composition. In assessing structure however, plants are not identified to species. In fact no distinction is made between native and exotic plants in the structural survey, as both contribute to forest structure. By comparison a floristic survey will identify trees to their species and DBH class and will be able to identify whether plant species known to provide resources for habitat are present at the site.

5.4.4. Site Condition Assessments

It is important to regularly assess the condition of revegetated sites to determine the extent of successful revegetation and identify any problems that the site may be experiencing and adjust maintenance accordingly. Site condition assessments are linked with routine monitoring events to avoid doubling up of costs and include additional physical and site observations, recorded through standard proformas (provided with the Monitoring Revegetation Projects in Rainforest Landscapes Toolkit).

The main purposes of condition assessment are:

1. To inform practitioners of the condition of sites and to help prioritise maintenance effort;
2. To inform funding bodies of the condition and extent of revegetation projects

The attributes used to assess the site condition are strongly interlinked e.g. sites where mortality of planted trees is high tend to have a relatively open canopy and a grassy ground cover. The particular attributes used have been selected for their relevance to reforested sites; additional attributes may need to be used for remnant enhancement and regrowth management projects.

Assessment of condition in the Monitoring Revegetation Projects in Rainforest Landscapes is primarily based on the following attributes:

- The survival of planted trees (a major influence on establishment success);
- Canopy cover (a key regulator of the rainforest environment);
- Ground cover (influences plant recruitment and growth);
- Problem weeds (plants which can adversely affect site development); and
- Recruitment (determines the long-term composition of a site)

5.5. Recommendations

The Monitoring Revegetation Projects in Rainforest Landscapes is recommended as a toolkit for use in restoration and/or revegetation projects.

The RPCU will develop project specific monitoring templates based on the Monitoring Revegetation Projects in Rainforest Landscapes to ensure standardised reporting across this results area.

A suggested work plan for monitoring progress towards habitat restoration at revegetation sites is described below. Monitoring schedules may change due to cost or personnel constraints however a minimum of baseline monitoring and annual indicator monitoring must be adhered to.

	Year One	Year Two	Year Three	Year Four
Sites	Reference, Target, Management site	Management Site	Management Site	Reference, Target, Management site
Survey Type	Site descriptions, baseline assessment	Monitoring, Site Condition	Monitoring, Site Condition	Monitoring, site condition assessment
Record Keeping	Construction, maintenance activities	Maintenance activities, monitoring events	Maintenance activities, monitoring events	Maintenance activities, monitoring events
Timing	Prior to construction	Annual	Annual	Annual
Attributes	Observations, forest structure, plant species composition	Observations, survival of planted trees, canopy cover, ground cover etc.	Observations, survival of planted trees, canopy cover, ground cover etc.	Observations, survival of planted trees, forest structure, plant species composition
Personnel	Two field staff, one week per site	Two field staff, one week per site	Two field staff, one week per site	Two field staff, one week per site
Access	Requires access to sites	Requires access to sites	Requires access to sites	Requires access to sites
Cost (indicative only)	Staff salary Equipment start up Consumables	Staff salary Consumables	Staff salary Consumables	Staff salary Consumables
Outputs	Site Assessments, Baseline Report, Construction Report	Monitoring Reports, updated database	Monitoring Reports, updated database	Monitoring Reports, Site Condition Assessments, updated database

6. Catchment Protection Measures

6.1. Introduction

Catchment management represents an alternative to conventional, capital-intensive treatment solutions by focusing instead on working with land owners and other stakeholders to tackle problems at source, rather than just treat the symptoms. Catchment protection approaches include improving agricultural practices, promoting sustainable forestry activities, developing strategic land use plans and gazetting land for conservation or protection.

The catchment protection results area is concerned with measuring the extent of catchment that is under improved catchment protection defined as *ha under improved management*. This indicator is vague and options for refining a more quantifiable indicator will be discussed below.

Projects seeking to improve catchment management for the benefit of watershed protection and sustainable use of resources will vary in complexity in accordance with management objectives, available resources and site characteristics.

6.2. Intervention Benefits

There are seven countries with this results area, Cook Islands, Niue, Fiji, Solomon Islands, PNG, RMI and FSM. Cook Islands proposes to protect 8,018ha through improved catchment management; Niue proposes to protect 4,608ha through improved catchment management; Fiji proposes to protect 606ha through mangrove management planning; Solomon Islands proposes to protect 3,027ha through Sustainable Land Use Strategy; PNG proposes to protect 7,151ha through protected coastal areas; RMI proposes to protect 544ha through improved catchment protection and; FSM proposes to protect 1,905ha through improved catchment protection (Table 11).

Table 11: Benefits of Catchment Protection at ProDoc writing

Country	Measure	Benefit at ProDoc
Cook Islands	Improved catchment management	8,018ha
Niue	Improved catchment management	4,608ha
Fiji	Mangrove management planning	606ha
Solomon Islands	Sustainable land use strategy	3,027ha
PNG	Protected coastal areas	7,151ha
RMI	Improved catchment management	544ha
FSM	Improved catchment management	1,905ha

6.3. Potential Indicators

The catchment protection results area is not specific about the indicator to be used and simply states *ha under improved management* as the reporting measurement. It is not defined what is meant by 'improved' management. The following table presents some options for indicators that could be used to assess 'improved' management. It is suggested that one or two of the following be chosen and used across all countries for comparability. It is also suggested that indicators be chosen that are already being measured in other aspects of the GEF Pacific R2R Programme so as to utilise the equipment, expertise and time involved in monitoring.

Table 12: Summary of potential indicators for catchment protection results area

Indicator	Definition	Why do we use this indicator	How do we measure this indicator
Catchment Condition Indicators			
Native Vegetation			
Native Vegetation Extent	This indicator measures the extent of native vegetation in the [name of catchment plan] area.	Native vegetation extent provides an indication of the current coverage, as well as extent to which vegetation and landscapes have changed, and the extent of remnant native flora and fauna habitat.	Native vegetation is assessed through site visits and typical observation of number and species type of native vegetation.
Native Vegetation Quality	This indicator measures the quality or condition of native vegetation in the [name of catchment plan] area.	Information on native vegetation condition can help us understand the ability of existing native vegetation to provide habitat for native plants and animals. This contributes to our understanding of the resilience of biodiversity.	In addition to assessing the extent the same observation event will record details on the condition of vegetation, including impacts of invasive species and fire or storm events. It will also assess the capacity of the vegetation to regenerate.
Threatened Species and Populations			
Conservation status of native plants and animals	This indicator refers to the number of native plant and animal taxa (species, sub-species or varieties) listed as extinct or threatened in the [name of catchment plan] area.	Extinction of native species represents a loss in species diversity. The number of threatened species provides an indication of the risk of further loss of biodiversity.	Information can be sourced from IUCN Red List or nationally held Advisory Lists or similar. There may however be limits to the usefulness of these sources for the following reasons: <ul style="list-style-type: none"> • Limited available knowledge base • Limited survey effort particularly for lichen, fungi, and invertebrates • Irregular reviews of the status of species
Threatened plant and animal populations	This indicator reports on estimates of current condition of, and level of threat to, a sample of threatened plant and animal populations and communities in the [name of catchment plan] area.	It is not possible to determine the status of all plant and animal populations in the [name of catchment plan] area given our limited knowledge of many species. This indicator provides an insight into particular threatened plant and animal populations, and may be considered a surrogate indicator for the general condition of plant and animal populations in the [name of catchment plan] area.	Populations can be selected from across the [name of catchment plan] areas that are generally those considered by the Project to be of high priority for management. Estimate of the current condition and the overall level of threat to populations of a species or community in its habitat from empirical data and expert opinion can be used. This information is then combined and modelled to reflect the status of a population or community at a given point in time.

Soils			
Soil Condition	This indicator reports on specific direct measures of soil condition across the [name of catchment plan] area.	Soil underpins the sustainability and productivity of the land, and its health is paramount. Robust soil health is essential to provide a full range of ecosystem services and to maintain productivity.	Typical measurements of soil condition can include salinity, acidity, threat of erosion and soil nutrients. Acidity can be measured using a pH meter. Salinity and nutrients can be measured using the same instruments and methods as that used for wastewater monitoring or with additions or modifications to those instruments. Erosion can be modelled using satellite imagery.
Rivers and Streams			
Stream Flow	This indicator reports on the [name of catchment plan] area average stream flows as a percentage of long-term average flows (where known)	Effective management of water resources to meet current and future urban, rural and environmental needs requires knowledge of how much water is where, who uses it and how this changes over time. To manage water use sustainably it is important to ensure that there are sufficient flows to maintain river and floodplain environments	Continuous data can be collected at surface water monitoring stations. Gauging stations are available for major rivers in most countries?
River and Stream Condition	Stream condition is measured through the Index of Stream Condition (ISC). The ISC is an integrated measure of the overall condition of a river/stream reach based on the assessment of five component subindices – hydrology, water quality, physical form, streamside vegetation and aquatic life. It is a measure of a stream's change from a natural or ideal condition.	The Index of Stream Condition provides a generally consistent, integrated method for reporting on the condition of rivers and streams. The use of condition benchmarks allows for comparisons over time. The ISC is used by the Department of Environment and Primary Industries, Victoria Australia. It is possible to take several of the subindices that are reasonable to monitor in the PICS such as water quality, streamside vegetation, and physical form, using these as a modified integrated stream condition that would be comparable across the region.	For streamside vegetation and physical form it is possible to use LiDAR which records a three dimensional image of the earth's surface and vegetation structure, producing a comprehensive and accurate baseline. The alternative is to take random location sampling along the river/stream reach. Water quality includes pH, turbidity, EC and TP and can be conducted using in-situ probes and instruments from wastewater monitoring.
Wetlands			
Wetland Extent	This indicator reports on the extent of wetlands in the [name of catchment plan] area.	Information on wetland extent can help determine the degree to which wetland ecosystems and their diversity are being maintained. Reduction in wetland extent occurs when wetland habitat is permanently lost (for example, through activities such as drainage or infilling). The loss of	Site mapping and survey can be used to determine the extent of wetland areas. Methods can be found at "Alluvium (2011) Statewide wetland geospatial inventory update project outcomes"

		wetland habitat impacts adversely on wetland biodiversity.	
Wetland Condition	This indicator reports on wetland condition using the Index of Wetland Condition as used by the Dept of Environment and Primary Industries, Victoria Australia. The IWC is based on the assessment of six sub-indices that are critical to the function of wetlands. These are intensity of land use and extent and fragmentation of native vegetation adjacent to wetlands, physical form, hydrology, water properties (salinity, acidity, nutrients), soils and biota.	Changes in wetland condition (for example, through altered hydrology, water pollution, nutrient enrichment or pest plant and animal invasion) can lead to biodiversity loss and impair wetland functioning. Changes in wetland condition may be localised or may be indicative of broader changes in surface and groundwater flow regimes and catchment condition.	Depending on the subindices chosen some methods can be borrowed from monitoring Rivers and Streams.
Groundwater			
Groundwater levels	This indicator reports on the groundwater levels in the [name of catchment plan] area.	Groundwater level data, coupled with knowledge of the aquifer, the climate and groundwater use can be used as an indicator of sustainable use of the resource.	Baseline groundwater level data can be collected at monitoring boreholes in the [name of catchment plan] area where available and applicable.
Groundwater Quality	This indicator reports on groundwater salinity, nutrient and pathogen levels.	Excessive groundwater salinity and nutrients levels limits use by agriculture, residential, industrial users and the productivity of the lands and coastal areas that receive groundwater either as irrigation or flow	Baseline groundwater level data can be collected at monitoring boreholes in the [name of catchment plan] area where available and applicable.
Catchment Management Indicators			
Indicator	Definition	Why do we use this indicator	How do we measure this indicator
Voluntary management activities by stakeholders and/or landowners	This indicator reports on the land management activities undertaken voluntarily by the stakeholders and/or landowners in the [name of catchment plan] area.	Stakeholders and landowners in the catchment area are critical to the success of the catchment management plan. Their voluntary participation in activities results in long-term improvements to natural resource systems of a catchment.	Attendance at targeted stakeholder workshops/trainings/events can be recorded and tracked. Site visits to stakeholders and/or landowners can demonstrate whether activities are being applied within the catchment area. If it is acceptable to the stakeholders, return visits can be made to monitor their progress. The number of voluntary groups that arise and develop independent conservation activities and/or

			participate with the authority in conservation activities can be monitored.
On-ground operational works by the catchment authority	This indicator reports on the on-ground operational works, activities and maintenance that is performed by the authority tasked with care of the catchment management plan	On ground operational works can lead to the improvement of the environmental state of the catchment. For example clearing invasive species, replanting natives, and riparian restoration all contribute to improving the ecosystem functions of a catchment.	All operational works, maintenance activities and general activities undertaken by the catchment authority are planned, recorded, tracked and reported. These actions should be regularly monitored for their effectiveness at achieving catchment plan objectives. An operational budget can be used to identify the expenditure on activities. However expenditure should not be used as a direct measure of management effectiveness – the amount of dollars spent on managing the environment does not necessarily relate to any change in natural resource condition, particularly over a short time period
Community Engagement Activities	This indicator reports on the community engagement activities undertaken by the catchment authority tasked with care of the catchment management plan	The involvement of citizens in the planning and activities of the catchment authority is important for ensuring the responsiveness, quality and effectiveness of authority programs and services. It is also an outcome characterized by effective information exchange, consultation and participation between the authority and the community that strengthens the two-way conversation around natural resource management and livelihoods.	Activities that are planned and implemented by the catchment authority are recorded, tracked and reported against. The number and effectiveness of these, the continuity of participants where applicable, and the sex/age disaggregated data are used.
Planning Controls Implemented	This indicator reports on the planning controls such as restricted land use, zoning, building codes, weed controls etc. that are designed and implemented in the catchment plan area.	Planning controls such that restrict land use or zone areas for protection or conservation demonstrate the proactive management of the catchment. The outcomes of these actions will be a measurable improvement in the environmental status of the catchment area.	Planning and implementation documents can be used to show the number and type of planning controls. The associated monitoring and reporting of them can also be used to show their effectiveness over time.
Data collection and control	This indicator reports on the type, number, quality and usage of data collected and can be viewed as a metadata collection of reporting associated with the catchment management plan.	Collecting data and interpreting data to understand changes in the state of the environmental status or social capital in the catchment management area is critical to the long-term success of the plan. Collecting more data in itself will not support future decisions about management improvements. However, the systematic analysis and use of quality data will help the catchment management authority show trends, identify areas for	The number of continual and complete metadata sets kept by the catchment authority is reported on

		improvements and communicate successes. Tracking metadata (that which describes and gives information about all the data collected by the authority) enables the authority to assess where monitoring 'blackholes' are occurring.	
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6.4. Assessment Framework

The diverse nature of catchment protection measures, means that defining a single system for evaluating management effectiveness will not be able to address all needs and circumstances. However too much diversity in systems may limit the ability to compare and learn across countries and projects. An overall framework for evaluation is needed guide management effectiveness assessment, within which can sit standardised methods.

The IUCN-WCPA has developed an internationally recognised framework that provides a consistent basis for designing assessment systems (Hockings, et al., 2006). It gives guidance about what to assess and provides broad criteria for assessment. It is designed for assessing the management effectiveness of protected areas, and can be adapted to assess the effectiveness of the multitude of interventions in the GEF R2R Programme.

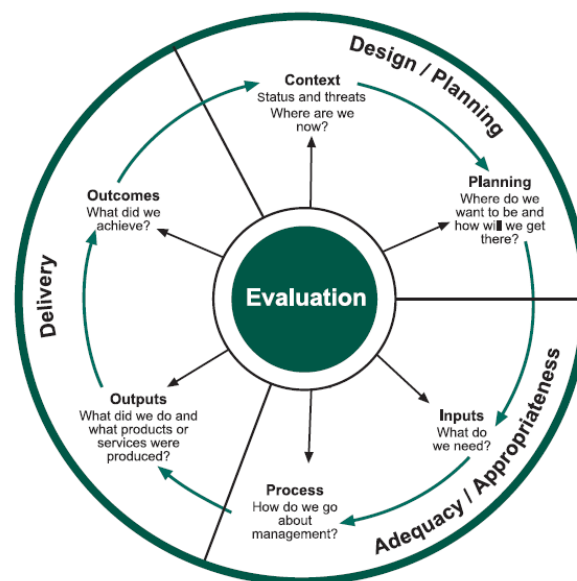


Figure 3: A framework for assessing management effectiveness of protected areas

The framework is based on the idea that protected area management follows a process with six distinct stages, or elements:

- it begins with reviewing context and establishing a vision for site management (within the **context** of existing status and pressures),
- progresses through **planning** and
- allocation of resources (**inputs**), and
- as a result of management actions (**process**),
- eventually produces goods and services (**outputs**),
- that result in impacts or **outcomes**.

It could be stated that all our intervention work follows a similar process with similar elements. It is recommended that the R2R Programme adopt this framework for assessing the stress reduction activities in the IW and STAR Projects. The full document can be found at [IUCN Library](#).

This document seeks to elaborate methodologies to be used during both the design and delivery stage.

- what attributes will be considered;
- what indicators of this attribute will be measured/assessed; and
- methods to be used in measuring the indicator

6.5. Methodology

The methodology for this results area will be dependent on the indicators chosen and in many instances will be able to draw on the methodologies described for the other results areas as already described. In

addition a number of regionally developed or appropriate toolkits have been identified for the various potential indicators.

6.6. Recommendations

There are many existing publications which document monitoring procedures for the multiple environmental areas the R2R Programme is addressing, in particular in the broad results area of catchment protection measures. Those described below have been chosen because they are particular to the Pacific region and enjoy wide spread use, or because they represent best practice and can be easily adapted to the Pacific context. Many of them have a focus on community monitoring of key environmental attributes. This list is not exhaustive nor specific to catchment protection but can be used as a starting point for any of the results areas. Key examples include the following with a brief description and links to relevant websites where the document is held.

Table 13: Suggested toolkits for use in monitoring

Results Area	Document Title	Brief Description	Link
Habitat Restoration	South East Queensland Ecological Restoration Manual	A technical but easy to use guide to all aspects of ecological restoration. This document is reflective of current best practice, and provides the minimum acceptable solutions to ecological restoration.	http://www.seqcatchments.com.au/seq-ecological-restoration-framework
Revegetation	Monitoring Revegetation Projects in Rainforest Landscapes Toolkit	This toolkit has been written to assist community groups and restoration practitioners record the details of their revegetation projects, assess their condition and monitor their outcomes for biodiversity and carbon sequestration	https://www.griffith.edu.au/environment-planning-architecture/environmental-futures-research-institute/publications/materials-for-environmental-managers/monitoring-revegetation-projects-in-rainforest-landscapes-toolkit-version-3
Mangroves	Manual for Mangrove Monitoring in the Pacific Island Regions	This manual adapts international accepted mangrove monitoring methods for the Pacific region. It focuses on describing practical and low cost qualitative methods for assessing mangrove extent, community structure, status and health.	https://www.sprep.org/Publications/manual-for-mangrove-monitoring-in-the-pacific-islands-region
Seagrasses	Manual for Community (Citizen) Monitoring of Seagrass Habitat: Western Pacific Edition	This manual provides a step by step guide and outlines initially the monitoring process and how to map seagrass using a variety of approaches. The methods are applicable across a wide geographic range. The manual also provides an inventory of (low cost) equipment that can be used to assess seagrass assemblages.	http://www.seagrasswatch.org/manuals.html
Fisheries	Assessing Tropical Marine Invertebrates	This manual provides instructions on how to design and plan surveys, detailed instructions on survey techniques and methodologies, and data management. This manual promotes the use of standardised survey methodologies and analytical procedures to enable comparison across countries and/or regions.	http://www.spc.int/Coastfish/publications/425.html
Water Quality	R2R Coastal Monitoring Protocol	This protocol provides instructions on survey techniques and methodologies and data management for near coastal waters. It promotes the use of standardised procedures to enable comparison across countries and/or regions.	GSD-SPC Ridge to Reef Programme Annex 2: Draft Coastal Monitoring Manual

	R2R Wastewater and Eco-sanitation Monitoring Protocol	This protocol provides instructions on survey techniques and methodologies and data management for compost toilets and waste water. It promotes the use of standardised procedures to enable comparison across countries and/or regions.	GSD-SPC Ridge to Reef Programme Annex 3: Draft Sanitation and Wastewater Monitoring Manual
Marine Spatial Planning	Marine Spatial Planning in the context of the Convention of Biological Diversity	A report that reviews marine spatial planning experiences, provides detail on theory, practical tools and methodologies and describes challenges and potential solutions.	http://www.stagef.org/marine-spatial-planning-in-the-context-of-the-convention-on-biological-diversity/

7. Conserved/Protected Fish Refugia

7.1. Introduction

Fish use a range of habitats during critical stages of their life cycles such as when spawning, as larvae, and for feeding. These habitats include mangroves, sea grass beds, coral reefs and wetlands. Loss of these habitats due to development, mangrove harvesting, dredging and other human activities leads to a decline in fish stocks and places added pressure on the resilience of coastal communities. Similar to marine protected areas, fish refugia are spatially and temporally defined marine and coastal areas that are placed under specific management. Fish refugia however focuses on the link between fish stocks and habitats and improving their resilience. Fish refugia develops areas for specific management measures to protect economically important fish at critical stages of their life cycle rather than focussing on traditional 'no-take' zones. This approach improves resilience of the fish stock and the food security and livelihoods of the coastal communities that depend upon them.

The concept of fisheries refugia as used by the GEF is outlined as follows:

“Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use”. (Paterson , et al., 2013)

The conserved and/or protected fish refugia results area is concerned with measuring the extent of area that is placed under conservation or protective fish refugia management measures in *ha protected*.

7.2. Intervention Benefits

There are two countries with this results area, Solomon Islands and Tonga. Solomon Islands proposes to protect 200ha of fish refugia through an Integrated Coastal Management Plan for Honiara, and Tonga proposes to protect 90ha of fish refugia habitat in the development of coastal and fisheries management plans.

Table 14: Benefits of Protected Fish Refugia at Prodoc writing

Country	Measure	Benefit at ProDoc
Solomon Islands	Integrated Coastal Management Plan	200ha
Tonga	Coastal and Fisheries Plans	90ha

7.3. Potential Indicators

The conserved/protected fish refugia results area is not specific about the indicator to be used and simply states *ha protected* as the reporting measurement. This results area could simply measure the area of refugia that is put under management in writing through the respective protection plans. However it is important to assess effectiveness of fish refugia protection plans. Baseline assessments of the area and ongoing site condition assessments will need to be conducted in order to assess effectiveness.

Considering the short term nature of the current project lifespan the indicators chosen to measure fish refugia management should reflect this. The table below presents some options for short-term objective indicators that could be used to assess coastal management plans. It is suggested that several of the following be chosen and used across all countries for comparability.

Table 15: Potential indicators for monitoring fish refugia. Taken from ref?

Resource-Related Objectives	Indicator	How do we measure this indicator
Short-term Objectives		
1. Reduced capture of juveniles and pre-recruits of	Abundance of juveniles in fishery refugia areas:	a) Results of fishery dependant and independent surveys b) Interviews of fishers, fishing, communities and traders

commercially important fish and invertebrate species	a) Fishing effort dynamics in fishery refugia areas b) Selectivity of fishing operations conducted within juvenile refugia c) Frequency of inappropriate fishing operations in fishery refugia d) Volume and size composition of commercially important fish (pelagic and demersal) and invertebrate species landed and traded in main markets	c) Results of studies of species and size composition conducted within refugia d) Observations/reports of illegal or destructive fishing in fishing refugia areas e) Results of studies of the volume and size of fish landed at main landing places and traded in main market
2. Reduced targeting and capture of commercially important fish (pelagic and demersal) and invertebrate species in spawning condition and when forming spawning aggregations	a) Fishing effort dynamics in fishery refugia areas b) Selectivity of fishing operations conducted within juvenile refugia c) Gonosomatic index (GSI) of commercially important fish and invertebrate species landed and traded in main markets d) Abundance of eggs and larvae of commercially important species in key spawning areas	a) Results of fishery dependant and independent surveys b) Interviews of fishers, fishing, communities and traders c) Results of studies of the gonosomatic condition of commercially important species landed and traded in main market d) Results of surveys of egg and larval fish density in key spawning areas

7.4. Methodology

The methodology for this results area will be dependent on the indicators chosen and in many instances will be able to draw on the methodologies described in Table 13: Suggested toolkits for use in monitoring above. Options for measuring fish refugia range in cost and difficulty and should be chosen with the following considerations:

- affordable, portable, light and robust
- methods based on accepted international and/or regional methods
- produce replicable and accurate results
- be able to be used by personnel with basic training

7.4.1. Record Keeping

Identifying changes in fish stocks and health as a result of established fish refugia is inherently a long-term activity. It may take several years before consistent results are noticeable and even longer for changes to populations to be observed. Over this time staff may come and go and unless basic records are kept it will become increasingly difficult to monitor and maintain those projects over the long-term.

It is suggested that consistent proformas be used to assist project teams in recording basic information about revegetation projects. To facilitate storage of information in a database (e.g. a national or regional directory of revegetation projects), the proformas should include the fields Project ID and Site ID, for unique codes to identify each project and site.

Project details are recorded for every monitoring survey.

7.4.2. Baseline Assessment

The following information box can be used to assist in setting baselines and identifying priority actions at fish refugia sites.

Framework process for baseline setting and identifying priorities for intervention at fishery <i>refugia</i> sites	
1. Identification of issues and problems with fish stock and coastal habitat linkages	<ul style="list-style-type: none"> Identify compromises of, and threats to, aquatic uses, resources and amenities, associated hazards to human health and legitimate uses of the aquatic environment, as well as associated limitations on traditional and cultural activities Scientifically evaluate the aquatic environmental issues and problems (e.g., types and volume/magnitude of pollutants entering the system; rates of loss of coastal habitats/ecosystems; changes in species composition and catch per unit effort in fisheries; increases in sedimentation and algal density)
2. Quantification of the compromises to fish stock and coastal habitat linkages	<ul style="list-style-type: none"> Conduct social and economic evaluation of the aquatic environmental issues and problems (e.g., economic costs of environmental impacts; social costs of the issues such as adverse effects on human health and welfare).
3. Initial prioritization of problems	<ul style="list-style-type: none"> Based on the system description, identify and quantify compromises (steps one to three above) and threats, and produce an initial prioritization of the compromises, hazards and limitations to legitimate uses and activities
4. Identification and characterization of immediate, secondary, and higher level causes of the degradation of fish stock and critical habitat linkages (" <i>causal chain analysis</i> ")	<ul style="list-style-type: none"> Determine and describe the immediate causes of identified issues Determine and describe of the secondary causes of identified issues Determine and describe the tertiary...to penultimate causes of identified issues
5. Identification and characterization of ultimate (root) causes of the degradation of fish stock and critical habitat linkages	<ul style="list-style-type: none"> Determine and describe the ultimate/root causes of identified issues
6. Identification and characterization of options for intervention	<ul style="list-style-type: none"> Identify and then describe options for intervention, with emphasis on potential interventions at the most fundamental levels of cause (however, potential options at all levels should be characterized where possible)
7. Analysis of options for intervention	<ul style="list-style-type: none"> Examine options for intervention for commonalities and crosstalk/conflicts Establish criteria for net benefit analyses of options
8. Determination of comparative net benefit of options for intervention	<ul style="list-style-type: none"> Establish costs of intervention, potential benefits of intervention (preferably in monetary terms) taking account of feedback loops/conflicts to determine the most effective options for intervention
9. Identification of priority options for intervention	<ul style="list-style-type: none"> Identify, characterize and specify any conditions that should be imposed upon priority options for intervention based on the magnitude of their net benefit and ability to resolve/ameliorate multiple issues

7.5. Recommendations

It is important that the similarities and differences between Marine Protected Areas, Locally Managed Marine Areas, and fisheries refugia be adequately explored and communicated to stakeholders. Where possible, project teams are encouraged to draw on the coastal fisheries programme of SPC in the design and conduct of monitoring surveys.

A monitoring workplan will depend on the indicators and methodologies chosen. The generic workplan described in Annex 1 can be referred to as a guide to the frequency of monitoring. At a minimum, baseline and annual assessments must be made of the chosen indicators.

8. Cost Analysis for GEF Indicator Sampling

8.1. Introduction

GEF Pacific R2R Programme monitoring involves many possible costs including paying and training staff, buying equipment, travel expenses, and processing of samples. Funding availability often determines how much sampling is feasible, therefore it is important to evaluate cost as a factor in developing a monitoring program.

This assessment details cost estimates for the following indicators: wastewater chemistry and revegetation. Catchment protection costs can be easily estimated once indicators are chosen. Cost estimates for each indicator include:

- the cost for each item of equipment needed to sample each indicator and whether it is likely to already be owned, if it is shared by several indicators, and if it is consumable
- the length of time it takes each person to sample each site for each indicator
- the cost and time needed to train staff in the protocols for sampling each indicator
- cost estimates for external lab processing of waste/water chemistry

8.2. Equipment

Cost estimates were developed for each piece of equipment used in the sampling of each of the indicators. Costs were obtained from a detailed quotes from several scientific equipment suppliers and from online research. When possible at least three cost estimates were found for each item. Cost estimates for wastewater sampling equipment are given in Table 16 and revegetation monitoring in Table 17.

The total investment in monitoring for municipal wastewater pollution reduction is approximately \$18,695 for a kit using the spectrophotometer for analysis and \$14,927 for a kit using the colorimeter for analysis. Only one of these pieces of equipment needs to be purchased. Both provide accurate results however the spectrophotometer delivers greater confidence in the value and is a more robust method.

The Regional IW R2R Programme will be developing a portable water quality testing kit to measure the range of parameters described below. It is envisioned that this kit will be available for IW Projects measuring results against the Municipal Wastewater Pollution Reduction and Aquifer Pollution Reduction results areas.

Table 16: Cost estimates of equipment need for sampling wastewater

Use	Equipment	Cost (AUD)	Consumable/no n consumable (C/N)	generally owned/ not owned (O/N)	Use for field sampling/onsite lab processing (F/L)
Sampling	cooler	8	N	O	F
	ice packs	10	N	O	F
	gloves	15	N	N	F
	thermometer	20	N	N	F
	Chemwipes	5	C	N	L
	whirlpaks	10	C	N	L
	calibration rack	66	N	N	L
	sample tubes	42	C	N	L
	nalgene bottles (12pk)	108	N	N	L
	volumetric flasks 50ml	59.9	N	N	L

	volumetric flasks 100ml	62.2	N	N	L
	graduated cylinder 100ml	47.4	N	N	L
	filters	300	N	N	L
	beaker (1)	97.1	N	N	L
	filtering unit	456	N	N	F
	hand pump	189	N	N	F
	Syringes (100pk)	91.5	N	N	L
	syringe filters (50pk)	388	C	N	L
	Secchi disk	136	N	N	F
BOD	Portable LBOD Kit	3695	N	N	L
	BOD bottles (25pk)	165	C	N	L
	BOD bottle stoppers (25/pk)	171	C	N	L
	Field case	240	N	N	L
Multprobe	HQ40D multiprobe meter	4413	N	N	F
	Field case	260	N	N	F
Colorimeter	DR900 Colorimeter	2489	N	N	F
	Field Case	147	N	N	F
Spectro- photometer	DR 1900 Spectrophotometer	5416	N	N	F
	Field case	295	N	N	F
	USB+ Power module	693	N	N	F
Phosphate	Phosver 3 (100pk)	64.4	C	N	F
	sample cells (6pk)	83.6	N	N	F
	stopper for 18mm tubes	48.6	C	N	F
	Phosphate standard solution (16pk)	96.1	C	N	F
Ammonia	AmVer test N Tube (50pk)	200	C	N	F
	funnel	8	N	N	F
	pipette TenSette 01-1.0mL	537	C	N	F
	pipette tips for TenSette (50pk)	22.6	C	N	F
	Test tube rack	131	N	N	F
	nitrate ammonia standard solution	45.2	C	N	F

The total investment in revegetation monitoring is relatively inexpensive and provides great return when monitoring is conducted regularly to assess the success of plantings and site capture. In addition to the

initial investment of approximately \$1241 for all equipment (though it may not be necessary to purchase all) there may be recurring cost for consumables such as flagging tape, specimen collection bags and markers depending on individual project circumstances.

Table 17: Cost estimates of equipment needed for monitoring revegetation

Equipment	Cost (AUD)	consumable/non consumable (C/N)	generally owned/not owned (O/N)	Shared with other indicators (Y/N)
50 m tape	38.25	N	N	Y
flagging tape	150	C	N	Y
dbh tape	49.95	N	N	Y
2.5 m pole	12	N	N	Y
Compass	22.95	N	N	Y
Camera	80	N	O	Y
clipboard and proforma	22.95	N	N	Y
GPS	350	N	N	Y
plant tags and bags	80	C	N	Y
binoculars	185	N	N	Y
clinometer	250	N	N	Y

Table 18: cost estimates for start-up and consumables for each results area

Indicator	Start-up cost (AUD)	Consumables (AUD)
Wastewater with colorimeter	18,287	2610
Wastewater with spectrophotometer	22,055	2610
Habitat Restoration	1241	230
Catchment Protection	-	-

8.3. Laboratory Analysis

Quotes were received from the Institute of Applied Science (IAS) Water Quality Laboratory at the University of the South Pacific and The Fiji Ministry of Agriculture Koronivia Laboratory. IAS is an International Standards Organisation 17025 certified water quality testing facility, Koronivia conducts analytical test on soils and sediments and is not certified.

There is potential in using these facilities to verify the methods used in-field and in some instances conducting analysis on samples. Water and biological samples will not be able to be analysed except when they originate from Fiji due to quarantine restrictions. Soil and sediment samples can be analysed but are subject to UV radiation upon entry to Fiji.

Cost estimates for the relevant tests are provided below for IAS and Koronivia.

Test	Method Detection Limit (MDL)	Method Reference No.	Cost/sample (FJD)
Nitrate	4.50 µg/L as N-NO3	APHA 4500-NO3-	81-00
	19.9 µg/L NO3		
Nitrite	4.00 µg/L N-NO2	APHA 4500-NO3-I	81-00

	13.1 µg/L NO ₂		
Total Phosphorus	0.013 mg/L	APHA 4500 P, B & E	81-00
pH	NA	APHA 4500-H+B	25-00
Electrical Conductivity	NA	APHA 2510B	25-00
Turbidity	0.02 NTU	APHA 2130B, Modified	32-00
Dissolved Oxygen	0.05 mg/L	APHA 4500-OG	25-00

Test	Cost/Sample (FJD)
Sample preparation	6.50
pH	3.00
Total nitrogen	4.50
Olsen phosphorus	4.50
Organic matter	4.00
Moisture factor	2.50

8.4. Training

The selection of Water Quality methods has been based in part on their ability to be performed by people with little to no analytical training. That being said, training in the use, maintenance, care and analysis of the equipment and the data it produces will be necessary. Likewise it will be important for staff to be trained in the correct methods of field sampling and health and safety aspects of working with contaminated samples and chemical reagents. This can be provided through the RPCU at no cost and would usually take up to 8.5hours. The possibility for training from the equipment supplies is also available however this will be at additional cost.

The Monitoring Revegetation Projects in Rainforest Landscapes was chosen as a starting point for monitoring revegetation because it does not require any specialist skill and can be learned and used by anyone. If any training is required it may be for project management teams in plant species identification for regular maintenance and site condition surveys. This could be provided by a local NGO or through the Department of Environment at no cost if working in partnership and would typically take up to 4 hours of in-field training.

The amount of time and cost of training will depend on the requirements of each project but should be factored in to all monitoring plans.

Table 19: Estimate of sampling time and training time and cost

Person-time values	Time per site per person (in hours)	Time required to train people (in hours)	Cost for training per person (AUD)
Wastewater	3	8.5	\$100
Habitat Restoration	5	8	\$50

9. Data Management System

9.1. Introduction

While the details will vary, some of the key elements of good data management include data validation and verification (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc).

The water and wastewater quality monitoring protocols have more detailed proformas and data management examples. These will be expanded upon and refined after trial use in countries.

9.2. Resources

Suggested proformas to be developed (by RPCU) for use by countries in baseline assessment and long term monitoring include:

- Record Keeping
 - Project Proforma
 - Site Proforma
 - Description of on-ground works
 - Project Journal
- Baseline Assessment
 - Standard Report Format
- Indicator Monitoring
 - Check box field data sheets
 - Field survey proformas
 - Chemistry analysis proformas
- Site Condition Assessments

9.3. Standardised Reporting Format

Results of baseline and monitoring assessments should be interpreted and narrated in standard, easy-to-read report format. These should enable all the stakeholders and other users to understand the current situation of the selected stress reduction indicators and clarify subtleties which cannot be explained quantitatively. The following is the proposed Outline of the Baseline Report:

Executive summary	The executive summary should be a brief presentation on the project focus, the context under which the baseline assessment was done, general findings and general conclusions.
Table of contents	In the table of contents, the section headings should follow the numbering format suggested in these guidelines but this can be adapted where necessary
1. Background	<p>This section should include some background information on the project, objectives, an overview of the expected results, the extent of its activities, its geographic scope, and the situation in which it operates.</p> <p>Include a brief on the project results and stress reduction indicators that have been assessed. Issues to include are the context in which the assessment is conducted (e.g. socio-economic, physical, cultural, political etc which might have bearing on expected results), implementing partners, and target stakeholder categories.</p>

	<p>1.1 Purpose and Objectives</p> <p>The purpose and objectives of the baseline assessment should be presented and clarified.</p>
2. Methodology	<p>This section should include discussion of the following:</p> <p>2.1 The general framework of the assessment</p> <p>2.2 Techniques employed in information gathering</p> <p>2.3 Tools used to collect and analyze the information</p> <p>2.4 The composition of the assessment team</p> <p>2.5 The range of stakeholders involved</p> <p>2.6 The limitations or constraints in terms of information gathering, the tool or other constraints faced by the evaluation team.</p>
3. Analysis of the findings	<p>This section should include an interpretation of the results within the context in which the assessment was conducted. Key stress reduction indicators should be elaborated in detail clearly indicating the data elements, data source, analytical tools used, the data and interpretation. Identify components which may need further assessment.</p>
4. Conclusions	<p>Conclusions sum up the findings of the assessment. They facilitate the formulation of general and specific recommendations for tracking the indicators</p>
Annexes/appendices	<p>This section should include relevant documents, data, tables, assessment ranking, a glossary and other information the assessment team deem necessary. Each annex/appendix should be numbered and listed by title in the table of contents.</p>

References

Baldwin, D. S., Nielsen, D. L., Bowen, P. M. & Williams, J., 2005. *Recommended Methods for Monitoring Floodplains and Wetlands*. s.l.:Murray Darling Basin Commission.

Hockings, M. et al., 2006. *Evaluating Effectiveness: A framework for assessing management effectiveness of protected areas. 2nd edition*. s.l.:IUCN.

Kanowski, J. et al., 2010. *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3..* Cairns: Reef and Rainforest Research Centre.

Paterson, C. J. et al., 2013. Fisheries refugia: A novel approach to integrating fisheries and habitat management in the context of small-scale fishing pressure. *Ocean and Coastal Management*, Volume 55 (B), pp. 214-229.

Annex 1: Generic Workplan for annual monitoring

Name:

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Project:

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Date:

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Activity	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data Collection																
Develop monitoring tools	x	x	x	x												
Baseline Assessment data collection (target, reference, management sites)			x	x												
Revision of survey tools					x	x								x	x	
Data Analysis and Management	x	x	x	x												
Indicator Monitoring						x				x				x		
Site Condition Surveys						x				x				x		
Site maintenance (and as required)						x				x				x		x
Report Development																
Develop database & establish reporting system	x	x	x	x					x							
Baseline Assessment Report (target, reference, management sites)			x	x												
Activity Report				x												
Site Condition Report (target, reference, management sites)						x									x	
Half-Yearly Monitoring and/or Maintenance Report (management site)						x		x		x		x		x		x
Mid-term Evaluation report									x							
Dissemination			x		x				x				x			x
Data Management																
Generating fact sheets and other communication materials					x				x				x			
Assess and consolidate existing data	x	x	x	x												
Populate regional and national database				x		x		x		x		x		x		x
Data Sharing						x		x		x		x		x		x

Annex 2: Draft Coastal Monitoring Manual

DRAFT COASTAL MONITORING MANUAL –

GEF PACIFIC R2R PROGRAMME

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1 Description of the GEF Pacific R2R Coastal Monitoring Program

1.1. Aims of the program

As a long-term (i.e. ongoing over many years) program, the principal aim is to assess long-term changes or trends in water quality and coastal health. In other words, the program is designed to address the general question—is water quality getting better or worse or staying the same? Trends might be negative due to increased development or positive as a result of improved management of point or diffuse pollutant sources.

In addition to meeting the main aim, the data from the program also aims to address questions about current condition, i.e. does water quality meet guideline values?

The data collected will also represent a valuable information resource and is intended to be used for a number of other related purposes. These include use as baseline data for characterising priority coastal sites; as background for undertaking and assessing environmental impact statements; and as a general data source for members of the public, particularly catchment and land care groups, to gain an understanding of water quality in their area. The data is also intended for use in national and regional State of the Coast reporting to inform Integrated Coastal Management strategy development.

1.2. Scope of coastal monitoring program

The GEF Pacific R2R Programme regional coastal monitoring program will be initiated with the inception of the programme (2016). The monitoring program is ambitious in scope and endeavours to cover the 14 participating R2R countries. Initially however several countries will be selected to trial the recommended methods before extending to selected priority sites in the remaining countries. These sites will include estuaries, open coasts and lagoons. Sites will be surveyed to assess baseline conditions and depending on available resources, annually thereafter.

1.3. Selection of Indicators

The regional coastal water monitoring program is aimed at assessing basic coastal water quality characteristics and recommends including the indicators described in Table 20 for condition assessment.

Standard methods as described in various publications including the Examination of Wastewater and Water (APHA, 2012), the Guideline for Fresh and Marine Water (ANZECC & ARM CANZ, 2000) and A Guide to the Sampling of Wastes, Wastewater, Soils and Sediments (EPA, 2000), require extraction methods, digestions steps and analysis by one of spectrophotometric, fluometric or titration methods. These analyses are accurate in multiple tests and applications and are the procedures generally accepted for reporting in

scientific literature. However, these methods have significant disadvantages. They are time consuming and usually require a dedicated water chemistry laboratory and an experienced, efficient analyst to generate consistently accurate and reproducible results.

Due to the geographic isolation of a lot of sampling sites, and limited access to analytical resources and personnel much of the analysis will need to be performed in-situ. It is important to remember that the results of in-situ analysis will not be as accurate as results from certified extractive analysis procedures. They do provide estimates of parameter concentrations and in-field procedures will be verified against standard methods where possible.

Table 20: Recommended coastal water biophysical indicators for condition assessment

Water – Field	Water – Lab	Sediment (sent to lab)	Biotic
Temperature	Orthophosphate (HACH)	TOC	Benthic invertebrates
Dissolved oxygen	Ammonia (HACH)	Total nitrogen	
pH	Nitrate (HACH)	Total phosphorus	
Conductivity			
Turbidity			
Secchi depth			
ISE (nitrate, nitrite, ammonium)			
Chlorophyll-a fluorimeter	Coliform	Total nitrogen (digestion?)	
	BOD		

Field readings (temperature, dissolved oxygen, pH, conductivity, turbidity, *chlorophyll a*, secchi depth and some nutrients) will be recorded at all sites. Water column nutrients, coliforms, and sediment TOC and nutrients will preferably be sampled at all sites but may be restricted due to resource, personnel or logistical restrictions. Benthic invertebrates will be sampled in those sites where invertebrate indicator species are known.

1.4. Monitoring framework

A monitoring framework is essential to the design and adaptation of an effective monitoring program. It establishes a simple sequential structure that encourages thoroughness, facilitates communication within and between different levels of operation and management, and provides overall direction and focus essential to achieving success in such large-scale and long-term studies. The framework adopted for the GEF Pacific R2R is summarised in the figure below. It is adapted from the Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ, 2000). This manual covers the sections indicated by a star in Figure 4.

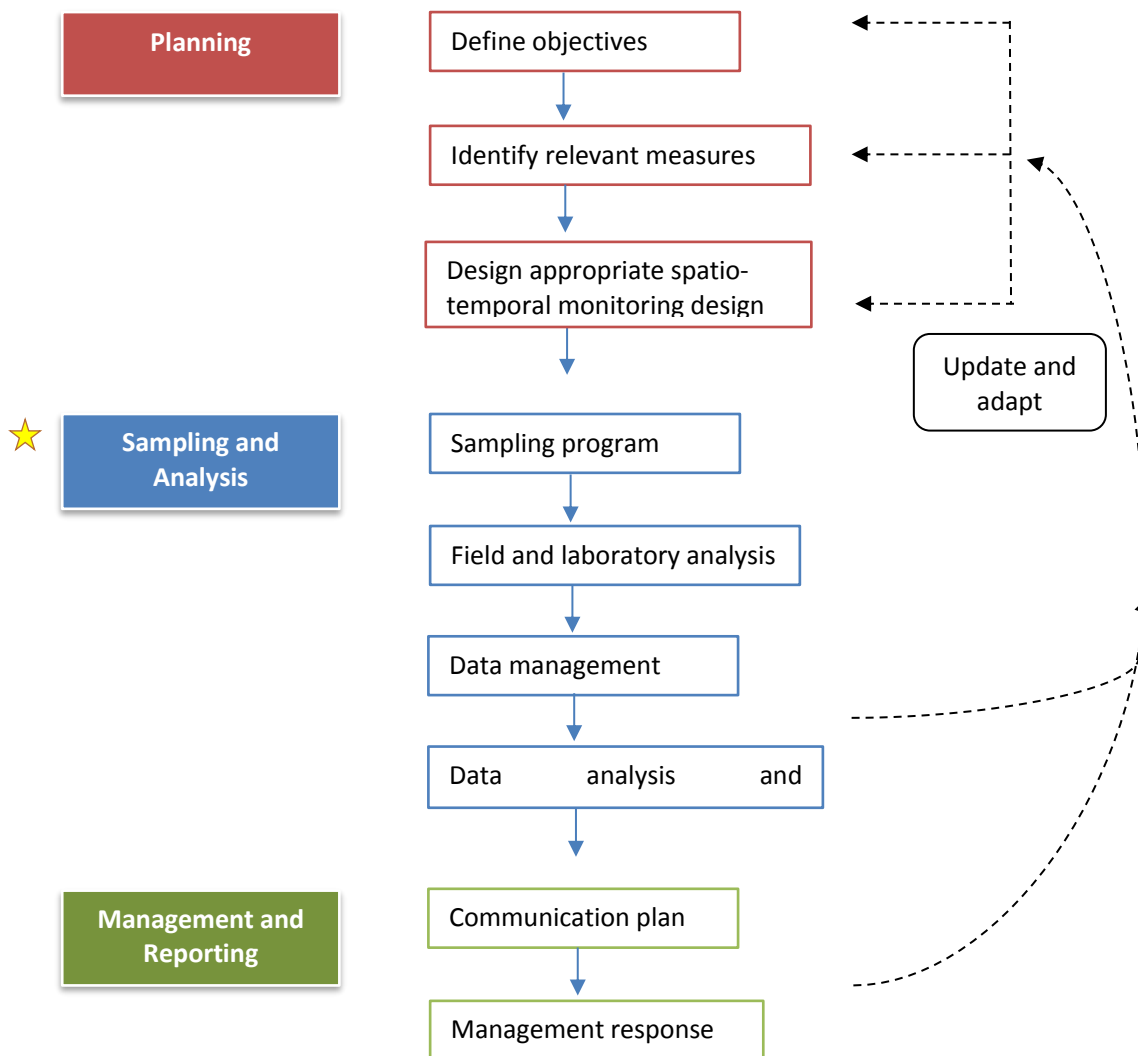


Figure 4: Proposed monitoring framework

1.5. Acknowledgements

Combinations of existing protocols were used to develop this standard operating procedure for measuring the required coastal water quality indicators for the GEF Pacific R2R Programme. The Australia and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ, 2000), US EPA Guidelines for Developing Standard Operating Procedures (2007), A Guide to the Sampling and Analysis of Water, Wastewater, Soils and Wastes (EPA, 2000) and Standard Methods for the Examination of Water and Wastewater (APHA, 2012) were all consulted to create this document. This document was reviewed by the University of the South Pacific, Institute for Applied Science [person or dept] on [insert date] for completeness and correctness.

2 Introduction to the manual

2.1. Purpose of the manual

The purpose of the manual is to provide the common techniques, methods and standards for sample collection, handling, quality assurance and control, and data management, for use by project staff and communities in the GEF Pacific R2R Programme. The manual is a part of an integrated monitoring framework to decide the objectives, indicator selection, data analysis and reporting, as shown in Figure 4 above.

2.2. Intended users of the manual

This manual is intended to be used by:

- GEF Pacific R2R International Waters and STAR Project teams
- Consultants conducting monitoring on behalf of the GEF Pacific R2R Programme
- Community groups in association with the GEF Pacific R2R Programme

2.3. Content of the manual

Australian and New Zealand and relevant international standards were considered during the preparation of this manual. This manual presents an overview of and standard operating procedures for:

- sampling design
- sampling in the field:
 - making in situ tests and water quality measurements
 - taking samples for water quality assessments, including samples of wastewaters, environmental waters, sediments and biota
 - preserving and storing samples for water quality assessments, including samples of wastewaters, environmental waters, sediments and biota
 - security and transport of samples
- arranging laboratory analysis
- data analysis and interpretation.

Standard operating procedures for the relevant sections are provided at the end of this document and can be printed and stored in the appropriate location.

2.4. Limitations

The manual cannot cover every set of circumstances encountered when determining a ‘protocol’ for sampling, and may not always provide sufficient or relevant directions. In situations where the user has little confidence that the samples might produce useful data, this should not stop them from being collected, particularly if there is no other opportunity to obtain the information they could provide.

2.5. Standards

The Standards Australia/Standards New Zealand were used as guidance for the development of this manual. Source documents for sampling design are shown in Table 21.

Table 21: A selection of relevant Australian and New Zealand standards related to water and sediment

AS/NZS 5667.1:1998	Water quality—Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples
AS/NZS 5667.9:1998	Water quality—Sampling Part 9: Guidance on sampling from marine waters
AS/NZS 5667.11:1998	Water quality—Sampling Part 11: Guidance on sampling of groundwaters
AS/NZS 5667.12:1998	Water quality—Sampling Part 12: Guidance on sampling of bottom sediments

3 Preparation and Cleaning

3.1. Preparation

Before going out on any field monitoring event, whether it is with the regular field monitoring crew or a community monitoring group, you must mark off the checklists available in Appendix x. Print several of these out and keep in a dedicated checklist folder. By marking off the checklist as you collect each item you can be sure that you have not forgotten anything that will be essential to field monitoring.

Before leaving for a monitoring event make sure that you have informed your supervisor or designated contact in the office of where you are going, when you are expected to return and your contact details in case of emergency.

Calibrate all field instruments according to manufacturer guidelines outlined in Chapter 3 of this document and enter the calibration information into the calibration log sheet. A template for the calibration log sheet is available in Appendix A.

The following list provides an overview of the sequence of events that take place on a general field monitoring day. This sheet is also provided in Appendix ? and should be printed and referred to prior to each monitoring event to familiarise with the schedule.

	Activity
1	Review field equipment check list and collect necessities
2	Create a new field form for each monitoring station, printed on waterproof paper (or kept in waterproof folder)
3	Prepare sample bottles and labels in advance and place in a cooler.
4	Conduct daily calibration of appropriate meters and probes.
5	Inspect boat (if applicable) and ensure all safety gear is on board, load boat with sampling equipment
6	Move to the first monitoring site location – by car, boat or on foot depending.
7	Refer to description of monitoring site location, directions, maps, and photo to verify correct location. Verify coordinates on GPS unit. Complete field observation form
8	Measure field water quality variables per Section 3.3 and SOP# (multiprobe and in-situ test kits or portable colorimeters).
9	Collect samples for water and sediment quality per SOP# and biota per SOP#
10	Be sure that all samples are correctly labelled and preserved on ice.
11	Verify that field proforma is completely filled out, and initial the form.
12	If sampling from more than one monitoring station in a day, follow procedures for decontamination of equipment per Section x, and go back to step 6, above.
13	Return to office or field station.
14	Process samples according to Section x. Refrigerate or freeze samples, as required and package samples for sending to analytical laboratory.
15	Clean sampling equipment per Section 3.3. Rinse sensors with deionized water and perform calibration re-checks as per Section x.
16	As soon as possible after returning from the field, review both hardcopy and multiprobe data; upload multiprobe data onto computer; review laboratory data as it is received

3.2. Sampling Equipment

Different sampling equipment requires different cleaning methods based on its use in the field. Non-metallic materials, such as plastic, are used whenever possible for the collection of samples for metals. For the collection of organic samples, non-organic or inert materials, such as stainless steel or Teflon, are used.

The majority of sample sites are sampled using grab sampling equipment. To ensure the highest quality of data results, this equipment must be well maintained. A full equipment list is provided in Appendix x. Below are several general items to follow when transporting grab sampling equipment out into the field.

- Never store or carry equipment such as the sampling spool in the sample bucket. Doing so can contaminate the equipment and cause nicks and scratches to the bucket
- Examine the equipment for obvious signs of dirt, rust or scratches, and replace when necessary. Dirt, rust, and scratches can contaminate samples by allowing dirt and bacteria to survive cleaning or allow residue to contaminate sensitive samples.
- Look at sample containers to see if cracks or contamination is present. If so, dispose the container in question and obtain a replacement.
- When assembling plastic sample containers, the use of clean hands or powder free gloves will reduce potential contamination from entering the bottle.

3.2.1. Water sampling equipment

- Rope on spool
- An appropriately sized stainless steel bucket with a fitting for the bacteria sample bottle mounted on the inside, or a suitable water sampling device (pump and hose)
- Clean sample bottles and/or cubitainers suitable for the samples being collected
- Syringe, filter paper, filter holder etc. for samples requiring filtering.

3.2.2. Sediment sampling equipment

- Rope on spool
- Certified pre-cleaned glass jar(s) with plastic lids
- Plastic spoon, and stainless steel spoon
- Appropriate corer depending on sediment type and depth of water
- Appropriately sized stainless steel pan

3.2.3. Laboratory and sampling glassware

- Volumetric flasks
- Graduated cylinders
- Beakers of varying sizes
- BOD bottles

3.3. Sampling equipment preparation and cleaning

The subsections below cover routine sampling encountered by field monitoring crews. If sampling for compounds or matrices outside this scope contact relevant government staff or the RPCU for further information. Cleaning and maintenance schedules are provided for separate printing in Appendix A. Print these out and display in the field office.

3.3.1. Water sampling equipment cleaning and maintenance**At the end of each sampling day:**

- 1) Rinse sampling buckets at the end of the sampling day with DI water and allow to air dry at room temperature.
 - a. If rinsing the bucket does not remove build-up before the weekly cleaning schedule, clean bucket with lab grade soap as directed in the weekly schedule.
- 2) If a pump and hose apparatus is used, pump 2L of DI water through the pump and hose system and completely drain

Weekly maintenance:

- 1) Wash sampling buckets with lab grade soap (brand to be determined) at the end of each week using a brush to ensure the removal of all particulate matter or surface film.
- 2) Rinse thoroughly with tap water, then DI water, and allow to air dry at room temperature.
- 3) If sampling buckets have rust stains or other hardened deposits, use a paste made of baking soda and water to scour the deposits using a soft brush or clean cloth. Scour in the direction of the grain of the steel. After cleaning, repeat steps 1 and 2.

Monthly maintenance:

- 1) Pump 15L of a 5% vinegar solution through hose and pump apparatus
- 2) Pump 5L of DI water through hose and pump apparatus
- 3) Replace worn or used parts

Annual maintenance:

- 1) Replace hose if necessary
- 2) Perform maintenance on pump as specified by manufacturer

3.3.2. Sediment sampling equipment cleaning and maintenance

At the end of each sampling day:

- 1) Wash equipment thoroughly with clean scrub brushes using (brand to be determined) detergent.
- 2) Rinse with DI water until all residues are removed.
- 3) Repeat washing procedure using (brand to be determined)
- 4) Rinse with DI water until all residues are removed.
- 5) Rinse with pesticide grade ethanol or methanol to remove organic compounds.
- 6) Rinse thoroughly with DI water until all ethanol or methanol is removed.
- 7) Dry equipment at room temperature away from potential sources of contamination.
- 8) Visually inspect equipment for any contamination prior to storage. Such contamination would include water spots, dust or sediment, rust and similar substances.
- 9) Cover the clean equipment with clean aluminium foil until use

Weekly maintenance:

- 1) Wash sampling buckets with lab grade soap (brand to be determined) at the end of each week using a brush to ensure the removal of all particulate matter or surface film.
- 2) Rinse thoroughly with tap water, then DI water, and allow to air dry at room temperature.
- 3) If sampling buckets have rust stains or other hardened deposits, use a paste made of baking soda and water to scour the deposits using a soft brush or clean cloth. Scour in the direction of the grain of the steel. After cleaning, repeat steps 1 and 2.

Monthly maintenance

- 1) Wash sampling buckets with 5% vinegar solution
- 2) Rinse sampling buckets with DI water
- 3) Air dry and cover clean equipment with aluminium foil until use

Sampling Glassware

At the end of each sampling day:

- 1) Wash all glassware with (brand to be determined) phosphate free detergent
- 2) Rinse thoroughly
- 3) Allow glassware to air dry

From time to time, laboratory glassware (specifically volumetric flasks and glass graduated cylinders) will become dirty despite routine cleaning methods. This 'dirty' glassware will show spots of water along the inner wall of the glassware when lab grade water is applied.

- 1) Before starting the acid wash, wash all glassware with (brand to be determined) phosphate free detergent and rinse well 3 times.
- 2) After washing if water spots form then proceed with acid washing. If not water spots form then the glassware is clean and does not require acid washing.

- 3) Fill the glassware with the vinegar/bleach mix and slowly rotate glassware to coat the entire inner surface.
- 4) Once coated, slowly pour out the vinegar/bleach mix into an appropriate waste container for safe disposal
- 5) Rinse the glassware using 3 rinses of DI water
- 6) Observe the glassware to see if water spots form, if so repeat steps 3-5. Otherwise allow to air dry and cap with stopper or aluminium foil to prevent dust entering.

4 Calibration and Maintenance of Field Instruments

This section covers the calibration and use of electronic field parameter equipment. Although the use of equipment may vary by country and project, all teams should perform the same general calibration and end of day check procedures. Specific instructions will be made available once equipment models are known.

Calibrate sensors in a controlled environment such as in the designated field preparation room. Avoid calibrating units in the field since it can introduce error. If calibration must be performed in the field, it should be conducted indoors or in an area that is close to room temperature. Allow the probe to stabilize before calibrating. A probe is considered stable if the readout does not significantly change (<0.1 units in ten seconds).

It is essential that unambiguous written records are kept of instrument maintenance and calibration. See Box ? for guidance.

4.1. MultiProbes

4.1.1. General Calibration Guidelines for Multiprobes

Calibrate using standards that are within the printed expiration date or within six months of the date of opening/date of preparation if no expiration date is printed. Calibrate probes each day the units go into the field. Table x outlines calibration tolerances to reference standards. Table 22 outlines calibration tolerances to reference standards.

4.1.1.1. Temperature Verification

Once every three calibrations of the field probe, compare the temperature readout to a laboratory thermometer. Record the both temperature measurements on the log sheet. If the temperature difference is greater than 0.5 C, notify the RPCU Science Officer.

4.1.1.2. Conductivity Calibration

For specific conductance, staff should calibrate using a conductivity solution that is close to the expected values encountered in the field. Be sure to rinse the probe with DI water and then the conductivity solution before calibrating with fresh conductivity solution. After calibration, the probe should be within 1.0% of the buffer value used.

4.1.1.3. Clark Cell Dissolved Oxygen Calibration

For dissolved oxygen calibration, calibrate or verify probes using procedures outlined in this chapter based on the probe make and model. After calibration, the readout must be within ± 0.2 of the theoretical dissolved oxygen saturation calculated using the table provided in Appendix x.

4.1.1.4. Optical Dissolved Oxygen Calibration

Daily calibration of optical dissolved oxygen sensors is necessary, as they are prone to damage if not properly stored. After calibration, the probe must be within +0.1 mg/l of the theoretical dissolved oxygen saturation calculated using the table provided in Appendix x.

4.1.1.5. pH Calibration

For pH calibration, use freshly prepared pH 7.0 buffer and pH 4.0 and/or pH 10.0 buffers depending on the expected values encountered in the field. For example, when performing saltwater monitoring, pH values are assumed to be above 7.0 so calibrating with 7.0 and 10.0 buffer is acceptable.

If the expected pH is unknown, whenever possible, sample teams should calibrate pH probes with 4.0, 7.0, and 10.0 buffers if the instrument is capable of such calibration. Probe readouts must be within ± 0.2 S.U. of the buffer value.

At least once per month it is important to verify the calibration of a two buffer calibrated probe (4 and 7 or 7 and 10) by immersing the probe in the third buffer not used to calibrate the sensor to determine if the calibration curve would accurately display pH at this range. If the probe cannot accurately read this value, servicing is necessary

Table 22: Error limits for daily calibration

Parameter	Value
Conductivity	± 1% of calibrated standard
Clark Cell DO	± 0.2mg/L of theoretical level
Optical DO	± 0.2mg/L of theoretical level
pH	± 0.2 SU of calibration buffer

4.1.2. General Transport of Probeware

Many of the sensors, such as those reading pH and dissolved oxygen, can easily dry out during transport resulting in inaccurate readings and damaged equipment. To prevent this, transport sensors in a humid environment. Ideally, attaching the sensor storage cup provided with the probeware which includes a moist sponge or 10-20 ml of pH 4 buffer will ensure probes do not dry out during transport. The 4 buffer will also reduce microbial growth on the sensors and ensure the pH sensor is not compromised, as would be the case with tap or lab grade water. If using water in the storage cup, avoid letting the water touch the sensors as much as possible. Remove the storage cup and affix the sensor guard (if provided) before deploying at the site.

4.1.3. Quality Assurance of Field Probes

4.1.3.1. Midday DO Check

For multiprobe units with a DO sensor, it is useful to perform a DO % saturation confirmation in the middle of run. This check will determine if the calibration of the DO sensor is still accurate to reduce the risk of invalidating the entire sample run worth of dissolved oxygen readings. To perform the midday check, place the DO sensor in a 100% air/water saturation environment such as a wet towel or in the storage cap with small amount water in it. Allow the probe to equilibrate, record the DO % saturation on the field data sheet then transfer it to CEDS in the comment field. The reading should be 95 to 105% saturation. If DO % saturation is out of the specified range, the unit will need to be recalibrated in the field.

4.1.3.2. End of Day Check of Probes

When returning from the field, teams must verify the accuracy of the field probe equipment by performing an end of day check. The end of day check is not a calibration, but a method where the probeware is verified by checking against standards in a controlled environment. If the check exceeds criteria outlined in Table 3.2, enter a note along with the data that the measurements may be considered invalid and a repeat monitoring will have to be performed.

4.1.3.2.1. Conductivity Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 1) Rinse the conductivity probe with DI water and blot dry. Ensure the reading is 0 uS/cm.
- 2) Immerse the probe in conductivity solution of the same strength used during calibration.
- 3) Allow the conductivity probe to stabilize. This may take several minutes.
- 4) Record the reading in the appropriate section of the calibration log sheet.
- 5) If the conductivity value is off more than 5% (conductivity solution <1000uS/cm) or 10% when using higher strength conductivity solutions, conductivity readings collected during the run are considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed.

4.1.3.2.2. Dissolved Oxygen Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 1) Once the temperature is stabilized, place the oxygen sensor in the calibration chamber following the instructions provided by the particular probe manufacturer or as outlined later in this chapter.
- 2) Allow the probe dissolved oxygen reading to stabilize. A stable reading is one that does not significantly change (< 0.1units) for ten seconds. This may take several minutes depending on the age of the sensor.
- 3) When the probe temperature and dissolved oxygen readings are stable, record the values on the end of day check portion of the calibration log sheet
- 4) Using the table in Appendix x, determine the theoretical dissolved oxygen saturation value. Record this on the calibration log sheet in the appropriate section.
- 5) If the difference between the observed reading and theoretical value greater than or equal to 0.5 mg/L, dissolved oxygen data collected during the day is considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed

4.1.3.2.3. pH Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 1) Rinse the pH probe with freshly prepared 7.0 buffer or buffer used during the morning calibration. Fill the calibration chamber (or appropriate container) with freshly prepared 7.0 buffer or clean 7.0 buffer used during the morning calibration.
- 2) Allow the probe pH reading to stabilize. A stable reading is one that does not significantly change (<0.1 units) for ten seconds. This may take several minutes depending on the age of the sensor.
- 3) Record the reading in the appropriate section of the calibration log sheet. If the probe can display millivolt (mV), record this as well.
- 4) Repeat steps 1 through 3 for pH 4.0 and/or 10.0 buffer. Use the same strength standards used during the morning calibration. a. If field pH readings were outside the standard two buffer calibration curve, verify the accuracy of the pH sensor by immersing in the buffer (4.0 or 10.0) which would have bracketed the observed field readings.
- 5) If the pH values for any of the calibrated buffers exceed 0.2 S.U., pH data collected during the run is considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed.

Table 23: Maximum error limits for end of day checks

Parameter	Value
Dissolved Oxygen	±0.4 mg/L of theoretical value
pH	±0.2 SU of calibration buffer
Conductivity <1000uS/cm	±5% of calibration standard

Conductivity >1000us/cm	±10% calibration standard
-------------------------	---------------------------

4.2. Field Analysis Kits

5 Field Sampling Procedures

5.1. Introduction

This section details the collection of water and sediment samples and is guided by the ANZECC Guidelines (2000) and Standard Methods for the Evaluation of Water and Wastewater (APHA, 2012). Specifically it covers sampling of wastewater, both liquid and sludge, soil and compost. Described here are the general procedures for sampling, exact details of site access and sample numbers will vary according to national projects. These details will be expanded upon and documented with national project teams. Procedures are also available as separate sheets in Appendix x, these can be printed and stored in the field binder for reference on field sampling trips.

Experience with and knowledge of the sampling equipment and the collection, storage, and processing of water samples for subsequent laboratory analyses are critical for collecting data of high quality. Figure 5 highlights key considerations in the sampling process.

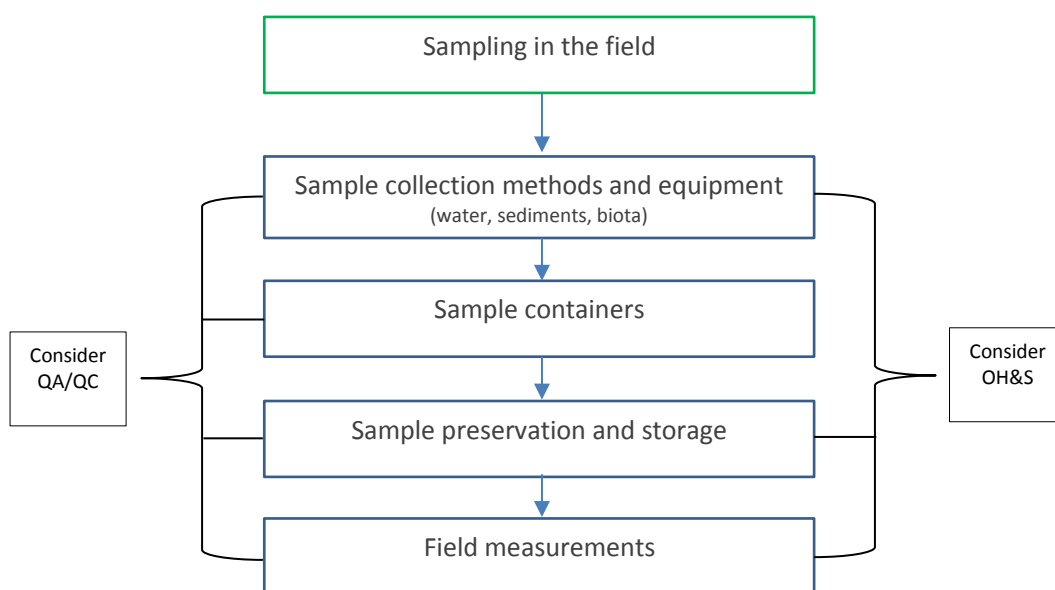


Figure 5: Materials and equipment considerations for sampling and field measurements

Refer to the checklist of supplies and equipment needed for field sampling (Appendix ?) prior to each sampling trip. Keep on hand all necessary forms, calibration logbooks, field logbooks, field data forms, procedural manuals, and equipment instructional manuals. The general procedures for collecting samples of water, wastewater, soils or sediments is summarised in Figure 6.

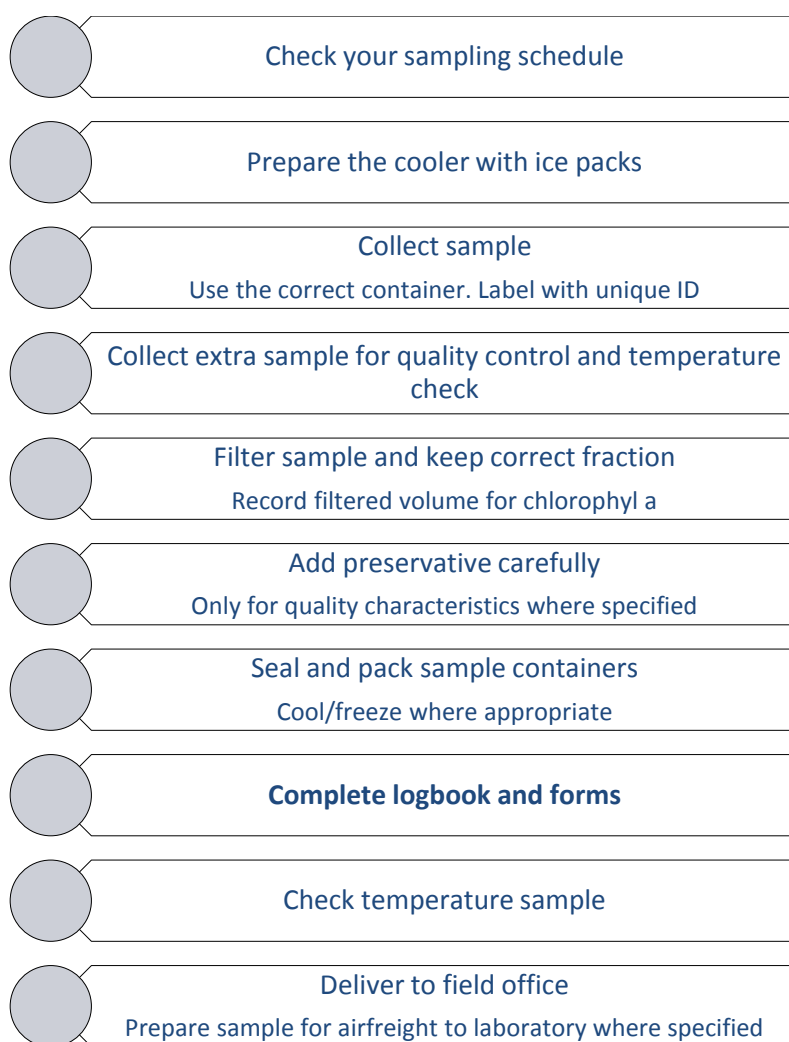


Figure 6: Steps in the sampling procedure

5.1.1. Observations

General observations of the site area can provide additional information useful in recognizing trends or impacts of a non-functioning system. When at a site it is important to take notes in the field logbook as well as digital photos of the area. Make note of outstanding odours, scum or algae, ponding, state of vegetation and general state of the system.

5.1.2. Labelling

Adequate sample description and labelling are extremely important in sampling. Complete the labels at the sampling site and record matching details in your notebook. To guard against possible confusion between samples, each sample should be given a unique number. This number can be made up of parts containing codes for different pieces of information, if required. However, the label must include the following information:

- Sample location
- Sample number/ID
- Sampler name
- Date

(picture of a label)

5.1.3. Sample containers and preservation

Ideally, analysis of samples should be performed in situ or at least on site. For some analytical indicators this is not possible and samples must be stored for analysis at the lab or field office. In this instance it is essential that you follow correct procedures for collection, preservation and transport of samples to the field office for analysis or packaging for shipping. This section details for water, wastes and soils.

Appropriate containers and preservation methods are necessary to avoid risks of contamination of the sample and/or losses of analytes of interest during storage and transit prior to analysis. Details of sample containers and preservation are given in Appendix ?. The requirements are taken from *A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Waters* (EPA, 2000).

The information in Appendix ? is intended as a field reference with specific directions that can be followed without need for detailed knowledge of analytical procedures. It is important that you follow these specifications exactly. If this is not possible, ensure you make a written record of what methodology you adopted.

5.1.3.1. Sample Containers

For samples of waters, wastes and bottom sediments, each sample should be collected and stored in a container appropriate for the quality characteristics of interest.

The requirements listed in Appendix ? include:

- the type of material/s suitable to contain the sample (container body and cap)
- the suitable method/s of pre-cleaning sampling containers
- preservation procedures
- maximum holding times
- comments on sampling procedures.

Containers will be supplied by either the RPCU or the lead agency involved with the monitoring. It is important to double check that the containers supplied will be suitable for the analysis intended for the sample.

If using an intermediate container to collect the sample (a grab, tray or composite bucket) make sure that the container has been subject to the same pre-cleaning and –pre-rinse as the final container to ensure that no contamination or degradation of the sample occurs.

5.1.3.2. Preservation and storage

5.1.4. Preventing Contamination

Avoiding sample contamination is an important aspect of sampling. There are always potential sources of contamination, and the aim should be to keep the risk of contamination to a practical minimum, consistent with the types of analytical tests required. Possible sources of contamination include:

- Sunscreens (zinc oxide) or insect repellents (organic chemicals) on skin could contaminate a sample if transferred by some unintentional means to the material sampled.
- Residual sample material from previous tests could give incorrect readings when measurements are being made with field instruments. Special attention should be given to probe and test kit item rinsing after each field measurement in order to prevent future contamination. See section 3.1.1 concerning intermediate containers.
- Avoid smoking and wear Nitrile gloves at all times.
- Corrosion and oxidation of metal components in probe cathodes, electrodes and membranes could contaminate a sample and yield inaccurate readings.
- Note that some container caps have inserts; never touch the inserts with the skin or remove them from the caps.

- Cover work spaces used for sample handling (e.g. vehicle tray or tailgate) with new alfoil or plastic to provide a clean working surface. Replace it after driving to a new site.

Record any incident where contamination has or possibly has occurred. It is better to record these details than have analysis that appears out of range with no information on why that might be so.

5.1.5. Equipment Rinse

When collecting samples, the collection equipment shall be rinsed once with sample water before the actual sample is taken. For a sampling bucket, fill the bucket with site water, swirl the water around and dispose of the rinse water away from the sampling site. For sampling devices, clean the device inside and out by dipping it into and out of the site water or by washing with site water.

5.2. Safety

5.2.1. Field Safety

General points regarding field safety that should be taken into consideration while sampling and analysis is undertaken in the field.

- Let someone know where and how long you will be sampling for
- Wear appropriate clothing (shoes, hat, shirt)
- Always wear gloves when handling waste or contaminated samples
- Do not allow children to sample or test – do not let children undertake adult tasks
- Use common sense around areas that may be unstable, eroded banks, deep waters etc.

5.2.2. Chemical Safety

All of the manufacturer methods used in this manual come with their own chemical safety instructions. Make sure you have read and understood these before using the equipment and materials. MSDS are supplied for the major chemicals used in Appendix x. The following are general guidelines for using chemical reagents:

- Read all warnings and procedures of first aid before chemicals are used and have them available if spills or accidents occur.
- Take care when handling chemicals. Always use safety equipment i.e., safety gloves and glasses, and read the chemical labels when using the kits,
- Do not drink water from the source you are testing as it may be polluted. In particular when testing do not put your hands near your mouth or eat and drink while testing water or solids.
- When finished using the chemicals and testing is complete, ensure hands are washed thoroughly.
- All chemical waste used in water and wastewater quality testing should be collected in a plastic bottle and disposed of correctly.

5.3. Surface Water Sampling

5.3.1. General Sampling Techniques

Safety always comes first. All sampling should be conducted with the proper equipment and least amount of danger to field personnel.

Sampling staff are responsible for determining safe site access. If access is needed on private property, staff must obtain permission from landowners

Care should be taken not to disturb the bottom when sampling. When entering a stream, always walk in an upstream direction towards the sample site. Take samples at the beach at mid or low tide.

If collecting water samples and sediment samples at the same location, collect water samples first to avoid disturbed sediment contaminating the water sample

Whenever possible, collect field measurements (DO, pH, temp, etc.) directly from a stream/ocean and not from a sample bucket. If the field parameters need to be measured in the bucket, collect water quality samples (nutrients, etc.) first before placing the multiprobe instrument in the bucket.

When there are obvious standing pools of water during low or no flow conditions, do not collect samples or field measurements. Make a note of this on the field sheet and upon return to the office include a remark in database to explain the site conditions.

When collecting bacteria samples:

- Do not rinse the bacteria sample bottle before collecting the sample.
- Never collect bacteria samples in an unsterilized sample container and transfer to a sterile container.
- Be careful not to insert fingers into the mouth of the container or on the interior of the cap. Bacteriological sampling must always be collected as a grab sample and must never be composited.
- If the volume of sample exceeds the mark on the bacteria sample bottle, pour off sufficient sample so the volume is approximately equal to or above the mark on the bottle shoulder and securely cap and label the container.

5.3.2. Equipment

- Rope on spool and/or extension pole
- An appropriately sized stainless steel bucket
- Clean sample bottles and/or large containers suitable for the samples being collected
- Syringe, filter paper, filter holder etc. for samples requiring filtering (see section 6.5 for more details).
- Gloves – for personal protection and prevention of cross-contamination
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen - used to label samples
- Trash Bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.3.3. Procedure for stream or river

- 1) Wade into approximately 2.5 feet of water
- 2) Collect surface water samples facing upstream and in the center of main area of flow. Unless safety is an issue, obtain samples from a bridge or directly instream.
- 3) Remove the bottle lid. Invert the bottle, plunge the bottle into the water about 15 cm (6 inches), and tip the bottle mouth up (still submerged).
 - 1) Prior to sampling, rinse sample bottles with a small amount of sample water (except bacteria bottles or if sample bottles contain acid preservative). Dump rinse water away from the sample bucket or sample location.
 - 2) Allow the bottle to fill for the sample, and then take it out of the water.

- 3) If sampling in an area with floating debris in the water (like algae, seaweed, or beach wrack) unscrew the bottle cap and leave the bottle cap on the bottle with a small opening (Figure x). Plunge the bottle with the cap still on into the water 15 cm (6 inches) filling the bottle and avoiding particulate in the water. Note on the Field Data Form the sampling technique and the kind of debris/particulate in the water.
- 4) If the bottle is filled above the shoulder, then immediately pour out enough excess sample to ensure the sample volume is at or near the shoulder. Replace the bottle lid
- 5) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.

5.3.4. Procedure for streambank

- 1) If wading into the stream is not possible, using a bucket attached to a rope, throw the bucket to the water where the flow is the most representative of the stream. Allow the bucket to partially fill and retrieve using the rope. Alternately follow procedure for extension pole in Section 6.2.5.
- 2) Rinse the sample bucket with stream water and discard rinses away from the water to avoid disturbing sediment. Repeat rinse one more time.
- 3) After rinsing, throw the bucket into the stream at the most representative location of the stream and allow the fill. Carefully retrieve the bucket with the rope avoiding disturbing the sediment to the point it may enter the bucket.
- 4) If collecting a chlorophyll sample, follow the steps described in Section x prior to collecting any further samples.
- 5) Pour sample water into appropriate containers.
- 6) If the bottle is filled above the shoulder, then immediately pour out enough excess sample to ensure the sample volume is at or near the shoulder.
- 7) Add appropriate preservatives as described in Section x.
- 8) Replace the bottle lid.
- 9) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.

5.3.5. Procedure for a beach or coastal site

- 1) Wade into approximately 2.5 feet of water.
- 2) Remove the bottle lid. Invert the bottle, plunge the bottle into the water about 15 cm (6 inches), and tip the bottle mouth up (still submerged). Allow the bottle to fill, and then take it out of the water.
- 3) If sampling in an area with floating debris in the water (like algae, seaweed, or beach wrack) unscrew the bottle cap and leave the bottle cap on the bottle with a small opening (Figure x). Plunge the bottle with the cap still on into the water 15 cm (6 inches) filling the bottle and avoiding particulate in the water. Note on the Field Data Form the sampling technique and the kind of debris/particulate in the water.
- 4) If collecting a chlorophyll sample, follow the steps described in Section x prior to collecting any further samples.
- 5) If the bottle is filled above the shoulder, then immediately pour out enough excess sample to ensure the sample volume is at or near the shoulder.

- 6) Add appropriate preservatives as described in Section x.
- 7) Replace the bottle lid.
- 8) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.

5.3.6. Extension pole method

- 1) Secure the sample bottle in the extension pole clamp (figure x)
- 2) Remove the lid and position the bottle over the desired sample location, in approximately 2.5 feet of water.
- 3) Invert the bottle and, in one quick motion, plunge the mouth of the bottle into the water about 15 cm (6 inches) below the surface. Then tip the bottle mouth up (still submerged) to fill the bottle.
- 4) Take the bottle out of the water. If the bottle is filled above the shoulder then pour off enough excess sample so the sample volume is at or near the shoulder.
- 5) If collecting a chlorophyll sample, follow the steps described in Section x prior to collecting any further samples.
- 6) Add appropriate preservatives as described in Section x.
- 7) Replace the lid.
- 8) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.

5.4. Groundwater Sampling

5.4.1. General Sampling Techniques

This section provides information about how to obtain a representative groundwater sample from bores and the procedures that have to be followed before sampling can begin. The Groundwater Sampling and Analysis – Field Guide (Sundaram, et al., 2009) has been used as the main reference for this section.

5.4.2. Total Depth to Bore

When monitoring unequipped bores the first parameter to be measured is total depth (TD) of the bore. Note that all depth measurements are conventionally taken from the top of the casing or bore shield (at a marked point, such as the padlocking point). Hence, the height above the ground surface of this reference point should also be measured.

5.4.2.1. Equipment

Total bore depth can be measured using a weight attached to a tape measure. Use a tape measure that is at least as long as the deepest bore to be measured. To avoid mistakes in depth measurements use quite a heavy weight that can easily reach the bottom of the bore.

5.4.2.2. Procedure

- 1) Lower the weight into the casing until it reaches the bottom of the hole – as this happens the tape will become slack.
- 2) Lift and drop the tape several times to ‘feel’ the bottom of the bore.
- 3) Remember to add the length of the weight onto the tape measurement (if this has not been accounted for).
- 4) Subtract the height of the casing above the ground level from the measurement.

- 5) Record the result as total depth (in metres) of the bore on the Bore Information Sheet.
- 6) Clean the tape before using it again.

5.4.3. Depth to Water Table

The depth to the water level in the bore is also called depth to groundwater or the standing water level (SWL). Depth to water table should be measured and recorded before every sampling event.

This measurement will use a plover and tape measure method, this method makes a sound upon impact with the water surface. It uses a 15 to 20 cm stainless steel tube and a tape measure (Figure 7). The metal tube is sealed at the end at which it is attached to the tape with a loop wire. The other end that touches the water should be left open. When the tube is lowered into the bore and touches the water surface it makes a distinctive plopping sound.



Figure 7: Plover/sampler and tape measure

5.4.3.1. Procedure

- 1) Lower the plover into the bore until it hits the water.
- 2) Lift and drop the plover several times to find the exact water level, this should give a reading accurate to within 1 cm.
- 3) Remember to add the length of the plover onto the tape measurement (if this has not been accounted for).
- 4) Subtract the height of the casing above the ground level from the measurement.
- 5) Record the result as water level (in metres) with the date of the measurement on the Bore Information Sheet.
- 6) To record the water level relative to the ground surface, the measured distance between the measuring point (eg top of casing) and the ground surface is subtracted. If the water level in the bore is below ground, record the result as negative (–) and positive (+) if it is above ground (water standing in the casing above ground).
- 7) Wash the tape and the plover thoroughly with tap water before using it again to prevent contamination of the next bore. Dry and roll the tape.

5.4.4. Collecting a Representative Sample

The purpose of groundwater sampling is to retrieve a water sample that represents the characteristics of water below the ground surface. To obtain a representative sample it is necessary to remove the stagnant water from the bore casing before a sample is taken. This is called purging. It is recommended that at least three casing volumes of water should be removed before sampling. Usually pumping of the bore is continued even after three casing volumes have been removed until such time as the pH, EC and temperature of the discharge water are observed to stabilise. Only then is the obtained sample considered to be representative of groundwater residing in the aquifer surrounding the bore screen.

There are two main techniques for purging. The first is with a bailer and the second using a pump. Both techniques will be described here. The type of bore and depth of water table or well will determine which technique is most suitable. A shallow well can easily be purged using a bailer however a deep well or monitoring bore will take a lot of time and effort to purge using a handheld bailer. Note that when a bailer is used care is needed to make sure that water being sampled is representative of the groundwater and not just well water, which shows the conditions of the well and surrounding environment rather than the groundwater conditions.

Steps for calculating volume of water and time to purge are provided in Appendix X as extracts from the Groundwater Sampling and Analysis – Field Guide (Sundaram, et al., 2009).

5.4.4.1. Purging using a bailer

A bore can be purged using a bailer only when a reasonably small volume of water is to be removed. It will take a considerable length of time to purge even a very shallow bore. When using a bailer it is difficult to ensure that all stagnant water has been removed from the bore and consequently the sample may represent a mixture of fresh and stagnant water

Procedure

- 1) Lower the bailer to the level of the slotted part of the casing (screened interval).
- 2) Lower and withdraw the bailer slowly and try not to disturb the water column by splashing.
- 3) Use a bucket of known volume to record the volume of water being discharged.
- 4) Remove the calculated volume of water.
- 5) Continue purging until pH, EC and temperature readings stabilise

5.4.4.2. Purging using a pump

Truly effective purging that can guarantee the integrity of the sample can be done using a pump.

Procedure

- 1) Lower the pump to about 1 m above the screens (if known) or to about 1–2 m from the bottom of the bore if the screen depth is not known; beware of the risk of drawing silt into the pump which can occur if it is set too close to the screens.
- 2) After starting the pump, establish the highest flow rate possible without causing the bore to stop yielding.
- 3) Calculate the flow rate (refer section below).
- 4) Once a constant flow rate is established, the bore can be 'vacuumed'. This is done by slowly lifting the pump to near the top of the water column while pumping, then slowly lowering it to the previous depth. This way the column of stagnant water sitting in the casing above the slotted level is evacuated.
- 5) Pump for calculated length of time needed to remove the three casing volumes of water or until pH, EC and temperature measurements stabilise.

5.4.4.3. Calculate flow rate

Measure the time needed to fill a 10 L bucket with discharge water.

Calculate flow rate (FR) in litres per minute (L/min) using the formula:

$$\text{FR (L/min)} = (60 \text{ divided by time in seconds taken to fill 10 L container}) \times 10$$

See Appendix 3 for flow rate conversion for different times.

Knowing the volume of water standing in the casing (V) and the flow rate (FR), calculate how much time (T) it will take to pump out three casing volumes using the formulae:

$$T = (V/FR) \times 3$$

5.5. Sediment Sampling

5.5.1. General Sampling Techniques

Collect any water chemistry and field measurements prior to collecting sediment samples. In shallow water, sediment samples may be collected with a handheld scoop and tray or handmade corer. This manual does not cover deep water sediment sampling.

When sampling in shallow streams, collect samples from the submerged streambed and not from the stream bank or from the floodplain. The most representative samples are from recently deposited sediments with ideal sediment containing fine particles with high organic content. Sediments with high organic content will appear dark brown or black. When sampling from the coast or beach, sample at low tide, mark a 50m x 50m transect and collect 30 samples.

5.5.2. Equipment

- Spade, shovel, trowel or scoop – used for collecting samples from shallow waters
- Corer – used for collecting samples from shallow waters
- Collection containers
- Gloves – for personal protection and prevention of cross-contamination
- Sampling flags and tape measures – used to mark the transect boundary
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen - used to mark soil boring tubes and for documentation of field logbooks and data sheet
- Stainless Steel lab spoon - or equivalent. Used for homogenizing sediment samples
- Stainless Steel Buckets - used for compositing samples. Must have 10 - 12 litre capacity
- Rubbish Bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.5.3. Procedure for sampling with corer

A simple corer for sampling can be easily constructed with materials from a local builders hardware. You will need a length of 50mm diameter PVC drain pipe (at least 25cm long) and a PVC cap.

Cut the PVC pipe into a length of approximately 25cm using a hacksaw. Clean the cut edges with a light sandpaper. At 10cm from one end of the PVC pipe, make a mark on the outside using the hacksaw. Continue the mark around the entire pipe.

The following procedure will be used to collect sample with a corer:

- 1 Layout a 50m x50m fixed transect site with sampling flags at each corner, at low tide. Samples will be taken at every 10m mark.

- 2 At the start of transect 1, take a core on the 0 metre mark. The cores are always taken on the right hand side of the tape measure and adjacent to the 0.25 metre squared quadrat.
- 3 Push the PVC corer into the sediment to a depth of 10 cm (the saw mark). Cap the corer and extract from sediment (Figure 8).



Figure 8: Example of coring procedure

- 4 Transfer the sample into an appropriate sample or homogenization container. Ensure that non-dedicated containers have been adequately decontaminated.
- 5 Surface water should be decanted from the sample or homogenization container prior to sealing or transfer; care should be taken to retain the fine sediment fraction during this procedure.
- 6 Continue to the next 10 metre mark and repeat the procedure. Continue along the transect sampling every 10 metres until the transect is completed. Then repeat the process mid-way between and along the remaining transects. When sampling between transects, you may estimate the distance and position, it does not have to be precise (Figure 9).
- 7 At the completion of sampling, check that the data sheets are filled in fully
- 8 Remove all tent pegs and roll up the tape measures. If the tape measures are covered in sand or mud, roll them back up in water.

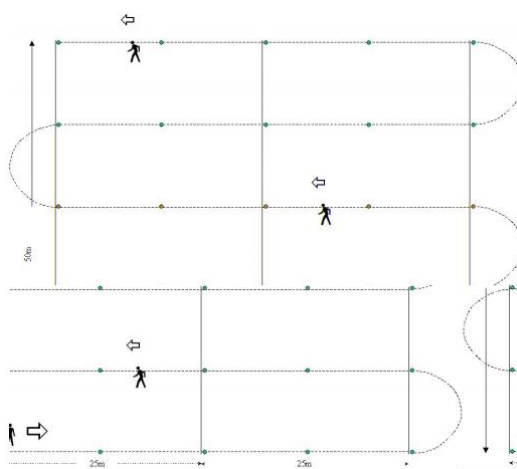


Figure 9: Suggested sampling approach for a field transect

5.5.4. Procedure for sampling with a trowel, spade or scoop

Collection of surface sediment from beneath a shallow aqueous layer can be accomplished with tools such as spades, shovels, trowels, and scoops. Although this method can be used to collect both unconsolidated/consolidated sediment, it is limited somewhat by the depth and movement of the aqueous layer. Take care when sampling from fast flowing waters.

The following procedure will be used to collect sediment with a scoop, shovel, or trowel:

- 1) Layout a 50m x50m fixed transect site with sampling flags at each corner, at low tide. Samples will be taken at every 10m mark.

- 2) At the start of transect 1, take a core on the 0 metre mark. The cores are always taken on the right hand side of the tape measure and adjacent to the 0.25 metre squared quadrat.
- 3) Using a decontaminated sampling implement, remove the desired thickness and volume of sediment from the sampling area.
- 4) Transfer the sample into an appropriate sample or homogenization container. Ensure that non-dedicated containers have been adequately decontaminated.
- 5) Surface water should be decanted from the sample or homogenization container prior to sealing or transfer; care should be taken to retain the fine sediment fraction during this procedure.
- 6) Continue to the next 10 metre mark and repeat the procedure. Continue along the transect sampling every 10 metres until the transect is completed. Then repeat the process mid-way between and along the remaining transects. When sampling between transects, you may estimate the distance and position, it does not have to be precise.
- 7) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.
- 8) Remove all tent pegs and roll up the tape measures. If the tape measures are covered in sand or mud, roll them back up in water.

5.6. Chlorophyll a Collection

An important factor in field filtration is to note that the equipment used for the filtering task is an 'intermediate container' and as such the equipment is a potential source of contamination of the sample (see section 6.1.3) so that pre-rinsing and the use of field blanks (see section x) is advisable.

5.6.1. Equipment

- Handheld vacuum system with filter tower (to be determined) and/or
- 150cc polypropylene syringe filter
- 500mL measuring cylinder
- Whatman GF/F filters (47-mm and 0.7um)
- Plastic wash bottle, 500-mL filled with DI water
- Filter tweezers
- Opaque sample bottles,
- Seed envelopes
- Ziploc bags
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen – used to label samples
- Rubbish bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.6.2. Procedure for sampling with a syringe filter

Field filtration for Chlorophyll a can be done using a syringe and filter housing. Use of the syringe to collect Chlorophyll a samples is ideal when needing only a few samples or the vacuum apparatus would not be

appropriate. Samples and filter papers should not come into contact with the skin, as oil and dirt can contaminate samples.

The use of the syringe method requires the filtering of approximately 300 ml of site water (or sufficient volume to produce a visible green residue on the filter) through a 150cc polypropylene syringe as follows:

- 1) Open the filter holder and remove the “O-ring”. Using clean tweezers, place a filter on the holder with a GF/F filter. Replace the O-ring, rinse the filter with at least 30 ml of DI water, close the filter holder and set aside.
- 2) Rinse the syringe by drawing a small amount (20 to 50 ml) of sample water up into the syringe and shaking it then discard the rinse water. The best way to do this would be to have the plunger situated at about the 100 ml mark and then draw up the rinse water to ensure rinsing the entire syringe interior. Expel all rinse water and air by fully depressing the syringe plunger.
- 3) Fill the syringe past the 150cc mark (150cc mark is the middle of “Y” on the syringe). Holding the syringe upward, tap on the side to eliminate as many air bubbles as possible and depress the plunger until the first ridge of the plunger aligns with the middle of “Y” on the syringe.
- 4) Screw the syringe into the filter holder and apply gentle pressure on the plunger. The goal is to filter 300 ml of sample or until the filter paper clogs and there is green colour on the filter. If at any time, you feel back pressure from the filter, the filter is clogged so stop the filtration and record the volume filtered on the field data sheet.
 - a. To refill the syringe, carefully detach the filter assembly, fill the syringe past the 150cc mark, remove any air bubbles, push the plunger to 150cc mark and continue with the filtration until the desired volume has been processed or until no water will pass through the filter with gentle pressure.
 - b. If at any time the filter becomes clogged due to suspended solids, stop the filtration and record the volume filtered on the field data sheet.



Figure 10: Pushing water through the syringe filter for chlorophyll a sampling

- 5) Record the final volume of the sample water filtered on the field data sheet.
- 6) Remove the filter holder from the syringe and open the holder. Using forceps, carefully remove the filter from its holder and gently fold it in half so the pigment is inside. Should the filter tear during the removal process, discard the filter and start over again.



Figure 11: Using tweezers to grab the filtered sample

- 7) Using tweezers, place another GFC filter paper over the first and fold the filter paper in half, and then into quarters. Place the filter papers into the appropriately labelled seed envelope with the site written on it.
- 8) Place the sample envelop into a Ziploc bag and store the bag in the cooler on top of the wet ice. Make sure the opening of the bag hangs out of the cooler when the lid is lowered.
- 9) Rinse the filter holder apparatus thoroughly twice using 20 to 50 ml D.I. water to clean the syringe for the next sample.
- 10) Enter the volume filtered into database along with the other field data.

5.6.3. Procedure for vacuum filtration method

- 1) Rinse all individual parts of the filter tower with de-ionised water prior to site visit and between sites
- 2) Assemble filter tower (Figure 12), placing a glass fibre (GF/C) filter onto filter membrane using tweezers.



Figure 12: Filter tower with handheld vacuum

- 3) Attach hand held vacuum pump to vacuum port adaptor.
- 4) Rinse a 500 mL measuring cylinder with 10 mL sample water three times, and then accurately measure 500 mL of sample water into the measuring cylinders. Two 500 mL samples are filtered.
- 5) A total volume of 1000 mL should be poured through the filter paper. Do not wash filter paper with sample prior to filtration. If the filter paper becomes blocked, return the remaining water sample from the top of the funnel to the measuring cylinder and record the volume
- 6) The minimum volume to be filtered is 500 mL. If the filter paper is blocked prior to 500 mL being filtered, return the remaining sample to the measuring cylinder and disassemble the filter tower and remove the chlorophyll paper. Replace with a new GFC, reassemble the tower and return the remaining water sample from the measuring cylinder.
- 7) Record the number of GF/C filters used in the field data sheet
- 8) Record to the nearest 5 mL the volume that is filtered through the filter paper onto the field data sheet. The laboratory requires this information when analysing the sample.
- 9) Using tweezers, place another GFC filter paper over the first and fold the filter paper in half, and then into quarters. Place the filter papers into the appropriately labelled seed envelope with the site written on it.
- 10) Place the sample envelop into a Ziploc bag and store the bag in the cooler on top of the wet ice. Make sure the opening of the bag hangs out of the cooler when the lid is lowered.
- 11) Rinse the filter holder apparatus thoroughly twice using 20 to 50 ml D.I. water to clean the syringe for the next sample.

12) Enter the volume filtered into database along with the other field data.

6 Field Measurement Procedures

6.1. Introduction

This section details the procedures for conducting analysis using field instruments and is guided by the ANZECC Guidelines (2000) and Standard Methods for the Evaluation of Water and Wastewater (APHA, 2012) and instrument manufacturer's procedures. Specifically it covers measurements using handheld multiprobes, portable colorimeter/spectrophotometer, and water and soil test kits. Procedures are also available as separate sheets in Appendix x, these can be printed and stored in the field binder for reference on field sampling events. Manufacturer's user manuals must also be carried on field sampling events for reference and guidance on troubleshooting.

Experience with and knowledge of the field measurement equipment are critical for collecting data of high quality. Multiprobes must be calibrated as per Section 4. Figure 5 highlights key considerations in the sampling process

Field measurements should represent, as closely as possible, the natural condition of the surface water at the time of sampling. To ensure consistent, high-quality data, always:

- Make field measurements only with calibrated instruments that have been error-checked.
- Maintain a permanent log book for each field instrument for recording calibrations and repairs. Review the log book before leaving for the field. This book should also be used for recording results of pre-and post-calibration checks.

- Test each instrument (meters, sensors, portable test kits) before leaving for the field. Become familiar with new instruments and new measurement techniques before collecting data.
- Have backup instruments readily available and in good working condition, whenever possible.
- Follow quality assurance/quality control procedures. Such protocols are mandatory for every data collection effort, and include practicing good field procedures and implementing quality control checks. Make field measurements in a manner to minimize artefacts that can bias the result.

6.1.1. Recording Field Information

Consistent methods are important to long-term data quality. In actuality, the ideal conditions are not always met in the field or in the lab and changes in staff occur. Therefore, documentation of procedures, site conditions, laboratory analysis, and reasons for deviations of any kind is important. Personnel are encouraged to write down more than they feel may be necessary in the moment, as the future interpretation of their data will depend on the written record and not the memory of an individual.

Field data forms (available in Appendix ?) should be prepared ahead of time, labelled with the project and site IDs. Field data forms are used to record the physical and chemical water quality variables measured at the time of sample collection. In addition to recording the field variables, any samples collected for laboratory analyses must be so indicated. Documentation should include calibration data for each instrument, field conditions at the time of sample collection, visual observations, and other information that might prove useful in interpreting these data in the future.

While at each monitoring site, the information recorded on field data forms should include:

- Date
- Time of arrival
- Names of field team members
- GPS coordinates, to verify location
- Current weather (air temperature and wind speed) and relevant notes about recent weather (storms or drought), including days since last significant precipitation
- Observations of water quality conditions (see below)
- Multiparameter meter (model), calibration date, and field measurements of core suite variables
- Portable colorimeter (model), calibration date, and field measurements of core suite variables
- List of sample IDs and collection times for lab analysis variables or quality assurance samples
- Whether any samples were not collected, and reason
- Quality assurance/quality control procedures followed
- Time of departure

Upon arrival at the monitoring station, record visual observations of water quality conditions that will be useful in interpreting water quality data into filed observation forms.

- Water appearance — General observations on water may include colour, unusual amount of suspended matter, debris, or foam.
- Biological activity — Excessive macrophyte, phytoplankton, or periphyton growth. The observation of water colour and excessive algal growth is important in explaining high chlorophyll-a values. Other observations to note include types of fish, birds, or spawning fish.
- Unusual odours — Examples include hydrogen sulphide, mustiness, sewage, petroleum, chemicals, or chlorine.
- Watershed activities — Activities or events that are impacting water quality; for example, road construction, timber harvest, shoreline mowing, or livestock watering.

6.1.2. Multiple Readings

As with all water samples, when taking instrument-based field measurements multiple readings should be taken and recorded. Reference sites should be used to acquire background or 'normal' data for comparison purposes

6.1.3. Record Keeping

As with all sampling it is important to keep consistent and complete records of all measurements taken in the field. Each national project conducting coastal monitoring will have dedicated logbooks for storing calibration data and field measurement data. These are to be used in addition to the electronic data that is held in the field instrument and are used to record any observations on the day.

Your observations during measurements can be extremely important in assessing atypical events or long-term trends, especially when investigating pollution incidents. Such observations could include:

- atypical water colour or clarity (such as greenish, muddy, pale brown and cloudy)
- odours
- wind speed and direction
- surface scum
- heavy algal or plant growths
- dead or dying vegetation in waterways or on banks
- dead or dying fish
- flotsam
- dumped material
- nearby earthworks or other construction activity
- nearby agricultural activities
- nearby industrial or commercial establishments, wastewater treatment works etc.

As visible conditions could be difficult to describe accurately in words, it is strongly advised to take photographs if possible. You should keep a record of the photograph number on the memory card to avoid any later confusion, and record this in the logbook.

6.2. Field Measurement Procedures

Information in this subsection is provided to help you take water quality measurements in a scientifically valid manner so that the results will represent the field conditions fairly. On-site (in-situ) measurements are taken to obtain accurate results of the quality of the natural environment. The characteristics that are measured in-situ are:

- Temperature
- Dissolved oxygen
- pH
- Conductivity
- Turbidity
- Clarity - Secchi depth

The multi-parameter meter recommended for use in the GEF R2R Programme is the HACH HQ 40D and is capable of measuring all these characteristics except for Secchi depth and turbidity (Figure 13).



Figure 13: HQ40D Multiparameter meter

The on-site colorimeter test unit recommended for use in the GEF Pacific R2R Programme is the HACH DR900 and is capable of measuring a range of parameters. Initially for this monitoring program it will be used to determine ammonium and orthophosphate in waters in the field (Figure 14). Other parameters can be added to the analysis suite.



Figure 14: HACH DR900 Portable Colorimeter

6.2.1. Overview of Field Measurements

6.2.1.1. Temperature

Temperature (T) is measured in units of degrees Celsius ($^{\circ}\text{C}$) and recorded to the nearest degree or tenth of a degree depending on the instrument used. Accurate temperature measurements are required for accurate determinations of pH, specific electrical conductance, and dissolved oxygen. You need to be aware whether the instrument you are using compensates for factors such as temperature when measuring another parameter, or whether results need to be adjusted by calculation.

Stratification is common in warmer climates where surface waters are warmer than bottom waters. Accordingly, unless the water is shallow (less than 0.5 metres) and flowing, take temperature readings at different (measured) depths.

Warm water is less capable of retaining dissolved oxygen than cold water. For this reason, temperature should be measured at the same place within the waterbody at which dissolved oxygen is measured. This allows the correlation between the two parameters to be observed.

6.2.1.2. Dissolved Oxygen

The maximum concentration of dissolved oxygen (DO) in water under ambient conditions is typically within the range of about 6–10 mg/L, depending on the atmospheric pressure and the water temperature and salinity. Dissolved oxygen concentrations are most often reported in units of milligrams of oxygen gas (O_2) dissolved in each litre of water, i.e. mg/L (the unit mg/L is equivalent to parts per million = ppm).

An alternative measure is dissolved oxygen saturation (per cent). This is the percentage of dissolved oxygen concentration present relative to what the concentration would be if water at the specified temperature and salinity was fully saturated with dissolved oxygen. Most dissolved oxygen probes compensate automatically for temperature and salinity when calculating dissolved oxygen saturation in water (check the instrument manual). Note that under natural conditions such as high algal density during sunlight, super-saturation (more than 100 per cent DO) can occur.

Considerable differences between DO concentrations at the surface and in the lower depths can result from stratification of the water column, due to temperature or salinity effects. This effect is more pronounced in warmer climates when surface waters are much warmer than bottom waters. Accordingly, unless the water is shallow (less than 0.5 metres) and flowing, take readings at different (known) depths.

Troubleshooting tips:

- Equilibration time is critical; the steeper the DO gradient, the longer the equilibration time. It may take >5 minutes when DO drops abruptly to near zero.
- Accuracy of an optical DO probe can be compromised if it is covered with a residue that inhibits or increases oxygen reaching the sensor surface. Algae on the sensor surface may increase DO measurements, while oils or sediments may lower them. If measurements seem suspect, or if the instrument was used in contaminated water, the sensing surface should be cleaned with a soft brush and a mild detergent.

6.2.1.3. pH

A pH of 7 is called neutral, above 7 is basic (or alkaline), and below 7, acidic. Strong mineral acids such as concentrated phosphoric acid can have pH less than 1; strong alkalis such as caustic soda solutions can have pH approaching 14.

Troubleshooting tips:

- Does the value look totally wrong? Is the instrument out of calibration? Having pH standards in the field can help verify values that fall outside the expected range. For example, the expected pH is around 7.0 and the reading is 9.5. A known standard can be put in the instrument storage cup to determine if the instrument is reading correctly or out of calibration.
- As with dissolved oxygen, a pH probe can take longer to equilibrate when the gradient from the previous measurement is large (>1.0 pH SU).

6.2.1.4. Electrical Conductivity

Electrical conductivity (abbreviated EC, and often simply called 'conductivity'), the ability of water to carry an electric current, is used as an indicator of salinity and the concentration of dissolved salts in a waterbody. The unit of measurement for conductivity is siemens (S) per unit of length. A commonly used example of this unit is microsiemens per centimetre ($\mu\text{S}/\text{cm}$).

Typical values of EC in $\mu\text{S}/\text{cm}$ are:

- De-ionised water in equilibrium with the atmosphere approximately 1
- Potable waters 50–500
- Freshwater less than 1500 (varies widely between catchments)
- Seawater approximately 52,000

Note that conductivity varies with temperature, and values reported are usually those corresponding to 25°C. A difference of 5°C can alter conductivity by approximately 10 per cent. Many conductivity meters have compensation functions so that EC at 25°C can be read directly. However, if necessary, a manual correction can be made by using the formula

$$K_{25} = \frac{Kt}{1+0.019(t-25)}$$

Where t = water temperature °C where conductivity is measured

Kt = conductivity at temperature t °C

K_{25} = corrected (25°C) conductivity of the water

6.2.1.5. Turbidity

The turbidity of a water body is a measure of the presence or absence of soluble, suspended and colloidal particles that hinders the transmission of natural light at the surface to the lower depths. Turbidity affects the potential rate of photosynthesis, and hence the growth of plants or algae in the water body.

6.2.1.6. Clarity – Secchi depth

The clarity of a water body is an indication of the presence or absence of suspended and colloidal particles that hinder the transmission of natural light from the surface to the lower depths. Clarity affects the potential rate of photosynthesis at any given depth, and hence the growth of green plants or algae in the water body.

This method is based on the common experience that the deeper a submerged object is, the less easy it is to see from the water surface, and the more cloudy the water, the less easy to see at a fixed depth. It entails the use of a Secchi disk (see figure x) and is a relatively simple and quick way to obtain a measure of clarity, without the need to take samples and analyse them for turbidity or suspended solids. The Secchi disk also has the advantage of integrating turbidity over depth (where variable turbidity layers are present). Detailed instructions for using a Secchi disk are provided in Appendix ?.

Troubleshooting tips:

- A Secchi disk should not be used in shallow waters where the disk can be seen resting on the bottom. In such cases take only turbidity readings.
- The observer's visual acuity will affect the perception of the disc. It should be observed with the normal corrective eyewear of the observer, do not wear sunglasses as this will affect the depth at which the disk can still be seen.
- Be sure that the measurement is taken without shadow from either the observer or the boat blocking the disk.

6.2.2. HACH HQ 40D Multiprobe Meter

General considerations (need to confirm brand and manual)

6.2.2.1. Calibration

6.2.2.2. Field Measurement Procedures

Surface Water?

Groundwater?

6.2.2.3. Maintenance

6.2.3. HACH DR900 Portable Colorimeter

6.2.3.1. Calibration

6.2.3.2. Field Measurement Procedures

Follow all manufacturer instructions as provided in Appendix x. These must be printed out, stored in the three ring binder that accompanies the field team and referred to at each sampling event. A brief outline for each parameter is provided in the sections below.

6.2.3.2.1. Orthophosphate

Because phosphorous may occur in combination with organic matter, a digestion method to determine total phosphorous must be able to oxidise organic matter effectively to release phosphorous as orthophosphate. As digestion steps require dedicated laboratory equipment, the HACH Method 8048 for the determination of orthophosphate is equivalent to USEPA and Standard Method 4500 P-E for wastewater however does not require the digestion step.

6.2.3.2.2. Nitrate

Nitrate (NO_3^-) is reduced almost quantitatively to nitrite (NO_2^-) in the presence of cadmium (Cd). The HACH Method 8039 is based on the Standard Cadmium Reduction Method 4500-NO3- E. This method uses

commercial grade cadmium and through reactions forms a highly coloured azo dye that is measured colorimetrically.

6.2.3.3. Maintenance

6.2.4. Ion Selective Electrodes

Need to confirm brand and manual

6.2.4.1. Calibration

6.2.4.2. Field Measurement Procedures

6.2.4.3. Maintenance

6.2.5. Chlorophyll a Fluorimeter

Need to confirm brand and manual

6.2.5.1. Calibration

6.2.5.2. Field Measurement Procedures

6.2.5.3. Maintenance

6.2.6. Test Kits

A range of commercial field kits are available for rapid testing of water and soil quality. These include tests for analytes such as pH, metals and nutrients (among others). Test kits are a substitute (surrogate) for a range of instrumental techniques of which probes are just one. These kits can provide valuable on-the-spot information, although caution is advised in their use. It should not be assumed that a test kit will perform as specified by the manufacturer, nor are they as accurate as laboratory analysis.

The GEF Pacific R2R Programme will use a [brand to be determined] Water Test Kit and a [brand to be determined] Soil Test Kit for rapid on-site assessment of standard characteristics. Initially kits will be used in-situ and then verified for their purpose through a series of validation experiments covering the analytical range being investigated.

Manufacturer and full procedures should be followed when using the kits. It is important to remember the following points:

- Test kits are utilised in field environments and can be subjected to extreme physical conditions which will impact on kit performance. How do you know the test kit is functioning adequately? Has its performance characteristics changed since the last time it was used?
- Most kits have expiry dates for reagents that should be checked and adhered to.
- Test kits will require storage in an appropriate fashion (e.g. within certain temperature ranges; out of direct sunlight).
- Test kits can behave differently in fresh, waste and salt waters.
- Water containing particulate or suspended matter (even at small concentrations) can severely impact on the test kit producing a reliable result. For these types of samples, they should be filtered appropriately before using the test kit.

6.2.7. Secchi Disk Measurement

- 1) Use a Secchi disk measuring 20cm in diameter and attached to a line or chain marked in 0.1 m increments with paint or tape. Note: the marks need to be checked once a year with a measuring tape for accuracy.
- 2) Lower the Secchi disk into the water on the shaded side of the boat until the black and white quadrants are no longer distinguishable. Do not wear sunglasses while obtaining this reading.
- 3) Note the depth where the line meets the water when the disk is no longer distinguishable. Lower the disk several increments and then raise the disk until the quadrants are again distinct. Note the depth of this second reading.
- 4) The recorded Secchi depth is the average of the two depths to the closest 0.1 m

7 Analytical Procedures

Analytical procedures have been sourced from several documents including the Standard Methods for the Examination of Water and Wastewater (APHA, 2012), WA EPA Water Quality Sampling Guide,

7.1. Introduction

Need to confirm brand of BOD equipment, e.coli and helminth method

8 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) refers to all those things that are done to make sure measurements are correct (accurate; the absolute true value), reproducible (precise; consistent), and include good estimates of uncertainty.

As outlined in sections 4.1 of this manual, it is important for field teams to properly calibrate and perform quality assurance checks of field parameter instruments. Table 3 and 4 lists the acceptable calibration and end of day check ranges.

The various steps conducted throughout the monitoring program and their related QA and QC activities are outlined in Table 24 adapted from the Freshwater Guidelines (ANZECC & ARMCANZ, 2000)

Quality Assurance: a system of documented procedures and plans established to ensure that the water monitoring program produces data of known precision and bias. This includes staff training programs, calibration processes, written procedures and record keeping. This also includes a quality control program.

Quality Control: operational activities that confirm the quality assurance methods are functional and that information collected is accurate, precise and properly recorded. Therefore, consistent QA/QC activities produce data of known quality.

Table 24: Methods for QA and QC

Step	Quality Assurance	Quality Control
Staff are properly trained	Staff are appropriately trained in an induction and provided with field/lab procedures	Supervision of new staff
Use of specialised equipment	Calibration procedures – all water monitoring equipment is calibrated using controlled standard solutions (section 4) Equipment maintenance procedures are in place	Limits placed on calibration results Any equipment failing calibration is not used until the problem resolved Equipment maintained as per appropriate specific manual for that equipment
Sample collection	Provide training in sampling techniques Methods outlined in water quality sampling manual (this document and associated SOP) Controlled field data sheets with clear site locations and the appropriate samples for each location Controlled and accurate sample labelling Controlled use of consumables – defined bottles appropriate for samples being collected	Use of field blanks
Record keeping	Data 'double recorded' – manually on worksheets and electronically within equipment memory	Data validation – data checked by second technical officer after being entered into the database
Storage and transport	Defined methods for storage of samples (e.g. use of ice, foil and minimisation of time between collection and storage)	Fridges and freezers monitored by use of data loggers
Sample analysis	Samples analysed using defined methods (including outsourced to accredited laboratory) Methods based on text: 'Standard Methods for the Examination of Water and Wastewater'	Use of calibration standards and laboratory blanks

8.1. Quality Control for Water Samples

Quality control samples are used with the collection of samples in the field. The purpose of these samples is to validate the precision and accuracy of laboratory or field equipment data, and to determine the adequacy of preservation techniques, equipment cleaning and preparation, and sampling procedures. These control tests are outlined in Table 25.

Table 25: Types of quality control and their uses

Sample Type	Description	Purpose	Collection Method
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Duplicate samples	These are obtained when two or more samples are taken from the same site at the same time, using exactly the same methods. They are representative of the same environmental condition.	Replicate samples can be used to detect both natural variations in the environment and variations caused by field sampling methods.	At least two but preferably three samples are collected simultaneously (same site, date, time, depth, matrix and method) to establish the reproducibility of sampling.
Equipment blank	Rinsate (or equipment) blanks are created from the water or solvent used to rinse the field equipment	Rinsate blanks measure contamination introduced through contact with sampling equipment or the sampler.	Sampling equipment is cleaned and then the final rinse water or solvent is collected in a clean container, preserved as per normal and analysed.

8.1.1. Duplicate Samples

The purpose of a duplicate sample is to estimate the inherent variability of a procedure, technique, characteristic or contaminant. Duplicate samples are collected and duplicate analyses may be made in the field:

- 1) as a form of field quality control;
- 2) to measure or quantify the homogeneity of the sample, the stability and representativeness of a sample site, the sample collection method(s) and/or the field team's technique

Duplicates are analysed in the field or the laboratory space in the same way as the sample and are required for all field sampling events and each sample type. The results must have a Relative Percent Difference (RPD) less than or equal to the guidelines in Table 26.

The field data sheet and report, and laboratory data sheet and report must show test results for the duplicates, blanks and spikes, the method and the results for summary quality control statistics calculations. Copies of these reports are a permanent part of the site file.

Table 26: Frequency, acceptable range, and corrective actions for duplicate samples.

Type of duplicate	Frequency	Acceptable range for precision	Corrective Action
Field duplicate (samples)	Minimum of 1 per trip per parameter or 10% of all samples per parameter per day	Chlorophyll-a, TSS and nutrients $\pm 30\%$ RPD; all other parameters $\pm 15\%$ RPD (need to check this for portable kits)	Audit field personnel and verify sample collection procedure; resample; reanalyze; revise SOP; audit and train field personnel; project manager determines whether associated data is usable
Field duplicates (multiprobes)	Minimum of 1 per trip per parameter or 10% of all samples per parameter per day	All parameters $\pm 10\%$ RPD	Re-calibrate instrument; replace batteries; perform instrument field check with different standards; repair or replace instrument; notify management; audit and train field personnel; project manager determines whether

8.1.2. Equipment Blanks

Blanks are an integral part of quality control (QC) and are required for all sampling activities. Their creation should be noted in the field log book. Blanks establish that there is no sample contamination from the containers during custody, transportation, and or pre-analysis preparation either in the field or in the laboratory space. Blanks establish the level of constituents introduced into a sample by the equipment used for sampling, preservatives, and/or containers. We will conduct equipment blanks prior to each field season in each country and occasionally during the field season between field sites to ensure field rinsing is adequate.

Collect an equipment blank prior to the field season as follows:

- 1) Clean all equipment used to collect, store and process water samples according to Part A of this protocol.
- 2) Rinse the equipment used to collect and store water samples with laboratory reagent grade water three times and discard.
- 3) Fill the sample collection container with a fourth aliquot of laboratory reagent grade water and handle and process this aliquot as if it were a sample to be analysed.

Another source of systematic error is sample cross contamination from field sampling equipment used to handle a multiple number of samples. The compositing jugs/buckets are to be rinsed in the field three times at each site prior to taking a sample. Either piece of equipment may be a source of cross contamination. Collect periodic equipment blanks as follows:

- 1) In between sample sites, rinse the equipment used to transfer water samples (integrating sampler and compositing jug) with laboratory reagent grade water three times and discard.
- 2) Fill the integrating sampler with a fourth aliquot of laboratory reagent grade water and handle and process this aliquot as if it were a lake sample to be analysed.

This sample is labeled as an equipment blank and information kept on a datasheet describing the source of the blank. Results for all parameters should be non-detect. This type of blank is a check for cross contamination between sampling sites and control for bias introduced by cross contamination.

Other types of blanks will be used as needed: field sampling conditions or ambient blanks, if there is any reason to suspect that ambient air pollution has the potential to contaminate water quality samples; preservative blanks, if there is any reason to suspect that a preservative may be contaminated; or bottle blanks, any time sample collection bottles are of uncertain quality or cleanliness or from a source not previously used.

8.1.3. Summary of Quality Control in the Field

Quality assurance protocols are means to ensure data collected are as representative of the natural environment as possible. Quality assurance procedures are required in all data collection efforts as part of this monitoring protocol (Table 27).

Table 27: Summary of QA/QC documentation and sampling methods

Procedure	Reason/Description
Instrument Calibration Logs	Each instrument must have a log in the form of a permanently bound logbook. Calibration schedule must be observed, using fresh calibration standards.
Project Folder	Containing: checklist of QA/QC reminders, copies of decontamination, sample collection and processing SOPs, copies of equipment calibration and troubleshooting instructions, blank field forms.
Site Folder	Containing: GPS coordinates for verification of correct sampling location, table of previous field measurements to compare with new measurements
Field Forms	Field forms are the only written record of field measurements, so copies are placed in site folders and originals must be kept on file indefinitely.
Field Instrument Methods	Require consistent measurement methods and detection limits
Sample preservation and minimum holding time	Water quality variable concentrations are maintained as close to sampling conditions as possible.
Chain-of-custody	A chain-of-custody includes not only the form, but all references to the sample in any form, document or log book which allow tracing the sample back to its collection, and documents the possession of the samples from the time they were collected until the sample analytical results are received.
Laboratory methods	Require consistent analytical methods and detection limits

Routine quality assurance gives greater confidence in the data being collected and the reproducibility of the results. Some general rules to follow are:

- Use calibrated instruments for all field measurements. Test and/or calibrate the instruments before leaving for the field. Each field instrument must have a permanent log book for recording calibrations and repairs. Review the log book before leaving for the field.
- All manually recorded field measurement data will be collected on field forms; data that are automatically recorded will be captured electronically and the equipment used will be documented on field forms. Hard and electronic copies will be made as soon as possible after surveys and kept at a separate location as backup.
- Complete records will be maintained for each sampling station and all supporting metadata will be recorded appropriately (field forms or electronically).
- Make field measurements in a manner that minimizes bias of results.
- Check field-measurement precision and accuracy. Follow the procedures in section 5.2
- Collect 10% duplicate water samples; conduct duplicate measurements of field parameters at approximately 10%.
- Create field blanks prior to the beginning of each field season and periodically throughout the season.

9 Data Management

While the details will vary, some of the key elements of good data management include data validation and verification (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc).

9.1. Data Collection

Data values are measured, observed, or estimated according the GLKN inland lakes water quality monitoring protocol at various monitoring locations (sample sites) and recorded on field forms. Field team members are responsible for legible, accurate entries on field forms and in log books, including the calibration log. As a first step to verify data, field team members will check and double-check the recorded values on the day of data collection.

Data collected with a multiparameter probe and/or field instruments are stored directly on the probe and recorded on the field sheets at the time of sampling. The hard copy of the data serves as a back-up should something happen to the electronic data.

Digital images of sample sites are acquired during site establishment and periodically as sites change. Field team members are responsible for proper settings and use of digital camera equipment and should refer to the user manual for details specific to the camera.

GPS coordinates are recorded on the field sheets. Team members should refer to the user manual for details specific to the GPS Unit.

Water samples are collected, labeled, and packaged for laboratory analysis according to section 5. Identification numbers on sample containers, chain of custody forms, laboratory reports, and on the field data collection form facilitate management of laboratory results.

9.2. Data Verification and Data Validation

For the purposes of this manual, the term data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method and/or procedure. The goal of data verification is to ensure and document that the data are what they show to be, that is, that the reported results reflect what was actually done. Data verification applies to activities in the field as well as in the laboratory.

Sampling protocols, analytical methods, and project-specific planning documents are examples of sources that can provide the specifications for the environmental data collection activity. Data verification evaluates how closely these documents and procedures were followed during data generation.

For the purposes of this manual, the term *data validation* is an analyte and sample-specific process that determines the analytical quality of a specific data set. Validation asks the question, 'Given that the data are verified (that it is complete, correct and to requirements) is it valid to have it say what it says?' For example, the lab may have reported a low BOD result, and it may have been captured accurately and completely into the database, but other measurements taken on the day indicate there should have been a higher result. This needs to be followed up. Data validation applies to activities in the field as well as in the laboratory.

Once data is in the database, it will be verified and validated by the national project manager and sent to the RCPU Science Officer for secondary validation.

9.3. Data Security

Make at least one backup copy of the data on a suitable long-lasting medium (e.g., CD or USB). The original field proformas and raw lab analysis data (and backup copies) should be stored in a secure and well maintained filing system in the National Project Management Office. For additional security, send an electronic soft copy of field and lab data to the RCPU and it will be stored in the RCPU files.

9.4. Data Folder and File Organisation

All data from this water quality protocol should be stored, at the earliest possibility, on the national Project computer system and the GEF Pacific R2R central server.

Files should be named following these guidelines. Files have a 'R2R' prefix, defines IW or STAR, defines the country, a descriptive element, and finish with a date element. For example the following contains field data from Kiribati, South Tarawa on 15th June 2016. Do not use spaces in file names.

R2R_IW_Kiribati_ST_Field_Data_15062016.doc

9.5. Maintaining Metadata

Keep a description of the data and the methodology used to collect the data (e.g., a copy of the methods) with the field proformas, raw lab analysis data and the backup data. Keep a written record of where the data are stored, the data format and the names of relevant computer files with the field proformas and backup data. An example of the type of metadata that might be stored with the results of a monitoring survey is given in the below. The blank metadata form is available in Appendix x.

Project Name:	<i>Tuvalu IW Pilot Project</i>		
Assessed by:	<i>Bobby</i>	Date Assessed:	<i>12/08/2016</i>
Database Info	Project ID: <i>DLP809</i>	Site ID: <i>FunOS001</i>	Year: <i>2016</i>
Data Description:	<i>Results of water quality testing (BOD,N,P and e.coli) of the dry litter piggery site on the ocean side of Funafuti</i>		
Data Type:	<i>Spreadsheet Excel in 2007 format</i>		
Methodology:	<i>Data were collected using the protocol for monitoring municipal waste reduction indicators provided in Water and Waste Monitoring Toolkit version 1 (copy kept with this file)</i>		
Location of Files:	<i>The data and the original hard copy of this file is kept with IW Project Manager; a copy is stored on file with the Regional Project Coordinating Unit, SPC-GSD, Suva</i>		

9.6. Summary of Data Management

Data management procedures are a means to ensure that data is correctly recorded and most importantly that it is logically filed for easy retrieval for sharing and report writing. The steps below must be followed at every monitoring event

Procedure	Reason/Description
Instrument Calibration Logs	Complete as per section 3 and 4.
Field Forms	Complete field forms for every site and sample in the monitoring event Check and double-check each measurement as they are produced on the day
Field Form Review and Storage	Hand-written field sheets with field instrument data should be reviewed for completeness immediately upon returning to the office. Make photocopies as soon possible and file them appropriately. Download and back up data from the multisensor datalogger as soon as possible.

10 Cost Estimates of Equipment and Materials

To be completed

Glossary

To be completed

References

To be completed

Annex 3: Draft Sanitation and Wastewater Monitoring Manual

**DRAFT SANITATION AND WASTEWATER MONITORING
MANUAL**

GEF PACIFIC R2R PROGRAMME

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1. Description of the GEF Pacific R2R Sanitation and Wastewater Monitoring Program

1.1. Aims of the monitoring program

As a long-term (i.e. ongoing over many years) program, the principal aim is to assess the effectiveness of various sanitation systems and to monitor changes in wastewater and soil quality in the system's area. Specifically there are two areas of interest as they relate to eco-sanitation systems and onsite sewage treatment systems. Firstly to build an understanding of the principal operating conditions under which eco-sanitation systems are optimised, and secondly to relate treatment performance of onsite sewage treatment systems to soil and/or water conditions at the site.

In addition to meeting the main aim, the data from the program also aims to address questions about current conditions, i.e. does wastewater and compost quality meet guideline values?

The data collected will also represent a valuable information resource and is intended to be used for a number of other related purposes. These include use as baseline data for sanitation systems in the area; as background for undertaking and assessing environmental impact statements; and as a general data source for members of the public, particularly catchment and land care groups, to gain an understanding of water quality in their area and the impacts of sanitation systems. The data may also be used in national and regional State of the Coast reporting to inform Integrated Coastal Management strategy development.

1.2. Scope of the monitoring program

The GEF Pacific R2R Programme regional Sanitation and Wastewater Monitoring Program will be initiated with the inception of the programme (2016/2017). The monitoring program is ambitious in scope and endeavours to cover the participating R2R countries that are implementing new sanitation technologies or have implemented sanitation technologies as part of the GEF Pacific IWRM Project. Initially however several countries will be selected to trial the recommended methods before extending to other sites in the remaining countries. These sites will include eco-sanitation toilets, secondary treatments systems and improved septic tank systems. Sites will be surveyed to assess baseline conditions and depending on available resources, annually thereafter. Some sites will be chosen for in-situ continual monitoring to gain a better understanding of the processes at work.

1.3. Selection of Indicators

The regional sanitation and wastewater monitoring program is aimed at assessing basic waste and water quality characteristics and recommends including the indicators described in Table 1 for condition assessment. Three of the indicators are reporting requirements for the GEF as N, P and BOD.

Standard methods as described in various publications including the Examination of Wastewater and Water (APHA, 2012), the Guideline for Fresh and Marine Water (ANZECC & ARMCANZ, 2000) and A Guide to the Sampling of Wastes, Wastewater, Soils and Sediments (EPA, 2000), require extraction methods, digestions steps and analysis by one of spectrophotometric, fluometric or titration methods. These analyses are accurate in multiple tests and applications and are the procedures generally accepted for reporting in scientific literature. However, these methods have significant disadvantages. They are time consuming and usually require a dedicated water chemistry laboratory and an experienced, efficient analyst to generate consistently accurate and reproducible results.

Due to the geographic isolation of a lot of sampling sites, and limited access to analytical resources and personnel much of the analysis will need to be performed in-situ. It is important to remember that the results of in-situ analysis will not be as accurate as results from certified extractive analysis procedures. They do provide estimates of parameter concentrations and in-field procedures will be verified against standard methods where possible.

Table 28: Recommended indicators for sanitation and wastewater monitoring

Solid waste (eco-sanitation system)	Wastewater (Septic tank effluent)	Soils (leach fields etc.)
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Temperature	Temperature	Temperature
pH	pH	pH
Phosphorus	Orthophosphate (HACH)	Phosphorus
Nitrogen	Ammonia (HACH)	Nitrogen
Helminth Ova	Nitrate (HACH)	Helminth Ova
Coliform	Coliform	Coliform
Moisture Content	Biochemical Oxygen Demand (BOD)	
Solar Exposure		

1.4. Wastewater Quality Objectives

International standards

Country standards

1.5. Monitoring framework

A monitoring framework is essential to the design and adaptation of an effective monitoring program. It establishes a simple sequential structure that encourages thoroughness, facilitates communication within and between different levels of operation and management, and provides overall direction and focus essential to achieving success in such large-scale and long-term studies. The framework adopted for the GEF Pacific R2R is summarised in the figure below. It is adapted from the Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ, 2000). This manual covers the sections indicated by a star in Figure 4.

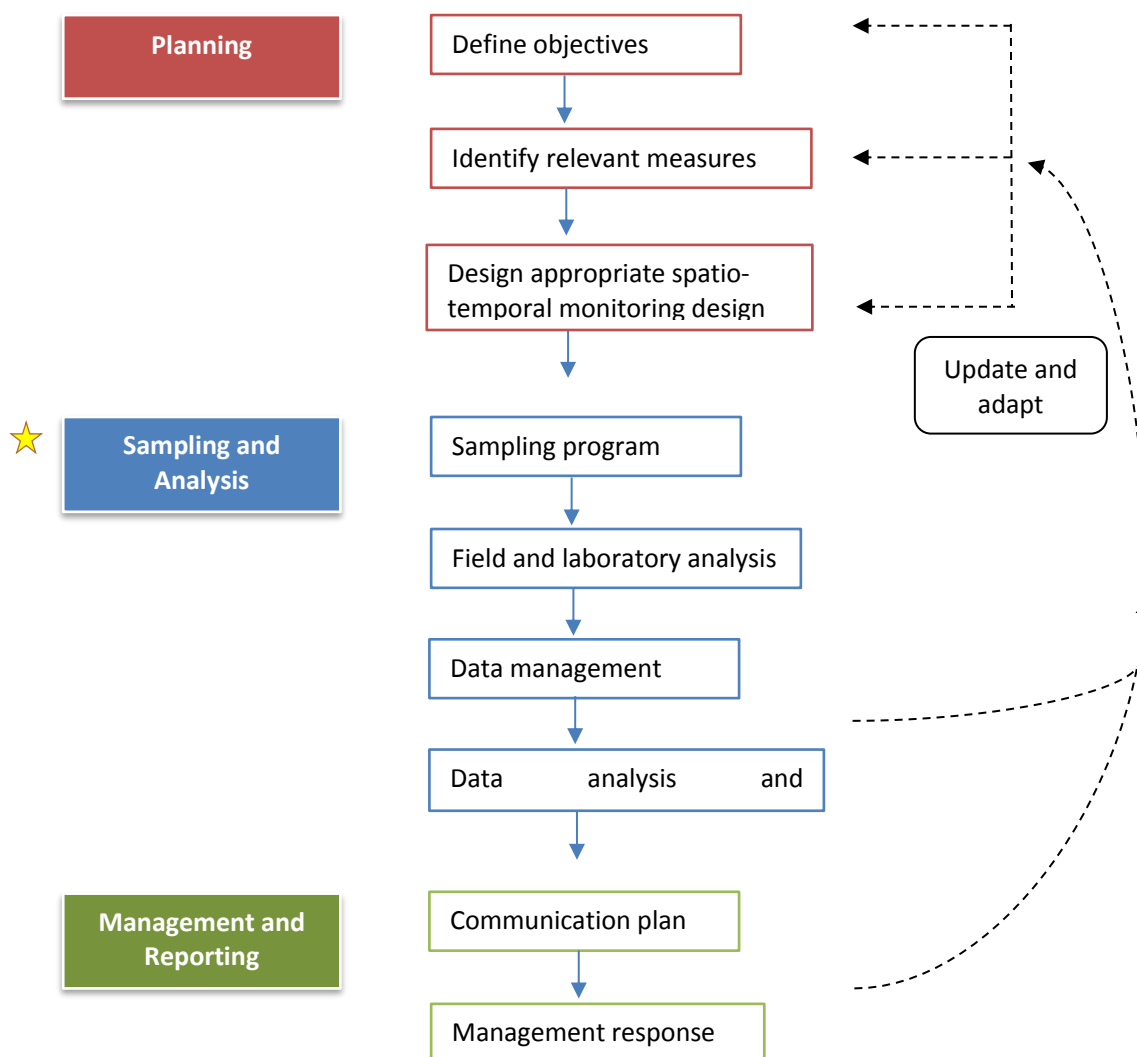


Figure 15: Proposed monitoring framework

2. Introduction to the manual

2.1. Purpose of the manual

The purpose of the manual is to provide the common techniques, methods and standards for sample collection, handling, quality assurance and control, and data management, for use by project staff and communities in the GEF Pacific R2R Programme. The manual is a part of an integrated monitoring framework to decide the objectives, indicator selection, data analysis and reporting, as shown in Figure 4 above.

Individual National Project Sampling Plans will be developed and will include specifics about:

- Sample compositing procedures
- Days and times of collection
- Required equipment
- Instructions for labeling samples and ensuring chain of custody

- A list of contact persons and telephone numbers in case unexpected difficulties arise during sampling.

2.2. Intended users of the manual

This manual is intended to be used by:

- GEF Pacific R2R International Waters and STAR Project teams
- Consultants conducting monitoring on behalf of the GEF Pacific R2R Programme
- Community groups in association with the GEF Pacific R2R Programme

2.3. Content of the manual

Australian, New Zealand and relevant international standards were considered during the preparation of this manual. This manual presents an overview of and standard operating procedures for:

- sampling design sampling in the field:
 - making in situ tests and wastewater quality measurements
 - taking samples for solid waste and wastewater quality assessments
 - preserving and storing samples for solid and wastewater quality assessments,
 - security and transport of samples
- arranging laboratory analysis
- data analysis and interpretation.

Standard operating procedures for the relevant sections are provided at the end of this document and can be printed and stored in the appropriate location.

2.4. Limitations

The manual cannot cover every set of circumstances encountered when determining a 'protocol' for sampling, and may not always provide sufficient or relevant directions. In situations where the user has little confidence that the samples might produce useful data, this should not stop them from being collected, particularly if there is no other opportunity to obtain the information they could provide.

3. Preparation and Cleaning

3.1. Setting up a Field Lab

Due to the challenges of monitoring in the Pacific (geographic remoteness, cost of travel etc.) and the absence of dedicated wet chemistry laboratories in most countries, measurements described in this manual have been designed to be conducted in field. There are a few however that cannot be conducted in situ, as such a small field laboratory can be set up to accommodate these and serve as a base for the duration of the monitoring events.

There are some key considerations when choosing the site for a temporary field laboratory. These are accessibility, size, cleanliness, bench space, storage, running water, power supply, lighting, ventilation and internet service.

The space will need to be easily accessible with security and in a useable state, meaning that there is only superficial cleaning needed to be undertaken to use the space, not complete renovation. An unused office in the main government buildings, a disused shed in the maintenance department for example, should suffice in most circumstances. The room will need to be a comfortable size (~3.5m x 3.5m), not a closet, with windows for light and ventilation, or overhead lights and air conditioning. The room will need to have sufficient bench space (Figure 16) to house the monitoring equipment and space to store the portable in situ measurement units, consumables and materials.



Figure 16: Example of bench space required for field laboratory

Running water is essential as it is required for the analysis and cleaning of equipment. There will need to be a reliable power supply and preferably access to an internet service, either through wireless or network. If possible the use of a small refrigerator would be desirable to store chemicals and samples not being analysed straight away. This can be a small bar fridge.

For the comfort of the staff conducting field work, chairs will be used and if space allows a table for completing field notes and logging data onto the computer.

3.2. Preparation

Before going out on any field monitoring event, whether it is with the regular field monitoring crew or a community monitoring group, you must mark off the **checklists available in Appendix x**. Print several of these out and keep in a dedicated checklist folder. By marking off the checklist as you collect each item you can be sure that you have not forgotten anything that will be essential to field monitoring.

Before leaving for a monitoring event make sure that you have informed your supervisor or designated contact in the office of where you are going, when you are expected to return and your contact details in case of emergency.

Calibrate all field instruments according to manufacturer **guidelines outlined in Chapter 3** of this document and enter the calibration information into the calibration log book. A template for the calibration log book is available in **Appendix A**.

The following list provides an overview of the sequence of events that take place on a general field monitoring day. This sheet is also provided in **Appendix ?** and should be printed and referred to prior to each monitoring event to familiarise with the schedule.

	Activity
1	Review field equipment check list and collect necessities
2	Create a new field form for each monitoring station, printed on waterproof paper (or kept in waterproof folder)
3	Prepare sample bottles and labels in advance and place in a cooler.
4	Conduct daily calibration of appropriate meters and probes.
5	Move to the first monitoring site location
6	Refer to description of monitoring site location, directions, maps, and photo to verify correct location. Verify coordinates on GPS unit. Complete field observation form

7	Measure field wastewater quality variables per Section 3.3 and SOP# (multiprobe and in-situ test kits or portable colorimeters).
8	Collect samples for wastewater, solid waste and sediment quality per section
9	Be sure that all samples are correctly labelled and preserved on ice.
10	Verify that field proforma is completely filled out, and initial the form.
11	If sampling from more than one monitoring station in a day, follow procedures for decontamination of equipment per Section 4, and go back to step 6, above.
12	Return to office or field station.
13	Process samples according to Section x . Refrigerate or freeze samples, as required and package samples for sending to analytical laboratory as required.
14	Clean sampling equipment per Section 4. Rinse sensors with deionized water and perform calibration re-checks as per Section x .
15	As soon as possible after returning from the field, review both hardcopy and multiprobe data; upload multiprobe data onto computer; review laboratory data as it is received

3.3. Sampling Equipment

Different sampling equipment requires different cleaning methods based on its use in the field. Non-metallic materials, such as plastic, are used whenever possible for the collection of samples for metals. For the collection of organic samples, non-organic or inert materials, such as stainless steel or Teflon, are used.

The majority of sample sites are sampled using grab sampling equipment. To ensure the highest quality of data results, this equipment must be well maintained. **A full equipment list is provided in Appendix x**. Below are several general items to follow when transporting grab sampling equipment out into the field.

- Examine the equipment for obvious signs of dirt, rust or scratches, and replace when necessary. Dirt, rust, and scratches can contaminate samples by allowing dirt and bacteria to survive cleaning or allow residue to contaminate sensitive samples.
- Look at sample containers to see if cracks or contamination is present. If so, dispose the container in question and obtain a replacement.
- When assembling plastic sample containers, the use of clean hands or powder free gloves will reduce potential contamination from entering the bottle.

3.3.1. Wastewater sampling equipment

- Plastic bucket
- Clean sample bottles and/or cubitainers suitable for the samples being collected
- Syringe, filter paper, filter holder etc. for samples requiring filtering.

3.3.2. Compost and soil sampling equipment

- Plastic bucket
- Plastic tray
- Certified pre-cleaned glass jar(s) with plastic lids
- Stainless steel trowel or spade
- Plastic spoon, and stainless steel spoon
- Soil auger – can be made from plumbing PVC pipes

3.3.3. Laboratory and sampling glassware

- Volumetric flasks

- Graduated cylinders
- Beakers of varying sizes
- BOD bottles

3.3.4. General supplies

- Plastic zip lock bags
- Permanent markers, pens and pencils
- Field data information sheets
- Calibration notebooks

3.4. Sampling equipment preparation and cleaning

The subsections below cover routine sampling encountered by field monitoring crews. Equipment that is used to collect wastewater, compost and potentially contaminated soils needs to be sterilised after each use. A 10% household bleach solution (1 part bleach, 9 parts water) is readily available and works well. However, bleach is corrosive and may also affect the microbial population of a sample and does need to be adequately removed from the equipment prior to sample collection.

Cleaning and maintenance schedules are provided for separate printing in Appendix A. Print these out and display in the field office.

3.4.1. Wastewater sampling equipment cleaning and maintenance

At the end of each sampling day:

- 1) Make up the 10% bleach solution in a clean plastic bucket.
- 2) Immerse each piece of clean equipment in the solution for a minimum contact time of a minute.
- 3) Rinse the equipment in another bucket containing sterile or boiled water.
- 4) Let the equipment air dry for a few minutes or dry with sterile paper or cloth towels.
- 5) After drying, place the equipment in a paper bag or storage container

Weekly maintenance:

- 4) Wash sampling buckets with lab grade soap (**brand to be determined**) at the end of each week using a brush to ensure the removal of all particulate matter or surface film.
- 5) Rinse thoroughly with tap water, then DI water, and allow to air dry at room temperature.
- 6) If sampling buckets have rust stains or other hardened deposits, use a paste made of baking soda and water to scour the deposits using a soft brush or clean cloth. Scour in the direction of the grain of the steel. After cleaning, repeat steps 1 and 2.

3.4.2. Solid Waste and Sediment sampling equipment cleaning and maintenance

At the end of each sampling day:

- 10) Make up the 10% bleach solution in a clean plastic bucket.
- 11) Immerse each piece of clean equipment in the solution for a minimum contact time of a minute.
- 12) Rinse the equipment in another bucket containing sterile or boiled water.

- 13) Let the equipment air dry for a few minutes or dry with sterile paper or cloth towels.
- 14) After drying, place the equipment in a paper bag or storage container
- 15) Visually inspect equipment for any contamination prior to storage. Such contamination would include water spots, dust or sediment, rust and similar substances.
- 16) Cover the clean equipment with clean aluminium foil until use

Weekly maintenance:

- 4) Wash sampling buckets with lab grade soap (**brand to be determined**) at the end of each week using a brush to ensure the removal of all particulate matter or surface film.
- 5) Rinse thoroughly with tap water, then DI water, and allow to air dry at room temperature.
- 6) If sampling buckets have rust stains or other hardened deposits, use a paste made of baking soda and water to scour the deposits using a soft brush or clean cloth. Scour in the direction of the grain of the steel. After cleaning, repeat steps 1 and 2.

Monthly maintenance

- 4) Wash sampling buckets with 5% vinegar solution
- 5) Rinse sampling buckets with DI water
- 6) Air dry and cover clean equipment with aluminium foil until use

3.4.3. Sampling Glassware**At the end of each sampling day:**

- 4) Wash all glassware with the 10% bleach solution
- 5) Wash all glassware with detergent (**brand to be determined**)
- 6) Rinse thoroughly
- 7) Allow glassware to air dry

From time to time, laboratory glassware (specifically volumetric flasks and glass graduated cylinders) will become dirty despite routine cleaning methods. This 'dirty' glassware will show spots of water along the inner wall of the glassware when lab grade water is applied. One safe way that uses commonly found items to wash with a mixture of apple cider vinegar and household bleach.

- 7) Before starting the acid wash, wash all glassware with (**brand to be determined**) phosphate free detergent and rinse well 3 times.
- 8) After washing if water spots form then proceed with acid washing. If not water spots form then the glassware is clean and does not require acid washing.
- 9) Fill the glassware with the vinegar/bleach mix and slowly rotate glassware to coat the entire inner surface.
- 10) Once coated, slowly pour out the vinegar/bleach mix into an appropriate waste container for safe disposal
- 11) Rinse the glassware using 3 rinses of DI water
- 12) Observe the glassware to see if water spots form, if so repeat steps 3-5. Otherwise allow to air dry and cap with stopper or aluminium foil to prevent dust entering.

4. Calibration and Maintenance of Field Instruments

This section covers the calibration and use of electronic field parameter equipment. Although the use of equipment may vary by country and project, all teams should perform the same general calibration and end of day check procedures. Specific instructions will be made available once equipment models are known.

Calibrate sensors in a controlled environment such as in the designated field preparation office. Avoid calibrating units in the field since it can introduce error. If calibration must be performed in the field, it should be conducted indoors or in an area that is close to room temperature. Allow the probe to stabilize before calibrating. A probe is considered stable if the readout does not significantly change (<0.1 units in ten seconds).

It is essential that unambiguous written records are kept of instrument maintenance and calibration. **See Box ? for guidance.**

4.1. MultiProbes

4.1.1. General Calibration Guidelines for Multiprobes

Calibrate using standards that are within the printed expiration date or within six months of the date of opening/date of preparation if no expiration date is printed. Calibrate probes each day the units go into the field. **Table x** outlines calibration tolerances to reference standards. Table 22 outlines calibration tolerances to reference standards.

4.1.1.1. Temperature Verification

Once every three calibrations of the field probe, compare the temperature readout to a laboratory thermometer. Record the both temperature measurements on the log sheet. If the temperature difference is greater than 0.5 C, notify the RPCU Science Officer.

4.1.1.2. Conductivity Calibration

For specific conductance, staff should calibrate using a conductivity solution that is close to the expected values encountered in the field. Be sure to rinse the probe with DI water and then the conductivity solution before calibrating with fresh conductivity solution. After calibration, the probe should be within 1.0% of the buffer value used.

4.1.1.3. Clark Cell Dissolved Oxygen Calibration

For dissolved oxygen calibration, calibrate or verify probes using procedures outlined in this chapter based on the probe make and model. After calibration, the readout must be within ± 0.2 of the theoretical dissolved oxygen saturation calculated using the table provided in **Appendix x**.

4.1.1.4. Optical Dissolved Oxygen Calibration

Daily calibration of optical dissolved oxygen sensors is necessary, as they are prone to damage if not properly stored. After calibration, the probe must be within +0.1 mg/l of the theoretical dissolved oxygen saturation calculated using the table provided in **Appendix x**.

4.1.1.5. pH Calibration

For pH calibration, use freshly prepared pH 7.0 buffer and pH 4.0 and/or pH 10.0 buffers depending on the expected values encountered in the field. For example, when performing saltwater monitoring, pH values are assumed to be above 7.0 so calibrating with 7.0 and 10.0 buffer is acceptable.

If the expected pH is unknown, whenever possible, sample teams should calibrate pH probes with 4.0, 7.0, and 10.0 buffers if the instrument is capable of such calibration. Probe readouts must be within ± 0.2 S.U. of the buffer value.

At least once per month it is important to verify the calibration of a two buffer calibrated probe (4 and 7 or 7 and 10) by immersing the probe in the third buffer not used to calibrate the sensor to determine if the calibration curve would accurately display pH at this range. If the probe cannot accurately read this value, servicing is necessary

Table 29: Error limits for daily calibration

Parameter	Value
Conductivity	± 1% of calibrated standard
Clark Cell DO	± 0.2mg/L of theoretical level
Optical DO	± 0.2mg/L of theoretical level
pH	± 0.2 SU of calibration buffer

4.1.2. General Transport of Probeware

Many of the sensors, such as those reading pH and dissolved oxygen, can easily dry out during transport resulting in inaccurate readings and damaged equipment. To prevent this, transport sensors in a humid environment. Ideally, attaching the sensor storage cup provided with the probeware which includes a moist sponge or 10-20 ml of pH 4 buffer will ensure probes do not dry out during transport. The 4 buffer will also reduce microbial growth on the sensors and ensure the pH sensor is not compromised, as would be the case with tap or lab grade water. If using water in the storage cup, avoid letting the water touch the sensors as much as possible. Remove the storage cup and affix the sensor guard (if provided) before deploying at the site.

4.1.3. Quality Assurance of Field Probes

4.1.3.1. Midday DO Check

For multiprobe units with a DO sensor, it is useful to perform a DO % saturation confirmation in the middle of run. This check will determine if the calibration of the DO sensor is still accurate to reduce the risk of invalidating the entire sample run worth of dissolved oxygen readings. To perform the midday check, place the DO sensor in a 100% air/water saturation environment such as a wet towel or in the storage cap with small amount water in it. Allow the probe to equilibrate, record the DO % saturation on the field data sheet then transfer it to CEDS in the comment field. The reading should be 95 to 105% saturation. If DO % saturation is out of the specified range, the unit will need to be recalibrated in the field.

4.1.3.2. End of Day Check of Probes

When returning from the field, teams must verify the accuracy of the field probe equipment by performing an end of day check. The end of day check is not a calibration, but a method where the probeware is verified by checking against standards in a controlled environment. If the check exceeds criteria outlined in Table 3.2, enter a note along with the data that the measurements may be considered invalid and a repeat monitoring will have to be performed.

4.1.3.2.1. Conductivity Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 6) Rinse the conductivity probe with DI water and blot dry. Ensure the reading is 0 uS/cm.
- 7) Immerse the probe in conductivity solution of the same strength used during calibration.
- 8) Allow the conductivity probe to stabilize. This may take several minutes.
- 9) Record the reading in the appropriate section of the calibration log sheet.
- 10) If the conductivity value is off more than 5% (conductivity solution <1000uS/cm) or 10% when using higher strength conductivity solutions, conductivity readings collected during the run are considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed.

4.1.3.2.2. Dissolved Oxygen Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 6) Once the temperature is stabilized, place the oxygen sensor in the calibration chamber following the instructions provided by the particular probe manufacturer or as outlined later in this chapter.
- 7) Allow the probe dissolved oxygen reading to stabilize. A stable reading is one that does not significantly change (< 0.1units) for ten seconds. This may take several minutes depending on the age of the sensor.
- 8) When the probe temperature and dissolved oxygen readings are stable, record the values on the end of day check portion of the calibration log sheet
- 9) **Using the table in Appendix x**, determine the theoretical dissolved oxygen saturation value. Record this on the calibration log sheet in the appropriate section.
- 10) If the difference between the observed reading and theoretical value greater than or equal to 0.5 mg/L, dissolved oxygen data collected during the day is considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed

4.1.3.2.3. pH Check

Upon returning from the field, turn on the probe and allow the temperature to stabilise to room temperature. If temperature is slow to adjust due to from returning from extreme hot or cold environments, you may place the sensor(s) in a room temperature water bath for faster adjustment. Remove from the bath before proceeding with the end of day check.

- 6) Rinse the pH probe with freshly prepared 7.0 buffer or buffer used during the morning calibration. Fill the calibration chamber (or appropriate container) with freshly prepared 7.0 buffer or clean 7.0 buffer used during the morning calibration.
- 7) Allow the probe pH reading to stabilize. A stable reading is one that does not significantly change (<0.1 units) for ten seconds. This may take several minutes depending on the age of the sensor.
- 8) Record the reading in the appropriate section of the calibration log sheet. If the probe can display millivolt (mV), record this as well.
- 9) Repeat steps 1 through 3 for pH 4.0 and/or 10.0 buffer. Use the same strength standards used during the morning calibration. a. If field pH readings were outside the standard two buffer calibration curve, verify the accuracy of the pH sensor by immersing in the buffer (4.0 or 10.0) which would have bracketed the observed field readings.
- 10) If the pH values for any of the calibrated buffers exceed 0.2 S.U., pH data collected during the run is considered invalid, you will need to enter a note along with the data, and a repeat monitoring will have to be performed.

Table 30: Maximum error limits for end of day checks

Parameter	Value
Dissolved Oxygen	±0.4 mg/L of theoretical value
pH	±0.2 SU of calibration buffer
Conductivity <1000uS/cm	±5% of calibration standard
Conductivity >1000us/cm	±10% calibration standard

4.2. Field Analysis Kits

Will wait until decision is made on what kits we will use to write the protocol.

5. Field Sampling Procedures

5.1. Introduction

This section details the collection of water and sediment samples and is guided by the Control of Pathogens and Vector Attraction in Sewage Sludge (EPA, 2003) and Standard Methods for the Evaluation of Water and Wastewater (APHA, 2012). Specifically it covers sampling of wastewater, both liquid and sludge, soil and compost. Described here are the general procedures for sampling, exact details of site access and sample numbers will vary according to national projects. These details will be expanded upon and documented in Procedures are also available as separate sheets in Appendix x, these can be printed and stored in the field binder for reference on field sampling trips.

Experience with and knowledge of the sampling equipment and the collection, storage, and processing of water samples for subsequent laboratory analyses are critical for collecting data of high quality. Figure 5 highlights key considerations in the sampling process.

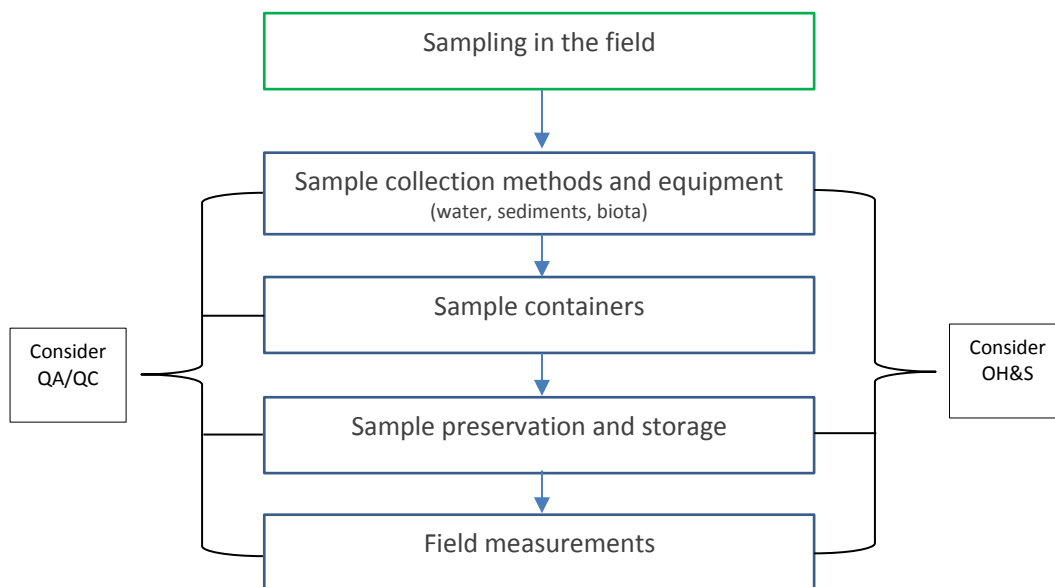


Figure 17: Materials and equipment considerations for sampling and field measurements

Refer to the checklist of supplies and equipment needed for field sampling (Appendix ?) prior to each sampling trip. Keep on hand all necessary forms, calibration logbooks, field logbooks, field data forms, procedural manuals, and equipment instructional manuals. The general procedures for collecting samples of water, wastewater, soils or sediments is summarised in Figure 6.

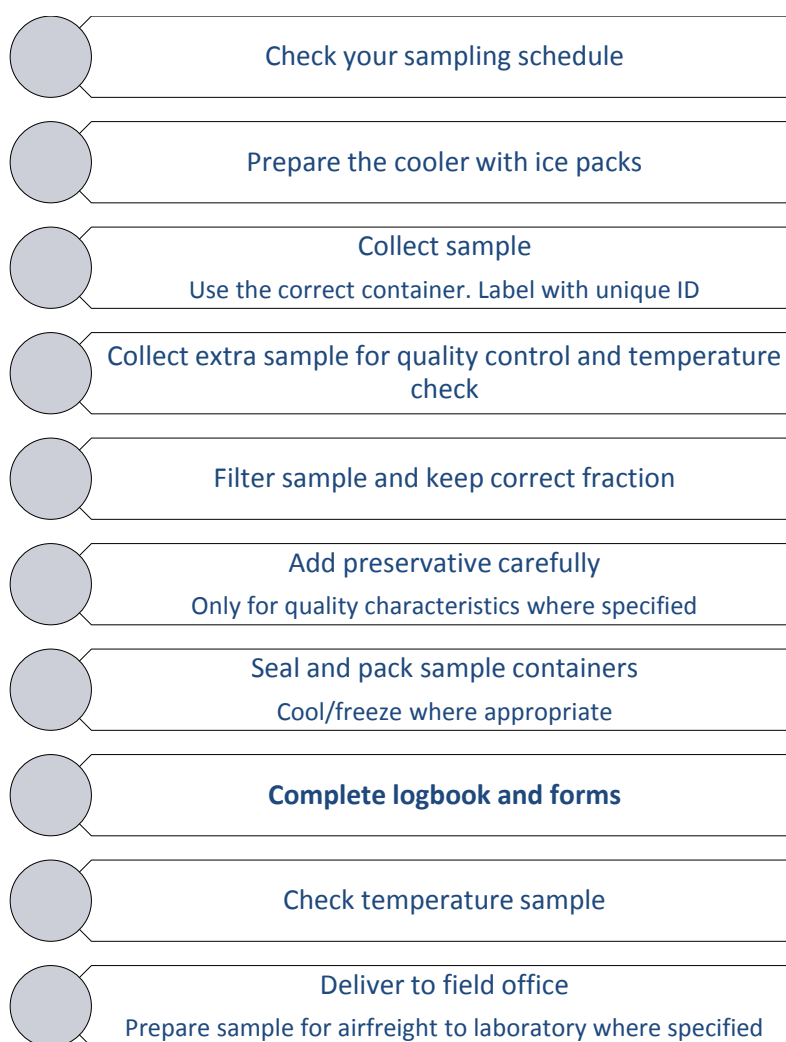


Figure 18: Steps in the sampling procedure

5.1.1. Observations

General observations of the site area can provide additional information useful in recognizing trends or impacts of a non-functioning system. When at a site it is important to take notes in the field logbook as well as digital photos of the area. Make note of outstanding odours, scum or algae, ponding, state of vegetation and general state of the system.

5.1.2. Labelling

Adequate sample description and labelling are extremely important in sampling. Complete the labels at the sampling site and record matching details in your notebook. To guard against possible confusion between samples, each sample should be given a unique number. This number can be made up of parts containing codes for different pieces of information, if required. However, the label must include the following information:

- Sample location
- Sample number/ID
- Sampler name
- Date

(picture of a label)

5.1.3. Sample containers and preservation

Ideally, analysis of samples should be performed in situ or at least on site. For some analytical indicators this is not possible and samples must be stored for analysis at the lab or field office. In this instance it is essential that you follow correct procedures for collection, preservation and transport of samples to the field office for analysis or packaging for shipping. This section details for water, wastes and soils.

Appropriate containers and preservation methods are necessary to avoid risks of contamination of the sample and/or losses of analytes of interest during storage and transit prior to analysis. Details of sample containers and preservation are given in **Appendix ?**. The requirements are taken from *A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Waters* (EPA, 2000).

The information in **Appendix ?** is intended as a field reference with specific directions that can be followed without need for detailed knowledge of analytical procedures. It is important that you follow these specifications exactly. If this is not possible, ensure you make a written record of what methodology you adopted.

5.1.3.1. Sample Containers

For samples of waters, wastes and bottom sediments, each sample should be collected and stored in a container appropriate for the quality characteristics of interest.

The requirements listed in **Appendix ?** include:

- the type of material/s suitable to contain the sample (container body and cap)
- the suitable method/s of pre-cleaning sampling containers
- preservation procedures
- maximum holding times
- comments on sampling procedures.

Containers will be supplied by either the RPCU or the lead agency involved with the monitoring. It is important to double check that the containers supplied will be suitable for the analysis intended for the sample.

If using an intermediate container to collect the sample (a grab, tray or composite bucket) make sure that the container has been subject to the same pre-cleaning and –pre-rinse as the final container to ensure that no contamination or degradation of the sample occurs.

5.1.3.2. Preservation and storage

5.1.4. Preventing Contamination

Avoiding sample contamination is an important aspect of sampling. There are always potential sources of contamination, and the aim should be to keep the risk of contamination to a practical minimum, consistent with the types of analytical tests required. Possible sources of contamination include:

- Sunscreens (zinc oxide) or insect repellents (organic chemicals) on skin could contaminate a sample if transferred by some unintentional means to the material sampled.
- Residual sample material from previous tests could give incorrect readings when measurements are being made with field instruments. Special attention should be given to probe and test kit item rinsing after each field measurement in order to prevent future contamination. See section 3.1.1 concerning intermediate containers.
- Avoid smoking and wear Nitrile gloves at all times.
- Corrosion and oxidation of metal components in probe cathodes, electrodes and membranes could contaminate a sample and yield inaccurate readings.
- Note that some container caps have inserts; never touch the inserts with the skin or remove them from the caps.

- Cover work spaces used for sample handling (e.g. vehicle tray or tailgate) with new alfoil or plastic to provide a clean working surface. Replace it after driving to a new site.

Record any incident where contamination has or possibly has occurred. It is better to record these details than have analysis that appears out of range with no information on why that might be so.

5.1.5. Equipment Rinse

When collecting samples, the collection equipment shall be rinsed once with sample water before the actual sample is taken. For a sampling bucket, fill the bucket with site water, swirl the water around and dispose of the rinse water away from the sampling site. For sampling devices, clean the device inside and out by dipping it into and out of the site water or by washing with site water. For sludge, compost and soils no rinse is necessary.

5.2. Safety

5.2.1. Field Safety

General points regarding field safety that should be taken into consideration while sampling and analysis is undertaken in the field.

- Let someone know where and how long you will be sampling for
- Wear appropriate clothing (shoes, hat, shirt)
- Always wear gloves when handling waste or contaminated samples
- Do not allow children to sample or test – do not let children undertake adult tasks
- Use common sense around areas that may be unstable, eroded banks, deep waters etc.

5.2.2. Chemical Safety

All of the manufacturer methods used in this manual come with their own chemical safety instructions. Make sure you have read and understood these before using the equipment and materials. MSDS are supplied for the major chemicals used in Appendix x. The following are general guidelines for using chemical reagents:

- Read all warnings and procedures of first aid before chemicals are used and have them available if spills or accidents occur.
- Take care when handling chemicals. Always use safety equipment i.e., safety gloves and glasses, and read the chemical labels when using the kits,
- Do not drink water from the source you are testing as it may be polluted. In particular when testing do not put your hands near your mouth or eat and drink while testing water or solids.
- When finished using the chemicals and testing is complete, ensure hands are washed thoroughly.
- All chemical waste used in water and wastewater quality testing should be collected in a plastic bottle and disposed of correctly.

5.3. Wastewater sampling

The variety of conditions at different sampling locations requires that considerable judgment be exercised regarding the methodologies and procedures for the collection of representative samples of wastewater. However, the primary approach in sampling a wastewater treatment system is to sample from “clean” to “dirty.” This approach means that sampling begins at the point where the effluent passes beyond the ability to collect a sample and work up stream. For example, if sampling a packed bed filter system with a dispersal field, begin with the effluent pipe of the packed bed filter and last, sample the septic tank. This ensures that we do not inadvertently contaminate a downstream or “cleaner” sample with upstream or “dirty” effluent. Multiple samples will be taken at each site to represent the length of the treatment chain. A suggested chain of sampling is shown in Figure 5, the numbers represent the order of sampling.

5.3.1. Sample site selection

5.3.1.1. Influent

Influent wastewaters are preferably sampled at locations of turbulent flow in order to ensure good mixing; however, in many instances the most desirable location is not accessible. Professional judgement will be required when selecting the most appropriate sample location at individual sites and will depend on access. Preferable influent wastewater sampling locations include:

- 1) up flow distribution box following pumping from house;
- 2) grit chamber;
- 3) downstream of preliminary screening;
- 4) septic tank inlet

5.3.1.2. Effluent

Effluent samples should be collected at the most representative site downstream from all entering wastewater streams prior to discharge into the receiving waters/environment. At some sites this may be the septic tank outlet, secondary baffle reactor tank, or the distribution box to dispersal field. Suitable sites will have access to liquid discharge.

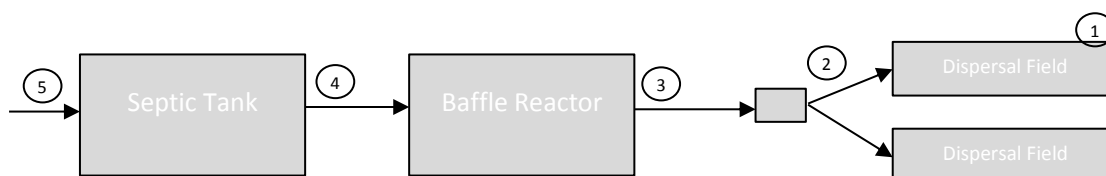


Figure 19: Suggested sample locations for wastewater at onsite sewage treatment system

5.3.1.3. Ponds and lagoons

Generally, composite effluent wastewater samples should be collected from ponds and lagoons. Even if the ponds or lagoons have long retention times, composite sampling is necessary because of the tendency of ponds and lagoons to have flow paths that disrupt designed retention times.

5.3.2. Equipment

- Plastic bucket
- Sample collection containers – Nalgene 500mL bottles
- Gloves – for personal protection and prevention of cross-contamination
- Antimicrobial wipes
- Large ziplock bags
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen - used to mark soil boring tubes and for documentation of field logbooks and data sheet
- Stainless Steel Buckets - used for compositing samples. Must have 10 - 12 litre capacity
- Rubbish Bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.3.3. Procedure for sampling wastewater effluent

Great care must be taken when sampling hazardous wastes. Wear protective gloves and shoes while sampling, and dispose of gloves after sample is bagged for transport. It is best to use the use the actual sample container which will be used to transport the sample to the laboratory, this eliminates the potential for cross-contamination. It may be necessary to collect a large sample in a plastic bucket first, and then take a subsample for analysis.

- 1) Remove any covering to access the waste stream if necessary
- 2) Select a location in the waste stream that is well mixed
- 3) Dip the container into the water or wastewater stream so that the mouth of the container faces upstream.
- 4) If the bottle is filled above the shoulder, then immediately pour out enough excess sample to ensure the sample volume is at or near the shoulder. Replace the bottle lid
- 5) If taking composite samples, take samples at 5-10min intervals and collect in an intermediate container. Note the length of time between each sample on the field data sheet.
- 6) Place containers into large, labelled zip lock bags for transport or proceed with in situ analysis as described in Section 6.
- 7) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.
- 8) Remove gloves at the completion of sampling, wash and decontaminate the sampling equipment before moving to the next site.

5.3.4. Procedure for sampling sludge

Great care must be taken when sampling hazardous wastes. Wear protective gloves and shoes while sampling, and dispose of gloves after sample is bagged for transport. It is best to use the use the actual sample container which will be used to transport the sample to the laboratory, this eliminates the potential for cross-contamination. Sludge samples will be composite samples as conditions will be different in different places of the sludge.

- 1) Remove any covering to access the waste stream if necessary
- 2) Select a location that appears well mixed.
- 3) Take samples from waste stream and collect in an intermediate container. Note the number of samples taken on the field data sheet.
- 4) Place containers into large, labelled zip lock bags for transport or proceed with in situ analysis as described in Section 6.
- 5) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.
- 6) Remove gloves at the completion of sampling, wash and decontaminate the sampling equipment before moving to the next site.

5.4. Soil Sampling

5.4.1. General Sampling Techniques

The variety of conditions at different sampling locations requires that considerable judgment be exercised regarding the methodologies and procedures for the collection of representative samples of soil. In some

instances the soil will be collected in the area directly surrounding the sanitation systems, in some it will be around dispersal fields. Therefore professional judgements will be required as to the number and location of samples. Collect any wastewater chemistry and field measurements prior to collecting soil samples.

5.4.2. Equipment

- Spade, shovel, trowel or scoop
- Corer
- Plastic bucket
- Sample collection containers
- Stainless Steel lab spoon - or equivalent. Used for homogenizing sediment samples
- Large tray
- Gloves – for personal protection and prevention of cross-contamination
- Sampling flags and tape measures – used to mark the transect boundary
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen - used to mark soil boring tubes and for documentation of field logbooks and data sheet
- Rubbish Bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.4.3. Procedure for sampling with corer

A simple corer for sampling can be easily constructed with materials from a local builders hardware. You will need a length of 50mm diameter PVC drain pipe (at least 25cm long) and a PVC cap.

Cut the PVC pipe into a length of approximately 25cm using a hacksaw. Clean the cut edges with a light sandpaper. At 10cm from one end of the PVC pipe, make a mark on the outside using the hacksaw. Continue the mark around the entire pipe.

The following procedure will be used to collect sample with a corer:

- 1) Depending on the site, layout a fixed transect site with sampling flags at each corner. The transect site will need to be large enough to encompass the dispersal field of either composting toilet or onsite treatment system
- 2) At the start of transect 1, take a core on the 0 metre mark. The cores are always taken on the right hand side of the tape measure and adjacent to the 0.25 metre squared quadrat.
- 3) Push the PVC corer into the soil to a depth of 10 cm (the saw mark). Cap the corer and extract from soil (Figure 8).



Figure 20: Example of coring procedure (note this is on sand not soil)

- 4) Transfer the sample into the tray. Ensure that non-dedicated containers have been adequately decontaminated.
- 5) Care should be taken to remove woody debris, grass and any other non-representative media from the sample
- 6) Continue to the next metre mark and repeat the procedure. Continue along the transect sampling every (depends on site dimensions) metres until the transect is completed. Then repeat the process mid-way between and along the remaining transects (Figure 9).
- 7) When all samples are collected homogenise in the tray. Spread the soil evenly and divide into quarters. Remove opposite quarters and return to the field. Mix the remaining soil sample. Continue this procedure until there is roughly 500g of soil sample remaining.
- 8) Place the sample into five 100mL sample containers and place in large labelled zip lock bags. Place in cooler with ice pack for transport or proceed with in situ analysis as described in Section 6.
- 9) At the completion of sampling, check that the data sheets are filled in fully. Wash and decontaminate sampling equipment.
- 10) Remove all marker pegs and roll up the tape measures. If the tape measures are covered in soil or mud, take care to wash them then roll up.

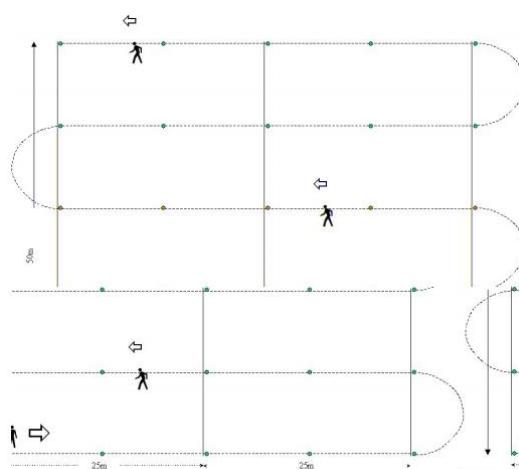


Figure 21: Suggested sampling approach for a field transect

5.4.4. Procedure for sampling with a trowel, spade or scoop

Collection of soil can be accomplished with tools such as spades, shovels, trowels, and scoops.

The following procedure will be used to collect soils with a scoop, shovel, or trowel:

- 9) Depending on the site, layout a fixed transect site with sampling flags at each corner. The transect site will need to be large enough to encompass the dispersal field of either composting toilet or onsite treatment system

- 10) At the start of transect 1, take a core on the 0 metre mark. The cores are always taken on the right hand side of the tape measure and adjacent to the 0.25 metre squared quadrat.
- 11) With the spade cut a V shaped hole in the soil and remove a ~10cm slice
- 12) Transfer the sample into the stainless steel tray.
- 13) Care should be taken to remove woody debris, grass and any other non-representative media from the sample
- 14) Continue to the next metre mark and repeat the procedure. Continue along the transect sampling every (depends on site dimensions) metres until the transect is completed. Then repeat the process mid-way between and along the remaining transects.
- 15) When all samples are collected homogenise in the tray. Spread the soil evenly and divide into quarters. Remove opposite quarters and return to the field. Mix the remaining soil sample. Continue this procedure until there is roughly 500g of soil sample remaining.
- 16) Place the sample into five 100mL sample containers and place in large labelled zip lock bags and then into cooler with ice pack for transport or proceed with in situ analysis as described in Section 6.
- 17) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly. Wash and decontaminate sampling equipment.
- 18) Remove all marker pegs and roll up the tape measures. If the tape measures are covered in soil or mud, take care to wash them then roll up.

5.5. Compost sampling

Samples will be collected from the inside of the closed of composting chamber. Some piles will be deep and others shallow, therefore a visual survey of the compost pile is performed to determine how many samples are able to be taken. Conditions will be different in different places of the compost pile therefore a composite sample will be collected.

5.5.1. Equipment

- Spade, shovel, trowel or scoop – used for collecting samples from shallow waters
- Corer – used for collecting samples from shallow waters
- Sample collection containers – 50mL
- Zip lock bags - large
- Stainless Steel lab spoon - or equivalent. Used for homogenizing sediment samples
- Stainless Steel Buckets - used for compositing samples. Must have 10 - 12 litre capacity
- Gloves – for personal protection and prevention of cross-contamination
- Field logbook – a bound book used to record progress of sampling effort and record any problems and field observations during sampling.
- Three-ring binder book- to store necessary forms used to record and track samples collected at the site
- Permanent marking pen - used to mark soil boring tubes and for documentation of field logbooks and data sheet
- Rubbish Bag - used to dispose of gloves and any other non-hazardous waste generated during sampling
- Decontamination supplies/equipment

5.5.2. Procedure for sampling compost

Depending on the size and depth of the chamber take 5 samples. One from the middle of the pile and four samples around the middle of pile, see Figure 8.

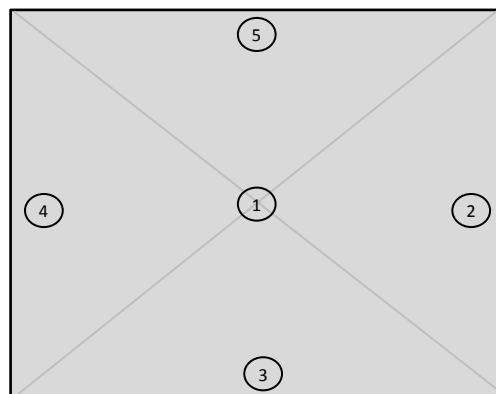


Figure 22: Suggested sampling points for compost in chamber

- 1) Collect samples with a stainless spoon, corer or spade depending on the consistency of the compost and place directly into stainless bucket
- 2) Once all samples have been collected thoroughly homogenise samples in the collection bucket with the stainless steel spoon
- 3) Place homogenised samples into 50mL sample containers and properly seal.
- 4) Place containers into labelled ziplock bags and then into cooler with ice pack for transport or proceed with in situ analysis as described in Section 6.
- 5) At the completion of sampling, check that the data sheets are filled in fully and that all sample containers are labelled correctly.
- 6) Remove gloves at the completion of sampling, wash and decontaminate the sampling equipment before moving to the next site.

6. Field Measurement Procedures

6.1. Introduction

This section details the procedures for conducting analysis using field instruments and is guided by the ANZECC Guidelines (2000) and Standard Methods for the Evaluation of Water and Wastewater (APHA, 2012) and instrument manufacturer's procedures. Specifically it covers measurements using handheld multiprobes, portable colorimeter/spectrophotometer, and water and soil test kits. Procedures are also available as separate sheets in **Appendix x**, these can be printed and stored in the field binder for reference on field sampling events. Manufacturer's user manuals must also be carried on field sampling events for reference and guidance on troubleshooting.

Experience with and knowledge of the field measurement equipment are critical for collecting data of high quality. Multiprobes must be calibrated as per Section 4. Figure 5 highlights key considerations in the sampling process

Field measurements should represent, as closely as possible, the natural condition of the wastewater and sludge at the time of sampling. To ensure consistent, high-quality data, always:

- Make field measurements only with calibrated instruments that have been error-checked.
- Maintain a permanent log book for each field instrument for recording calibrations and repairs. Review the log book before leaving for the field. This book should also be used for recording results of pre-and post-calibration checks.
- Test each instrument (meters, sensors, portable test kits) before leaving for the field. Become familiar with new instruments and new measurement techniques before collecting data.
- Have backup instruments readily available and in good working condition, whenever possible.
- Follow quality assurance/quality control procedures. Such protocols are mandatory for every data collection effort, and include practicing good field procedures and implementing quality control checks. Make field measurements in a manner to minimize artefacts that can bias the result.

6.1.1. Recording Field Information

Consistent methods are important to long-term data quality. In actuality, the ideal conditions are not always met in the field or in the lab and changes in staff occur. Therefore, documentation of procedures, site conditions, laboratory analysis, and reasons for deviations of any kind is important. Personnel are encouraged to write down more than they feel may be necessary in the moment, as the future interpretation of their data will depend on the written record and not the memory of an individual.

Field data forms (available in Appendix ?) should be prepared ahead of time, labelled with the project and site IDs. Field data forms are used to record the physical and chemical water quality variables measured at the time of sample collection. In addition to recording the field variables, any samples collected for laboratory analyses must be so indicated. Documentation should include calibration data for each instrument, field conditions at the time of sample collection, visual observations, and other information that might prove useful in interpreting these data in the future.

While at each monitoring site, the information recorded on field data forms should include:

- Date
- Time of arrival
- Names of field team members
- GPS coordinates, to verify location
- Current weather (air temperature and wind speed) and relevant notes about recent weather (storms or drought), including days since last significant precipitation
- Observations of water quality conditions (see below)
- Multiparameter meter (model), calibration date, and field measurements of core suite variables
- Portable colorimeter (model), calibration date, and field measurements of core suite variables
- List of sample IDs and collection times for lab analysis variables or quality assurance samples
- Whether any samples were not collected, and reason
- Quality assurance/quality control procedures followed
- Time of departure

Upon arrival at the monitoring station, record visual observations of water quality conditions that will be useful in interpreting water quality data into filed observation forms.

- Water appearance — General observations on water may include colour, unusual amount of suspended matter, debris, or foam.
- Biological activity — Excessive macrophyte, phytoplankton, or periphyton growth. The observation of water colour and excessive algal growth is important in explaining high chlorophyll-a values. Other observations to note include types of fish, birds, or spawning fish.
- Unusual odours — Examples include hydrogen sulphide, mustiness, sewage, petroleum, chemicals, or chlorine.
- Watershed activities — Activities or events that are impacting water quality; for example, road construction, timber harvest, shoreline mowing, or livestock watering.

6.1.2. Multiple Readings

As with all water samples, when taking instrument-based field measurements multiple readings should be taken and recorded. Reference sites should be used to acquire background or 'normal' data for comparison purposes

6.1.3. Record Keeping

As with all sampling it is important to keep consistent and complete records of all measurements taken in the field. Each national project conducting coastal monitoring will have dedicated logbooks for storing calibration data and field measurement data. These are be used in addition to the electronic data that is held in the field instrument and are used to record any observations on the day.

Your observations during measurements can be extremely important in assessing atypical events or long-term trends, especially when investigating maintenance issues. Such observations could include:

- atypical water colour or clarity (such as black, blue, frothy etc.)
- excessive odours
- wind speed and direction
- heavy algal or plant growths
- dumped material
- nearby earthworks or other construction activity
- nearby agricultural activities

As visible conditions could be difficult to describe accurately in words, it is strongly advised to take photographs if possible. You should keep a record of the photograph number on the memory card/film to avoid any later confusion, and record this in the logbook.

6.2. Field Measurement Procedures

Information in this subsection is provided to help you take wastewater quality measurements in a scientifically valid manner so that the results will represent the field conditions fairly. On-site (in-situ) measurements are taken to obtain accurate results of the quality of the natural environment. The characteristics that are measured in-situ are:

- Temperature
- Dissolved oxygen
- pH
- Conductivity

The multi-parameter meter recommended for use in the GEF R2R Programme is the HACH HQ 40D and is capable of measuring all these characteristics (Figure 13). The suitability of the parameter to be used in situ will be decided at each site depending on clarity, ease of access and any other mitigating factors.



Figure 23: HQ40D Multiparameter meter

The on-site colorimeter test unit recommended for use in the GEF Pacific R2R Programme is the HACH DR900 and is capable of measuring a range of parameters. Initially for this monitoring program it will be

used to determine ammonium and orthophosphate in wastewaters in the field (Figure 14). Other parameters can be added to the analysis suite.



Figure 24: HACH DR900 Portable Colorimeter

6.2.1. HACH HQ 40D Multiprobe Meter

General considerations (need to confirm brand and manual)

6.2.1.1. Calibration

6.2.1.2. Field Measurement Procedures

Wastewaters?

6.2.1.3. Maintenance

6.2.2. HACH DR900 Portable Colorimeter

6.2.2.1. Calibration

6.2.2.2. Field Measurement Procedures

Follow all manufacturer instructions as provided in Appendix x. These must be printed out, stored in the three ring binder that accompanies the field team and referred to at each sampling event. A brief outline for each parameter is provided in the sections below.

6.2.2.2.1. Orthophosphate

Because phosphorous may occur in combination with organic matter, a digestion method to determine total phosphorous must be able to oxidise organic matter effectively to release phosphorous as orthophosphate. As digestion steps require dedicated laboratory equipment, the HACH Method 8048 for the determination of orthophosphate is equivalent to USEPA and Standard Method 4500 P-E for wastewater however does not require the digestion step.

If the water sample is free from debris, algae or silt it is ready for direct sampling. From the sample container, directly take 10mL of sample in pipette and add to one sample cell. From here follow the steps provided in the manufacturers method instructions.

If the sample is not clear then it will need to be filtered through a 45um filter paper and tower. Instructions can be found in Appendix B. Once a clear sample is achieved, take 10mL of sample in pipette and add to one sample cell. From here follow the steps provided in the manufacturers method instructions.

6.2.2.2.2. Nitrogen, Ammonia

If the wastewater sample is free from debris, algae or silt it is ready for direct sampling. From the sample container, directly take 0.1mL of sample water in Pipette and add to one AmVer Diluent Reagent Test 'N'

Tube for high range ammonia nitrogen. From here follow the steps provided in the manufacturers method instructions.

If the sample is not clear then it will need to be filtered through a 45um filter paper and tower. Instructions can be found in Appendix B. Once a clear sample is achieved, take 0.1mL of sample water in Pipette and add to one AmVer Diluent Reagent Test 'N' Tube for high range ammonia nitrogen. From here follow the steps provided in the manufacturers method instructions.

6.2.2.2.3. Nitrate

Nitrate (NO_3^-) is reduced almost quantitatively to nitrite (NO_2^-) in the presence of cadmium (Cd). The HACH Method 8039 is based on the Standard Cadmium Reduction Method 4500-NO₃- E. This method uses commercial grade cadmium and through reactions forms a highly coloured azo dye that is measured colorimetrically.

6.2.2.3. Maintenance

7. Field Laboratory Analysis

Due to the geographic remoteness of many of the monitoring sites and the absence of dedicated wet chemistry laboratories in most sites, most of the measurements have been designed to be conducted in field. There are a few however that cannot be conducted in situ. A suitable field lab can be set up (see section 3.4) to accommodate the following analytical procedures:

- 1 Biochemical Oxygen Demand in wastewater
- 2 Recovery and Enumeration of Helminth Ova in compost and soils
- 3 Detection of total coliforms and *E.coli* in wastewater, compost and soils (Colitag or Colilert system)

7.1. Biochemical Oxygen Demand

Method will be described in a full SOP and summarised in text when the specific manufacturer has been chosen.

7.1.1. Summary of Method

Traditionally, the BOD measurement is performed according to a standardised method, described in the International Standards ISO 5815-1:2003 and ISO 5815-2:2003. The protocol consists of putting the samples potentially contaminated with organic matter into specific bottles, aerating them, and adding a microbial population. The bottles are then hermetically sealed and incubated in a dark room at 20 C. After an incubation period of 5 days, an electrochemical probe is inserted into the sealed bottle to measure the dissolved oxygen concentration in the sample in real time. This test however is not suitable for field based measurements due to the extended time period, dedicated working space, and may not be able to detect high organic loads.

Because of these factors the HACH Lange cuvette test has been chosen for trial for its portability, increase in measurement range and reduction in working space. The tests follow the same protocol as the standard method (dilution of samples with high organic loads, incubation at 20 C in a dark room, variability of the microbial population, and required analysis time) and are based on the dissolved oxygen consumption by the microorganisms present in the samples analysed during this period. The dissolved oxygen is analysed before and after the analysis period directly in the cuvettes. In the Hach Lange tests, the dissolved oxygen, after the addition of several reagents to the test cuvettes, forms a red dye proportional to the dissolved oxygen concentration. The measurement of this red dye by spectrophotometry allows the estimation of the oxygen consumption and, therefore, the BOD (Jouanneau, et al., 2014).

OR

Method 8043??

7.1.2. Equipment

7.1.3. Sample Collection and Preservation

The main consideration with sample collection is to prevent contamination of the sample with atmospheric oxygen.

- Analyse the samples immediately. The samples cannot be preserved for later analysis.
- Collect samples in 300 mL glass BOD bottles. Completely fill the bottles with de-ionised water.

7.1.4. Procedure

7.2. *E.Coli* and Total Coliform

Method will be described in a full SOP and summarised in text when the specific manufacturer has been chosen.

7.2.1. Summary of Method

7.2.2. Equipment

7.2.3. Sample Collection and Preservation

7.2.4. Procedure

7.3. Helminth Ova

7.3.1. Summary of Method

7.3.2. Equipment

7.3.3. Sample Collection and Preservation

7.3.4. Procedure

8. Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) refers to all those things that are done to make sure measurements are correct (accurate; the absolute true value), reproducible (precise; consistent), and include good estimates of uncertainty.

As outlined in sections 4.1 of this manual, it is important for field teams to properly calibrate and perform quality assurance checks of field parameter instruments. Table 3 and 4 lists the acceptable calibration and end of day check ranges.

The various steps conducted throughout the monitoring program and their related QA and QC activities are outlined in Table 24 adapted from the Freshwater Guidelines (ANZECC & ARMCANZ, 2000)

Quality Assurance: a system of documented procedures and plans established to ensure that the water monitoring program produces data of known precision and bias. This includes staff training programs, calibration processes, written procedures and record keeping. This also includes a quality control program.

Quality Control: operational activities that confirm the quality assurance methods are functional and that information collected is accurate, precise and properly recorded. Therefore, consistent QA/QC activities produce data of known quality.

Table 31: Methods for QA and QC

Step	Quality Assurance	Quality Control
Staff are properly trained	Staff are appropriately trained in an induction and provided with field/lab procedures	Supervision of new staff
Use of specialised equipment	Calibration procedures – all water monitoring equipment is calibrated using controlled standard solutions (section 4) Equipment maintenance procedures are in place	Limits placed on calibration results Any equipment failing calibration is not used until the problem resolved Equipment maintained as per appropriate specific manual for that equipment
Sample collection	Provide training in sampling techniques Methods outlined in water quality sampling manual (this document and associated SOP) Controlled field data sheets with clear site locations and the appropriate samples for each location Controlled and accurate sample labelling Controlled use of consumables – defined bottles appropriate for samples being collected	Use of field blanks
Record keeping	Data 'double recorded' – manually on worksheets and electronically within equipment memory	Data validation – data checked by second technical officer after being entered into the database
Storage and transport	Defined methods for storage of samples (e.g. use of ice, foil and minimisation of time between collection and storage)	Fridges and freezers monitored by use of data loggers
Sample analysis	Samples analysed using defined methods (including outsourced to accredited laboratory) Methods based on text: 'Standard Methods for the Examination of Water and Wastewater'	Use of calibration standards and laboratory blanks

8.1. Quality Control for Samples

Quality control samples are used with the collection of samples in the field. The purpose of these samples is to validate the precision and accuracy of laboratory or field equipment data, and to determine the adequacy of preservation techniques, equipment cleaning and preparation, and sampling procedures. These control tests are outlined in Table 25.

Table 32: Types of quality control and their uses

Sample Type	Description	Purpose	Collection Method
Duplicate samples	These are obtained when two or more samples are taken from the same site at the same time, using exactly the same methods. They are representative of the same environmental condition.	Replicate samples can be used to detect both natural variations in the environment and variations caused by field sampling methods.	At least two but preferably three samples are collected simultaneously (same site, date, time, depth, matrix and method) to establish the reproducibility of sampling.
Equipment blank	Rinsate (or equipment) blanks are created from the water or solvent used to rinse the field equipment	Rinsate blanks measure contamination introduced through contact with sampling equipment or the sampler.	Sampling equipment is cleaned and then the final rinse water or solvent is collected in a clean container, preserved as per normal and analysed.

8.1.1. Duplicate Samples

The purpose of a duplicate sample is to estimate the inherent variability of a procedure, technique, characteristic or contaminant. Duplicate samples are collected and duplicate analyses may be made in the field:

- 3) as a form of field quality control;
- 4) to measure or quantify the homogeneity of the sample, the stability and representativeness of a sample site, the sample collection method(s) and/or the field team's technique

Duplicates are analysed in the field or the laboratory space in the same way as the sample and are required for all field sampling events and each sample type. The results must have a Relative Percent Difference (RPD) less than or equal to the guidelines in Table 26.

The field data sheet and report, and laboratory data sheet and report must show test results for the duplicates, blanks and spikes, the method and the results for summary quality control statistics calculations. Copies of these reports are a permanent part of the site file.

Table 33: Frequency, acceptable range, and corrective actions for duplicate samples.

Type of duplicate	Frequency	Acceptable range for precision	Corrective Action
Field duplicate (samples)	Minimum of 1 per trip per parameter or 10% of all samples per parameter per day	Nutrients $\pm 30\%$ RPD; all other parameters $\pm 15\%$ RPD (need to check this for portable kits)	Audit field personnel and verify sample collection procedure; resample; reanalyze; revise SOP; audit and train field personnel; project manager determines whether associated data is usable
Field duplicates (multiprobes)	Minimum of 1 per trip per parameter or 10% of all samples per parameter per day	All parameters $\pm 10\%$ RPD	Re-calibrate instrument; replace batteries; perform instrument field check with different standards; repair or replace instrument; notify management; audit and train field personnel; project manager determines whether

8.1.2. Equipment Blanks

Blanks are an integral part of quality control (QC) and are required for all sampling activities. Their creation should be noted in the field log book. Blanks establish that there is no sample contamination from the containers during custody, transportation, and or pre-analysis preparation either in the field or in the laboratory space. Blanks establish the level of constituents introduced into a sample by the equipment used for sampling, preservatives, and/or containers. We will conduct equipment blanks prior to each field season in each country and occasionally during the field season between field sites to ensure field rinsing is adequate.

Collect an equipment blank prior to the field season as follows:

- 4) Clean all equipment used to collect, store and process water samples according to Part A of this protocol.
- 5) Rinse the equipment used to collect and store water samples with laboratory reagent grade water three times and discard.
- 6) Fill the sample collection container with a fourth aliquot of laboratory reagent grade water and handle and process this aliquot as if it were a sample to be analysed.

Another source of systematic error is sample cross contamination from field sampling equipment used to handle a multiple number of samples. The compositing jugs/buckets are to be rinsed in the field three times at each site prior to taking a sample. Either piece of equipment may be a source of cross contamination. Collect periodic equipment blanks as follows:

- 3) In between sample sites, rinse the equipment used to transfer water samples (integrating sampler and compositing jug) with laboratory reagent grade water three times and discard.
- 4) Fill the integrating sampler with a fourth aliquot of laboratory reagent grade water and handle and process this aliquot as if it were a lake sample to be analysed.

This sample is labeled as an equipment blank and information kept on a datasheet describing the source of the blank. Results for all parameters should be non-detect. This type of blank is a check for cross contamination between sampling sites and control for bias introduced by cross contamination.

Other types of blanks will be used as needed: field sampling conditions or ambient blanks, if there is any reason to suspect that ambient air pollution has the potential to contaminate water quality samples; preservative blanks, if there is any reason to suspect that a preservative may be contaminated; or bottle blanks, any time sample collection bottles are of uncertain quality or cleanliness or from a source not previously used.

8.1.3. Summary of Quality Control in the Field

Quality assurance protocols are means to ensure data collected are as representative of the natural environment as possible. Quality assurance procedures are required in all data collection efforts as part of this monitoring protocol (Table 27).

Table 34: Summary of QA/QC documentation and sampling methods

Procedure	Reason/Description
Instrument Calibration Logs	Each instrument must have a log in the form of a permanently bound logbook. Calibration schedule must be observed, using fresh calibration standards.
Project Folder	Containing: checklist of QA/QC reminders, copies of decontamination, sample collection and processing SOPs, copies of equipment calibration and troubleshooting instructions, blank field forms.
Site Folder	Containing: GPS coordinates for verification of correct sampling location, table of previous field measurements to compare with new measurements
Field Forms	Field forms are the only written record of field measurements, so copies are placed in site folders and originals must be kept on file indefinitely.
Field Instrument Methods	Require consistent measurement methods and detection limits
Sample preservation and minimum holding time	Water quality variable concentrations are maintained as close to sampling conditions as possible.
Chain-of-custody	A chain-of-custody includes not only the form, but all references to the sample in any form, document or log book which allow tracing the sample back to its collection, and documents the possession of the samples from the time they were collected until the sample analytical results are received.
Laboratory methods	Require consistent analytical methods and detection limits

Routine quality assurance gives greater confidence in the data being collected and the reproducibility of the results. Some general rules to follow are:

- Use calibrated instruments for all field measurements. Test and/or calibrate the instruments before leaving for the field. Each field instrument must have a permanent log book for recording calibrations and repairs. Review the log book before leaving for the field.
- All manually recorded field measurement data will be collected on field forms; data that are automatically recorded will be captured electronically and the equipment used will be documented on field forms. Hard and electronic copies will be made as soon as possible after surveys and kept at a separate location as backup.
- Complete records will be maintained for each sampling station and all supporting metadata will be recorded appropriately (field forms or electronically).

- Make field measurements in a manner that minimizes bias of results.
- Check field-measurement precision and accuracy. Follow the procedures in section 5.2
- Collect 10% duplicate water samples; conduct duplicate measurements of field parameters at approximately 10%.
- Create field blanks prior to the beginning of each field season and periodically throughout the season.

9. Data Management

While the details will vary, some of the key elements of good data management include data validation and verification (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc).

9.1. Data Collection

Data values are measured, observed, or estimated according to the GLKN inland lakes water quality monitoring protocol at various monitoring locations (sample sites) and recorded on field forms. Field team members are responsible for legible, accurate entries on field forms and in log books, including the calibration log. As a first step to verify data, field team members will check and double-check the recorded values on the day of data collection.

Data collected with a multiparameter probe and/or field instruments are stored directly on the probe and recorded on the field sheets at the time of sampling. The hard copy of the data serves as a back-up should something happen to the electronic data.

Digital images of sample sites are acquired during site establishment and periodically as sites change. Field team members are responsible for proper settings and use of digital camera equipment and should refer to the user manual for details specific to the camera.

GPS coordinates are recorded on the field sheets. Team members should refer to the user manual for details specific to the GPS Unit.

Water samples are collected, labeled, and packaged for laboratory analysis according to section 5. Identification numbers on sample containers, chain of custody forms, laboratory reports, and on the field data collection form facilitate management of laboratory results.

9.2. Data Verification and Data Validation

For the purposes of this manual, the term data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method and/or procedure. The goal of data verification is to ensure and document that the data are what they show to be, that is, that the reported results reflect what was actually done. Data verification applies to activities in the field as well as in the laboratory.

Sampling protocols, analytical methods, and project-specific planning documents are examples of sources that can provide the specifications for the environmental data collection activity. Data verification evaluates how closely these documents and procedures were followed during data generation.

For the purposes of this manual, the term *data validation* is an analyte and sample-specific process that determines the analytical quality of a specific data set. Validation asks the question, 'Given that the data are verified (that it is complete, correct and to requirements) is it valid to have it say what it says?' For example, the lab may have reported a low BOD result, and it may have been captured accurately and completely into the database, but other measurements taken on the day indicate there should have been a higher result. This needs to be followed up. Data validation applies to activities in the field as well as in the laboratory.

Once data is in the database, it will be verified and validated by the national project manager and sent to the RCPU Science Officer for secondary validation.

9.3. Data Security

Make at least one backup copy of the data on a suitable long-lasting medium (e.g., CD or USB). The original field proformas and raw lab analysis data (and backup copies) should be stored in a secure and well maintained filing system in the National Project Management Office. For additional security, send an electronic soft copy of field and lab data to the RCPU and it will be stored in the RCPU files.

9.4. Data Folder and File Organisation

All data from this water quality protocol should be stored, at the earliest possibility, on the national Project computer system and the GEF Pacific R2R central server.

Files should be named following these guidelines. Files have a 'R2R' prefix, defines IW or STAR, defines the country, a descriptive element, and finish with a date element. For example the following contains field data from Kiribati, South Tarawa on 15th June 2016. Do not use spaces in file names.

R2R_IW_Kiribati_ST_Field_Data_15062016.doc

9.5. Maintaining Metadata

Keep a description of the data and the methodology used to collect the data (e.g., a copy of the methods) with the field proformas, raw lab analysis data and the backup data. Keep a written record of where the data are stored, the data format and the names of relevant computer files with the field proformas and backup data. An example of the type of metadata that might be stored with the results of a monitoring survey is given in the below. The blank metadata form is available in [Appendix x](#).

Project Name:	<i>Tuvalu IW Pilot Project</i>		
Assessed by:	<i>Bobby</i>	Date Assessed:	<i>12/08/2016</i>
Database Info	Project ID: DLP809	Site ID: FunOS001	Year: 2016
Data Description:	<i>Results of water quality testing (BOD,N,P and e.coli) of the dry litter piggery site on the ocean side of Funafuti</i>		
Data Type:	<i>Spreadsheet Excel in 2007 format</i>		
Methodology:	<i>Data were collected using the protocol for monitoring municipal waste reduction indicators provided in Water and Waste Monitoring Toolkit version 1 (copy kept with this file)</i>		
Location of Files:	<i>The data and the original hard copy of this file is kept with IW Project Manager; a copy is stored on file with the Regional Project Coordinating Unit, SPC-GSD, Suva</i>		

9.6. Summary of Data Management

Data management procedures are a means to ensure that data is correctly recorded and most importantly that it is logically filed for easy retrieval for sharing and report writing. The steps below must be followed at every monitoring event

Procedure	Reason/Description
Instrument Calibration Logs	Complete as per section 3 and 4.
Field Forms	Complete field forms for every site and sample in the monitoring event Check and double-check each measurement as they are produced on the day
Field Form Review and Storage	Hand-written field sheets with field instrument data should be reviewed for completeness immediately upon returning to the office. Make photocopies as soon possible and file them appropriately. Download and back up data from the multisensor datalogger as soon as possible.