HONIARA

Ecosystem and Socio-economic Resilience Analysis and Mapping

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Our vision: The Pacific environment, sustaining our livelihoods and natural heritage in harmony with our cultures.

This report produced by BMT WBM for the Secretariat of the Pacific Regional Environment Programme (SPREP) presents Volume 3 (of three volumes) prepared as part of the Solomon Islands Ecosystems and Socio-economic Resilience Analysis and Mapping (ESRAM) to assess and prioritise climate change-related ecosystem-based adaptation options for selected locations in Solomon Islands. Volume 3 is the ESRAM report for the National capital, Honiara.

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List of Abbreviations

ADB	Asian Development Bank
CDC	community development committees
EbA	ecosystem-based adaptation
ESRAM	ecosystem and socio-economic resilience analysis and mapping
GIS	Global Information Systems
HCC	Honiara City Council
MECDM	Ministry of Environment, Climate Change, Disaster Management and Meteorology
MLHS	Ministry of Land, Housing and Survey
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
PSUP	Participatory Slum Upgrading Programme (UN-Habitat programme)
R2R	ridge-to-reef
SIWA	Solomon Islands Water Authority
SPC	The Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
TOL	temporary occupation licenses
WAC	Ward Advisory Committee

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- Ministry of Fisheries and Marine Resources
- Ministry of Infrastructure Development
- Ministry of Lands, Housing and Survey
- Honiara City Council
- Lord Howe Community
- Ren-Lau Community
- Koa Hill Community
- EHD / HCC
- No. 3 Community
- IS Zone 19
- Fijian Quarters
- UN-Habitat
    - Ecological Solutions Solomon Islands
    - Marble Street;

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- members of the local community who spoke with us opportunistically during site visits to share their views and concerns.

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Executive summary

Project overview

This report, *Solomon Islands ESRAM: Volume 3 Honiara,* presents the third in a series of three Solomon Island reports on ecosystem services, resilience and analysis mapping (ESRAM), prepared simultaneously for the Secretariat of the Pacific Regional Environment Programme (SPREP). It serves as the ESRAM study for one of three locations/scales selected as the focus for SPREP's present Pacific Ecosystem-based Adaptation to Climate Change (PEBACC) project in Solomon Islands, namely Honiara, the national capital and a major urban centre. This ESRAM study (and its counterparts in Vanuatu and Fiji) represent the first time such extensive and broad scale assessments have been undertaken to guide ecosystem-based adaptation (EbA) implementation in the Pacific region.

Aims and objectives

The aim of the ESRAM study was to provide a baseline overview of ecosystems and ecosystem services, to inform subsequent EbA phases of the PEBACC project involving the identification of EbA options for strengthening the resilience of Solomon Islands to the effects of climate change.

The objectives of the ESRAM study are listed below.

(1) Identify ecosystem types, ecosystem services and threats in the context of: ecosystem types present, the present condition or health of the ecosystems, key ecosystem services in terms of direct community dependencies, the role of ecosystem services in providing socio-ecological resilience, critical ecosystem linkages or dependencies, and the main existing threats to an ecosystem and/or ecosystem service.

(2) Map key ecosystems and related ecosystem services (where possible), including high-use areas and/or major threats based on existing spatial data.

(3) Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.

(4) Undertake a total economic valuation to define the economic value of key ecosystem services relevant to ESRAM.

(5) Assess the vulnerability of ecosystem services to the effects of climate change, based on climate change projections and in the context of other existing threats.

(6) Provide broad recommendations regarding strategic EbA options.

It is intended that this report (Volume 3) be read in conjunction with Volume 1 (BMT WBM 2017a), which provides further background about the broader ESRAM study and PEBACC project, along with a detailed description and justification of the approach and methodology employed for the Solomon Islands ESRAM study. The second volume (Volume 2, BMT WBM 2017b) presents the ESRAM assessment for the location/scale, Wagina Island in Choiseul Province.

Ecosystem-based adaptation options

Ecosystem-based adaptation (EbA) aims to increase the ability of local communities and ecosystems to adapt to the effects of climate change. Well-managed and healthy ecosystems are critical for the provision of essential services to maintain the health, well-being and livelihoods of all Honiara communities. The importance of ecosystem services is intensified in areas where basic infrastructure and services are lacking or

are unaffordable (e.g. water supply, subsistence-based living) for a large sector of the population. The ESRAM process has identified the vulnerabilities of social ecological systems to climate and non-climate change threats and impacts.

Based on the vulnerable ecosystem services identified, EbA options have been proposed to protect, restore and strengthen ecosystems and thereby increase the resilience of Honiara's communities and economies. Building environmental resilience to give ecosystems the best chance to adapt will, in turn, increase the likelihood of human adaptation to the adverse effects of climate change.

An effective governance structure within Honiara City Council (HCC) will be critical in building resilience to the effects of climate change, while collaboration between all levels of government is needed to assist HCC to increase its technical and long-term capacity to manage Honiara's ecosystems and their services. Building the skills and capacity across all relevant agencies is critical, so that essential services and infrastructure are effectively distributed to all residents of Honiara and adequately managed in the urban environment. Mainstreaming climate change into all regulations, policies and programmes is also essential to ensure that all decision-making processes consider climate adaptation and contribute to building a climate-resilient city.

Urban population growth and development is a key threat to the increased degradation of ecosystems and further reduces the resilience of communities to natural hazards, particularly in informal settlement zones, where overcrowding and exposure to natural hazards are currently high. All levels of government must work together to improve the existing infrastructure and services, enforce building regulations and monitor all new developments. The provision of affordable housing for low-income earners should also be explored by HCC and the Provincial Government to reduce the rapid urban growth rate of informal settlement zones.

By providing adequate access to basic services, infrastructure and shelter, the environmental, social and economic condition will be enhanced and Honiara's resilience to the effects of climate change will be strengthened.

Honiara ESRAM outcomes

Honiara is a highly populated urban centre; it is Solomon Islands' hub of commercial enterprises and government operations, and is the major air and sea connection to the rest of the world. Honiara is experiencing rapid rural-urban migration, predominantly in informal settlements, which are exposed to multiple natural hazards, are overcrowded and lack basic services. In both the upper and lower catchments, many households are largely subsistence-based, relying heavily on ecosystem services for their water and food provisions, shelter, income generation and overall health and well-being. However, the ability of these ecosystems to continue to provide these essential services is decreasing, due to activities such as logging, agriculture, pollution, and over-exploitation of marine resources. As Honiara's population growth rate exceeds the national growth rate, these activities will only intensify and are likely to have an increased detrimental effect on the communities and economies of Honiara. Without effective management of ecosystems, the direct and indirect effects of climate change and their interactions with human-induced threats are likely to reduce the resilience of social and ecological systems.

Freshwater ecosystem services

The key anthropogenic threats to Honiara's freshwater ecosystem services are land-clearing on steep slopes (for logging and cultivation purposes), pollution of waterways from poor sanitation and solid waste practices, rapid urban population growth, and unsustainable urban development. The key climate change threats to freshwater ecosystem services are the projected increase in extreme rainfall events and saltwater intrusion from sea-level rise. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure resilience under future climate conditions are:

- provision of drinking and domestic water provided by streams, rivers, groundwater and urban springs;
- provision of food provided by streams and rivers;
- flow regulation provided by streams and rivers;
- recreation uses (swimming) provided by streams and rivers;
- supporting habitat and biodiversity; and
- income generation (fishing and aquaculture) provided by streams and rivers.

The high reliance on freshwater resources for many households, predominantly informal settlements, combined with the reduced water quality and a rapid urban growth rate, are critical issues for building Honiara's resilience to future climate change effects. If effective measures are not implemented to conserve freshwater resources and improve water quality issues, Honiara residents who rely on the essential ecosystem services for their well-being and livelihoods, such as food and water supply, will need to find alternative means to strengthen their resilience to the future effects of climate change.

Coastal and marine ecosystems and services

Habitat loss and coastal development continue to severely degrade the city's coastline and expose the area to further coastal erosion and destruction, while the high level of pollution received from much of greater Honiara's day-to-day activities is severely affecting the marine water quality, sediment quality, and the condition of flora and fauna communities. Over-exploitation and unsustainable fishing practices are depleting

marine resources, and the increasing urban population growth will exacerbate these threats. In terms of climate change, sea-level rise, an increase in air and sea temperatures and associated ocean acidification and coral bleaching, and an increase in extreme rainfall events are projected to have the greatest effect on coastal and marine ecosystem services.

The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure Honiara's resilience under future climate conditions are:

- provision of food and income-generation from local fisheries (commercial and subsistence) and tourism from marine and coastal waters;
- provision of habitat and biodiversity provided by coastal and marine waters;
- provision of raw materials for building and construction, provided by coastal and marine waters;
- coastal hazard protection by the attenuation and buffering of wave and storm energy by reefs at Point Cruz and shoreline stabilisation by mangroves at the Lungga River delta; and
- provision of cultural artefacts and ornaments (shell money, ornaments, jewellery and decorations), cultural identity and status, and *kastom* medicine provided by coral.

Marine and coastal ecosystem services are vital to the livelihoods and well-being of a large number of households, particularly low-income households that are heavily subsistence-based, for both subsistence and income-generation purposes. The depletion of marine resources, and the corresponding reduced generation of income, will affect food security by forcing households to be more dependent on the market, which can have severe consequences due to fluctuating prices. The high reliance on resources for subsistence, combined with the depletion of marine resources and a rapid urban growth rate, are critical issues for building Honiara's resilience to future climate change effects. A balance between meeting the subsistence food needs of households and maximising economic benefits through the export and sale of marine products is needed to build social and economic resilience. In turn, marine ecosystem resilience needs to be enhanced by improving water quality, reducing coastal development pressures and managing fisheries resources sustainably.

Terrestrial watershed ecosystem services

Logging, timber-milling, land cultivation and the expansion of settlements are the major threats to the terrestrial watershed. These activities result in deforestation, soil erosion and reduced land stability, which have significant cumulative effects on downstream areas from increases in run-off, flooding, and an increased risk of landslides during periods of high rainfall. Cultivation activities are likely to introduce chemicals into the environment through the use of pesticides, while settlements and development increase pollution inputs from waste production. These activities increase the level of pollution entering the waterways and severely affect the receiving environments downstream. As the population is rapidly growing, land-clearing for settlements, development and cultivation is also increasing.

The climate change projections likely to have the greatest effect on ecosystem services of the terrestrial watershed are an increase in extreme rainfall events and an increase in air temperature. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure resilience under future climate conditions are:

- provision of food from cultivated gardens and plantations in upper and lowland areas (including backyard gardens) and waterways;

- erosion control and land stability;
- supporting habitat and biodiversity by forests and waterways;
- regulating services, including water quality and flow and air quality;
- provision of raw materials for building (timber) and fuel (fuelwood);
- cultural services, including the provision of medicinal plants and trees; provision of materials for traditional costumes, ornaments and cultural artefacts; and the provision of areas for reconnecting with traditional land-based cultural practices; and
- provision of shade and cooling mechanisms provided by urban green spaces.

Honiara City and greater Honiara area land-use change affects the levels of these regulating services, while the interaction of land-clearing and climate change is predicted to affect the provision of stable climatic conditions and threaten human health, food security and livelihoods. In order to tackle future climate change threats, it is critical to address the immediate development challenges associated with unregulated clearing, clearing of riparian areas, unsustainable logging and agricultural activities, and poor sanitation and waste management practices. As these activities continue to severely damage and deplete ecosystem services provided by the watershed, Honiara's resilience to current and future threats will continue to weaken. Building the resilience of ecosystems and communities to projected climate change effects through reforestation, clearing regulations and forest protection will need a collaborative approach from people across all catchment areas.

1 Introduction

1.1 Background

This report, *Solomon Islands ESRAM: Volume 3 Honiara,* presents the third in a series of three Solomon Island reports on ecosystem services, resilience and analysis mapping (ESRAM) prepared simultaneously for the Secretariat of the Pacific Regional Environment Programme (SPREP). It serves as the ESRAM study for one of two locations/scales selected as the focus for SPREP's present PEBACC project in Solomon Islands, namely Honiara, the national capital and a major urban centre.

1.2 Aims and objectives

The aim of the ESRAM study was to provide a baseline overview of ecosystems and ecosystem services to inform subsequent EbA phases of the PEBACC project involving the identification of ecosystem-based adaptation options for strengthening the resilience of Solomon Islands to the effects of climate change.

The objectives of the ESRAM study are listed below.

(1) Identify ecosystem types, ecosystem services and threats in the context of:

- ecosystem types present, in the context of the relevant ecosystem services;
- the condition or health of the ecosystems present, based on existing information if available and/or recent observations (qualitative or opportunistic) throughout the course of the assessment;
- key ecosystem services in terms of direct community dependencies;
- the role of ecosystem services in providing socio-ecological resilience;
- critical ecosystem linkages or dependencies; and
- the main existing threats to an ecosystem and/or ecosystem service.

(2) Map key ecosystems and related ecosystem services, including high-use areas and/or major threats based on existing spatial data.

(3) Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.

(4) Undertake a total economic valuation to define the economic value of key ecosystem services relevant to ESRAM.

(5) Assess the vulnerability of ecosystem services to the effects of climate change, based on climate change projections and other existing threats.

(6) Provide broad recommendations regarding strategic EbA options.

This ESRAM study (and its counterparts in Vanuatu and Fiji) represent the first time such extensive and broad scale assessments have been undertaken to guide EbA implementation in the Pacific region. An additional objective of the ESRAM studies is, therefore, to provide a case study for future knowledge sharing and developments in the application of EbA elsewhere.

1.3 Volume 3 report scope

While ESRAM considers three geographic locations/scales, this Volume 3 report is the Honiara scale assessment, which, along with the Wagina assessment, is a more detailed exercise than the national scale (higher-level) assessment.

It is intended that this report (Volume 3) be read in conjunction with Volume 1 (BMT WBM 2017a), which provides further background about the broader ESRAM study and PEBACC project, along with a detailed description and justification of the approach and methodology employed for the Solomon Islands ESRAM study. The second volume (Volume 2, BMT WBM 2017b) presents the ESRAM assessment for the location/scale, Wagina Island in Choiseul Province.

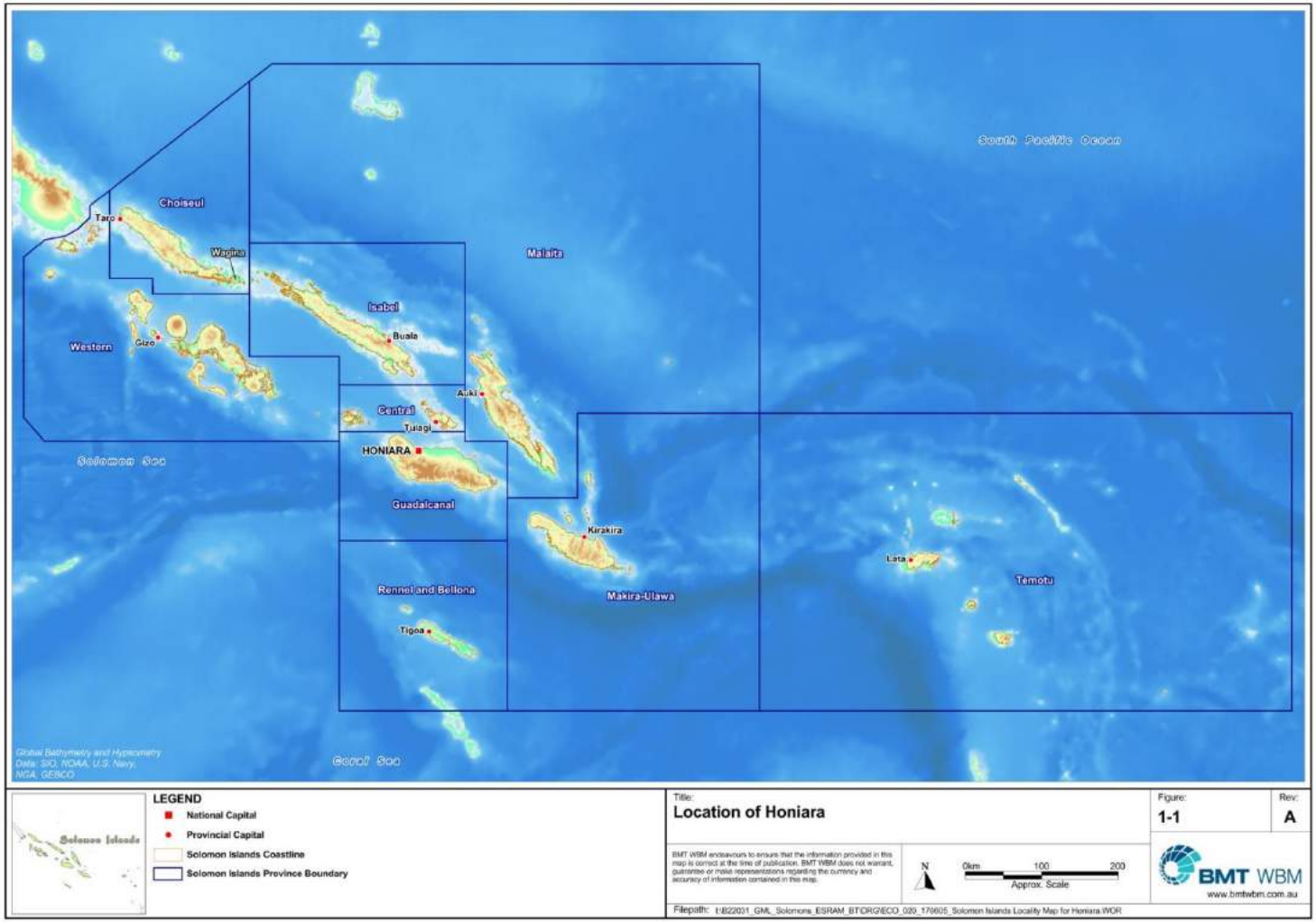

Figure 1-1 Location of Honiara

2 Honiara specific methodology

2.1 Study approach

The three Solomon Island ESRAM studies (national, local and city) follow the conceptual framework presented in Figure 2-1. This generic methodology has been adapted for each of the spatial scale/location contexts, depending on factors such as geographic extent, stakeholder engagement requirements and community/population size. Additional and/or specific methods relevant to the Honiara approach are detailed below.

The ESRAM assessment for Honiara was largely informed by existing information and information sourced through a participatory workshop with key stakeholder representatives, as described below.

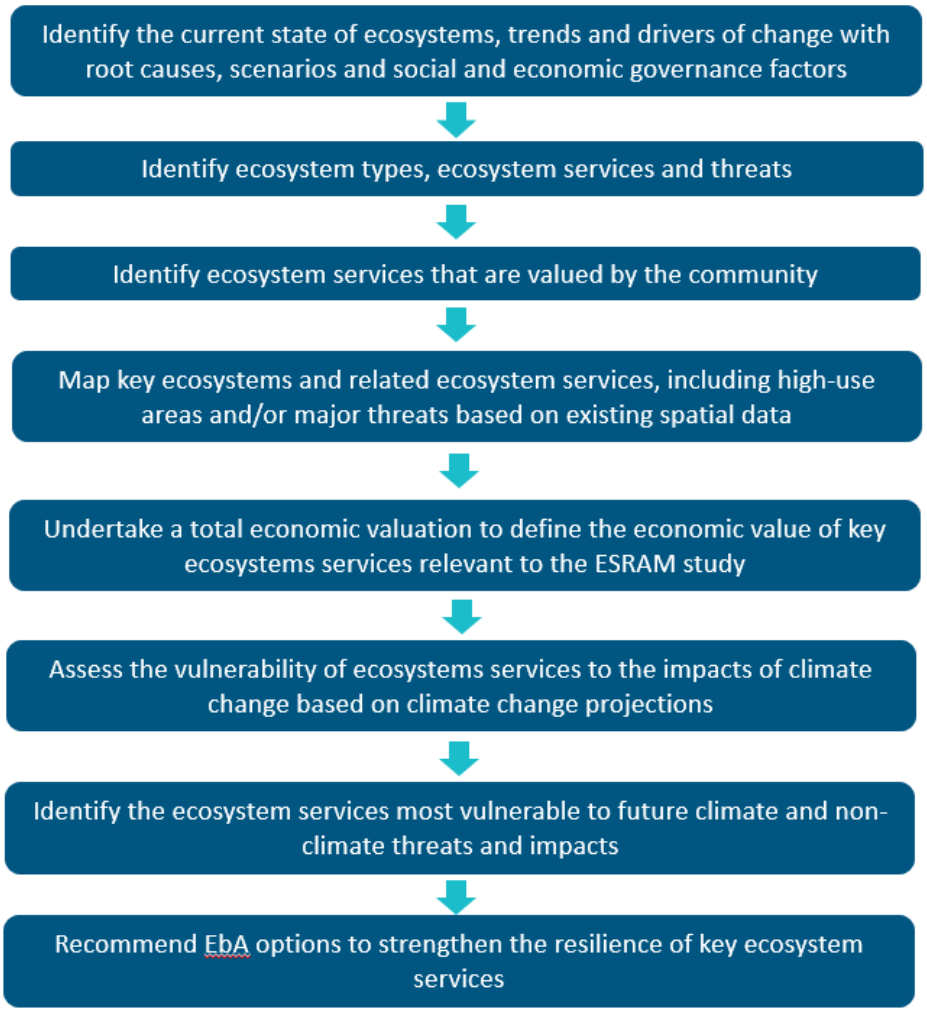

Figure 2-1 Conceptual framework

2.2 Review of existing information and validation

Key information sources and existing programmes with respect to climate change vulnerability and adaptation in Honiara reviewed in this project are listed below.

- *Honiara Urban Resilience and Climate Change Adaptation Plan: a joint strategy for the Honiara City Council and Solomon Islands Government* (UN-Habitat 2016a)
- *Cities and Climate Change Initiative, Honiara, Solomon Islands, Climate Change Vulnerability Assessment* (UN-Habitat 2014)
- *Solomon Islands National Report: TA7394 Strengthening the Capacity of Developing Member Countries to Respond to Climate Change* (ICEM 2012)
- *Solomon Islands National Climate Change Policy 2012–2017* (Wickham *et al.* 2012).

The information sourced from the workshop was validated and incorporated into the ESRAM study through a combination of complementary information-gathering methods, including:

- site inspections at key points of interest, particularly those highlighted through the workshop outcomes;
- remote sensing with high resolution satellite imagery;
- conferring with existing information sources, especially the available GIS data; and
- additional opportunistic on-ground observations.

An overview of the participatory stakeholder workshop is provided in Section 2.3.

Figure 2-2 Team members Simon Albert and Donald Kudu have informal discussions with community members at a) Ren-Lau and b) Win Valley settlements

The next stage of the project (i.e. options assessment and preparation of implementation plan) will incorporate further community liaison and site assessment at the selected project demonstration site(s) for Honiara.

2.3 Workshop methodology

The participatory workshop with key stakeholder representatives was held in Honiara on 10 August 2016. While not all key stakeholders were able to attend on the day, ongoing liaison has ocurred, and will continue to occur, as appropriate throughout the project.

Key objectives of the workshop-based consultation were:

- to provide follow up and further stakeholder consultation after SPREP's initial PEBACC Inception Workshop held in Honiara in March 2016 (i.e. more locally relevant information on the Honiara aspects of the ESRAM study and to a broader audience, including community representatives);
- to provide some awareness on ecosystems, ecosystem services and climate change in both the local (Honiara) context and that of the PEBACC projects;
- to utilise and document the local and professional knowledge of the stakeholders to inform the ESRAM study, with a particular focus on:
    - identifying local ecosystem types and locations;
    - documenting ecosystem services in terms of the community's direct dependence on their local land and sea resources; and
    - undertaking interactive mapping exercises to spatially document ecosystem services, with a particular focus on high-use areas;
- to identify existing threats to the ecosystems and/or ecosystem services, noting that there is often a strong overlap between ecosystem services and existing threats to ecosystems (e.g. in terms of over-exploitation of a particular land or sea resource); and
- to identify the key locations of concern with respect to existing threats, and nominate the threats perceived to be of highest priority.

For interactive aspects of the workshop, participants were split into four groups, each with a different broad geographic and/or ecosystem type to address, including:

(1) urban/built-up areas;

(2) coastal and marine areas;

(3) rivers and streams; and

(4) watershed (e.g. forested catchment).

This approach was found to enable participants to better focus on the activity by concentrating on a defined area, rather than more broadly addressing the whole of Honiara.

A summary of the workshop participants is provided Table 2-1. A total of 21 participants attended on the day, comprising a relatively even spread of government, community, and non-governmental stakeholders, e.g. land, planning and environmental consultants; church representatives; and professionals involved in the UN-Habitat project for Honiara). Gender diversity of the participants was skewed towards men. However, women were

still reasonably well represented, comprising one third of participants. A full list of the workshop participants is provided in Appendix A and photographs of participants engaged in an interactive exercise at the workshop are provided in Figure 2-3.

Table 2-1 Summary of workshop attendees, 10 August 2016

	Government	Community	Other	Total
Total number of participants	9	8	10	27
Proportion of men	67% (6)	62% (5)	70% (7)	**67%**
Proportion of women	33% (3)	38% (3)	30% (3)	**33%**

Figure 2-3 Stakeholders conducting participatory activities as groups: a) watershed, b) rivers and streams, c) coastal and marine, d) urban and commercial areas

3 Honiara ESRAM setting and context

This chapter provides the relevant context for the Honiara ESRAM study, including:

- information about the Honiara setting, such as geography and study extent; current state of the environment, including biodiversity and conservation; socio-economic profile; and governance, including climate change governance; and
- exploration of trends, drivers of change (non-climatic) and scenarios, and the environmental consequences of these changes specific to Honiara. (Trends and drivers of change that are representative across Solomon Islands, i.e. across the national, Honiara and Wagina scale, can be found in Section 5, Volume 1: ESRAM Introduction and National Assessment report.)

3.1 Geographic setting and study extent

Honiara is the capital of Solomon Islands and is located on Guadalcanal Island, the largest island in Guadalcanal Province. The city is located on the north-western coast of the island and is flanked inland by steep hills that have largely been cleared of forest (UN-Habitat 2012). The boundary of Honiara City Council (HCC) (Figure 3-1) is approximately 11.5 km by 2.7 km at its longest and widest (total area is around 23 square kilometres), extending from 9°25'30.68"S, 159°54'52.88"E to 9°25'25.44"S, 160° 1'22.61"E.

The HCC area traverses the lower reaches of three major watersheds – Kongulai, Mataniko and Lungga Rivers – as well as several smaller urban watersheds (Figure 3-1). Given the connectivity of watersheds, the ecosystems in these lower reaches are intrinsically linked to environmental processes and functions in the watershed reaches further upstream (i.e. outside the HCC boundary). Further, many consider some developed locations beyond the HCC boundary to be part of Honiara. For example, the international airport is located outside the HCC boundary. For these reasons, it was agreed (via consensus of ESRAM workshop participants) that, while the Honiara ESRAM project would focus on adaptation in the sense of priority needs for the community of HCC, it would also need to consider links with 'greater Honiara' and watershed reaches further upstream.

Much of the built-up areas of Honiara are confined to a relatively narrow coastal strip where the land is relatively flat. The close proximity of rugged hills and ridges to the coastline limit the feasibility of development extending excessively beyond the coastal strip. Some residential areas, primarily informal settlements, are extending southward into increasingly undulating topography. However, they are commonly restricted to the comparatively flat land adjacent to waterways (and prone to flooding) or on steep hillsides prone to erosion and landslides. Lateral land reclamation and development along the coastal strip of Honiara is also presenting relatively new planning issues. Illegal seafront developments are taking place at various coastal areas, including Point Cruz, Rove and Ranadi, with minimal intervention from government authorities. If development continues, Honiara is at risk of becoming landlocked.

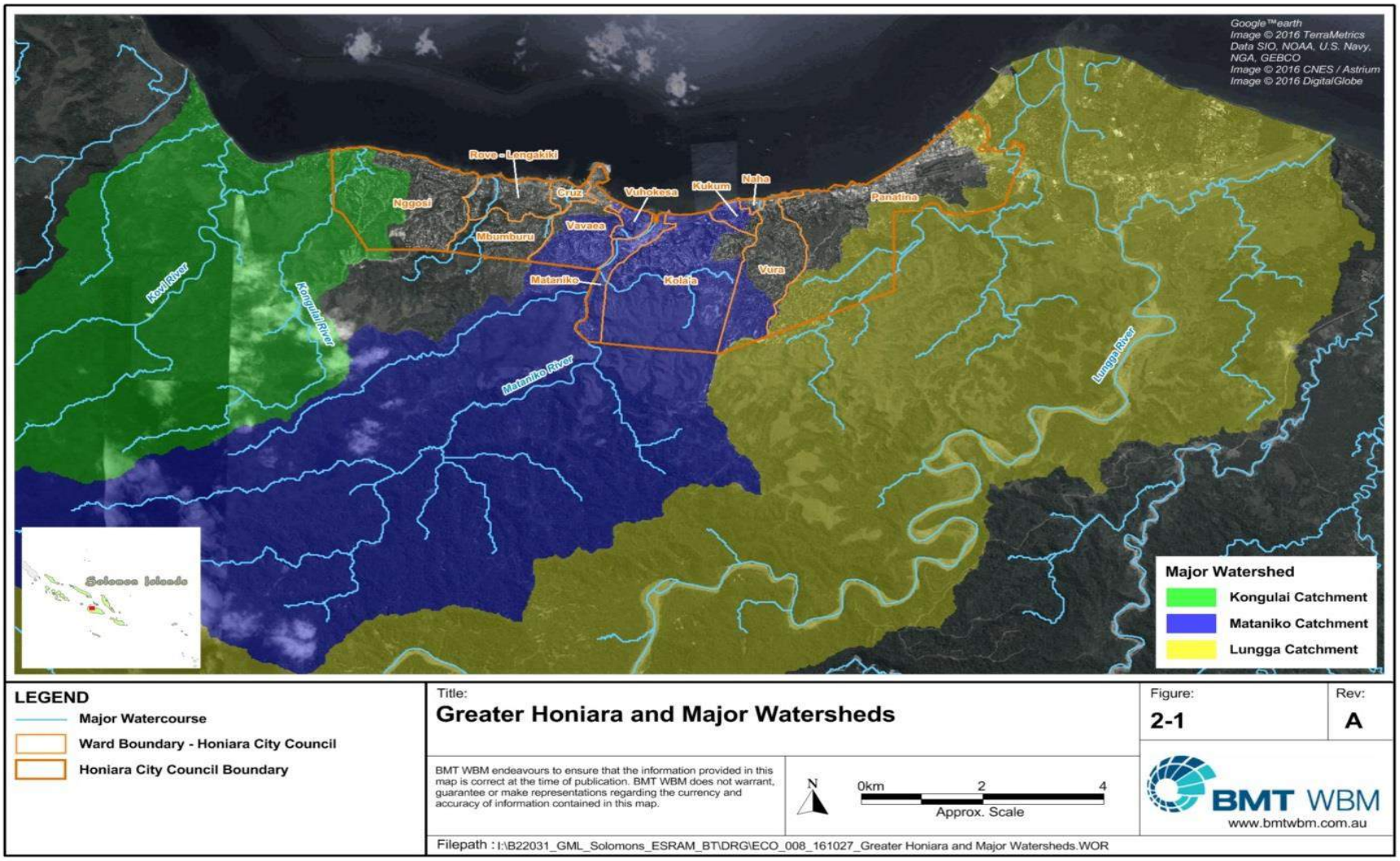

Figure 3-1 Greater Honiara and major watersheds

3.2 Environment and biodiversity

Honiara is in a highly developed state and does not contain areas of outstanding biodiversity value, in contrast to the widely recognised high biodiversity values in other parts of Solomon Islands. For this reason, the ecology of existing habitats in Honiara have not been the subjects of significant environmental research.

Despite being in a degraded state, existing ecosystems of Honiara provide a range of essential ecosystem services to the human population of Honiara. It is these uses and values that are documented and explored in this report.

Prior to the development of Honiara, terrestrial and coastal forests dominated the area. Along the coast, Point Cruz and the Lord Howe Settlement areas were mangrove swamps. Mangroves were cleared at Point Cruz and the land reclaimed to build the Solomon Islands Ports Authority, followed by the National Referral Hospital at the eastern part of Mataniko River mouth, where the Lord Howe Settlement exists today. A natural wetland system exists as part of the coastal area and Lungga River estuary, but disposal of raw sewage and rubbish, landfill activities from the Ranadi dump site, and uncontrolled sand-mining and land-reclamation along the coastal area, have caused severe degradation and erosion to the area (ICEM 2015).

Throughout the mid-catchment areas of Honiara, vegetation has been extensively logged and cleared for agriculture, while lowland hill areas (where secondary forest would have occurred) have been converted to subsistence gardens (*ibid*). ICEM (2015) reports that low fertile land in the lowland areas of the Lungga River catchment are frequently burnt for swidden cultivation. Riparian areas throughout the mid-catchment areas are vulnerable to erosion and mass soil movement (*ibid*).

Forests in the upper catchment outside Honiara City continue to be logged commercially, using small portable sawmills (ibid). Logging has resulted in increased rates of erosion, run-off and sedimentation in rivers and creeks downstream. Severely degraded areas with steep slopes are prone to landslides during periods of extreme rainfall, while areas of riparian agriculture are prone to flash flooding during the wet season. Upper catchment activities continually affect lower catchment areas, including coastal and marine ecosystems.

3.3 Existing climate

3.3.1 Overview

Honiara has a two-season tropical monsoon climate, marked by little variation in month-to-month temperatures but distinct variability in rainfall throughout the year (Figure 3-2). The minimum and maximum daily temperature range from 22°C to 23.5°C and 30.1°C to 30.7°C respectively (SIMS *et al.* 2013), while rainfall ranges between <100 mm in the dry season (May to October) to >300 mm in the wet season (November to April) (UN-Habitat 2016a).

The average annual rainfall is approximately 2,000 mm, which is lower than the average of 3,000 mm experienced by the country as a whole. The annual wet season, with rainfall averages of 210 to 380 mm per month) is associated with the northwest monsoon season. Monsoon rainfall, combined with tropical cyclones, results in flooding events in Honiara.

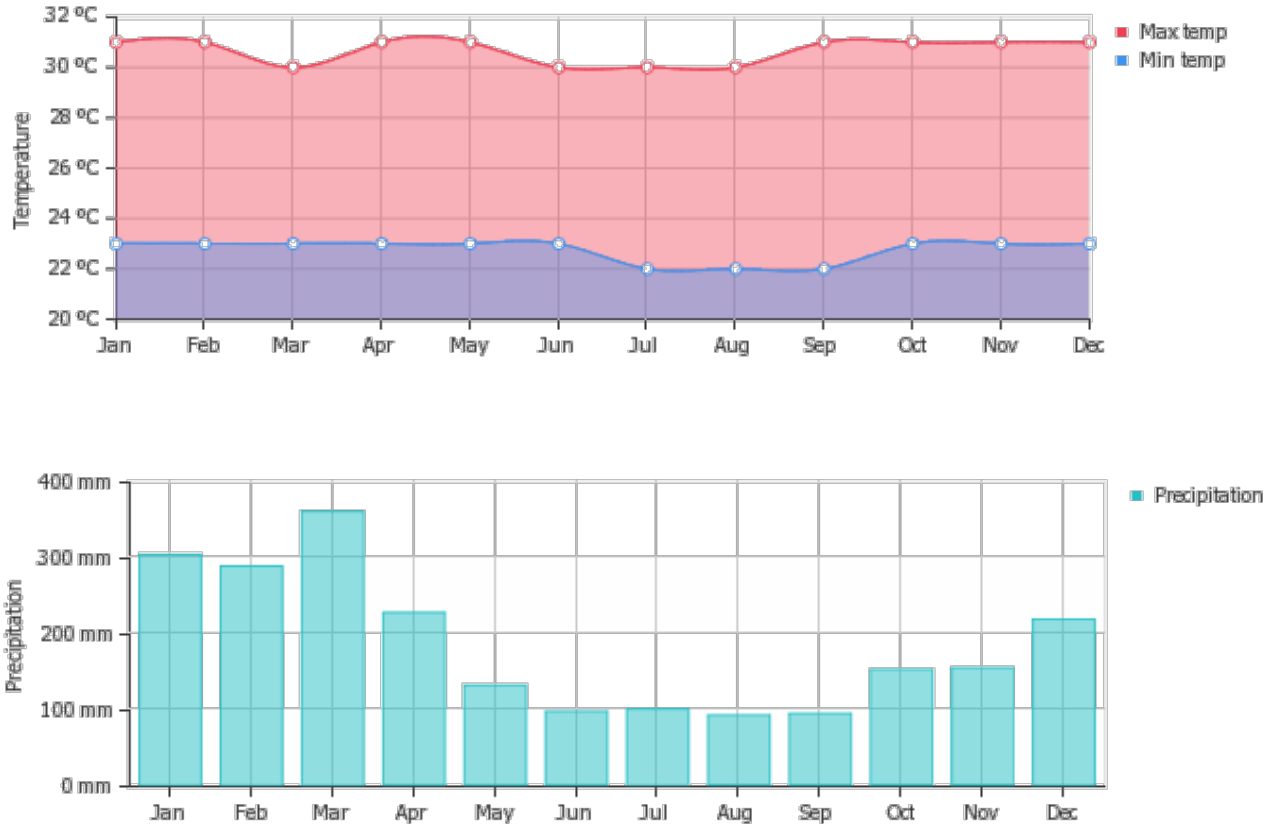

Figure 3-2 Average monthly minimum and maximum air temperatures (top) and rainfall (bottom) in Honiara (Source: 2010–2016 World Weather and Climate Information)

As Solomon Islands is located at the juncture of the South Pacific Convergence Zone, the Inter-Tropical Convergence Zone and the West Pacific Monsoon, there is significant inter-annual variability in climate, particularly in terms of total annual rainfall (UN-Habitat 2016a). Variation in long-term rainfall trends is demonstrated in the SIMS data shown in Figure 3-3.

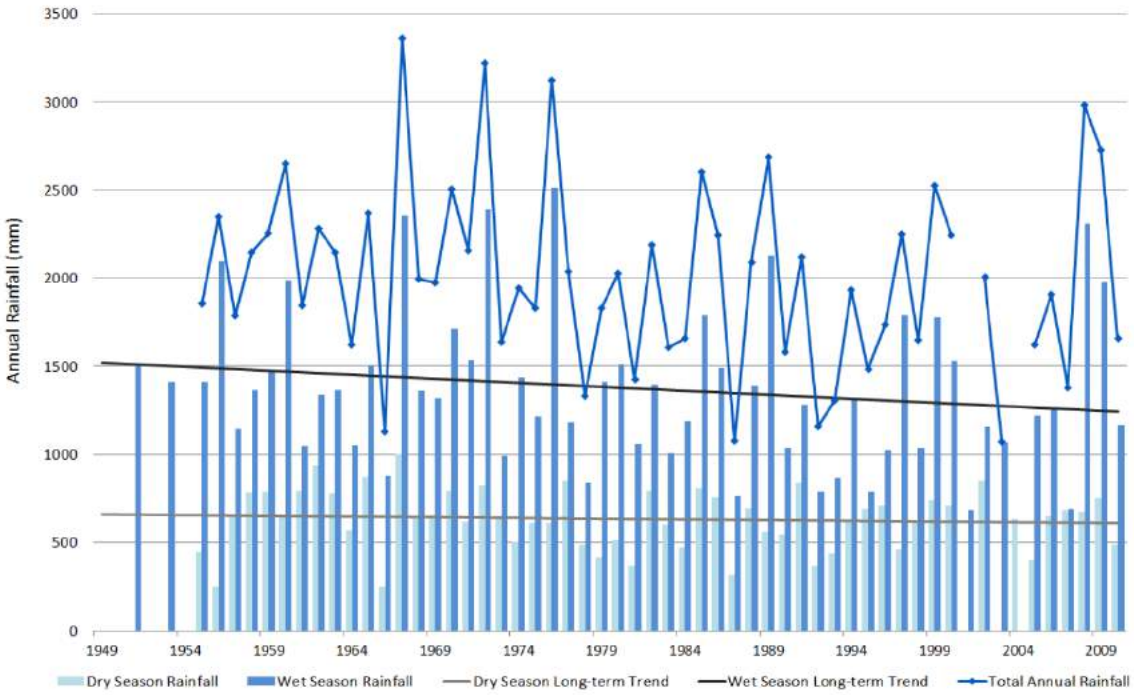

Figure 3-3 Honiara long-term rainfall variability and trends by season (reported in UN-Habitat 2016a)

3.3.2 Extreme weather events

The tropical climate and converging regional climate systems of Honiara expose the city to extreme weather events. These include:

- flash flooding (from overland flow) and riverine flooding;
- storm surges;
- tropical cyclones; and
- drought.

Flooding risks are the result of high levels of rainfall in the wet season (as described above) and the large catchment areas upstream of the city (UN-Habitat 2016a). UN-Habitat (2014) indicates that approximately 44% of the population in the city is prone to flooding, with the highest risk areas being adjacent to the Lungga and Mataniko rivers. The most extreme flooding event on record is the April 2014 flood, caused by a peak daily rainfall of 318 mm (3 April 2014). Modelling-based analysis of this event suggests it was caused by an event with a 1-in-100 year average recurrence interval (ARI) (Lal and Thurairajah 2011).

On average, one tropical cyclone passes within 400 km of Honiara each year. The occurrence of cyclones varies from year to year but are most likely to occur between November and April, during the north-west monsoon season. UN-Habitat (2016a) notes that cyclones are twice as likely to pass close to Honiara during El Niño conditions than during La Niña conditions. Cyclones cause storm surge events as well as heightened rainfall levels and extreme wind.

No assessment has been conducted on the typical storm surge events in Honiara. However, modelling conducted at Taro Island in Choiseul Province identified a storm surge of 3.1 m on mean sea level during the 1-in-100 year ARI event (BMT WBM 2014). While this is ~500 km north-west of Honiara, it is reasonable to expect similar storm surge levels in Honiara.

Cyclones and storm surges exacerbate coastal erosion because of more frequent and higher energy waves. Much of the coast of Honiara does not have natural or artificial defences from coastal processes, including waves, and is therefore considered to be at risk. Figure 3-4 presents indicative hazard areas associated with extreme weather events, as mapped by UN-Habitat (2016a).

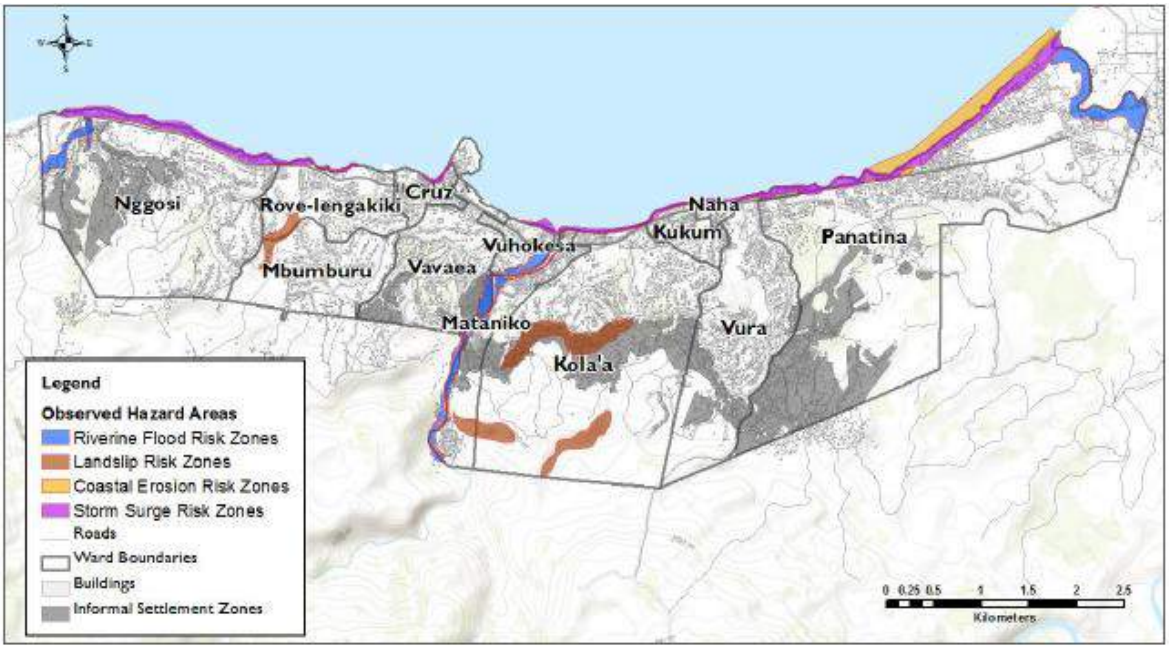

Figure 3-4 Climate-related hazard areas (UN-Habitat 2016a)

Drought events occur across Solomon Islands, and are often linked to El Niño events, but data on historical trends in drought events are limited.

3.3.3 Climate trends and projected changes specific to Honiara

Monitoring of rainfall and temperature trends for Honiara has been undertaken since the 1950s. Trends identified from this monitoring indicate that changes in annual rainfall are not statistically significant but warming is evident across mean, maximum and minimum air temperatures (UN-Habitat 2016a) (see Figure 3-5 and Figure 3-6). SIMS *et al.* (2013) also indicate a trend of warming sea-surface temperatures at a rate of 0.12°C per decade since the 1970s.

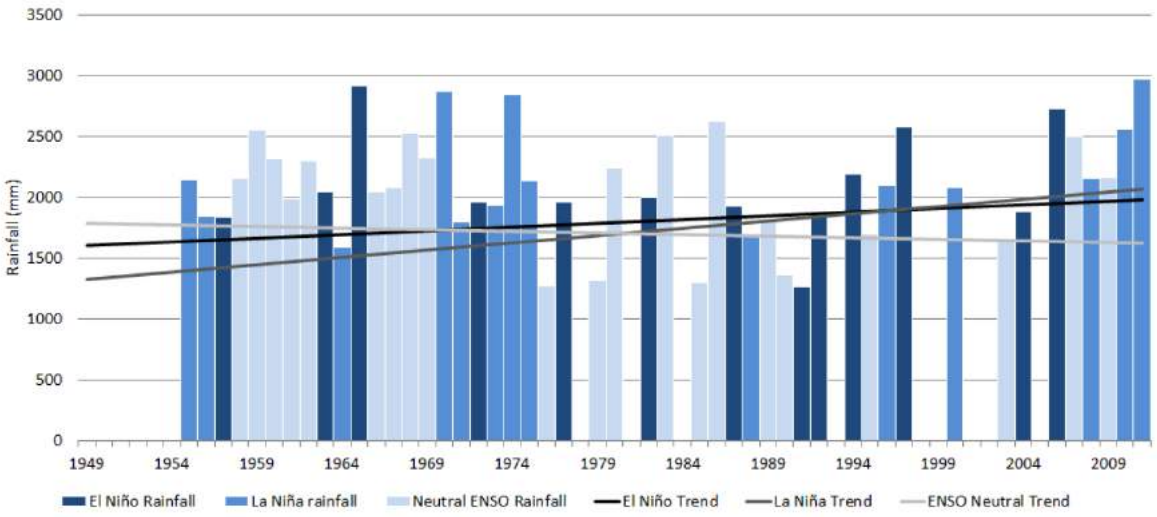

Figure 3-5 Long-term monitoring data and trends in Honiara rainfall (UN-Habitat 2016a)

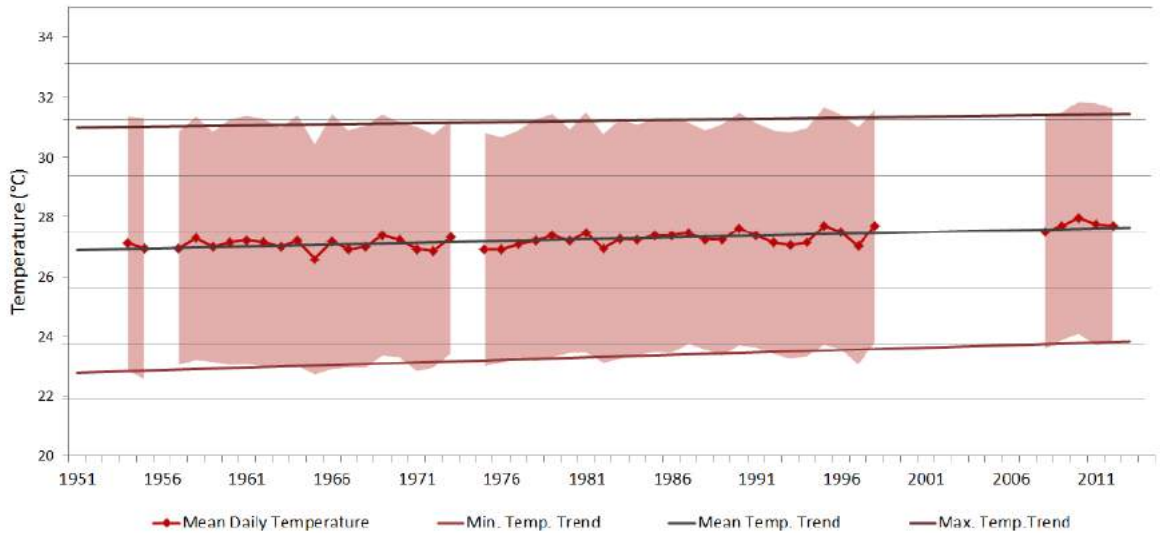

Figure 3-6 Long-term monitoring data and trends in Honiara air-surface temperature (UN-Habitat 2016a)

Climate change projections for Solomon Islands are outlined in Volume 1, Section 7.2 (BMT WBM 2017a). Climate projections (Australian Bureau of Meteorology and CSIRO 2014) are based on the very high IPCC emissions scenario Representative Concentration Pathways (RCP) 8.5, the highest scenario of the 5th Assessment Report, for the short term (2030) and longer term (2090). All projected changes represent the overall change relative to 1995 levels of each climate variable.

3.4 Socio-economic setting

3.4.1 Population

The population of Honiara in 2015 was reported to be 87,000 (UN-Habitat 2016a) which is a 35% increase from the 2009 population of 64,609 (2009 census data). As illustrated in the population growth scenario in Figure 3-7, Honiara's annual growth rate slowed from 1990 to 2010, but recent statistics indicate a growth rate of 2.7% in 2010 and a projected annual growth rate of 2.9% until 2020 (SINSO 2015; UN-Habitat 2016a). This spike in annual growth is expected to slow again from 2020 to 2050 to approximately 1.2%.

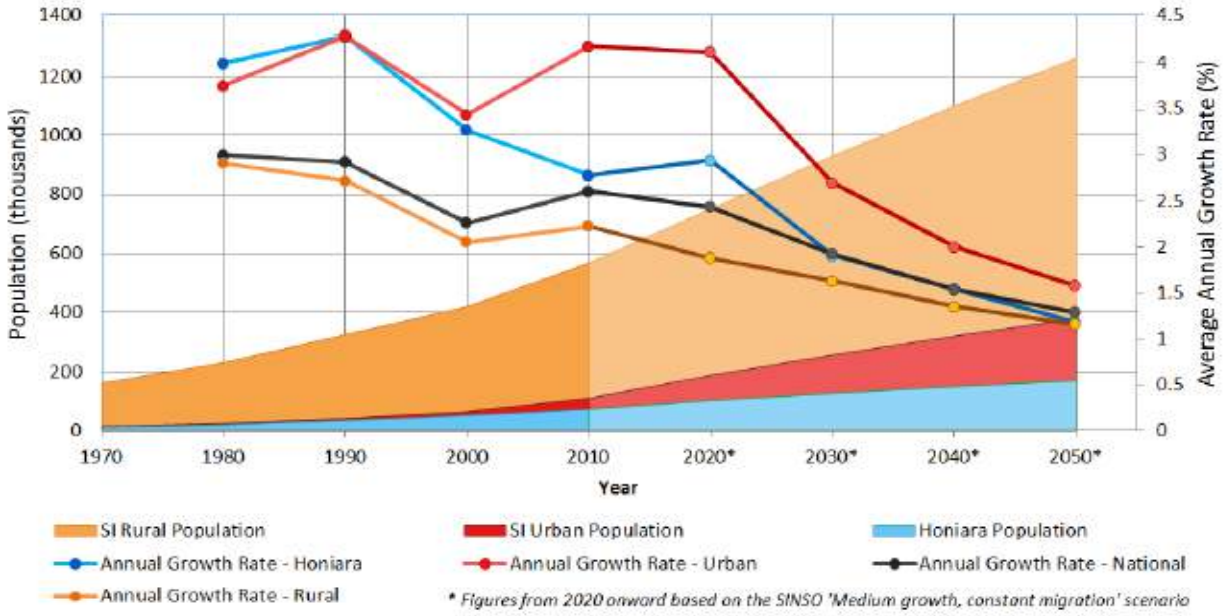

Figure 3-7 Solomon Island historical and projected population and growth dates (UN-Habitat 2016a)

A high population growth rate means increasing demands for terrestrial and marine resources. Increasing populations can lead to overfishing; an increased rate of land clearing; the use of destructive fishing methods; food shortages; the overall degradation of marine, freshwater and terrestrial ecosystems; and a depletion of resources.

3.4.2 Urbanisation

UN-Habitat (2015) has described the Pacific as being the world's fastest-urbanising region. Keen and Barbara (2015) indicate that, in almost all Pacific countries, urban growth rates are now higher than national growth rates.

Honiara's population represents approximately 20% of the total national population (SOE 2008; UN-Habitat 2016a, 2016b). Between 1999 and 2009, Honiara's annual urban growth was a high 4% (compared to the annual national population growth of 2.3%), representing a doubling time of 15 years (UN-Habitat 2016b). The pull factor for Honiara's urban migration is the increased economic opportunities and increased access to services and educational facilities that rural areas are unable to offer. An urban population scenario estimated

by the National Statistics Office (n.d.) using the medium growth and constant migration scenario, projects that the urban population will reach 25% of the total population by 2020, increase to 28% by 2030, and then increase to almost one-third of the total population by 2050 (equating to approximately 180,000 people). The rapid increase in urban migration and urbanisation places further pressure on Honiara's capacity to meet the demands of public infrastructure, employment opportunities, basic services (including health, education and waste management), and ecosystem services.

As in most capital cities and urban areas around the world, the drivers of employment, education and access to the global economy have attracted a large number of young people from rural areas and provincial urban areas to Honiara (*ibid*). UN-Habitat (2016a) estimates that 58% of Honiara's population is below 25 years old and a third of the population is below 15 years old. The high rate of youth can be seen as both an opportunity and a challenge. Youth can be a positive force for development when provided with the education, skills and opportunities needed to contribute to a productive economy. Honiara is a hub for education institutions, youth groups and strong social networks, which provides the grounds for a strong capacity of engagement. On the other hand, however, the high youth population also represents high youth unemployment and associated problems such as increased incidence of anti-social behaviour (*ibid*). Youth unemployment in Honiara is estimated to be very high, with an estimate in 2005/2006 for 15–19 year-olds of 75%, and 49% for 20–24 year-olds (Union Aid Abroad 2008).

3.4.3 Employment

As the commercial and administrative centre for the country, the services sector is the main source of economic activity in Honiara (UN-Habitat 2012), but employment data are limited (including at a national level). Based on anecdotal evidence, UN-Habitat (2016b) estimates that employment rates in the formal sector are relatively low. The formal sector, however, is supplemented by the informal sector, which provides a source of income for citizens without formal education, providing an important link between the urban and rural population (UN-Habitat 2012). The informal sector comprises a diverse range of activities from selling produced goods such as vegetables, baked goods, and handicrafts, to trading in tobacco and betel nut. Union Aid Abroad (2008) reports that the research shows that almost all informal sector livelihood activities had a higher return than casual or low-paid employment.

3.4.4 Poverty

The National Statistics Office (2015) reports that Honiara's poverty rate (those below the basic needs poverty line) was 15%,[1] the third highest poverty rate in the nation (see Figure 3-8). Honiara's high poverty rate is mainly due to poor infrastructure and lack of market integration, and is exacerbated by very high urban housing prices as a result of poorly functioning land markets (*ibid*). Nation-wide, Makira and Guadalcanal Provinces accounted for the highest proportions of poverty, 31% and 22% respectively.[2] Comparatively, when considering absolute numbers of people living in poverty, Honiara's share of poverty was reduced significantly, with rural areas representing the highest percentage of people living below the poverty line (Figure 3-9). UN-

[1] The National Statistics Office (2015) developed poverty profiles for Solomon Islands based on the 2012/13 House Income and Expenditure Surveys. The work calculated specific poverty lines (determining the minimum expenditure required to obtain basic food and non-food goods) that varied across the country. Honiara, for example, had the highest basic needs poverty line – as meeting basic needs in Honiara costs around twice as much as in the provinces, particularly due to the very high cost of housing in the city. The report also noted that this effect appeared to spill over into Guadalcanal Province, which had the second highest poverty line in the country.
[2] The poverty risk in Makira is much higher than in Honiara, despite much lower cost of living there, indicating that, in Makira, low income is the primary driver of poverty. In Guadalcanal, though nominal incomes are higher than in many other provinces, they are not sufficiently high to compensate for the higher price level there, likely influenced by the higher prices in the capital city (National Statistics Office 2015).

Habitat (2016b) notes that these findings indicate that poverty in Solomon Islands is largely a rural phenomenon, with rural households more likely to be poor compared to urban households, and the bulk of the poor (about 87%) living in rural areas.

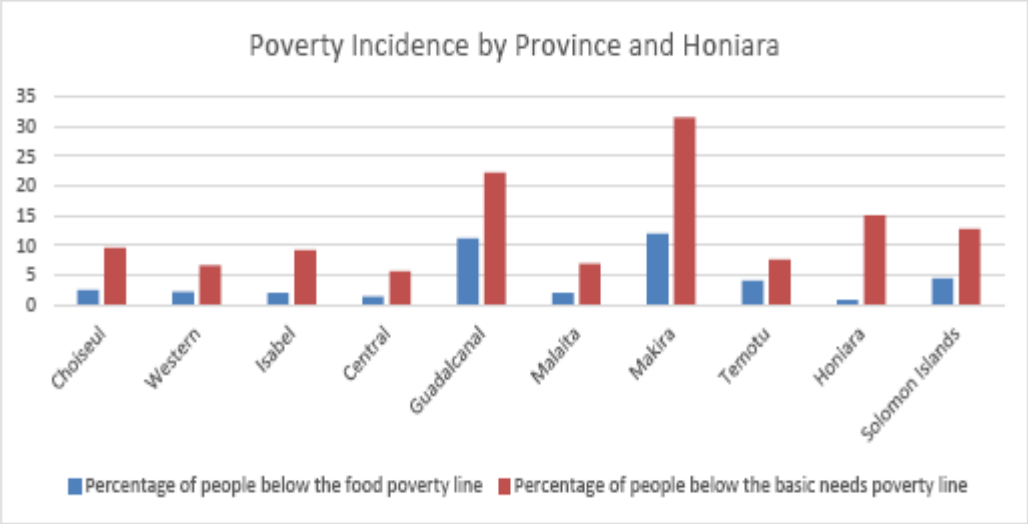

Figure 3-8 Poverty incidence by province and Honiara (National Statistics Office 2015)

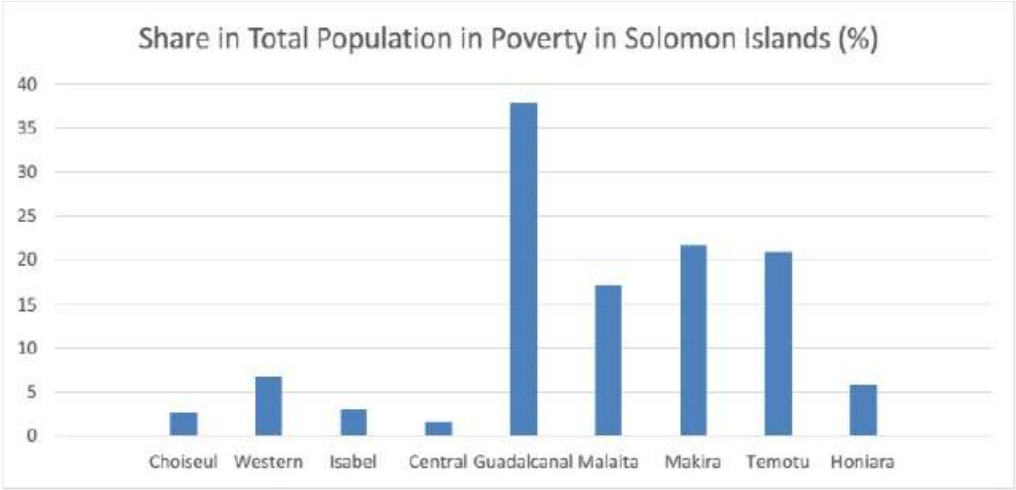

Figure 3-9 Share in total population in poverty by province and Honiara (National Statistics Office 2015)

3.4.5 Land administration

3.4.5.1 Planning and tenure

The update of the Local Planning Scheme (LPS) 2015 was informed by the *Study of the Honiara Local Planning Area* (MLHA and HCC 2014). The study explored many factors – land-use, socio-economic, infrastructure,

environmental and transport factors – and identified a number of planning issues stemming from Honiara's continued population growth and unregulated development. These include:

- uncontrolled land uses due to the lack of planning requirements, leading to inefficient use of land;
- increasing pressure on retaining existing available land for private development purposes, removing opportunities for key infrastructure, such as open space, community facilities and public parks;
- lack of recognition of the natural environmental hazards affecting some areas of the city, putting properties and people's lives at risk;
- lack of understanding of the infrastructure requirements of developments and the locations of the existing infrastructure, resulting in developments blocking access to key infrastructure;
- lack of requirements for building design, landscaping and car parking within developments; and
- lack of land to accommodate key public infrastructure to service the growing population.

These planning issues have been integrated into the LPS, with the intention of using zoning and overlays to control land uses and developments across the city and prevent unsafe development in areas exposed to natural hazards, using both existing and projected climate conditions. The LPS also includes future allocation of urban greenspace and a structure plan for the central business district. Urban development within Honiara is guided by the Town and Country Planning Board of the HCC but UN-Habitat (2016b) reports that meetings of the board are infrequent, resulting in development applications pending for extend periods of time. Such delays, together with developers who do not submit applications, result in developments proceeding without regulation. Adequate resources for enforcing compliance with HCC development processes and the LPS are also lacking, which means that there is little capacity for addressing environmental issues that result from inappropriate construction and development. There is a further reduction in planning controls outside the area covered by the LPS. Access to sites for development is also limited, leading to the preference of low-income urban dwellers to resort to informal settlements.

Other barriers to implementation of planning outcomes for the city include land tenure. The majority of land in Solomon Islands (87%) is customary land, with the remainder made up of state land (8%) and land held under perpetual estate and fixed term estate (5%) (ICEM 2012; UN-Habitat 2016b). Land ownership has important relationships with logging practices due to growing pressure on landholding communities to raise cash from their forest resources.

Honiara itself is built on alienated land, with 25% of the city's population living on state land, including most of the population in informal settlements (Chand and Yala 2008). Of this 25%, the majority have no legal right to the land on which they live, leading to a lack of tenure security. Access to land can be granted through temporary occupation licences (TOLs) issued by the Commissioner of Lands.

In addition to dwellings on state land, there is evidence of informal settlements occurring on land held under customary title, although it is uncertain if this has occurred through the TOL process, through negotiation with customary land-owners, or without any formal title arrangements (Chand and Yala 2008).

3.4.5.2 Informal settlements

The growing population of Honiara, coupled with the restriction in access to land for residential development, delays in planning approvals, and a lack of access to services and utilities, is forcing many Honiara residents

to live in informal settlements across various areas of the city (UN-Habitat 2016a). UN-Habitat (2016b) characterises Pacific informal settlements by insecurity of legal land tenure, poor quality housing, overcrowding, environmentally marginal locations, and absent or limited supporting services such as water, electricity, waste collection, and roads. An estimated 35%–40% (or 28,000 people in 4,000 informal settlement households) of the HCC population are living in informal settlements and the growth rate of these settlements is reportedly increasing faster than the rate of urban growth (UN-Habitat 2016b). If not adequately managed, the increasing population growth in informal settlements is likely to further degrade ecosystems and their services, thus reducing the communities' resilience to future climate effects.

Informal settlements present major planning and safety issues for both local and national government, as many settlements impede access to basic services and utilities and are located in areas prone to natural hazards and climate-related disasters such as floods, cyclones and tsunamis (UN-Habitat 2016a). There is a need to enforce building industry development controls to ensure compliance with zoning plans and improve the structural quality of buildings (ICEM 2015).

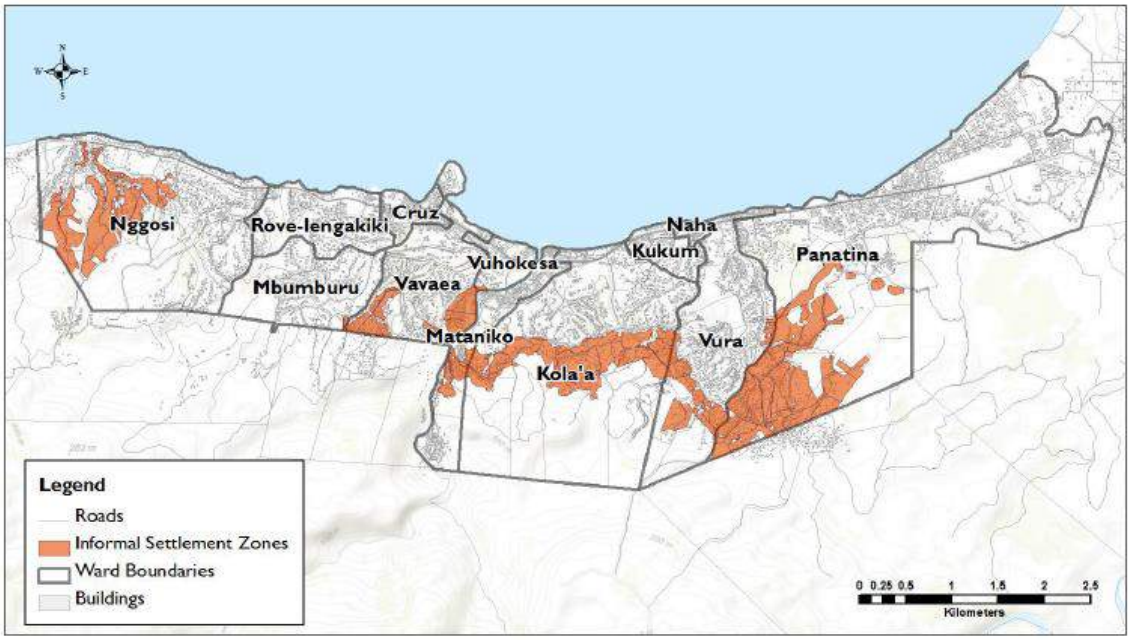

Figure 3-10 Map of Honiara's informal settlement zones determined by MLHS and UN-Habitat Country Team (in UN-Habitat 2016a)

3.4.6 Agriculture and fishing

Over 75% of the Solomon Island population is engaged in subsistence agriculture and fishing ((UN-Habitat 2016a, 2016b). While large agricultural areas and commercial plantations are absent in Honiara, many small-scale activities are undertaken by households that grow crops in backyard gardens, raise livestock, and fish (UN-Habitat 2014) to counter the high cost of living; an estimated 40.5% of all households in the HCC boundary grow their own food (UN-Habitat 2016a).

For many households, particularly those in lower socio-economic settlements, subsistence gardens are their primary source of income generation, particularly through cash sales at small roadside stalls and local markets. For example, produce at the White River market appeared to be largely sourced from subsistence producers within the local (or adjacent) communities. According to the 2009 Census, 74.6% of households in the greater

Honiara area were reliant on wages or salary for their principal income source, while 7.4% of households were reliant on sales of crops, fish, or handicrafts for their main income. Furthermore, 50.9% of households in the greater Honiara area were involved in subsistence food production and 16.4% in catching and collecting fish and shellfish (*ibid*).

Climate change has been affecting agricultural productivity (UN-Habitat 2014) and cash income. The decrease in productivity has forced households to find alternative sources of income, such as selling firewood from scrap logs, which in turn increases the clearing of trees in urban and upper catchment areas and the associated effects of sediment entering waterways and instability of steep slopes during high rainfall events.

In response to the effect on livelihoods, households are shifting to more service-oriented livelihoods. As Honiara continues to urbanise, it is likely that this trend will continue (UN-Habitat 2014).

3.4.7 Water supply

Honiara's official water supply is sourced from a combination of groundwater and freshwater springs that are located within or adjacent to the HCC boundary. Honiara is serviced by piped water managed by the Solomon Islands Water Authority (SIWA). According to the 2009 census, up to 25% of households within the municipal area do not currently have access to piped water (UN-Habitat 2016b); these numbers are expected to be higher within peri-urban areas and informal settlements (ICEM 2015). Figure 3-11 shows the distribution of households with access to piped water, with the lowest access correlated with informal settlement areas, especially in the Kola'a and Panatina wards.

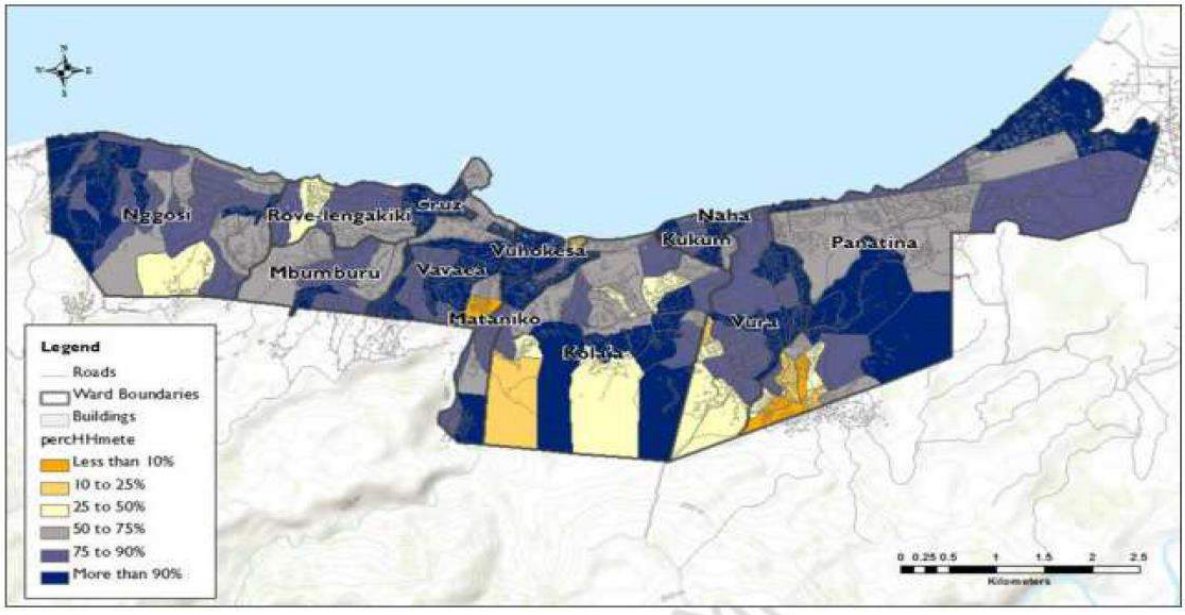

Figure 3-11 Households with access to metered water (UN-Habitat 2016b)

UN-Habitat (2016b) reports the following levels of usage within some areas of high informal settlements:

- Ward 8 – up to 39% of households do not have access to piped water. Of the 61% of households that are serviced, 53% are serviced only through community stand-pipes; and
- Aekafo – up to 85.3% of households do not have access to piped water.

Water demand is increasing due to the growth in population, urban migration and increases in property development (ICEM 2015). There is also an increasing risk associated with contamination of water supply. Up to 25% of households that have access to piped water experience low water pressure (UN-Habitat 2014).

Households without access to piped water utilise wells, rainwater tanks and streams (UN-Habitat 2016b). Wells and streams are expected to be vulnerable to contamination from human and solid waste, particularly in the informal settlements, while groundwater sources in low-lying coastal areas are vulnerable to saltwater intrusion. These trends are leading to increases in rainwater harvesting, system leakages, and water theft through illegal connections (ICEM 2015).

3.4.8 Sanitation and waste management

The Asian Development Bank (ADB 2014) estimated the total solid waste generation rate for Honiara as 1.0 kg per person per day. Using the ADB population estimate of 80,000, this indicates that a total of 80 tons per day is generated from the Honiara urban area, amounting to 29,000 tons per year. Considering current growth rates (see Section 3.4.1) solid waste generation is estimated to double within 18 years.

The main government agency responsible for pollution control and waste management is the Environmental Health Division. In Honiara, the HCC is responsible for the collection of household waste and waste from the central market, which is disposed of at the Ranadi dump site. ADB (2014) reports, however, that less than half of the Honiara population is provided with waste collection services. UN-Habitat (2016b) reports that, based on a 2009 population census, only 27% of households (36% in the municipal area) have access to waste collection services.

Informal settlements, outside the municipal boundary, are not currently provided with any waste collection services (ADB 2014; UN-Habitat 2016b). In some areas, HCC places skip bins that can be utilised by residents of informal settlements. The following waste disposal habits of households within Aekafo were identified, based on a survey conducted by Pauku (2015):

- use of HCC collection points for waste disposal – 21% of households;
- disposal of waste in nearby waterways – 33% of households;
- disposal of waste in nearby bushland – 12% of households;
- burning of waste – 62% of households; and
- burial of waste – 22% of households.[3]

ADB (2014) also reported that it is common for residences, government offices, businesses, vacant lots and street corners to have an active garbage pile that is regularly burnt.

Due to poor solid waste management, levels of pollution in Honiara are high (ADB 2014; UN-Habitat 2016b; ICEM 2015) while solid waste management practices have been linked to disease outbreaks, including the dengue fever outbreak in 2013. The large quantities of plastic waste entering the waterways also create a secondary environmental risk by reducing and, on some occasions, blocking water flow, leading to stagnation and vector-based disease exposure (UN Habitat 2016a) and localised flooding.

[3] More than one option could be selected by survey participants.

The Ranadi dump site is located approximately 6 km from Honiara on a former wetland site, within 20 m of the shore. The dump officially covers 1.5 ha but is thought to have spread to adjoining areas. A total of 20 to 30 tons of solid waste is disposed of at the site daily (ADB 2014). Access to the dump is unrestricted, and scavenging provides a source of income for several dozen nearby residents. The dump site was upgraded in 2013 to provide for better control of leachate and waste compaction; prior to this point, no leachate treatment or control was in place and uncontrolled burning was frequently used to control waste volumes (ADB 2014). All funding for waste management services is currently allocated to rubbish collectors (ADB 2014).

There is currently no segregation of waste in Honiara; the Ranadi dump site receives a combination of recyclable and non-recyclable inorganic waste, as well as large quantities of organic waste. However, there are currently three private recycling companies operating, all of which focus exclusively on metals (e.g. aluminium) (ADB 2014).

Sewerage is also a major issue for Honiara. Sewerage coverage in Honiara is limited, with only 6,400 persons in 2013 serviced by sewerage system connections provided by Solomon Islands Water Authority (ADB 2016). The 2009 census indicates the following patterns of toilet use per household within the Honiara municipal area (UN-Habitat, 2016b):

- 54% of all households have private flush toilets;
- 9% of households have shared flush toilets;
- 18% of households use private and shared water sealed toilets; and
- 19% of households use private and shared pit latrines.

Within informal settlements, the primary toilet use is expected to be pit latrines, as indicated by survey data of Aekafo, where 64% of households used a pit latrine and only 25% had a flush toilet connected to a septic tank (Pauku 2015). Figure 3-12 shows the distribution of households without access to sealed toilet facilities, with the lowest levels of access corresponding to informal settlement areas. In the Mataniko Ward, sewerage is currently entering the water table and river (UN-Habitat 2016a).

ICEM (2015) reports that SIWA, and other commercial industries' waste is disposed of directly into the nearshore environment. It is estimated that 75% of Honiara's sewage flows through a piped collection system directly into the ocean without treatment.

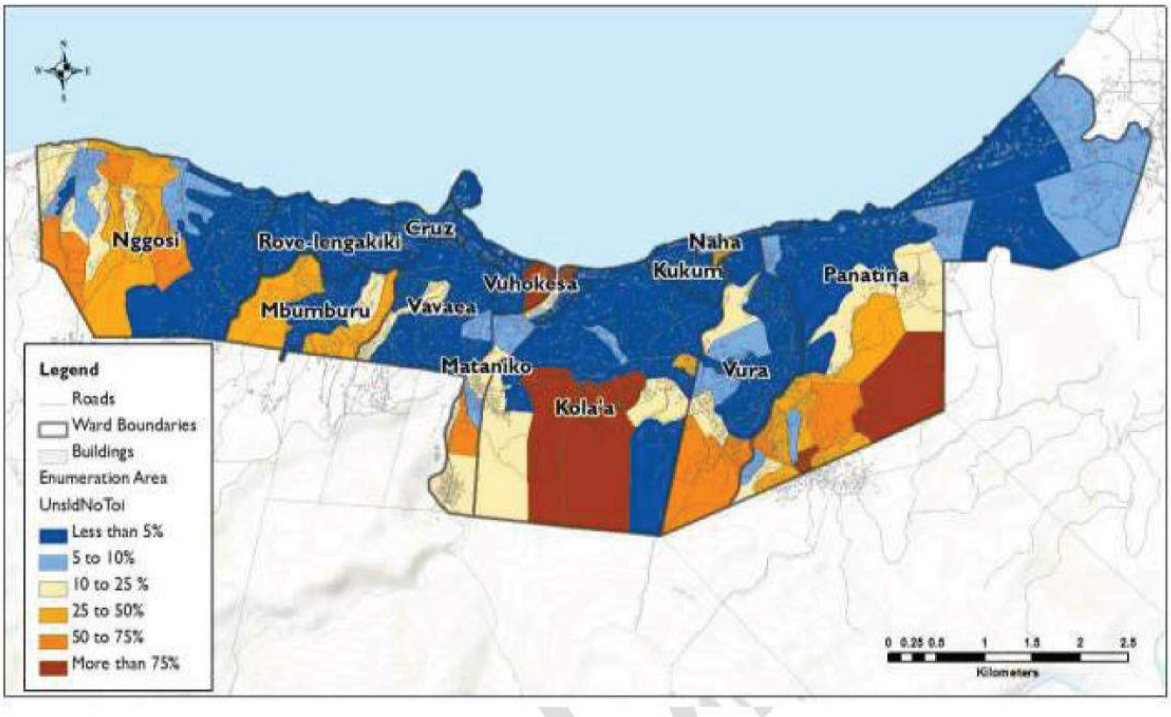

Figure 3-12 Households with unsealed or no sanitary/toilet facilities (UN-Habitat 2016b)

Waste management and general environmental degradation is a growing concern throughout Honiara. Roughan and Wara (2010) report that attitudes and governance are issues preventing a comprehensive approach to changing the mindset and behaviour of Honiara residents and businesses. Poor public awareness and the lack of environmental regulatory enforcement are resulting in environmental degradation occurring at an alarming rate, placing increasing pressure on HCC to manage and protect the environment that residents rely upon for their livelihoods.

3.5 Honiara governance

Governance within the HCC area is determined by the *Honiara City Act (1999*). HCC land releases and zoning are determined by the *Land and Titles Act (1996) (amended)*, under the directives of the newly-established Land Board, which consists of representatives from HCC, the Ministry of Land, Housing and Survey (MLHS), and permanent secretaries of several relevant ministries (UN-Habitat 2016). The amended *Land and Titles Act (1996)* provides the basis for land releases and zoning within the HCC boundary, led by the Land Board, which consists of representatives from HCC and MLHS and the permanent secretaries of relevant ministries (*ibid*). MLHS is responsible for the implementation of a city-wide initiative to subdivide and formalise the large areas of informal settlements through short-term TOLs delivered with the support of the UN-Habitat *Participatory Slum Upgrading Programme* (PSUP).

The HCC area is split into 12 wards, each represented by an elected councillor (UN-Habitat 2016a). An additional five council positions represent the Honiara city area and consist of four members appointed by the Minister for Home Affairs, including a female representative of the Solomon Islands Council for Women, and the premier of Guadalcanal Province (CLGF 2012). Each ward has a Ward Advisory Committee (WAC) set up to support urban governance, but UN-Habitat (2016b) reports that the committees lack policy guidance to take

true ownership over development initiatives in their ward and devise a strategic plan to better respond to community development needs and issues.

HCC is solely responsible for trade, businesses licences and waste management, and has dual responsibility with provincial and central governments for the regulation and conservation of the environment, public roads and drainage maintenance, education and health services. Honiara is the only established local government in Solomon Islands that is empowered to raise local revenue to support these services and infrastructure through property rates, business taxes and fees for services and licences.

HCC has a history of weak governance and administrative capacity, coupled with limited finances, resulting in the poor delivery of services to city residents. UN-Habitat (2012) reports that the council benefited from a five-year project (2006–2011) under the Commonwealth Local Government Forum Project (supported by the New Zealand Aid Programme) that helped strengthen the institutional and basic service delivery capacity of HCC. Further improvement is needed to ensure the distribution of basic urban services to all residents of Honiara, especially those living in the informal settlements.

Community governance in Honiara is largely absent or unique to a particular community (*ibid*). Within informal settlements, community development committees were set up as part of PSUP with the purpose of promoting community involvement in the upgrade schemes and disaster and climate change preparedness (*ibid*).

3.5.1 Climate change governance

The *Solomon Islands' National Climate Change Policy 2012–2017* (Wickham *et al.* 2012) was issued by the Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM). The policy, launched in June 2012, was developed by a number of government ministries and supporting organisations. The policy provides a framework for a national approach to addressing climate change effects and adaptation, and achieving sustainable development. Difficulties in climate change progress include a lack of governmental commitment, a lack of policy and institutional framework, poor coordination and links, a lack of data capacity, and budgetary constraints.

The nation's holistic ridge-to-reef approach to climate change adaptation is consistent with international, national and provincial commitments and planning policies, including the *Solomon Islands National Development Strategy 2011–2020* (MDPAC 2011); the *Solomon Islands' National Climate Change Policy 2012–2017*; and the *Solomon Islands National Biodiversity Strategy and Action Plan* (Pauku and Lapo 2009).

As alluded to in Section 1, there are other projects in Honiara focussing on climate change, with the most recent being primarily led by the UN-Habitat programme, in cooperation with the Solomon Island Government and Honiara City Council. These include the development of Honiara's Climate Change Vulnerability Assessment (UN-Habitat 2014) and Climate Change Adaptation Plan (UN-Habitat 2016a). Together, these presently provide the leading climate change assessments and recommendations that specifically concentrate on Honiara.

With a focus on urban settlements, the existing UN-Habitat programmes established strong links between urban planning and climate change initiatives in Honiara. This provides a foundation for a coordinated and streamlined approach between climate change adaptation and urban planning works. For example, a new Urban Planning Scheme was issued by the Ministry of Lands, Housing and Survey and the Honiara City Council in 2015. This scheme takes into consideration resilience, settlement upgrading, and well-planned and

managed public spaces (UN-Habitat 2012). To complement the Urban Planning Scheme, UN-Habitat supported the development of a city-wide settlement upgrading strategy for Honiara.

Facilitation and implementation of climate change adaptation in Honiara will ultimately require collaboration between HCC, as the local government, together with relevant ministries and other stakeholders. While HCC will be central to climate change adaptation through the provision of policies and services (e.g. land-use planning and regulation, infrastructure construction and maintenance, and waste management), national government ministries are leading some climate change action priorities (UN-Habitat 2014).

In the context of Honiara, both HCC and various national ministries have responsibilities relevant to the local implementation of adaptation priorities identified in the national adaptation programme (as part of the *Solomon Islands' National Climate Change Policy*, Wickham *et al.* 2012). These were identified by UN-Habitat (2014) and are summarised in Table 3-1. While the national government is taking the lead in some priority sectors for climate change action, there are several key areas where HCC plays, or can play, a significant role. These include: land-use planning and regulation, business regulation, construction and maintenance of feeder roads and small infrastructure, waste management, promotion of health and sanitation, and public information and education (UN-Habitat 2014).

Table 3-1 Roles of national ministries and Honiara City Council relevant to implementation of national adaptation programmes of action priorities in Honiara (adapted from UN-Habitat 2014)

National Adaptation Programmes of Action Priorities	Ministries	Honiara City Council
Increase the resilience of food production and enhance food security	Ministry of Agriculture responsible for projects relating to food security and agriculture	-
Increase the resilience of water resources management	Ministry of Mines and Energy, together with Solomon Islands Water Authority, manage water resources	Land use of catchment areas within Honiara regulated by council
Improve capacity for managing sea-level rise in human settlements	Supported by Ministry of Lands, Housing and Survey	Council responsible for planning and regulating settlements within Honiara
Increase capacity of health professionals to address adverse effects of climate change on human health	Ministry of Health and Medical Services responsibility	-
Promote climate change education, awareness and	Responsibility primarily with Disaster Management Arrangements Committee (chaired by National Disaster Management Organisation) with respect to public awareness and training on disasters.	Supported by council through HCC's Department of Education and

National Adaptation Programmes of Action Priorities	Ministries	Honiara City Council
information dissemination	Responsibility of Hazards Committee (chaired by Ministry of Mines) to make hazard information available. Ministry of Education manages education through schools.	Municipal Disaster Committee
Better manage effects of climate change on waste management	-	Waste management is the responsibility of council
Increase resilience and enhance adaptive capacity of coastal communities, socio-economic activities and infrastructure	Supported by Ministry of Lands, Housing and Survey. Major infrastructure undertaken by Ministry of Infrastructure Development	Planning and regulation and small infrastructure under council jurisdiction in Honiara

4 Ecosystems and ecosystem services

This section provides a description of the key ecosystems directly utilised by the Honiara community and additional ecosystems and/or ecosystem services (where relevant) identified by the project team. Note that the team concentrates on the former, since the ESRAM project aims to focus on ecosystems and ecosystem services upon which local communities are directly dependent.

First, an overview (Section 4.1) of the key ecosystems and ecosystem services is provided, followed by a more detailed examination of each ecosystem / service (Sections 4.2 to 4.48).

4.1 Overview – ecosystems and ecosystem services

At the workshop, the stakeholders recognised seven broad ecosystem types on which the people of Honiara are directly dependent. Some of these are an amalgamation of what might be considered to be separate ecosystems in other contexts. For example, the 'coastal and marine' ecosystem encompasses a full variety of habitats (e.g. intertidal shores, mangroves, reef and open water) that form a mosaic within the coastal and marine ecosystem utilised by the people of Honiara. This approach meant that some of the more prominent and/or unique ecosystem features characterising Honiara (e.g. urban features) could be explored in further detail. For the purposes of this assessment, the relevant key ecosystems of Honiara have been categorised as follows:

(1) urban greenspace;

(2) general landscaping;

(3) land (e.g. built environment);

(4) urban springs and groundwater;

(5) rivers and streams;

(6) coastal and marine; and

(7) terrestrial watershed (i.e. terrestrial vegetation and cultivated land).

A map showing the spatial distribution and extent of these ecosystems is provided in Figure 4-1. Note that this mapping has not been extensively ground-truthed and is, therefore, considered indicative only. Several ecosystem types, such as urban springs, groundwater resources and general landscaping, are not captured due to lack of base data.

As an urban environment, much of Honiara is comprised of the built features of its residential, commercial and industrial precincts. More natural ecosystem features, particularly in land-based environments, are typically isolated and patchy, forming a fragmented network of modified habitats. More continuous ecosystem features are evident in the water-based environments, such as waterways, marine environment and groundwater. However, while more continuous, these features are not necessarily in good condition. Ecosystems representative of more intact or natural environments are mostly located outside HCC in the mid to upper reaches of the surrounding watersheds.

Table 4-1 provides an inventory of the respective ecosystem services for each ecosystem, as identified through the outcomes of the participatory stakeholder workshop. This is summarised in Table 4-2. Some ecosystems were recognised for very discrete services. For example, springs and ground water are a vital water supply

(especially for communities without access to water utilities). In contrast, the terrestrial watershed, rivers and streams, and marine ecosystems were each recognised for a broad range of ecosystem services. These included numerous provisioning, regulating, habitat and cultural ecosystem services.

While the urban ecosystems of greenspace and landscaping were recognised as providing some ecosystem services (e.g. areas supporting recreation and tourism, habitat services and the provision of aesthetic values and shade), these were not the types of ecosystem services vital for community survival. Ecosystem services directly essential to the people of Honiara, such as provision of food, water supply, building materials and livelihoods, were categorised as follows:

- urban springs and ground water;
- terrestrial watershed;
- rivers, streams and other waterbodies; and
- coastal and marine areas.

The spatial distribution of some ecosystem services (in terms of direct community utilisation of land and sea resources) can be inferred from the ecosystems and land-use map in Figure 4-1. For example, key areas of land cultivation are mapped as 'cultivated land'; stretches of the coast used intensively for marine transport are mapped as 'wharves'. Additional ecosystem services (for which a distinct spatial distribution can be identified) are shown in Figure 4-2. These include uses such as:

- swimming and fishing along the coastline and major rivers;
- logging and timber-milling in the upper watersheds;
- large-scale food cultivation, primarily along the Lungga River;
- waste disposal along the coastline and downstream reaches of rivers;
- key areas of raw material (sand, gravel, stones) extraction, in the form of quarries or major river-based extraction operations (e.g. Lungga River); and
- local tourist entry points and drawcards (e.g. wrecks).

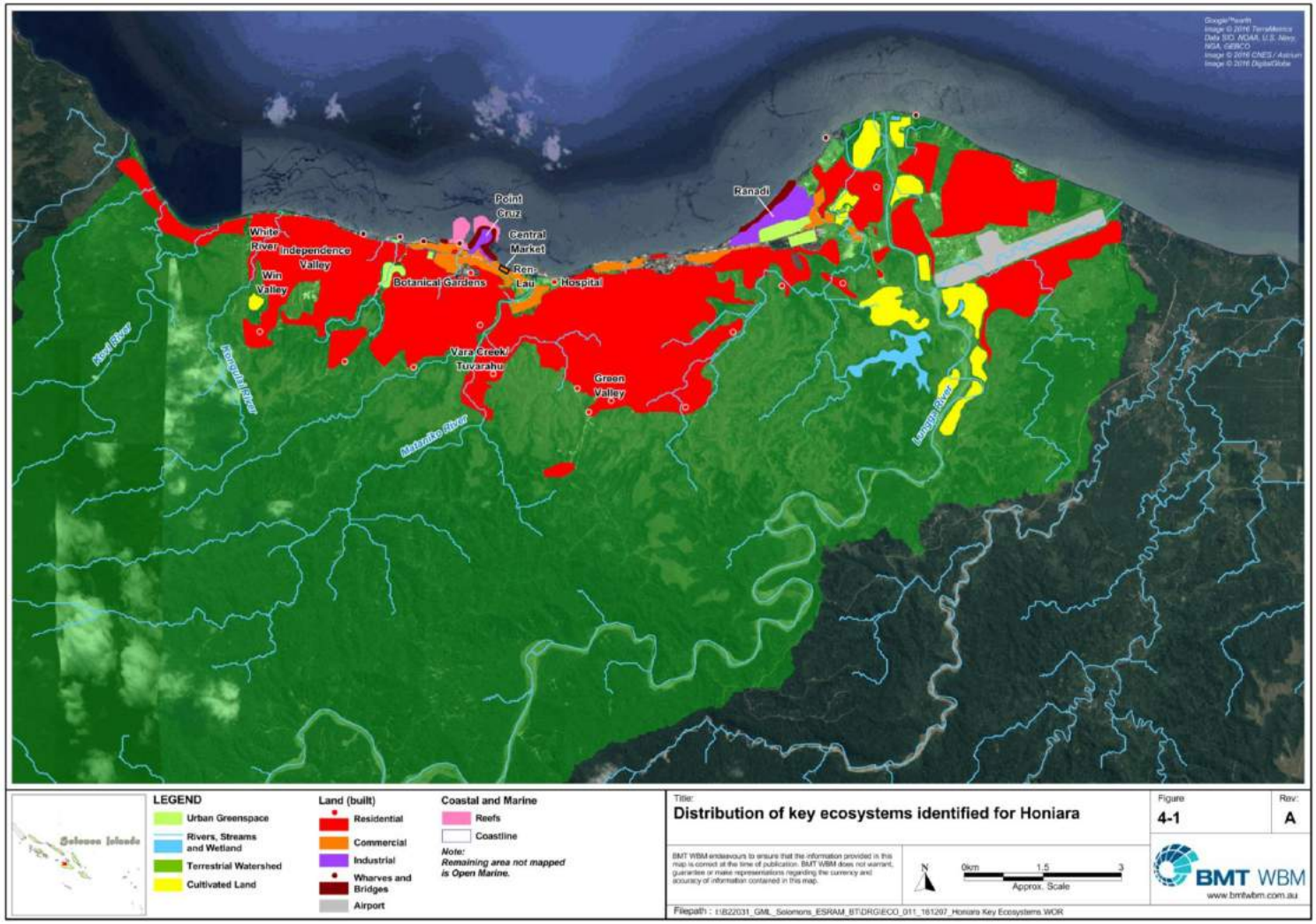

Figure 4-1 Distribution of key ecosystems and land-use types identified for Honiara

Table 4-1 Inventory of ecosystems and ecosystem services identified for Honiara

Broad Ecosystem Category	Key Ecosystem Services Identified during the Honiara Workshop
Urban green space (recreation areas, botanical gardens, parks, sporting fields)	Entertainment, recreation and leisure
	Tourist attraction (e.g. Honiara Botanic Gardens)
	Urban habitat and biodiversity corridor
	Shade provision
General landscaping (e.g. flower gardens and other landscaping around office buildings, hotels, main street, etc.)	Urban habitat and biodiversity corridor
	Shade provision
	Aesthetic values
Land (e.g. built environment)	High value commodity (esp. CBD)
	Provides land for housing, business and services – formal settlements, informal settlements, commercial and industrial areas, transport infrastructure (buses, roads, wharves), cemetery, landfill, airport, port area, market, vegetable – *sup sup* – gardens, *kastom* gardens, Parliament House, hospital, churches, Rove Prison Service, clinics, schools, Solomon Islands National University
	Supports cultural identity of the CBD and greater Honiara (e.g. cultural centres, museum, art gallery, historical sites and monuments, and landmarks such as Mt Austin skyline)
Urban springs and groundwater	Water supply (drinking water)
	Water supply (domestic uses)
Terrestrial watershed (i.e. vegetated areas of catchment/ watershed – includes forests, grasslands, cultivated land, etc.)	Habitat provision and supports biodiversity
	Areas for recreation, socialising, leisure, etc.
	Food provision (cultivated gardens and plantations)
	Building materials (timber, quarries)
	Provision of land for settlements/housing
	Provision of land for farming, livestock and other agriculture
	Supports industrial logging and timber milling
	Provision of fuel (i.e. firewood)
	Source of medicinal plants and trees
	Source of income (e.g. through logging, farming, market produce, etc.)
	Supports cultural values (e.g. source of raw materials for costumes)
Rivers, streams and other non-marine water bodies	Domestic use (washing/bathing, cooking)
	Recreational use (swimming)
	Source of food (fishing, crab, ura, water cress, kangkung)
	Transportation route (i.e. facilitates movement of goods and people)

Broad Ecosystem Category	Key Ecosystem Services Identified during the Honiara Workshop
	Habitat for wildlife
	Source of water for irrigation (i.e. supports both commercial and subsistence farming)
	Source of drinking water (to both water utility and communities not connected to utility)
	Source of gravel/stones for construction and ground oven
	Religious service (baptism)
	Water supply for industrial uses
	Source of income (fishing and minor aquaculture, e.g. tilapia farming)
	Cultural value (shells)
	Tourism (waterfall)
	Environmental regulation and protection from climatic events (i.e. channel rain and flood waters)
	Used for waste disposal and dispersal (i.e. both toilet waste and rubbish)
Coastal and marine environment (i.e. reefs, mangroves, beaches, shoreline)	Both commercial and subsistence fishing (i.e. source of food and income)
	Source of building and construction materials (sand, gravel, coral rocks, stones, mangrove timber)
	Coastal protection (e.g. reefs, shoreline and mangroves attenuate wave and storm energy)
	Recreation – sporting activities, leisure
	Support primary tourism industry (i.e. snorkelling/diving for historical wrecks of 'Iron Bottom Sound', as well as sailing, sunbathing, etc.)
	Support transport, industry and goods/people transfer (i.e. shoreline is location of coastal infrastructure such as wharves and jetties)
	Coral extraction (lime, building materials)
	Supplies cultural artefacts (e.g. shells for necklaces, ornaments and shell money)
	Waste disposal – sewage outlet, solid waste dispersal
	Source of other (non-fish) food (e.g. mangrove fruit)
	Fuel supply (mangrove timber)
	Habitat provision and biodiversity support

Table 4-2 Summary of ecosystem key sources for identified ecosystem services

Key Ecosystems / Services	Urban green space	General land-scaping	Land (e.g. built environment)	Urban springs and groundwater	Terrestrial watershed	Rivers, streams other water bodies	Coastal and marine
Recreation, leisure, entertainment	✓				✓	✓	✓
Tourist attraction	✓				✓	✓	✓
Habitat and biodiversity support	✓	✓			✓	✓	✓
Shade provision	✓	✓					
Aesthetic values		✓					
High value commodity			✓				
Land for buildings, infrastructure, etc.			✓		✓		
Provides land for agriculture			✓		✓		
Supports cultural /religious values			✓		✓	✓	✓
Water supply (drinking)				✓		✓	
Water supply (domestic use)				✓		✓	
Water supply (industrial)						✓	
Food provision					✓	✓	✓
Supports logging and timber industry					✓		
Building / construction materials					✓	✓	✓
Provision of fuel (firewood)					✓		✓
Source of *kastom* medicine					✓		
Source of income (primary industries)					✓	✓	✓
Transportation route						✓	
Environmental regulation					✓	✓	✓
Waste transfer						✓	✓
Coastal protection							✓

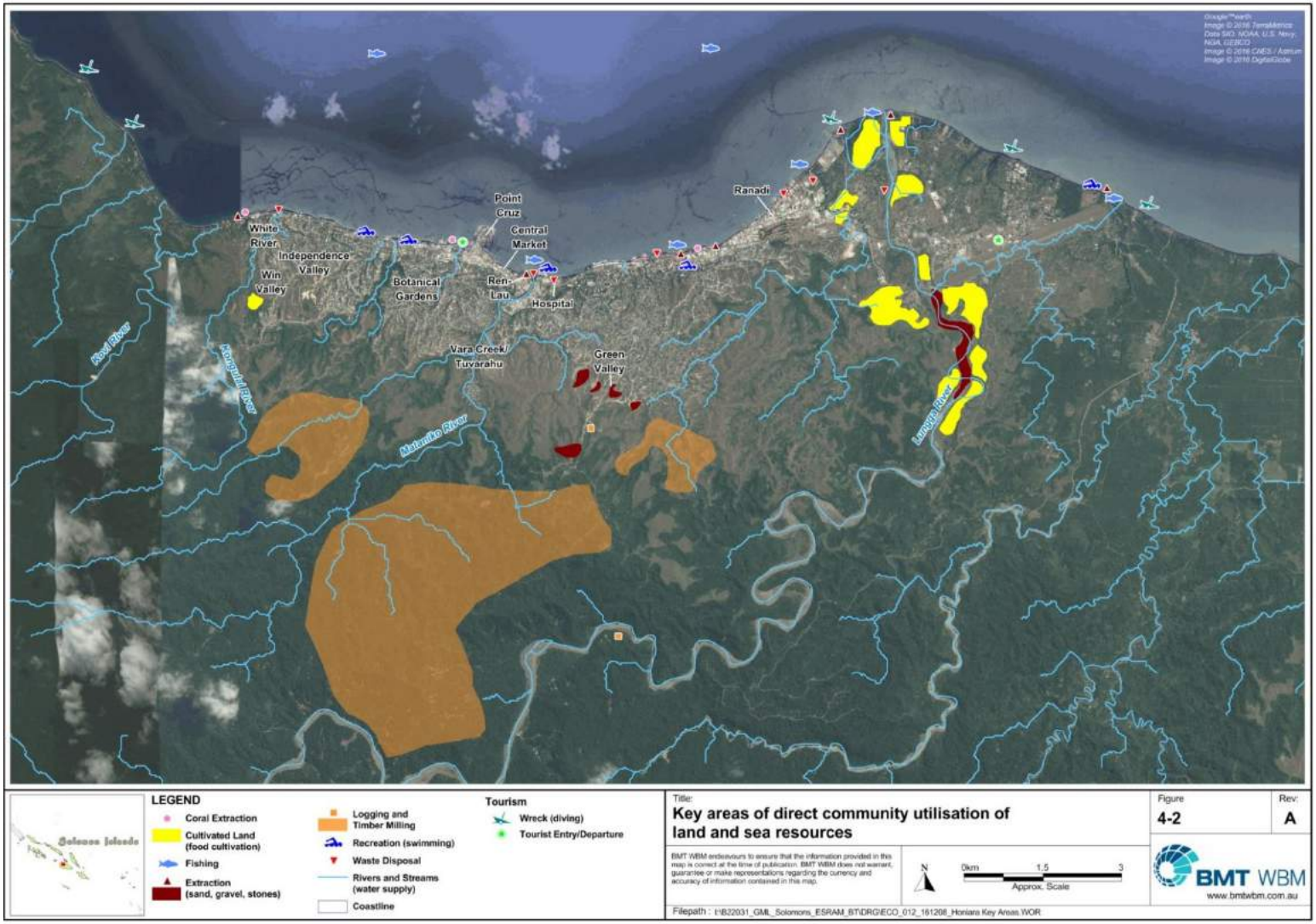

Figure 4-2 Key areas of direct community utilisation of land and sea resources

The workshop participants identified a wide variety of ecosystem services for Honiara, capturing a range of provisioning, regulating, habitat and cultural services. A review of de Groot *et al.* (2012) was then undertaken to identify any additional relevant ecosystem services not captured during the workshop. De Groot *et al.* (2012) lists typical ecosystem services for key service categories, which have been listed in general terms in Table 4-3. This is based on a study by de Groot *et al.* (2012), which builds on over 320 publications (and incorporates over 655 value estimates for ecosystem services). Note that the services listed apply differently to different ecosystems, and often apply to multiple ecosystems. For example, maintenance of habitat connectivity would apply to multiple ecosystems. In this manner, they also represent bundled or aggregated ecosystem services, e.g. raw materials could include rocks, wood, leaves and sand, depending on the ecosystem type.

Of the services listed in Table 4-3, the main ones omitted thus far that likely apply to Honiara include services such as air quality regulation, pollination, education and biological control. Note that fauna nursery services were repeatedly recognised (especially in the context of fish habitat requirements) and have been broadly captured as habitat services for the purposes of this assessment.

Table 4-3 General ecosystem services (adapted from de Groot *et al.* 2012)

Service category	Service
Provisioning services	Food
	Water
	Raw materials
	Genetic resources
	Medicinal resources
	Ornamental resources
	Supporting industry
Regulating services	Air quality regulation
	Climate regulation
	Disturbance moderation
	Regulation of water flows
	Waste treatment
	Erosion prevention
	Nutrient cycling
	Pollination
	Biological control
Habitat services	Biodiversity
	Nursery service
	Habitat connectivity
Cultural services	Aesthetic information
	Education
	Recreation
	Inspiration
	Spiritual experience

Service category	Service
	Cognitive development

4.2 Urban greenspace

4.2.1 Description of Ecosystem and Ecosystem Services

In a highly built environment, dedicated urban green spaces provide distinctive oases of vegetation and green space. In Honiara, notable green spaces include:

- the Honiara Botanic Gardens
- Golf course
- Rove children's park
- Other sport and recreations fields (Lawson/Tama).

From a community perspective, these locations provide ecosystem services in the form of: a focal point for recreational, leisure and entertainment purposes; shade provision (which has flow-on benefits to the health system); water supply for washing, bathing and recreational purposes; aesthetic value; education platform, and a tourist attraction. As a drawcard for tourists (e.g. cruise passengers visiting the Honiara Botanic Gardens) or location of major sporting events (i.e. attracting visitors from outside Honiara, as well as the local community), these facilities also provide a potential source of visitor-derived income. Green open spaces in urban areas have also been shown to reduce crime and aggression and contribute to psychological and health benefits (Carabine *et al.* 2015). In built--up areas, vegetation assists in reducing air and noise pollution and can reduce the head island effect (IPCC 2014).

The Honiara Botanic Gardens, in particular, provide a unique greenspace in that it is relatively large in area and is dominated by forest trees, including some trees that are rarely found elsewhere in Honiara (Figure 4-3). The Botanic Gardens maintain a linear fauna corridor along Rove Creek, with continuous habitat connectivity to the upstream reaches of this small coastal watershed due to relatively intact riparian vegetation. The large area of forest also provides hazard reduction services through storm water regulation and flood control, while reducing the sediment load entering Rove Creek and regulating water quality.

With the exception of the Botanic Gardens, large greenspaces in Honiara do not provide a high value environmental role with respect to habitat connectivity and fauna corridors within Honiara. This is due to their highly modified nature and isolation from other 'green' environments. Nonetheless, they retain habitat value as refuge islands for fauna in an otherwise built environment. This is likely to be especially important for transient visitors passing through Honiara (e.g. birds, bats, insects).

The habitat value of urban greenspaces can also result in undesirable environmental and management attributes, if it is acting as habitat for pest or stray species (e.g. stray dogs, pest bird species etc.). For example, stray dogs may present a safety issue that diminishes the community's utilisation or enjoyment of a greenspace.

4.2.2 Key threats

Key threats to urban greenspaces are primarily human derived and largely associated with inappropriate use or inadequate management. These include both threats to the greenspace in terms of its condition or ability to function as an ecosystem, as well as threats that deter the community from utilising the space for the beneficial ecosystem services it directly provides to the community. The key threats include:

- competition for other land uses, particularly the encroachment of industrial and urban development;
- pollution from industrial areas and unmanaged waste and rubbish disposal;
- harvesting of timber and *kastom* medicine (at Botanic Gardens, for example).
- undesirable human behaviour and use, including squatting, prostitution, substance abuse and riots;
- restrictive maintenance budgets and lack of public custodianship (i.e. prone to public abuse or misuse due to council tenure); and
- stray and pest animals (e.g. dogs, birds).

Coastal erosion was also identified as a threat to greenspaces located along public foreshores (e.g. Roves children's playground).

Figure 4-3 Honiara Botanic Gardens

4.3 General landscaping

4.3.1 Description of ecosystem and ecosystem services

Landscaping provides another means of introducing vegetative habitats to a highly built urban and/or commercial environment. Extensive landscaping is limited in Honiara, but is present to a degree in forms such as landscaped gardens, ornamental flower beds and planted trees around hotels, office buildings, the University of the South Pacific, shopping centres and the main street (Figure 4-4).

Similar to designated greenspaces, these landscaped areas provide similar (albeit usually smaller) patches of vegetation that can provide habitats for urban fauna (e.g. birds, insects, reptiles), as well as aesthetic value and shade for use by the Honiara community. Shade trees can be a valuable resource for the community in hot locations such as Honiara. This is particularly true in the central business district, where the environment is otherwise dominated by materials such as asphalt and concrete, and in locations such as schools where the community (e.g. young children) may be more vulnerable to hot temperatures.

Landscaped areas were not mapped as part of this assessment (i.e. too small to adequately detect via remote sensing). Note that trees and ornamental gardens in residential areas provide similar ecosystem functions.

Figure 4-4 Landscaping examples around Honiara: a) garden at Japanese War Memorial, b) hotel landscaping, c) trees in main street, d) garden beds at shopping centre

4.3.2 Key threats

Individual landscaped areas are usually small in size, and therefore sensitive to even small disturbances. Key threats that may reduce the condition and/or extent of landscaped areas, as well as the ecosystem services provided by them, include:

- encroachment of development and other land uses, such as new buildings and building expansions, road expansion, market huts; there is anecdotal evidence that HCC personnel remove shade trees in the city centre and utility companies damage or destroy trees to make way for infrastructure that is deemed more important;
- betel nut spitting, particularly to the aesthetic value of landscaped areas;
- pollution through solid waste disposal, including cigarette butt disposal;
- poor maintenance and physical damage by people or vehicles; and
- climate-related threats may include drought and cyclones.

4.4 Land (built environment)

4.4.1 Description of ecosystem and ecosystem services

Most of Honiara is comprised of built environments, which have been broadly classified here as residential (including settlements), commercial, and industrial areas. While not biological 'eco' systems, for completeness and given their extensive area, it is important to acknowledge these environments and the key values they provide to the community.

First and foremost, land for built areas is a very high value commodity. This is especially true in a commercial context for the central business district. It also applies somewhat to land for residential housing, since favourable land for building houses (i.e. not flood prone, landslide prone, or too steep, etc.) is becoming increasingly scarce.

More broadly speaking, land is an essential requirement for supporting valued assets, facilities and services in Honiara, not only for the local community, but in some cases for the nation as a whole. These include, for example (Figure 4-5):

- housing;
- business, commerce and trade (e.g. commercial, industrial and wharf areas);
- transport infrastructure (buses, roads, wharves, airport);
- historical monuments and landmarks, cultural sites, cemeteries and major cultural services (e.g. museum, art gallery);
- waste management (dump site);
- governance (national and local government administration and services);
- health, education and religious services (e.g. schools, university, hospital, clinics, churches);
- markets; and

- cultivated land and gardens.

Land around built-up areas provides an essential food source in the form of subsistence gardens (i.e. small-scale cultivated land, *sup sup* gardens, etc.). Having access to a garden is a vital safety net for many low-income households, including informal settlements (UN-Habitat 2016b). Over half the population of greater Honiara is engaged in subsistence food production, while 7.4% of households are reliant on their sale of crops, fish, or handicrafts for their main income (2009 Census).

The high proportion of households dependent on gardens for their well-being and livelihoods demonstrates the resilience that these ecosystem services provide Honiara communities, particularly during times of economic shocks (such as food price increases) (UN-Habitat 2016b) and following natural disasters when food provisions may not be readily available.

4.4.2 Key threats

While not necessarily threats to the land itself, threats to the community (either directly or indirectly) identified for these built locations include:

- overcrowding and limited (or poorly implemented/regulated) planning, particularly in informal settlements – it is estimated that informal settlement have a density of 52.7 residents per hectare compared with the Honiara average of 26.8 city-wide (UN-Habitat 2016c);
- poor enforcement of land development controls and environmental regulations and/or implementation of other management policies (e.g. waste management);
- dust;
- lack of individual tenure/ownership, leading to poor custodianship (i.e. individuals perceived not to be responsible for management and maintenance).

Both existing and future climates also pose a threat, particularly for land that is prone to flooding, erosion and landslides. Erosion and landslide risks are also exacerbated at locations that have been subject to inappropriate vegetation clearing, and physical disturbance from extraction (e.g. quarrying) and construction activities.

Figure 4-5 Land supporting valued assets trade and services, such as a) log industry, b/c) business and residential buildings, d) Ranadi dump site

4.5 Urban springs and groundwater

4.5.1 Description of ecosystem and ecosystem services

Urban groundwater springs and wells are a critical ecosystem, providing an essential supply of drinking water to Honiara. Approximately 50% of Honiara's total water distribution volume is supplied by the Kongulai spring (JICA 2006). Groundwater wells supply water for communities, especially informal settlements that do not have water utility access. They also provide water for daily domestic needs, such as cooking bathing and washing.

While not specifically mapped, springs and/or wells are known to be utilised at multiple locations in all settlements that have no alternative water supply (Figure 4-6).

Spring water also provides a commercial product for the local producers of bottled spring or mineral water. Services to the environment include the provision of environmental flows to local waterways and provision of habitat to groundwater-dependent fauna.

Figure 4-6 Examples of urban groundwater springs and wells in use in Honiara settlements

4.5.2 Key threats

The current major threat to urban groundwater is pollution, which arises through poor sanitation and waste management practices, as well as other pollution sources. Groundwater systems receive inputs from other environments (i.e. land, streams) via water run-off and intrusion. Key pollution sources include:

- human and animal (e.g. pig) faecal waste;
- solid wastes (e.g. household rubbish);
- industrial discharges; and
- chemicals from agricultural practices.

All these pollution sources pose significant human health risks to the people who are dependent on this resource, which has flow-on consequences for health services.

Additional threats include drought and population growth, which may both cause water supply to be insufficient in quantity to meet demand.

Examples of extensive stream pollution that affects groundwater quality for downstream communities are provided in Section 4.6.

4.6 Rivers and streams

4.6.1 Description of ecosystem and ecosystem services

Honiara crosses the lower downstream reaches of the major Kongulai, Mataniko, and Lungga waterway systems, as well as other smaller rivers (e.g. Rove, Kombito), urban streams, and wetlands (Figure 4-1). Typical examples are shown in Figure 4-7. Here, fresh and estuarine waters are considered together, since the same waterways are generally estuarine to brackish within Honiara and freshwater upstream. The condition of these waterways generally varies with proximity to human disturbance and/or the intensity of human disturbance, such that the waterways within Honiara are typically in poor condition and highly modified, but the condition improves further upstream. In the upstream reaches, disturbances are generally associated with the watershed's land uses for resource exploitation (such as logging) rather than disturbance directly to the waterway itself.

Within Honiara, the rivers, streams and other waterbodies are highly modified through human-derived disturbances, such as habitat modification; pollution; riparian vegetation clearing; bank disturbance, revetment and erosion; the presence of built structures instream (e.g. bridges); watershed clearing and land uses; and resource extraction (e.g. gravel extraction, fishing, water extraction). Natural climatic events such as flooding and drought also affect the condition of the waterways, particularly in instances where the natural resilience to accommodate such events has been undermined by human disturbance.

Rivers, streams and other waterbodies in Honiara are used on a daily basis as a water supply for domestic water uses such as cooking, washing and bathing. The Kongulai catchment provides the main source of drinking water for Honiara with the Kongulai spring providing approximately 50% of the total water distribution volume (JICA 2006). Members of the community without access to alternative water supplies are the most reliant on the provision of this ecosystem service. Likewise, they are also the proportion of the community most vulnerable to the degradation of rivers and streams through declining quality and quantity of water.

Waterways in Honiara and the broader surrounds provide among the broadest range of ecosystem services from any one ecosystem type, encompassing provisioning, regulating, habitat and cultural services. These services include:

- provision of water supply for drinking, domestic, industrial and agricultural (e.g. irrigation) uses;
- provision of food resources (e.g. fish. crabs, ura, water cress, kangkung);
- provision of raw materials for building and construction (e.g. sand, gravel, stones);
- provision of a means of income and livelihood (e.g. through fishing and raw materials extraction);
- provision of recreational (e.g. swimming) and leisure resources for both locals and visitors (e.g. visiting waterfalls);
- provision of habitats supporting flora, fauna and biodiversity (e.g. aquatic fauna, waterbirds).
- contribution to environmental regulation by regulating flood flows, water quality, carbon and nutrient cycling, etc.; and

- a source of cultural and religious values (e.g. ornamental shells, cultural identity and connection with the land, location for baptisms).

Figure 4-7 Mataniko River (a, b) and small urban streams in settlements, including Win Valley (c) and dry stream bed in Green Valley (d)

4.6.2 Key threats

Pollution from both solid waste and sanitation and sewerage discharges is the major existing threat to waterways in Honiara. HCC operates a new waste management facility (see dump site at Figure 4-5), but mechanisms for collecting household waste and transporting it to the facility appear to be inadequate. This, together with a lack of community awareness or poor attitudes, and a high reliance on plastic as opposed to biodegradable or reusable products, results in excessive disposal and accumulation of solid wastes in rivers and streams (Figure 4-8). Additional pollution inputs directly to rivers and streams in Honiara include contaminants from sanitation uses, industrial discharges, agricultural run-off, and watershed run-off (e.g. sediment inputs). These pose human health risks through the community's use of this ecosystem type, both directly (e.g. drinking, swimming) and indirectly (e.g. consumption of contaminated food). It also undermines the integrity and resilience of ecosystem components in the rivers and streams (i.e. flora, fauna and their habitats), as well as for downstream marine ecosystems.

Overall, stakeholder participants perceived the following to be the three most important threats to rivers, streams and other waterways:

(1) pollution from poor sanitation and sewage discharges;

(2) population growth and urban development increasing the intensity of threats (e.g. pollution) and resource exploitation (e.g. increased water extraction or fishing activities, etc.); and

(3) climate-related threats (landslides, heavy rainfall, flooding and drought).

The people of Honiara are acutely aware of the threats to their major river systems posed by heavy rainfall and flooding. The effects of the devastating floods of 2014 remain a stark reminder of the risks of river flooding. This is particularly true for the Mataniko River, where the 2014 flooding caused loss of life, major damage to buildings and infrastructure, as well as costs in the form of disaster management, business interruption and repairs. Understandably, the potential for climate change to increase the frequency or intensity of such events is a major concern.

Unsustainable, or inadequate, management practices for logging, gardening (e.g. gardening on stream banks), urban development and gravel extraction, were recognised as also posing significant threats to waterways as they contribute to increased soil erosion and sedimentation. Table 4-54 provides a summary of the key threats identified for each major waterway.

Table 4-4 Summary of key threats to major waterway systems and their watersheds

River / stream	Pollution / waste	Sedimentation	Landslides	Soil erosion	Flooding	Population growth	Logging	Urban development	Unsustainable gardening	Sewage disposal	Gravel/stone extraction	Vandalism	Heavy rainfall	Drought
Lungga Rv.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Mataniko Rv.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Rove	✓				✓				✓			✓	✓	✓
Kongulai		✓		✓	✓	✓		✓	✓	✓			✓	✓
Urban streams	✓				✓	✓					✓		✓	✓

a)

b)

Figure 4-8 Solid waste disposal at a) Vara Creek, tributary to Mataniko River, and b) White River

4.7 Coastal and marine

4.7.1 Description of ecosystem and ecosystem services

A combination of both natural and man-made habitats comprise the coastal and nearshore marine areas of Honiara, noting that 'natural' habitats are often in a highly modified condition. Sandy beaches, shallow reefal platforms, soft sediment marine substrata, and marine waters dominate the natural habitats (Figure 4-9). Small isolated patches of mangrove and seagrass also occur (e.g. sparse seagrass on reefal platform near Point Cruz, occasional mangroves within Lungga River delta). Constructed seawalls, breakwaters, wharves and jetties form artificial hard substrata that are colonised by marine flora and fauna (e.g. invertebrates, algae, fish).

Submerged World War Two wrecks in close proximity to Honiara (Figure 4-2) form part of the world-renowned 'Iron Bottom Sound', a major tourist attraction for Solomon Islands, drawing wreck divers from around the world. They also form artificial reefs that provide habitat for marine biota (e.g. corals, reef fish).

Figure 4-9 Examples of the more natural shoreline features still present in Honiara: a) rocky/reefal platform west of Point Cruz, b/c) sandy beaches, d) sandy dune vegetated by *Ipomoea pes-caprae*

The coastal and marine environment of Honiara provides a wide range of direct ecosystem services, providing sustenance, livelihoods, raw materials, transport opportunities and waste disposal services, as well as cultural values. The ecosystem services of most importance were generally recognised as including:

- support for both commercial and subsistence fisheries, which provide a source of food and income;
- the provision of raw materials for building and construction, such as sand, gravel, coral rock, stones and mangrove timber (Figure 4-10);
- coastal protection through the attenuation and buffering of wave and storm energy by the shoreline, reefs and coastal vegetation;
- the provision of recreation and leisure values as an area for sport and similar activities (e.g. swimming, sailing), as well as a bathing and washing area for coastal settlements (Figure 4-10);
- support for Honiara's tourism industry by providing access for visiting cruise ships and directly attracting diving tourists;
- the shoreline, which is the location of shipping and boating infrastructure such as wharves and jetties, and also provides informal boat landing areas (Figure 4-10). In this respect, the coastal area acts as a transport hub, supporting the transfer of goods (e.g. private and commercial domestic freight, international imports/exports), services (e.g. marine policing) and people (e.g. inter-island transport, local fishing and boating activities);
- provision of cultural artefacts and commercial ornaments, primarily shells for necklaces, ornaments and shell money, cultural identity and status, and *kastom* medicine (coral);
- provision of waste dispersal and dilution services via formal outfalls (i.e. eight major sewage outfalls located along the Honiara coastline, see Figure 4-11) and as the receiving environment for pollutant loads transported to the coast via Honiara's rivers, streams and drainage systems;
- supply of fuel (firewood) for coastal settlements reliant on coastal vegetation for this resource;
- provision of habitats for coastal and marine flora and fauna, and support of biodiversity generally.

Figure 4-10 Honiara shorelines used for recreation and bathing (a), sand and gravel collection (b), shipping (c) and wharf infrastructure (d)

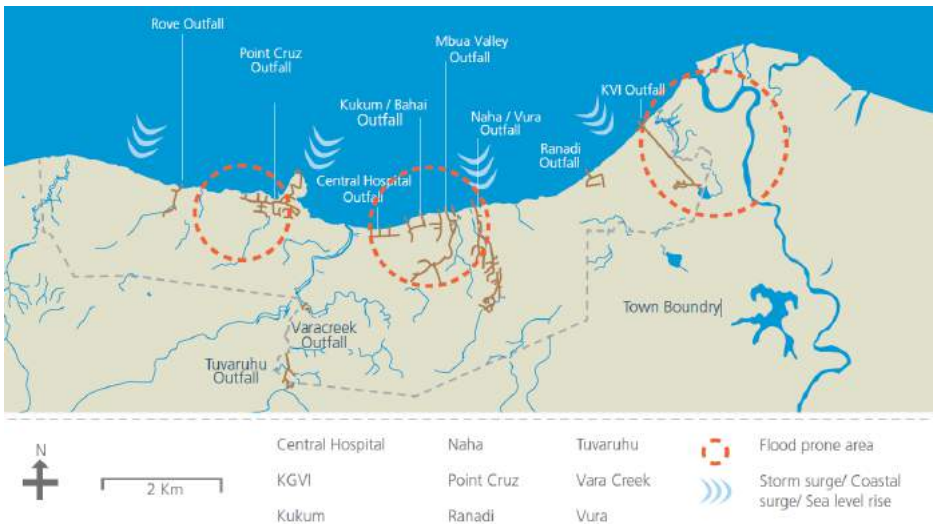

Figure 4-11 Location of sewage outfalls in Honiara (Source: UN-Habitat 2014)

4.7.2 Key threats

Pollution and habitat loss (i.e. ongoing physical and/or chemical deterioration of the ecosystem) are the two main threats to the coastal and nearshore marine environment of Honiara, both now and for the immediate future. Habitat loss and replacement continue along the coastline through ongoing reclamation and seawall construction (Figure 4-12), including current coastal reclamation and seawall works being undertaken near Lord Howe settlement. The retention of such habitats, albeit in a modified condition (i.e. not pristine), would be the preference for supporting the maintenance of current ecosystem function and provision of ecosystem services. Further, constructed hard coastlines pose a risk to adjacent sandy shores by interrupting sediment transport processes and exacerbating coastal erosion. For example, anecdotal evidence suggests that the sandy shore at Ren Lau community (Mataniko River mouth) has been affected by the construction of engineered seawalls/reclamation to the west at Ranadi and east of the river mouth.

The coastal and marine ecosystem is typically the ultimate receiving environment for all pollutants that become water-borne, either directly via outfalls and other point sources, or through run-off and infiltration from the watershed and impermeable built surfaces (e.g. roads, buildings, drains). In this respect, the coastal and marine ecosystem of Honiara is exposed to a wide range of pollutants, such as those from: agricultural and industrial activities; sewage; household waste disposal; hydrocarbons from both land-based (e.g. road run-off) and marine-based (e.g. shipping) leaks and spills; sediments mobilised from watershed clearing, erosion and construction; and boat and ship discharges (e.g. rubbish and unlawful ballast discharge). This pollution affects multiple components of the coastal marine ecosystem, including water quality, sediment quality, and the composition and condition of flora and fauna communities. Ultimately, it poses a human health issue to the population of Honiara where/when direct contact (e.g. through recreation/bathing) or food consumption (e.g. of contaminated fish or invertebrates) presents a significant risk. Note that the introduction of plastic wastes into the marine environment, including both macro- and micro-plastics, are increasingly raising concern globally because of their effects on marine fauna through consumption and entanglement.

Other notable threats to the coastal and marine ecosystem of Honiara include:

- over-harvesting of fish and other marine foods – given that Honiara is the largest and most densely populated community in Solomon Islands, it is likely that the local environment is also subject to very heavy fishing pressure;
- coastal erosion from natural hazards (e.g. storms) and human disturbance (i.e. reclamation works or construction of sea-walls interfering with natural sediment transport processes) (see Figure 4-12 c) and d);
- extraction activities to supply raw materials for building and construction (e.g. the extraction of sand, gravel/stones and coral rock);
- wrecks (e.g. Iron Bottom Sound, Ranadi coastline – see Figure 4-12 a) and b), Kukum coastal settlement) creating physical and chemical hazards in the environment and displacing natural habitats); and
- Honiara's rapid population growth, which, combined with some people's lack of awareness and/or irresponsible attitudes towards the environment, exacerbate the above threats.

Figure 4-12 Informal (a, b) and formal (c, d) shoreline protection measures and coastal reclamation works

4.8 Terrestrial watershed

4.8.1 Description of ecosystem and ecosystem services

This broad ecosystem type primarily captures the vegetated terrestrial areas of Honiara and the upstream watersheds of the city's major rivers. This mainly includes the natural vegetation cover types as mapped in Figure 4.13, as well as large cultivated lands that are particularly prominent adjacent to the downstream reaches and delta of the Lungga River (Figure 4-1) and smaller scale domestic gardens. The existing forest type mapping (Figure 4-13) classifies most of Honiara as degraded rainforest on hills or degraded lowland rainforest on near level land. Note that much of these forests was cleared and burned during historical deforestation, shifting agriculture, World War II forest clearances and bushfires, and was replaced by developed land for new settlements and gardens. Some freshwater swamp forests are also mapped within HCC, mostly in the downstream reaches of the Lungga River/delta and its tributaries.

Beyond the HCC boundary, the watersheds are dominated by (non-degraded) rainforests of mixed species composition on hills (4.13).

Some lowland and/or degraded rainforest also occurs immediately adjacent to the Lungga River. While much of HCC is dominated by various built or otherwise developed areas, it has a high degree of connectivity with these upstream reaches of its major watersheds, particularly with respect to the condition and functioning of waterways in the lower watersheds. Retaining the condition of the rainforest in the upper watersheds is critical to maintaining the resilience of downstream waterways and marine environments, particularly given the extent of anthropogenic activities in, and immediately adjacent to, Honiara.

Terrestrial lands, excluding both formal and informal built/developed lands, are primarily valued by the community for the following ecosystem services:

- provision of land for growing food for both the small domestic garden and larger commercial cultivation enterprises;
- provision of raw materials for building, particularly timber and leaves for the construction of houses, market stalls, fencing and retaining walls, and furnishings, such as furniture and mats;
- provision of fuelwood (i.e. fuel for cooking);
- provision of land and fodder for other domestic and commercial agriculture (i.e. farming livestock);
- support of cultural values and practices though the provision of materials for traditional costumes, ornaments and cultural artefacts (e.g. leaves, seeds, timbers), noting that mats, fans, jewellery, carvings and similar items also provide an income source through the handicraft trade;
- provision of areas and opportunities for socialising, recreation and reconnecting with traditional land-based cultural practices, the latter being particularly important in that many of the younger generation in Honiara are/have been raised in the city, geographically isolated from their family's village roots and associated cultural roots, much of Honiara's population having migrated from elsewhere in Solomon Islands);
- in the watersheds outside HCC, timber for timber milling, which remains a significant commercial enterprise; and
- provision of habitat for terrestrial fauna and birds, sustaining biodiversity, and environmental regulation services, such stabilising soils and maintaining air quality.

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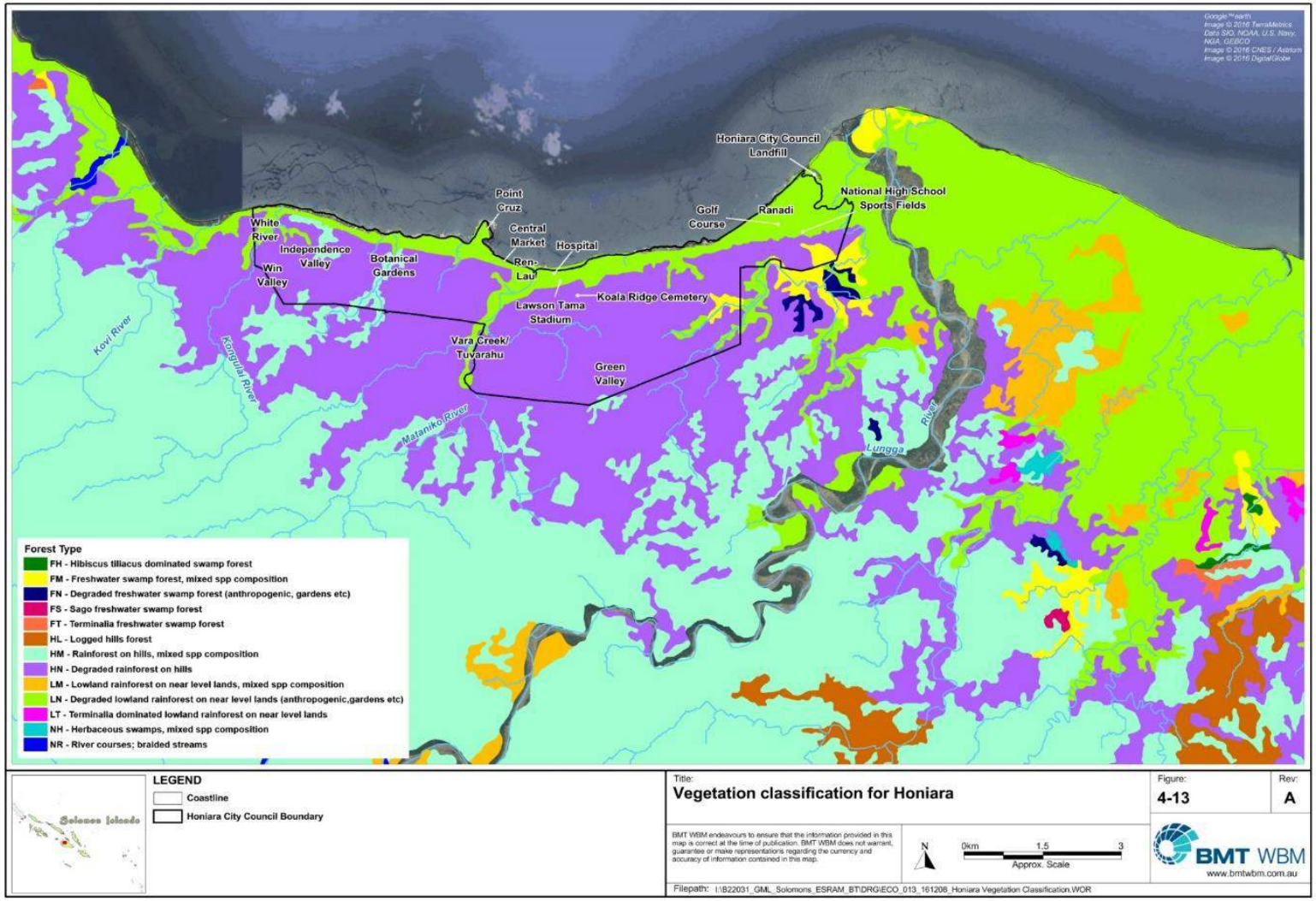

Figure 4-13 Vegetation classification for Honiara

4.9 Key threats

The primary human uses of vegetated lands in Honiara and its upstream watersheds pose the main existing threats to this ecosystem type and its functioning. Timber milling and the associated deforestation and erosion effects were perceived by the stakeholder workshop participants as the most pressing existing threat to the condition of the local watersheds and their terrestrial vegetation (i.e. forests, etc.). The deforestation and erosion have flow-on consequences for the ecosystem services provided by this terrestrial environment (i.e. provisioning services, habitat services, environmental regulation, etc.).

Additional threats to the vegetated terrestrial watershed include:

- gardening and commercial land cultivation, particularly with respect to: i) clearing of natural vegetation; ii) the introduction of agricultural chemicals such as pesticides into the environment; and iii) erosion effects resulting from the clearing of natural vegetation;
- expansion of settlements and other developments, encroaching on and replacing vegetated lands (i.e. continuing loss of habitat and other ecosystem services);
- pollution of the terrestrial ecosystem (i.e. via agricultural pollution, livestock, waste disposal and sanitation in the vicinity of settlements and recreation areas), noting that this pollution poses a risk for other ecosystems, such as waterways, if mobilised; and
- climate-related threats (drought and associated increase in fire risk, and heavy rainfall events, leading to landslides and flooding).

4.10 Summary of human induced threats to ecosystem services

Table 4-5 provides a summary of the key threats to Honiara's ecosystems and services. The concept of social-ecological resilience recognises the interdependence between people and nature, which is reflected in the city's heavy reliance on ecosystem services for survival. Despite the critical contribution ecosystem services provide to communities and economies of Honiara and beyond, ecosystems are subject to significant anthropogenic threats, such as land-use change, habitat loss and pollution through logging, urbanisation, expansion of agricultural land, infrastructure development, and overfishing. Furthermore, these threats are exacerbated by Honiara's rapid population growth from rural-urban migration and the current and projected adverse effects of climate change (explored further in Section 6).

By identifying key ecosystem services that are under threat by these pressures, targeted management options can be designed to build and strengthen the resilience of ecosystem services and, ultimately, the resilience of Honiara's communities and economies to future climate change effects.

Table 4-5 Summary of key threats to each ecosystem service

Key Ecosystems	Key Ecosystem Services identified by community	Climate-related Threats												Non-climate-related Threats										
		Sea level rise, tides,	Drought / decreased	Flooding / increased	Coastal erosion /	River, gully, stream	Hot days	Landslide	Ocean acidification	Cyclones (intens.	Invasives	Disease	Changing species	Pollution (water-	Tsunami	Solid waste Mngt.	Development (e.g.	Land clearing / habitat	Pop. Increase, loss of	Change in land use /	Inadequate resource	Economic pressures	Policy changes	Negative human
Urban greenspace	Recreation and leisure		✓	✓						✓	✓				✓	✓	✓			✓	✓			✓
	Tourism support		✓	✓						✓	✓				✓	✓	✓			✓	✓			✓
	Urban habitat and biodiversity		✓	✓						✓	✓				✓	✓	✓			✓	✓			✓
	Shade provision		✓	✓						✓	✓				✓	✓	✓			✓	✓			✓
General landscaping	Urban habitat and biodiversity corridor		✓				✓				✓					✓	✓				✓			✓
	Aesthetic value		✓				✓				✓					✓	✓				✓			✓
	Shade provision		✓				✓				✓					✓	✓				✓			✓
Land (e.g. built environment)	High value commodity	✓		✓	✓			✓							✓		✓			✓		✓	✓	
	Provision of land for development, business and services	✓		✓	✓			✓							✓		✓			✓		✓	✓	
	Supports cultural identity	✓		✓	✓			✓							✓		✓			✓		✓	✓	
Urban springs and groundwater	Water provision (drinking)	✓	✓											✓		✓	✓	✓	✓	✓	✓		✓	
	Water provision (domestic and other uses)	✓	✓											✓		✓	✓	✓	✓	✓	✓		✓	
Rivers, streams other water bodies	Water supply (drinking)	✓	✓	✓		✓		✓		✓				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Water supply (domestic)	✓	✓	✓		✓		✓		✓				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Water supply (other)	✓	✓	✓		✓		✓		✓				✓	✓	✓	✓		✓	✓	✓		✓	✓
	Recreational uses		✓	✓		✓		✓						✓	✓	✓	✓		✓	✓	✓			
	Food provision	✓	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Transport facilitation		✓					✓											✓			✓		
	Habitat provision and biodiversity	✓	✓			✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Raw materials provision							✓											✓		✓	✓	✓	✓
	Cultural and religious values													✓		✓	✓				✓			
	Support fisheries and aquaculture	✓	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Support tourism		✓					✓						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Environmental and event regulation		✓					✓		✓				✓		✓	✓	✓	✓	✓	✓		✓	✓

	Waste disposal and dispersal		✓																				
Coastal and marine	Support fisheries	✓		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Raw materials provision	✓							✓									✓		✓	✓	✓	✓
	Coastal protection	✓			✓					✓					✓					✓		✓	
	Recreation	✓		✓	✓				✓	✓	✓	✓			✓	✓	✓	✓		✓			
	Support tourism	✓		✓	✓				✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	
	Transport facilitation	✓								✓					✓						✓		
	Waste disposal and dispersal	✓													✓	✓	✓		✓	✓		✓	✓
	Food provision	✓		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
	Habitat provision and biodiversity support	✓		✓	✓				✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓
	Cultural values	✓			✓				✓		✓	✓			✓	✓	✓	✓			✓	✓	
Terrestrial watershed	Habitat provision and biodiversity support		✓	✓				✓		✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓
	Recreation and leisure		✓	✓				✓		✓						✓	✓	✓	✓	✓	✓	✓	✓
	Food provision (incl. cultivation)		✓	✓			✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Raw materials		✓	✓			✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
	Support logging industry and agriculture		✓				✓	✓		✓							✓	✓		✓	✓	✓	✓
	Medicinal materials provision		✓	✓				✓		✓	✓	✓	✓				✓	✓	✓	✓	✓		✓
	Cultural values		✓					✓		✓			✓			✓	✓	✓	✓	✓	✓	✓	✓

5 Valuation of ecosystem services

The purpose of quantifying values as part of the ESRAM process is to provide insights into the relative extent and magnitude of ecosystems and ecosystem service values across and between different environments. While it may be simple to identify the existence of ecosystem services, valuing ecosystem goods and services such as clean air, clean water, and biodiversity is complicated, as these goods are often not traded in markets, meaning that they do not have an obvious economic value revealed through consumers' willingness to pay (market prices). As a result, unregulated markets or goods and services, such as ecosystems services, often become compromised or collapse. By placing a value on ecosystem services, priorities can be given to protecting and restoring ecosystems through programmes, policies and actions. Additionally, if ecosystems and their services are not valued, they may be overused or damaged, as there is no incentive to protect or conserve the service (King and Mazzotta 2000).

Due to the highly modified nature of Honiara's urban ecosystems and their reduced ability to provide services compared to that of a healthy, stable ecosystem, the following valuations will not be considered in the Honiara ESRAM outcomes and analysis presented in Section 7. The economic valuations will, however, play a role in the subsequent phase of the PEABACC project: the EbA options development phase.

5.1 Grouping of ecosystem services for valuation

The ecosystem services presented above represent the full list of services identified from the Honiara workshop. All ecosystem services have been included, as they represent an important characterisation of the different services that the Honiara community rely upon and/or use. However, several ecosystem services could not be valued for the reasons listed below.

- The service is not an ecosystem service but a service from a built or heavily altered environment.
- There is insufficient data to attribute a value to the ecosystem service.
- The service was too specific or detailed and would be better considered within the geographic boundaries of a discrete option. For example, it is not practically possible to provide an ecosystem service value for 'urban greenspace' due to the heterogeneity of different greenspace types and associated services.
- The listed service is likely to be more of a negative ecosystem impact than a service, e.g. land for housing/airport/churches, etc.[4]
- The scope of the service extended beyond the area of Honiara and its direct surrounds.[5]
- The service was duplicated or captured under a different service/ecosystem category.

The following categories of ecosystem were utilised for the purpose of the valuation process:

- tropical forest;

[4] Note that the ecosystem services that support built environments would be captured in the ecosystem service values attributed to those ecosystems, not the built environment (the built environment being the recipient of the service, not the service).
[5] For this project Honiara has been considered as the government-owned land on which Honiara sits (approximately 22 square kilometres) as well as the ecosystem services that exist in the immediate surrounds and benefit the local community. Large-scale services, such as commercial mining, logging and fishing, have not been considered, as these extend beyond the limits of Honiara.

- mangrove;
- marine; and
- freshwater systems (streams, creeks and groundwater).[6]

This was informed by the long list of ecosystem services and the availability of valuation studies. There is a subsection for each of the ecosystems listed above, which discusses the key services of each and outlines ecosystem values. A key omission from this list of identified services is cultivated terrestrial land, which essentially refers to plantations and gardens. While these agro-ecosystems provide a range of services and products to humans, and can also perform ecosystem services such as regulation of soil and water, quality they can also cause ecosystem disservices, e.g. contaminating water and increasing sedimentation run-off. The exact value of these types of system are, therefore, a function of the services and disservices they provide and vary greatly, depending on the land-use type and the natural environment it is replacing. As a result, the values for gardens and plantations are not included.

5.2 Tropical forests

5.2.1 Overview

The hills around Honiara were once covered in primary forest, but they are now largely cleared and consist of open grassland. Human activities such as deforestation, shifting agriculture, bush fires, World War II forest clearances, new settlements and gardening, have all contributed to the change in vegetation. This means that several ecosystem services which would otherwise have been servicing the Honiara area have been lost.

While it was identified that the people of Honiara still receive some services, such as fuel for fire, building materials, food and cultural values, it is not appropriate to consider the values of a healthy tropical forest due to the reduced state of the ecosystem around Honiara. As a result, the proposed values below will need to be adapted, based on ecosystem condition. Alternatively, they may also be considered as potential benefits of restoring the ecosystem.

5.2.2 Input values

Appropriate local values could not be identified. As a result, global median values from de Groot *et al.* (2012) were applied.

5.2.2.1 Global median values

Tropical forests provide a range of provisioning, regulating, habitat and cultural services. Due to the lack of local use values, the full range of values from de Groot *et al*. (2012) have been included without duplicating (see Table 5-1). It should also be noted that the ecosystem condition for forested areas will need to be taken into account in applying these values to the Honiara setting.

Table 5-1 Summary of tropical forest values (source: adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Provisioning services	Water	42	330

[6] The project team would like to note that further consideration of ecosystem services that have not been valued here as a result of consolidation may be undertaken, where relevant and feasible, as part of the options assessment phase.

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
	Food	25	196
	Raw materials	47	370
	Medicinal resources	1,715	13,405
Regulating services	Climate regulation	377	2,950
	Disturbance moderation	32	250
	Regulation of water flows	777	6,079
	Waste treatment	7	53
	Erosion prevention	15	116
	Pollination	60	472
Habitat	Genetic services	8	62
Cultural services	Recreation	96	753
Total	-	3,202	25,037

5.3 Mangroves

5.3.1 Overview

Mangroves are important ecosystems that can provide a range of services, from land stabilisation through to food provision and biodiversity values. There are a few patches of mangroves within and around Honiara, including between the town centre and the airport.

Workshop participants identified mangrove ecosystem services to include timber for fuel and building materials, food (including fruit and fish), waste treatment and regulation. These services have been considered in developing the unit values presented below.

5.3.2 Input values

5.3.2.1 Localised values

At the local level, one Solomon Islands study was found with values for mangrove ecosystem services. The study by Warren-Rhodes *et al.* (2011) includes provisioning services based on market prices and provides values from three sites, including Talakali in Malaita Province. Talakali is approximately 100 km north-east of Honiara and is the closest of the three to Honiara, with the best access to markets and trade. Population increases have placed pressure on the Talakali mangrove ecosystems, thus changing the value of services. This is likely a shared trait with Honiara, so values from this site were considered appropriate for transfer to Honiara and have been included in

Table 5-2 below.

Additional services such as biodiversity, habitat, regulation, sanitation, cultural and recreational services were also identified during the Honiara workshop. Their values could not be quantified from localised studies (due to a lack of available information) and have instead been captured via median global values as outlined in the next section.

In addition to these values, MACBIO (2015) gives a value of USD 391 per annum per hectare for mangroves for carbon sequestration.

Table 5-2 Mangrove ecosystem services values (from Talakali)

Ecosystem good	USD 2015, household/p.a.	SBD 2015, household/p.a.	Source
Firewood	2,014	15,748	Warren Rhodes *et al.* (2011)
Building materials	27	214	Warren Rhodes *et al.* (2011)
Fishing in mangroves	1,980	15,477	Warren Rhodes *et al.* (2011)

5.3.2.2 Global median values

Mangroves provide a range of ecosystem services, including provisioning, regulating, habitat and cultural services. There are a number of more specific services listed under each of these categories, some of which duplicate the services valued above, and some of which are in addition to them. The additional services and their monetary values are shown in Table 5-3.

Table 5-3 Summary of mangroves values (source: adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Provisioning services	Water	54	19
	Medicinal resources	344	2,867
Regulating services	Climate regulation	13	98
	Disturbance moderation	2,324	18,174
	Waste treatment	1,182	9,243
	Erosion prevention	511	3,993
	Nutrient cycling	51	401
Habitat services	Nursery service	2,555	19,979
	Genetic services	1,246	9,742
Cultural services	Recreation	269	2,104
Total	-	8,549	67,020

5.4 Marine

5.4.1 Overview

Honiara residents utilise the marine environment extensively, including for fishing, building materials, recreation and income-generation. Additionally, the marine environment plays an important role in providing regulating and supporting services, such as natural hazard protection and sanitation services.

For the purposes of economic valuations, the marine environment for Honiara has been considered as the coastal zone, extending from the shoreline to the outer coral reefs (up to a few kilometres out to sea). This means the ecosystem was not exclusive of coral reefs, but included other habitats such as shallow sand/rubble, seagrass meadows and nearshore and open ocean. The marine environment did not consider mangroves, which have been considered separately. This may limit the exact economic boundary of ecosystem services received by Honiara residents (e.g. Honiara commercial fishers may go well beyond this zone), but these values were captured under the national scale values.

5.4.2 Input values

5.4.2.1 Localised values

Two key ecosystem valuation studies were identified as relevant to the Honiara marine environment: Albert *et al.* (2015) and MACBIO (2015). The first set of values, shown in Table 5-4, are from Albert *et al.* (2015) and provide a high degree of granularity across a range of marine ecosystem services. These services accord with the uses and practices identified by Honiara locals, including provision of building materials (e.g. sand and stone) and commercial and subsistence values. They do not, however, necessarily match the demographics of Honiara and hence would need to be adjusted. Furthermore, the study provided a similar approach to defining the ecosystem making the transfer more accurate.

Additional marine ecosystem services were also identified during the Honiara workshop, but their values could not be quantified from localised studies (due to a lack of available information). They have, however, been captured via median global values, as outlined in the next section.

Table 5-4 Marine ecosystem services values

Ecosystem good	Estimate value USD 2015/p.a.	SBD 2015/p.a.	Source	Method
Fish	1668	13,041	Albert *et al.* (2015)	Based on a range of market prices and quantity harvested
Shellfish	1751	13,690	Albert *et al.* (2015)	Based on a range of market prices and quantity harvested
Shark, shark fin	145/456	1,134 3,565	Albert *et al.* (2015)	Based on a range of market prices and quantity harvested
Total fisheries	5173	40,446	Albert *et al.* (2015)	Based on a range of market prices and quantity harvested
Coral products (Sand, rubble, stone etc.)	2213	17,303	Albert *et al.* (2015)	Based on a range of market prices and quantity harvest
Total	7,842	61,313	-	-

Notes The figures above are per person engaging in the activity based on respondents. This means that the values will need to be multiplied by the number of communities engaging in the activity at the community level to generate a figure. If this is not feasible, global median values may be used.

Supplementing these values, MACBIO (2015) provides the values in Table 5-5 for subsistence and commercial inshore fishing. It is worth noting that these values are for the population of Honiara, and not necessarily those who are most reliant on subsistence or inshore fishing, while the values from Albert *et al.* (2015) are from interviews with rural, coastal-dwelling and subsistence-based communities.

Table 5-5 Summary of Honiara marine ecosystem service values

Ecosystem good	USD 2015, per person/p.a.	SBD 2015, per person/p.a.
Subsistence fisheries	1,668	13,041
Commercial artisanal inshore fisheries	1,751	13,690

5.4.2.2 Global median values

The de Groot *et al.* (2012) study divides the marine environment into coral reefs and coastal systems. The values for each have been provided in Table 5-6 and Table 5-7 and will be applied, based on the characteristics of the study site. Coastal systems have been defined as sea-grass fields, shallow seas of continental shelves, rocky shores and beaches, which are found in the terrestrial near-shore as well as the intertidal zones, whilst coral reefs are considered as their own distinct biome.

The figures shown in Table 5-6 are for coral reefs, while the figures shown in Table 5-7 are coastal systems.

Table 5-6 Summary of marine values (coral reefs) (Source: adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Provisioning services	Genetic resources	37,675	294,564
Regulating services	Climate regulation	1,985	15,522
	Disturbance moderation	1,727	13,499
	Waste treatment	97	758
	Erosion prevention	175,423	1,371,564
Habitat services	Genetic services	47	365
Cultural services	Recreation	1,658	12,960
	Cognitive development	90	704
Total	-	218,702	1,709,936

Table 5-7 Summary of marine values (coastal systems) (Source: adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Regulating services	Erosion prevention	28,920	226,110
Habitat services	Nursery services	106	829
	Genetic services	205	1,604
Cultural services	Recreation	300	2,344
Total	-	29,531	230,887

5.5 Freshwater systems

5.5.1 Overview

Freshwater systems such as streams, creeks and groundwater are critically important resources for Honiara residents and are under stress from pollution and development. Rivers and streams are used for a variety of services, ranging from food and drinking water to irrigation water and transportation.

For the purposes of this study, it was not possible to include the services provided by groundwater due to a lack of local information. While an exceptionally important ecosystem service, groundwater has been poorly captured in past ecosystem valuation studies and there is no reliable global value that could be applied (see Greibler and Avramov 2013 for further information). While some values have been provided for the use value or purification value of groundwater systems, these were deemed not applicable to the study site and were also not representative of the full range of ecosystem services from groundwater (see Brink *et al*. 2011).

5.5.2 Input values

5.5.2.1 Localised values

It was not possible to identify localised values for freshwater services (including both surface water and groundwater) so global median values have been used instead.

5.5.2.2 Global median values

The freshwater ecosystem service values from de Groot *et al.* (2012) cover rivers and lakes, but do not cover saline lakes, wetlands and floodplains. The values are shown in Table 5-8.

Table 5-8 Summary of freshwater ecosystem values (Source: adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Provisioning services	Food	1,573	12,300
	Water	3,096	24,203
Regulating services	Waste treatment	404	3,155
Cultural services	Recreation	1,998	15,625
Total	-	7,071	55,289

5.6 Summary of ecosystem service valuations

As discussed at the start of Section 5, the highly modified state of Honiara's ecosystems reduces their ability to provide services to their full capacity (when comparing the level of services provided by healthy ecosystems). As a result, the economic values provided above are considered to be of more value in the development of adaptation options, as they could indicate the potential economic gain that communities and economies may benefit from if ecosystems were restored to their full capacity.

6 Climate change vulnerability assessment

The following climate change threats have been identified for Solomon Islands.

- Sea and air temperatures will continue to rise, potentially up to 1.0°C by 2030 and up to 2.0–4.0°C by 2090.
- Sea levels will continue to rise, with potential increases of 5–15 cm by 2030 and 20–60 cm by 2090.
- Ocean acidification will continue to increase with an associated decline in aragonite concentrations, potentially to 3.5 around 2030 and below 3.5 by 2045. They could potentially continue to decline to < 3.0 by 2090 and later.
- More extreme rain events could potentially occur with the current 1-in-20-year daily rainfall amount increasing by 9 mm by 2030 and 43 mm by 2090, and becoming a 1-in-4-year event by 2090.

As discussed in Volume 1, Section 2.5 (BMT WBM 2017a), the vulnerability of ecosystem services to climate change is the degree to which a system is susceptible to the adverse effects of climate change. This is a function of its exposure to climatic variations, its sensitivity to the climate variation and its adaptive capacity, or ability to adjust or cope, with climate change.

This section provides a vulnerability assessment to calculate exposure, sensitivity and adaptive capacity of key ecosystem services for Honiara to the main climate change threats identified for the Solomon Islands: temperature rise, sea-level rise, ocean acidification and more extreme rain events. Whilst this list of climate threats is not comprehensive, it includes those that have high to very high confidence of occurring and represent the highest risks to Solomon Islands. Projections for drought, more intense cyclones and altered wave patterns are not well established and have been considered only in the context of other climate change threats, where relevant. All projected changes are relative to 1995 levels for each climate variable (e.g. for sea-level rise in 2030, a mean increase of 13 cm to that of 1995 levels is projected).

The assessment of ecosystem service vulnerability is limited to the type of ecosystem and is not assessed at species level.

6.1 Climate vulnerability projections

6.1.1 Sea-level rise

2030 Sea-level Rise Projection Summary

- Sea-level rise of approx. 7–18 cm
- Mean change: 13 cm
- Confidence level is medium

By 2030, a range of Honiara's ecosystem services may be moderately vulnerable to the effects of sea-level rise, demonstrating community reliance on coastal ecosystems. This includes critical services, such as water quality, land source and food provision. At an overall ecosystem level, those potentially

2090 Sea-level Rise Projection Summary

- Sea-level rise of between approx.40–89 cm
- Mean change: 63 cm
- Confidence level is medium

most vulnerable to sea-level rise are rivers and streams, groundwater and low-lying backyard gardens. This is based on associated ecosystem services that are highly sensitive to, and have low adaptive capacity to, saline intrusion, including water supply (drinking, domestic and irrigation purposes), food (fish, ura, watercress, kangkung, backyard gardens that cannot be relocated), regulation of water quality, and biodiversity. Associated cultural services relating to recreation, tourism and aesthetics will not be vulnerable and provisional services provided by urban greenspaces, land (built) and general landscaping, are typically able to be relocated and overall have high adaptive capacity.

6.1.2 Air and sea temperature

As discussed in Volume 1, Section 6.1.2 (BMT WBM 2017a), surface air temperatures in the Pacific are closely related to sea-surface temperatures. Projected changes to air temperature therefore can be used as a guide to changes in sea-surface temperatures (Australian Bureau of Meteorology and CSIRO 2014a).

Although an increase in annual air temperature and an increase in extreme air temperature are varied, the potential effects from these climate threats, combined with the adaptive capacity of ecosystem services, result in the same level of vulnerability. Hence, for the purpose of this report, both climate variables are grouped and discussed as a single threat: increase in air temperature.

2030 Air and Sea Temperature Projection Summary

- Temp increase up to 1.0°C relative to 1995
- Mean change: 0.7'C
- Confidence level is very high.

2030 Extreme Air Temperature Projection Summary

- Temperature on extremely hot days is projected to increase the same amount as average temp.
- Frequency of extremely hot days is also expected to increase.
- Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C.

The coastal and marine ecosystems of Honiara are predicted to be the most vulnerable to the projected 2030 increase in air/sea temperature. This is predominantly due to the increased risk of coral bleaching and its associated effects on marine lagoon communities. Freshwater, mangrove and terrestrial forest ecosystem services are expected to demonstrate higher adaptive capacity to a projected 1.0°C temperature increase by 2030.

2090 Air and Sea Temperature Projection Summary

- Temp increase up to 2–4°C
- Mean change: 2.8'C
- Confidence level is very high

2090 Extreme Air Temperature Projection Summary

- Temperature on extremely hot days is projected to increase the same amount as average temp.
- Temp of the 1-in-20-year hot day is projected to increase by approx. 2.9°C.
- Confidence level is very high.

The projected 2090 increase in air temperature by 2–4°C presents a potential climate change threat to a broader range of services across marine, coastal and terrestrial ecosystems. Ecosystem services provided by reefs, such as coastal protection (dissipating wave and storm energy), fisheries, provision of food and raw material (e.g. coral, rubble), and marine biodiversity, are all intrinsically linked to the health of coral, which has a high sensitivity and low adaptive capacity to rapid and prolonged sea temperature rise.

Effects on mangrove ecosystems associated with temperature rise are anticipated, such as increased exposure to pests and disease and increased risk of drought and over-heating during tidal exposure. Whilst this may lead to local-scale changes in ecosystem composition and condition, overall, associated services, such as coastal protection, raw material (e.g. timber for construction and firewood), biodiversity and food provision, are expected to be moderately vulnerable to the projected 2090 temperature rise.

Similarly, effects on land-based and waterway ecosystem services associated with temperature rise are anticipated, due to their existing relatively disturbed condition, including commercial plantations and small-scale subsistence gardens. These include a potential decrease in crop yield, reduction in soil cohesion and stability, increased exposure to pests and disease, potential effects on water quality and increased risk of drought and other disturbances, such as fire. Whilst these may lead to local-scale changes in ecosystem composition and condition, overall, associated services may demonstrate moderate vulnerability to temperature rise alone.

6.1.3 Ocean acidification

Aragonite, a metastable form of calcium carbonate, is used by reef building corals and some other marine fauna to build skeletons and hard shells. As oceans acidify, the carbonate ion concentration in sea-water decreases, making it harder for corals and some fauna to grow (PACCSAP 2014b). For corals, saturation states above 4 are optimal, 3.5–4 adequate, and between 3–3.5 marginal, with no corals historically found below 3 (Guinotte *et al.* 2003).

2030 Ocean Acidification Projection Summary

- Median aragonite saturation state will transition to marginal conditions (3.5) around 2030.
- Mean change: –0.4 Ωar
- Confidence level is medium.

Based on 2030 projections, ocean aragonite concentrations may be adequate for coral and shell formation but by 2090 (and beyond), levels may decline to values where coral reefs have not historically been found (< 3.0).

2090 Ocean Acidification Projection Summary

- Median aragonite saturation state will continue to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0).
- Mean change: –1.5 Ωar
- Confidence level is medium.

As many of Honiara's marine and coastal ecosystem services are intrinsically linked to the health of coral, they may be highly vulnerable to the projected strong decline of aragonite saturation state by 2090. These services include, food, biodiversity, cultural values (e.g. shells for necklaces, ornaments and shell money), raw materials (coral rock) and fisheries support (e.g. crustaceans and molluscs). As ocean acidification continues, nutrient and energy cycles may also be altered and indirectly affect other marine flora and fauna, further decreasing the functionality and productivity of marine-based ecosystems (PACCSAP 2014b).

6.1.4 Extreme rainfall events

Extreme rainfall presents a potential threat to a broad range of ecosystem services by its direct impact on erosion and landslip within the terrestrial watershed and indirect effects on water quality. Ecosystem services in Honiara most vulnerable to extreme rainfall include: land stability and erosion control provided by the catchment, and subsequent effects on logging, agriculture and food provision of commercial plantations; small-scale subsistence gardens; and the water quality of receiving ecosystems, including waterways, coastal wetlands and marine lagoons.

2030 Extreme Rainfall Events Projection Summary

- Current 1-in-20-year daily rainfall amount to increase by approx. 9 mm
- 3% increase in annual rainfall
- Confidence level is high.

2090 Extreme Rainfall Events Projection Summary

- Rainfall to increase by approx. 43 mm
- Current 1-in-20-year daily rainfall event will become a 1-in-4 year event.
- 6% increase in annual rainfall
- Confidence level is high.

The vulnerability of the watershed to the effects of extreme rainfall will be exacerbated by other anthropogenic stressors, particularly vegetation clearing and other land disturbance. Improved land management practices, such as revegetation, land stabilisation and education on best practice land management, could help reduce these threats.

6.2 Summary of ecosystem service vulnerability

Under future climate change scenarios, Honiara is likely to face rising sea levels, increasing air and sea temperatures and an increase in extreme rainfall events. It is anticipated that these changes will put further stress on marine resources by increasing bleaching and the death of corals, molluscs and crustaceans from ocean acidification. Based on the vulnerability assessment to climate threats, Table 6-1 summarises the Honiara ecosystem services that are predicted to have high to very high vulnerability to climate change variables for both 2030 and 2090. Climate variables shaded grey are considered to present the greatest potential threat to ecosystem services (rated very high vulnerability).

Table 6-1 High to very highly vulnerable ecosystem services

Ecosystem	Ecosystem Services	2030 *		2090					
		Sea-level Rise	Extreme Rainfall Events	Sea-level Rise	Increased Sea Temp	Extreme Rainfall Events	Extreme Air Temp	Annual Air Temp	Ocean Acidification
Urban springs and groundwater	Water supply (domestic)	✓	✓	✓		✓			
	Water supply (drinking)	✓	✓	✓		✓			
Land (Built)	Food provision (subsistence gardens)		✓			✓	✓	✓	
Coastal and marine	Coastal protection			✓			✓	✓	
	Cultural and religious values				✓		✓	✓	
	Food provision				✓		✓	✓	✓
	Habitat provision and biodiversity support				✓		✓	✓	✓
	Raw materials provision			✓	✓		✓	✓	✓
	Support fisheries				✓		✓	✓	✓
	Support tourism						✓	✓	
Rivers, streams other water bodies	Environmental and event regulation		✓			✓			
	Food provision			✓					
	Habitat provision and biodiversity			✓					
	Support fisheries and aquaculture			✓					
	Water supply (domestic)		✓	✓		✓			
	Water supply (drinking)			✓		✓			
	Water supply (industrial and agriculture)					✓			
Terrestrial watershed	Erosion control and land stability					✓			

		2030 *		2090					
	Food provision (incl. cultivation)			✓		✓	✓	✓	
	Habitat provision and biodiversity support					✓	✓	✓	
	Medicinal materials provision					✓			
	Raw materials					✓			
	Recreation and leisure					✓			
	Support logging industry and agriculture					✓			
	Water quality and flow					✓			

* Based on the 2030 projections, ecosystem services are likely to be highly vulnerable to sea-level rise and an increase in extreme rainfall events and be low to moderately vulnerable to an increase in sea and air temperature and ocean acidification.

7 ESRAM outcomes

The vulnerability of Honiara's social and ecological systems to human activities such as logging, agriculture, pollution and the over-exploitation of marine resources is increasing. As Honiara's population growth rate has exceeded the national growth rate (which is also considered one of the most rapid growth rates in the world [SPREP 2016]), these activities will only intensify and have an increased detrimental efffect on the communities and economies of Honiara. The direct and indirect effects of climate change and their interactions with human-induced threats increases the vulnerability of critical ecosystems and ecosystems services. By highlighting these vulnerabilities, opportunities to protect and restore critical ecosystems and their services can be identified to retain and build on the strengths of social systems and effective governance structures, in turn increasing the resilience of both people and ecosystems.

The following section provides a summary of the vulnerabilities of Honiara's ecosystem services to climate and non-climate related threats and their effect on the resilience of the communities and economies of Honiara. The ESRAM outcomes are presented in three broad ecosystem types: freshwater (groundwater, urban springs, rivers and streams), coastal and marine (beaches, reefs, marine substrata, mangroves, seagrass and marine waters) and terrestrial watershed (forests, grasslands and cultivated land, both commercial and small-scale gardens).

7.1 Resilience of ecosystem services to human induced and climate change impacts

7.1.1 Freshwater ecosystems and services

Like most ecosystems in Honiara, the rivers and streams are highly modified by human-derived disturbances. Logging and saw-milling activities in Honiara's mid and upper catchment areas are resulting in high levels of soil erosion and the sedimentation of stream and river systems. These activities, combined with pollution from poor sanitation and solid waste practices, subsistence and commercial cultivation on sloping lands, and clearing areas for the rapidly increasing urban demand, are likely to be detrimentally affecting the water quality of freshwater systems. Rapid population growth and urbanisation will further increase these activities.

The projected increase in extreme rainfall events of 2090 and beyond is likely to intensify human-induced effects. Extreme rainfall events can lead to flash and localised flooding and severe riverine flooding due to the extensive catchment areas upstream of the city. Households and businesses in low-lying areas in proximity to river outlets and the coastline are highly vulnerable to these threats (ICEM 2015). The increase in unsustainable land practices, coupled with increased extreme rainfall events, could have disastrous flow-on effects to downstream ecosystems and lowland areas across Honiara.

Freshwater ecosystem services most likely to be highly vulnerable to these threats are critical services: the provision of drinking water and flood flow regulation services, both provided by streams and rivers. Approximately 44% of Honiara's population is vulnerable to flooding (UN-Habitat 2016a). This level of vulnerability to flood waters will only intensify throughout riverine flood-prone areas (see Figure 3-4) and expand into new areas with increased extreme rainfall events and watershed degradation. The high vulnerability of Honiara's drinking water supply was observed during the April 2014 floods, when 50,000 people were affected and half of these people had major difficulties in accessing clean drinking water.

Further land disturbances of the mid and upstream catchments will reduce the resilience of communities and ecosystems to increased extreme rainfall events. The provision of water for drinking and domestic purposes from groundwater and urban springs is also likely to be highly vulnerable to increased extreme rainfall events. During periods of extreme rainfall, seepage into groundwater systems from the probably highly-polluted floodwaters (as a result of poor sanitation and waste practices and upper catchment inputs such as chemicals, pesticides and fertilisers) may contaminate the city's drinking water supply. The increased extreme rainfall events are likely to worsen the existing levels of hazardous run-off at the Ranadi dump site, which currently leaches medical and hazardous waste, chemicals and septic effluent into the soil and surrounding waterways and shoreline (UN-Habitat 2016a).

Food, habitat (supporting aquatic fauna and waterbirds), and income-generation (fishing and aquaculture) services provided by rivers and streams are likely to be highly vulnerable to human-induced disturbances and declining water quality. Food sources, such as fish, crab, ura, water cress and kangkung, are important to many households in Honiara for both subsistence and income generation purposes. Severely degraded stream and river conditions undermine the integrity and resilience of ecosystem components in the rivers and streams (i.e. flora, fauna and their habitats), as well as for downstream receiving environments, including coastal and marine ecosystems. Communities and economies that rely on freshwater ecosystems for food and income-generation may be required to adapt to alternative ecosystems for these essential provisional services.

The effect on freshwater systems will be intensified by the threat of saltwater intrusion from rising sea levels and the high saline sensitivity of freshwater ecosystems and their low capacity to adapt to increased salinity levels. Ecosystem services likely to be less resilient to sea-level rise include the essential provisioning services discussed above: water supply for drinking and domestic purposes; food and habitat provision; and income-generation from fisheries and aquaculture.

The vital service of drinking water supply by urban springs and groundwater is a critical resilience issue for many people of Honiara. In the event that both groundwater and rivers/stream systems become contaminated, which would force the supply of drinking water to become unavailable, the population of Honiara would be at risk of serious health implications, particularly low-income households that cannot afford to purchase bottled water. The high vulnerability of water supply services to the effects of both human-induced and climate change threats severely reduces the resilience of Honiara's communities, particularly after natural or climate-related disasters and extreme heat events.

7.1.2 Coastal and marine ecosystems and services

Pollution, habitat loss and over-exploitation of marine resources are the key existing and medium-term threats to Honiara's coastal and nearshore marine ecosystems. Habitat loss and coastal development, including illegal sand reclamation works, continue to severely degrade the city's coastline and expose the area to further coastal erosion and destruction. Further exacerbating these threats is the high level of pollution received from much of greater Honiara's day-to-day activities, including: agricultural and industrial activities; logging and saw milling; sewage; household waste disposal; backyard livestock waste; hydrocarbons from both land-based (e.g. road run-off) and marine-based (e.g. shipping) leaks and spills; sediments mobilised from watershed clearing; erosion and construction; boat and ship discharges (e.g. rubbish and unlawful ballast discharge); and run-off from the Ranadi dump site.

The large volume of plastic waste entering the marine environment, including both macro- and micro-plastics, is also increasingly raising concern globally because of the effect on marine fauna through consumption and

entanglement. This pollution affects multiple components of the coastal and marine ecosystem, including water quality, sediment quality, and the structure, composition and condition of flora and fauna communities. The projected increase in extreme rainfall by 2090 and beyond is also likely to intensify the pollution and sediment run-off entering coastal systems from both upstream activities, such as logging and agriculture, and downstream activities, such as poor sanitation and waste management practices.

Over-exploitation and unsustainable fishing practices are affecting Honiara's marine fauna structure, composition and biodiversity, and the depleted fish stock of the local coastal areas cannot meet the current demand for fish (SPREP 2016). Increasing urban population growth will continue to draw on marine resources to a point where the local marine ecosystem threshold may be exceeded and resources could become exhausted.

The significant pollution, habitat loss and over-exploitation of marine resources present severe implications for the resilience of Honiara's communities, economies and ecosystems, with or without the projected effects of climate change. All ecosystem services provided by marine and coastal ecosystems, excluding the support of transport, industry and goods/people transfer, are likely to be highly vulnerable to these threatening processes. The effects of climate change will only exacerbate the vulnerability of ecosystem services that are heavily relied on by the communities and economies of Honiara.

Honiara's marine ecosystems are likely to be less resilient to the projected 2–4°C sea temperature increase by 2090 and beyond, due to reefs and seagrass having high sensitivity and low capacity to adapt to changes in sea temperature. An increase in sea temperature of this magnitude, combined with the increased risk of coral bleaching and marine over-exploitation and pollution, is likely to severely affect the provisioning services that are critical to the well-being and livelihoods of Honiara households. Provisioning ecosystem services identified as highly vulnerable include: food provision from local fisheries (commercial and subsistence); habitat and biodiversity near Point Cruz and mangroves within Lungga River delta; income and revenue generation, such as fisheries, building materials (coral rock) and tourism (snorkelling and diving); provision of raw materials (coral rock and lime production); and coastal hazard protection by the attenuation and buffering of wave and storm energy by reefs at Point Cruz. Cultural ecosystem services are also threatened by temperature changes, particularly those provided by corals, and include: cultural artefacts and commercial ornaments (shell money, ornaments, jewellery and decorations), cultural identity and status, and *kastom* medicine (coral).

The projected levels of ocean acidification by 2090 and the associated decline in aragonite concentrations will further reduce the resilience of coral reefs and species, such as crustaceans and molluscs, and associated ecosystem services. The effect of acidification on the health of reef and marine ecosystems is likely to be compounded by other stressors, including high sea temperatures (potentially leading to coral bleaching), poor water quality, storm damage, and inappropriate fishing practices. Intertidal ecosystems that provide food such as crustaceans and molluscs will be affected and further increase the vulnerability of local communities that rely on these ecosystems for essential services such as food, income and raw materials. They may be required to adapt to alternative ecosystems for provisional services by 2090.

The projected sea-level rise of 40 cm to 89 cm by 2090, together with Honiara's coastal development and reclamation, urban growth and pollution, will likely reduce the resilience of ecosystem services provided by the remaining patches of mangroves in the Lungga River delta to inundation and erosion of shoreline habitats. Mangrove ecosystem services assessed in this study that are likely to be highly vulnerable to 2090 sea levels include: coastal protection and shoreline stabilisation, habitat provision for intertidal fauna, raw materials for timber and fuelwood provision, and *kastom* medicine.

Marine and coastal ecosystem services are vital to the livelihoods and well-being of a large portion of households for both subsistence and income-generation purposes, particularly low-income households that are heavily subsistence based. The depletion of marine resources, and the corresponding reduced generation of income, will affect food security by forcing people to be more dependent on the market, which can have severe implications due to increasing prices. The high reliance on resources for subsistence, combined with the depletion of marine resources and a rapid urban growth rate, are critical issues for Honiara. The degradation of marine resources from both climate and human-induced threats is also likely to increase the rural-urban migration, as the provision of food and income becomes insufficient to meet the basic needs of rural households.

In order to build social and economic resilience, there needs to be a balance between meeting the subsistence food needs of households and maximising economic benefits through the export and sale of marine products. In turn, marine ecosystem resilience needs to be enhanced by improving water quality, reducing coastal development pressures, and managing fisheries resources sustainably.

7.1.3 Terrestrial watershed ecosystem services

For the purpose of this study, Honiara's terrestrial watershed captures the upstream watersheds of the city's major rivers and terrestrial areas of both upstream and downstream areas, including cultivated lands (both large and small-scale). There is a high degree of connectivity between Honiara City and the upstream reaches of its major watersheds, so retaining the condition of the upstream reaches is critical to the resilience of downstream waterways and marine ecosystems and their services.

In both the upper and lower reaches of the watershed, logging, timber milling, land cultivation and the expansion of settlements and other developments are the major threats to the watershed. These activities result in deforestation, soil erosion and reduced land stability, which have significant cumulative effects on downstream areas from increases in run-off, flooding, and an increased risk of landslides during periods of high rainfall.

Food gardens for subsistence and small-scale production throughout the mid and lower catchment areas are leading to more exposed soil due to unsustainable agricultural practices on riparian areas. The exposed land is causing an increase in bank collapse and a loss of vegetation. Furthermore, cultivation activities are likely to introduce chemicals into the environment through the use of pesticides, while settlements and development increase pollution inputs from human and animal waste production (i.e. livestock and poor sanitation and waste management). These activities increase the level of pollution entering the waterways and severely affect the receiving environments downstream.

The projected increase in extreme rainfall events by 2030 and beyond is likely to intensify existing soil instability and affect water quality. Many communities throughout Honiara are already highly exposed and sensitive to extreme rainfall events and flash flooding. The clearing of forests, coupled with intensive rainfall on steep slopes will lead to high volume run-off and flash flooding in the upland areas and steep lower catchment areas, particularly as more vegetation is cleared. Within the flatter areas of Honiara City, localised flooding will increase with more intensive rainfall. Areas where rubbish is blocking drainage and runoff, localised flooding will be exacerbated, as seen in the April 2014 floods. By impeding the drainage of floodwaters, there is an increased risk of vector-borne diseases from the stagnant water pooling for a prolonged period. An intensification of extreme rainfall events will increase the volume of chemicals and waste accumulated on land

entering the waterways and thus polluting the receiving environments in lowland areas, including marine ecosystems where all run-off is ultimately received.

All terrestrial watershed ecosystem services are likely to be affected by forest clearing and an increase in extreme rainfall events. Ecosystems services likely to be highly vulnerable are: food provision from cultivated gardens and plantations in upper, mid and lowland areas (including backyard gardens) and waterways (fish, crab, ura, water cress and kangkung); habitat provision and biodiversity provided by forests and waterways; water quality and flow; provision of building materials (timber) and fuel (fuelwood); and the provision of areas and opportunities for socialising and recreation. Cultural ecosystem services will also be highly vulnerable to extreme rainfall events and human-induced threats. These services include: the provision of medicinal plants and trees; the provision of materials for traditional costumes, ornaments and cultural artefacts (e.g. leaves, seeds, timbers); and the provision of areas for reconnecting with traditional land-based cultural practices.

While the primary human uses of terrestrial lands in Honiara and its upstream reaches present the dominant existing threats to the watershed and its functioning (i.e. logging and agriculture), the long-term provision of income-generation through logging, timber harvesting, and market produce is threatened by the self-same activities that generate the income. An increase in extreme rainfall events will increase the vulnerability of these services to flash flooding and potential landslides (see Figure 3-4 for existing landslip risk zones). Building the resilience of ecosystems and communities to an increase in extreme rainfall events, through reforestation, clearing regulations and forest protection, will need a collaborative approach from people across all catchment areas.

Honiara's food security will be increasingly threatened with the loss of crops from flooding and landslides (see riverine flood and landslip risk zones in Figure 3-4), loss of topsoil from erosion, water logging, saltwater intrusion in low-lying areas (e.g. storm surge risk zones in Figure 3-4), and a potential reduction in crop yield from the likely fluctuations in rainfall. This is a critical resilience issue for a large proportion of informal settlements that heavily rely on subsistence gardens for their livelihoods and well-being, and are also located in areas highly exposed to natural and climate disasters.

The projected increase in air temperature of 2–4°C by 2090 is also expected to reduce the resilience of food crops in both commercial plantations and subsistence gardens. Higher temperatures could adversely affect tropical staple crops such as sweet potato, yam, cassava and taro (ICEM 2015). Increased temperatures can reduce soil moisture content, which can stunt plant growth and affect productivity. An increase in air temperature can also increase the sensitivity of crops to pests and diseases. Climate, water and soil regulation provide suitable conditions for cultivated lands for food production and quality. Land-use change affects the levels of these regulating services, while the interaction of land-clearing and climate change is predicted to affect the provision of stable climatic conditions (Carabine *et al.* 2015), and threaten Honiara's food security and livelihoods. New plant species with tolerance to high temperature and fluctuating rainfall may need to be explored to build crop resilience to the projected increase in temperature and extreme rainfall events, and strengthen Honiara's food security.

The lack of shade provision in the HCC area, particularly with Honiara's hot climate, is a threat to human health and is likely to be contributing to increased temperatures in the city centre, also known as the heat island

effect.[7] As the rate of urban development increases in Honiara, the conversion of natural landscapes to hardscape developments is also increasing. A lack of trees also prevents the absorption of pollutants from the increasing traffic volumes, the burning of waste, and dust emissions during times of prolonged dry periods. Implementing the proposed urban greenspace network outlined in the Honiara's Local Planning Scheme will provide shade and absorb air pollutants, while building resilience to an increase in temperature from both the heat island effect and projected temperature changes from climate change.

The projected temperature increase is also likely to have detrimental effects on the biodiversity of forests and soil properties due to the disturbed condition of the upstream catchment. High temperatures can cause soil instability through decreased cohesion of particles. High temperatures can also affect temperature-sensitive plant species, resulting in changes in species composition and habitat modifications. Changes in species composition can also result in the introduction of pests and diseases that may affect forest and crop yields, and thus the income-generation potential and livelihoods of many Honiara households.

Similar to Honiara's marine ecosystems, the terrestrial watershed is significantly affected by these highly threatening activities, resulting in severe implications to the downstream communities and ecosystems, even without consideration of the projected climate changes. These threats will be exacerbated with increasing population growth and urbanisation. Addressing the immediate development challenges associated with unregulated clearing, clearing riparian areas, unsustainable logging and agriculture activities, and poor sanitation and waste management practices, is critical to tackle future climate threats. As these activities continue to severely damage and deplete ecosystem services provided by the watershed, Honiara's resilience to current and future threats will continue to weaken.

7.2 Ecosystem-based adaptation options for Honiara

Ecosystem-based adaptation (EbA) aims to increase the ability of local communities and ecosystems to adapt to the effects of climate change. Well-managed and healthy ecosystems are critical for the provision of essential services to maintain the health, well-being and livelihoods of all Honiara communities. The importance of ecosystem services is intensified in areas where basic infrastructure and services are lacking or are unaffordable (e.g. water supply, subsistence-based living) for a large sector of the population.

The ESRAM process has identified the vulnerabilities of social ecological systems to climate and non-climate change threats and effects. By restoring, protecting and strengthening ecosystems, Honiara's communities and economies will be stronger and more resilient now, and into the future.

The Honiara EbA options aim to build on existing climate change adaption work completed in the Honiara Urban Resilience and Climate Change Adaptation Plan (UN-Habitat 2016a) by providing a more holistic vulnerability and resilience assessment through examining Honiara's broader community's reliance on ecosystems and ecosystem services. Based on the highly vulnerable ecosystem services identified above, Table 7-1 presents high-level EbA options to be considered to increase the adaptive capacity and resilience of ecosystems. As EbA options have been grouped into the high-level ecosystem types, non-ecosystem specific EbA options are listed below:

[7] The heat island effect is an urban area that is significantly warmer than its surrounding rural areas generally caused by the modification of land surfaces. The heat island effect can develop as a result of replacing vegetated areas with asphalt or concrete which increases the surrounding area's night time temperature, or high night time temperatures remain high as the heat island effect limits night time cooling (Department of Health 2008). The lack of vegetation, and therefore the lack of evapotranspiration, shade and the cooling effect provided by trees, is also a key contributor to the heat island effect. Impacts are predominately heat related stress amongst the elderly, pregnant women, children and people with cardiovascular and respiratory diseases (Doick and Hutchings 2013).

- development of a waste improvement programme for HCC, focusing on waste collection and transport activities (HCC operates a new waste management facility, but mechanisms for collecting household waste and transporting it to the facility appear to be inadequate);
- development of a community waste education programme, to include awareness-raising (particularly on Honiara's high reliance on plastics), competitions between communities, celebration and announcement of winners, and establishment of an annual 'Waste Management Week';
- development of a Honiara disaster risk reduction and management plan (as proposed in UN-Habitat 2016a); and
- training in environmental compliance for HCC staff, covering the enforcement of HCC by-laws, Guadalcanal Province ordinances, and national environmental regulations. The training would be aimed at providing staff with the appropriate level of knowledge and tools required to undertake regulatory inspections and investigations.

Effective governance structures are critical in building a city's resilience to the adverse effects of climate change. While collaboration between all levels of government is needed to assist HCC to increase its technical and long-term management capacity of Honiara's ecosystems and their services, HCC is ultimately responsible for the priority issues that currently threaten the health of ecosystems and communities. HCC must build the skills and capacity across all relevant agencies so that essential services (e.g. infrastructure, shelter, water supply, and waste and sanitation) can be effectively distributed to all residents of Honiara and adequately managed in the urban environment. Mainstreaming climate change into all regulations, policies and programmes is also essential to ensure that all decision-making processes (e.g. town planning, infrastructure and housing, education and health) consider climate adaptation and contribute to building a climate resilient city.

Urban population growth and development is a key threat to the increased degradation of ecosystems and further reduces the resilience of communities to natural hazards, particularly in informal settlement zones, where overcrowding and exposure to natural hazards is currently high. All levels of government must work together to improve the existing infrastructure and services that cause ecosystem degradation (e.g. waste and sanitation services and infrastructure), enforce building regulations, and monitor all new developments. The environmental, social and economic condition of urban areas will also be improved by providing adequate access to basic services, infrastructure and shelter. The provision of affordable housing for low-income earners should also be explored by HCC and the Provincial Government to reduce the rapid growth rate of informal settlement zones. UN-Habitat (2016a) suggests a province-wide strategy of decentralising services and establishing 'pull' factors in townships outside Honiara to help reduce the rapid population growth rate expected for Honiara over the coming decades.

Climate change is inevitable, but by enhancing and protecting ecosystems and building a stronger, healthier, cleaner city, Honiara will increase its resilience to future conditions and continue to adapt to an ever-changing climate.

Table 7-1 Suggested EbA options to increase the adaptive capacity and resilience of Honiara ecosystems

High-level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-climate Stressors	Potential Climate Change-related Effects	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
Freshwater (groundwater, urban springs, rivers and streams)	• Water supply (drinking, domestic, irrigation for industry and agriculture) • Habitat and biodiversity • Environmental and event regulation • Food provision (fish, crab, ura, water cress, aquaculture) • Support fisheries and aquaculture	• Population growth • Vegetation clearing and land disturbance from logging, saw-milling, agriculture, urban development, gravel extraction • Sediment run-off from inappropriate land management activities such as logging and agriculture • Pollution from poor solid waste management and sanitation, chemical, pesticide and fertiliser inputs, urbanisation and extractive industries	• Soil erosion, sedimentation and landslip from extreme rainfall events. Exacerbated by more intense tropical cyclones • Salt-water intrusion from sea-level rise	• Relocate communities and businesses from vulnerable riparian areas to drier, higher ground • Vegetation protection and catchment and riparian revegetation programme • Land-use planning restrictions on steep and unstable soils • A clean water protection programme (similar to the proposed 'Protection of Water Resources' adaptation programme in the ecosystem-based adaptation and climate change vulnerability in Choiseul Province, Solomon Islands Synthesis report): - increasing and sustaining water storage capacity - restoration and management (including riparian and freshwater ecosystems) of water catchment areas - sediment control of freshwater streams and water quality testing. • City-wide environmental awareness and education programmes on: - sustainable land management practices, including importance of riparian vegetation - stormwater management systems - good waste management and sanitation practices	• Honiara City Council • Guadalcanal Provincial Government • Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Forests and Research • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board • Ministry of Infrastructure and Development • Botanic Gardens and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP
Coastal and Marine	• Commercial and subsistence fishing (source of food and income) • Habitat and biodiversity	• Population growth • Depletion of marine resources and loss of biodiversity from over-exploitation (over-fishing)	• Decline in reef ecosystem condition and coral dieback due to coral bleaching (rising temperature), ocean acidification,	• Designation of coastal and marine protection areas • Relocate communities and businesses from vulnerable coastal areas further inland or to higher ground • Sustainable fisheries management	• Honiara City Council • Ministry of Environment, Climate Change, Disaster Management and Meteorology

High-level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-climate Stressors	Potential Climate Change-related Effects	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
	• Support tourism industry (snorkelling and diving) • Source of building materials (sand, gravel, coral rock, stones and mangrove timber) • Raw materials (fuelwood, lime, coral rock) • Hazard protection (attenuation and buffering of wave and storm energy by reefs) • Cultural artefacts and commercial ornaments (shell money, ornaments, jewellery and decorations) • Cultural identity and status • *Kastom* medicine (coral)	• Sediment run-off from inappropriate land management activities such as logging and agriculture • Pollution from poor solid waste management and sanitation, chemical, pesticide and fertiliser inputs, urbanisation and extractive industries • Coastal development and vegetation clearing	poor water quality (sedimentation due to extreme rainfall events) Exacerbated by more intense tropical cyclones. • Shift in marine ecosystem structure due to rise in sea temperature • Altered capacity for oceans to regulate climate from increased sea temperatures • Sediment run-off from extreme rainfall events • Coastal erosion of mangroves patches from sea-level rise, storm surge and tropical cyclones • Permanent saltwater inundation of mangrove areas	• Coastal vegetation protection and revegetation • Land-use planning restrictions on coastal fringe • Installation of fish aggregating devices (FAD) near the reefal platform west of Point Cruz • City-wide environmental awareness and education programmes on the value of coral reefs for ecosystem services and sustainable fishing • Development of a coastal and intertidal rehabilitation programme: - educational programme on sustainable natural resource harvesting, including the consequences of over-harvesting and concentrated vegetation clearing (with no replanting) - mangrove and coastal revegetation programme, including the creation of vegetation buffers - educational signage - assign ‘’Reveg Champions’ (potentially a focus on high school students) – develop an understanding of the value of coastal vegetation and mangroves, key threats and adaptation protection measures	• Ministry of Fisheries and Marine Resources • Ministry of Education and Human Resources Development • Guadalcanal Provincial Government • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board • Ministry of Infrastructure and Development • Botanic Gardens and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP
Terrestrial	• Provision of food (subsistence and commercial cultivated lands) • Habitat and biodiversity • Erosion control and land stability	• Population growth • Depletion of forests and loss of biodiversity from clearing and development • Change of land use • Sediment run-off from inappropriate land management activities	• Soil erosion, sedimentation and landslip from extreme rainfall events Exacerbated by more intense tropical cyclones • Reduction in crop yield and soil cohesion and stability, and an	• Designation of protected areas • Honiara food security programme • Allocation of connected, green open space, throughout HCC area • Declaration of the Honiara Botanic Gardens as a protected area • Development of a biosecurity management programme	• Honiara City Council • Guadalcanal Provincial Government • Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Forests and Research

High-level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-climate Stressors	Potential Climate Change-related Effects	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
	• Regulating services including water quality and flow and air quality • Raw materials (timber and fuelwood) • Source of income (logging, farming, market produce) • Medicinal plants and trees • Materials for traditional costumes, ornaments and cultural artefacts (e.g. leaves, seeds, timbers) • Provision of areas for reconnecting with traditional land-based cultural practices • Shade provision	such as logging and agriculture • Soil degradation from chemical, pesticide and fertiliser inputs, and extractive industries • Pollution from poor solid waste management and sanitation	increase in invasive species due to increase in temperature	• Vegetation protection and catchment and riparian revegetation programme • Development of a rehabilitation programme for degraded lands in a selected catchment in response to logging activities, e.g. Kongulai, Mataniko, and Lungga (as proposed for the Lunnga River Basin in the Solomon Islands National Report (ICEM 2012). • City-wide education programme on the value of terrestrial watersheds and sustainable land management practices • Land-use planning restrictions on steep and unstable soils	• Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board • Ministry of Infrastructure and Development • Botanic Gardens and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP

Glossary

Adaptation (to climate change)	Making changes in order to reduce the vulnerability of a community, society or system to the negative effects of climate change
Adaptive capacity	The ability of an ecosystem service to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences
Biodiversity	Diversity within species, between species and of ecosystems; the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part
Climate change	Changes in the Earth's climate, due to human activities (anthropogenic climate change) or natural processes, which are already occurring or predicted to occur. Anthropogenic climate change is expected to happen much more rapidly than natural changes in the climate, posing an enormous challenge to both natural and human systems.
Ecosystem	A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment.
Ecosystem-based adaptation	An ecosystem-focussed approach to building the resilience of human communities to the negative effects of climate change
Ecosystem services	The benefits that an ecosystem provides to humans
Exposure	The degree to which an ecosystem service is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. coral bleaching in response to temperature rise) or indirect (e.g. seagrass dieback due to sedimentation from extreme rainfall events)
Resilience	The capacity of a community, society or natural system to maintain its structure and functioning through stress or change; the combination of resistance and recovery time influence the degree to which a system experiences long-term consequences of a stressor's impact (Folke 2006)
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain (Probability of physical event occurring x Consequences)
Sensitivity	The degree to which an ecosystem service is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. coral bleaching in response to temperature rise) or indirect (e.g. seagrass dieback due to sedimentation from extreme rainfall events)
Vulnerability (to climate change)	The degree to which exposed elements, such as human beings, their livelihoods and their assets, are susceptible and unable to cope with adverse effects of natural and climate change hazard events

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Appendix A Honiara workshop attendees

Table A-1 Honiara ESRAM workshop attendees (10 August 2016, Honiara)

Name	Affiliation
Mary Noela.Bibi	Ren-Lau Community
Paul Ramo	Koa Hill Community
Ben Abana Oeta	EHD / Honiara City Council
Maxino Kalita	Marble Street
Robert Misimaka	Ministry of Lands, Housing and Survey
Lorraine Livia	UN-Habitat
Steve Likaveke	UN-Habitat
Enoch Fa'abasu	ECD
Martin Rasu	No.3 Community
Rosemary Apa	Ministry of Environment, Climate and Disaster Management
Wendy Beti	Ministry of Environment, Climate and Disaster Management
Steven Bunabo	Ministry of Infrastructure and Development
Pr. Penvel Torakere	Church Pastor
Jones Sanga	IS Zone 19
Kalisito Kwaru	Not provided
Debra Potakana	ECD / Ministry of Environment, Climate and Disaster Management
Malachi Isatee	Ministry of Environment, Climate and Disaster Management /CCD
A. Olvana-Loti	Fijian Quarters
Claveni Rausi	Not provided
Junior Pikacha	Ecological Solutions SI
Ikuo Tigulu	Ecological Solutions SI
John Leqata	Ministry of Fisheries and Marine Resources
Mary Pako'o	Lord Howe Community
Donald Kudu	DREGAR Consulting
Fred Patison	SPREP
Simon Albert	University of Queensland
Beth Toki	BMT WBM

Appendix B Honiara vulnerability assessment results

	Climate Variable	SLR										Increasing sea temperature										Extreme rainfall event									
1	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- SLR of between approx. 7–18cm (very similar values for different RCPs) - Mean change: 13cm - Confidence level is medium					- SLR of between approx. 40–89 cm - Mean change: 63cm - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C relative to 1995 - Mean change: 0.7'C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8'C - Confidence level is very high					- The current 1-in-20-year daily rainfall amount is projected to increase by approx. 9 mm - 3% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high					- Rainfall to increase by approx. 43 mm - current 1-in-20-year daily rainfall event will become, on average, a 1-in-4- year event - 6% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high				
ID	Risk to Ecosystem Service?	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Urban greenspace	Recreation and leisure	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Urban greenspace	Tourism support	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Urban greenspace	Urban habitat and biodiversity	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Urban greenspace	Shade provision	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
General land- scaping	Urban habitat and biodiversity corridor	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
General land- scaping	Aesthetic value	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
General land- scaping	Shade provision	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Land (e.g. built environment)	High value commodity	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Land (e.g. built environment)	Provision of land for development, business and services	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Land (e.g. built environment)	Supports cultural identity	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Urban springs and groundwater	Water provision (drinking)	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	3	9	1	9	3	3	9	1	9
Urban springs and groundwater	Water provision (domestic and other uses)	1	3	3	3	9	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	3	9	1	9	3	3	9	1	9
Rivers, streams other water bodie	Water supply (drinking)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	2	18
Rivers, streams other water bodie	Water supply (domestic)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Rivers, streams other water bodie	Water supply (other)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Rivers, streams other water bodie	Recreational uses	1	1	1	2	2	2	1	2	2	4	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams other water bodie	Food provision	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Transport facilitation	1	0	0	1	0	2	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams other water bodie	Habitat provision and biodiversity	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Raw materials provision	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams other water bodie	Cultural and religious values	1	2	2	2	4	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams other water bodie	Support fisheries and aquaculture	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Support tourism	1	2	2	2	4	2	2	4	2	8	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Environmental and event regulation	1	2	2	2	4	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	2	6	3	18
Rivers, streams other water bodie	Waste disposal and dispersal	1	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3
Coastal and Marine	Support fisheries	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	2	6	3	18	1	1	1	1	1	2	2	4	2	8
Coastal and Marine	Raw materials provision	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	2	6	3	18	1	0	0	1	0	2	1	2	2	4
Coastal and Marine	Coastal protection	3	1	3	1	3	3	1	3	1	3	3	2	6	1	6	3	0	0	1	0	1	1	1	1	1	2	2	4	2	8
Coastal and Marine	Recreation	3	1	3	1	3	3	1	3	1	3	3	0	0	1	0	3	0	0	1	0	1	0	0	1	0	2	1	2	2	4
Coastal and Marine	Support tourism	3	1	3	1	3	3	1	3	1	3	3	2	6	1	6	3	2	6	1	6	1	0	0	1	0	2	1	2	2	4
Coastal and Marine	Transport facilitation	3	1	3	1	3	3	1	3	1	3	3	0	0	1	0	3	0	0	1	0	1	0	0	1	0	2	0	0	1	0
Coastal and Marine	Waste disposal and dispersal	3	1	3	1	3	3	1	3	1	3	3	0	0	1	0	3	0	0	1	0	1	0	0	1	0	2	0	0	1	0
Coastal and Marine	Food provision	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	2	6	3	18	1	1	1	1	1	2	2	4	2	8
Coastal and Marine	Habitat provision and biodiversity support	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	2	6	3	18	1	1	1	1	1	2	2	4	2	8
Coastal and Marine	Cultural values	3	1	3	3	9	3	1	3	3	9	3	2	6	1	6	3	2	6	3	18	1	0	0	1	0	2	0	0	1	0
Terrestrial watershed	Habitat provision and biodiversity support	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	2	18
Terrestrial watershed	Erosion control and land stability	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	3	27
Terrestrial watershed	Water quality and flow	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	3	27
Terrestrial watershed	Recreation and leisure	1	3	3	1	3	2	3	6	1	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	2	18
Terrestrial watershed	Food provision (incl. cultivation)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	2	18
Terrestrial watershed	Raw materials	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	2	18
Terrestrial watershed	Support logging industry and agriculture	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	3	27
Terrestrial watershed	Medicinal materials provision	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	2	18
Terrestrial watershed	Cultural values	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	1	9
Terrestrial watershed	Biodiversity	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	3	9	1	9

	Climate Variable	Ocean acidification										Increasing Air Temperature										Extreme Air Temperature									
1	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- Median aragonite saturation state will transition to marginal conditions (3.5) around 2030. - Mean change: -0.4 Ωar - Confidence level is medium					- Median aragonite saturation state will continue to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0). - Mean change: -1.5 Ωar - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C, relative to 1995 - Mean change: 0.7°C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8°C - Confidence level is very high					- Temp on extremely hot days is projected to increase by about the same amount as average temp - Frequency of extremely hot days is also expected to increase. - Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C - Confidence level is very high					- Projected hot day temp increase and frequency is expected to increase as per 2030. - Temp of the 1-in-20-year hot day is projected to increase by approximately 2.9°C - Confidence level is very high				
ID	Risk to Ecosystem Service?	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Urban greenspace	Recreation and leisure	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Urban greenspace	Tourism support	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Urban greenspace	Urban habitat and biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Urban greenspace	Shade provision	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
General land- scaping	Urban habitat and biodiversity corridor	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
General land- scaping	Aesthetic value	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
General land- scaping	Shade provision	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Land (e.g. built environment)	High value commodity	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Land (e.g. built environment)	Provision of land for development, business and services	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Land (e.g. built environment)	Supports cultural identity	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Urban springs and groundwater	Water provision (drinking)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Urban springs and groundwater	Water provision (domestic and other uses)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Water supply (drinking)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Water supply (domestic)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Water supply (other)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Recreational uses	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Food provision	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Transport facilitation	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Habitat provision and biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Raw materials provision	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Cultural and religious values	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Support fisheries and aquaculture	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Support tourism	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Environmental and event regulation	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams other water bodie	Waste disposal and dispersal	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Coastal and Marine	Support fisheries	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coastal and Marine	Raw materials provision	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coastal and Marine	Coastal protection	3	2	6	1	6	3	0	0	1	0	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Coastal and Marine	Recreation	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coastal and Marine	Support tourism	3	2	6	1	6	3	2	6	2	12	3	2	6	1	6	3	3	9	1	9	3	2	6	1	6	3	3	9	1	9
Coastal and Marine	Transport facilitation	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coastal and Marine	Waste disposal and dispersal	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coastal and Marine	Food provision	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coastal and Marine	Habitat provision and biodiversity support	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coastal and Marine	Cultural values	3	2	6	1	6	3	2	6	2	12	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Terrestrial watershed	Habitat provision and biodiversity support	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Erosion control and land stability	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Water quality and flow	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Recreation and leisure	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Food provision (incl. cultivation)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Raw materials	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Support logging industry and agriculture	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Medicinal materials provision	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Cultural values	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial watershed	Biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12

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