Planning for climate-resilient urban WASH in settlements research

TECHNICAL REPORT

Climate resilient and climate vulnerable WASH service delivery models in Melanesian urban informal settlements

OCTOBER 2022

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KEY MESSAGES from the research

Increasing the resilience of household access and use of water supply and sanitation in urban informal settlements across Melanesia is not just about adapting core infrastructure to improve its ability to withstand events. **Resilient WASH access relies upon resilient WASH service delivery models – from end to end** (where access to hygiene services flows in part from maintaining good water and sanitation access).

This research seeks to compare the **impacts of climate hazards** on different water and sanitation service delivery models and thus **assess the relative resilience of those models** across the different geographical and social contexts present within informal settlements.

- Identifying the **different points along a water or sanitation service delivery chain allows for better identification of risk from climate hazards and opportunities to adapt or mitigate those risks**, beyond just strengthening core infrastructure.

No single approach for water service delivery or sanitation service delivery is going to be appropriate to all households across a city. Diversity exists between and amongst settlements, both topographically, geographically, economically and socially, including preferences for different types of services.

- Different topographical and geographical areas, even within one city, are linked with different vulnerabilities to climate hazards. Different water and sanitation service delivery models have different levels of resilience to different climate hazards – some are better at coping with and adapting to droughts, others to floods and storms. So, in any one city, the different exposure of different areas to different climate hazards, means different water and sanitation service delivery models will be best suited locally.

Urban WASH Research Project

The **Planning for Climate-resilient Water, Sanitation and Hygiene in Urban Informal Settlements** research objective was to investigate how urban planning processes in Melanesia be strengthened through participation and integration to improve the resilience of WASH service delivery in informal settlements within the urban footprint. By doing this, we seek to increase the inclusiveness of WASH planning in urban Melanesia so residents in informal settlements have access to more resilience WASH services.

This study provides regionally appropriate evidence about what kinds of processes and systems could be explored within different urban contexts in Fiji, Vanuatu, Solomon Islands and Papua New Guinea**.** The mixed methods research included desktop research, spatial analysis, household surveys, interviews, photovoice techniques, and stakeholder engagement.

Based on this 1-year research program, some key lessons have emerged for practitioners and policymakers. This technical brief outlines some of the most important.

More information about the research program can be found here:

https://www.watercentre.org/research/research-impacts/planning-for-resilient-urban-wash-in-informal-settlements-in-pacific-islands/

- **Utilities** have preferred a single service type across their service area, but in addressing service area gaps, or expanding into new areas, they **will need to offer a diversity of service models, or coordinate with other service providers to ensure city-wide accessibility to safe and climate-resilient services.**
- The combination of user preferences and location-appropriate services should guide resilient service delivery selection.

Figure 1: conceptual model of integration between the three focus areas of the research

Decentralised and **transitionary** services can be part of a cost-effective and staged approach to upgrading WASH access in settlements. Transition services allow for unfamiliar services to be introduced into a new area in way that new users can progressively become comfortable and confident in how they work and increase the demand for the improved services. For example, water kiosks can be a transitionary service for settlements with households not used to, or unwilling, to pay for piped water, demonstrating the value-for-money and additional benefits of piped water.

Integrating **urban planning** processes (including spatial and GIS planning tools), **climate hazard data**, and **WASH service provision planning** is required to allow for aspects of WASH service chains that are beyond the remit of WASH utilities/departments – e.g., road planning, building approvals and standards, planning tools and climate hazard data (Figure 1).

INTRODUCTION

Urban populations are growing across Melanesia, with migration to cities increasing as people pursue economic, educational, healthcare and recreational opportunities, and to escape different types of insecurity (Haberkorn, 1992; Weber, Kissoon, & Koto, 2019). High population growth, combined with rural to urban migration, has seen high urban growth rates in most countries. Although data are limited, growth rates for PNG, Solomon Islands and Vanuatu are estimated at between 2.7 and 4.3% annually (World Bank, 2021). Much of this growth is in urban informal settlements.

Past research, including by International WaterCentre (IWC), indicates that access to WASH services in urban and peri-urban informal settlements across Melanesia is broadly inadequate (Souter & Orams, 2019). In addition, there is little evidence to suggest that WASH services that do exist for urban and peri-urban informal settlements are future-proof – they are not planned with resilience to shocks and change in mind, such as climate change or the needs of changing populations in water catchments.

This report aims to address the question of what sorts of water and sanitation service delivery models (SDMs) might provide a higher level of resilience to climate-related change for residents of informal settlements in Melanesia.

We note that informal settlement residents can face a range of social inclusion issues related to wealth and income disparity, educational opportunities, gender equity, disability access and support and others that affect access to sustainable and resilience water and sanitation SDMs (Mecartney & Connell, 2017). In addition, a range of other factors will influence which water and sanitation service delivery models are feasible and authorised for different households and settlements – in Melanesian settlements, the landowner and type of land tenure is one of these. While not the focus of this report, elements of this are addressed.

What is a water or sanitation service delivery model?

The provision of water or sanitation services is broader than just the point of use infrastructure, which is often the focus of water and sanitation assessments. A full water or sanitation service delivery model considers production to treatment and management of wastes. Service delivery models may include service utilities, private operators, governments, community groups and households.

For example, water SDMs include water source, treatment, conveyance to settlements and to households, access point such as taps, and drainage or wastewater management. Sanitation SDMs include user interfaces, waste containment, conveyance, treatment and end disposal or reuse.

Not all parts of a service delivery chain may be relevant in each different type of SDM. The benefit of thinking through the whole model can be more detailed consideration of risks along the chain and more opportunities to increase resilience.

IDENTIFYING URBAN INFORMAL SETTLEMENTS

This research project has collated several disparate sources of information to identify consolidated lists of informal settlements within the urban boundary of each of the four cities studied.

Port Moresby, Papua New Guinea

- 79 informal settlements named and located in the Towards 2030 Port Moresby town urban development strategy. Over half the population live in settlements (NCDC & Atlas Urban, 2022).

Suva, Fiji

- 128 settlements named by the Peoples Community Network and Un-Habitat in their Informal Settlement Analysis study (Peoples Community Network, 2016) and geo-located using GIS; 42 of these within the urban boundary published on Suva City Council's website.

Honiara, Solomon Islands

- 92 settlements named and located in a World Bank/IWC report (Souter & Orams, 2019)

Port Vila, Vanuatu

- 27 settlements identified by previous work conducted by the International WaterCentre (Sanderson & Souter, 2020); of these five were identified as peri-urban traditional villages, and five are located outside the Port Vila urban boundary.

WATER AND SANITATION SERVICE DELIVERY MODELS IN INFORMAL SETTLEMENTS

In informal settlements globally, a range of service delivery models exist, some provided by a utility service provider and some managed at the household level. In many settings the service delivery chains are incomplete in informal settlements as the different contextual factors interrupt services such as proper drainage or the emptying of septic tanks and other faecal sludge management activities (ADB, 2020). In Melanesia, sharing of WASH services is common in urban informal settlements and what's more, the arrangements for sharing take many forms. In Honiara, while Solomon Water have not in the past actively promoted sharing of household water connections because of concerns around reliability, quality and regulating metering services, sharing is not only common amongst residents but in many cases preferred (Souter & Orams, 2019). Residents in Suva appear to have the best access to water, compared to Port Vila, Honiara and Port Moresby; and open defecation is generally higher in Port Moresby and Honiara (Schrecongost, Wong, Dutton, & Blackett, 2015).

In Table xx, we identify a range of water and sanitation service delivery models that are either present in the four cities of this research or may present options for improved climate-related resilience. We note whether the particularly SDM has the potential to satisfy the JMP SDG6.1 definition of a safely managed service (World Health Organization, 2017).

Table 1: Water service delivery models present in Melanesian urban informal settlements

Water service delivery models		Suva [1]	Port Vila[2]	Honiara[3]	Port Moresby[4]	Has potential to satisfy SDG6.1 definition of safely managed water*
Type 1a	Individual private household water connections managed by utility (metered) (inside)	✓	✓	✓	✓	Yes (is possible)
Type 1b	Individual private household water connections managed by utility (metered) (outside house)	✓	✓	✓	✓	Yes (is possible)
Type 2	Individual private rainwater tanks, with back-up tankered water	✓	✓	✓	✓	Yes (is possible)
Type 3	Shared private water connections (metered) using pay-as-you-go fee structures	Shared but no pay-as-you-go	Shared but no pay-as-you-go	✓ "Cash water" trials	✗	Yes (is possible, depending on access location)
Type 4a	Water kiosks (private or public operator)	✗	✗	✗	✓	No (not onsite)
Type 4b	Bottled water from retail stores	Low rates	Low rates	Low rates	Low rates	No (not onsite)
Type 5	Backup community sources at established community centres (e.g., rainwater tank at churches)	✓	✓	✓	✓	No (not onsite)

[1] (Fiji Bureau of Statistics, 2017; Hay & Southcombe, 2016; Kiddle & Hay, 2017; Schrecongost et al., 2015)
[2] (Sanderson & Souter, 2020; Schrecongost et al., 2015)
[3] (Souter & Orams, 2019)
[4] (ADB, 2020)

Water service delivery models		Suva [1]	Port Vila[2]	Honiara[3]	Port Moresby[4]	Has potential to satisfy SDG6.1 definition of safely managed water*
Type 6	Shared deep groundwater / tubewell source with container collection (utility metered or not)	✓	✓ restricted areas	✓	Low rates	No (not onsite)
Type 7	Private unprotected dug wells or springs (shallow groundwater)	✓	✓	✓	✓	No (unimproved source, unless protected. Quality likely of concern)
Type 8	Household collection of surface water in containers	✓	✓	✓	✓	No (unimproved source)

Sanitation service delivery models		Suva	Port Vila	Honiara	Port Moresby	Has potential to satisfy SDG6.1 definition of safely managed sanitation*
Type 1a	Individual private household toilets (flushed, piped, central sewerage, utility managed)	✓	✗	✓	✓	Yes (is possible)
Type 1b	Shared toilet blocks (flushed, piped, central sewerage, utility managed)	✗	✓	✓	✓	No (not onsite)
Type 2a	Individual private household toilets (flushed, piped, serviced septic tanks)	✓	✓	✓	✓	Yes (is possible)
Type 2b	Low flow household to flush to septic	No data	No data	No data	No data	Yes (is possible)
Type 3	Simplified / decentralised sewer systems	✗	✗	✗	✓ Koki village	Yes (is possible)
Type 4a	Pour flush pit toilets, fully serviced, twin offset	✓	✗	✓	xx	Yes (is possible)
Type 4b	Raised Pour flush pit toilets, fully serviced, twin offset	No data	No data	No data	No data	Yes (is possible)
Type 4c	Pour flush toilets, not serviced	✓	✓	✓	✓	
Type 5a	Ventilated Improved Pit (VIP), fully serviced, single or twin offset	✓	✓	✓	✓	Yes (is possible)
Type 5b	Raised Ventilated Improved Pit (VIP), fully serviced, single or twin offset	No data	No data	No data	No data	Yes (is possible)
Type 6	Above-ground sanitation (container-based, fully serviced, or composting, maintained)	✗	✓ low rates	✓ low rates	No data	Yes (is possible)
Type 7	"Bush toilets" – unimproved pit toilets	✓	✓	✓	✓	No (unimproved)
Type 8	Hanging or floating toilets	✓	✗	✓	✓	No (unimproved)

* Depends on other criteria being met, such as water quality, availability and reliability, accessibility etc, and for sanitation, management of FSM. This assessment identifies SDMs that do not have the potential to meet the safely managed criteria.

CLIMATE IMPACTS TO WATER & SANITATION SERVICE DELIVERY MODELS IN SETTLEMENTS

Water and sanitation services can be impacted by climate-related hazards in several different ways. In informal settlements, a combination of different factors (insecure tenure, crowding, substandard building materials and building standards, lack of institutional support) can mean the impacts of climate hazards are experienced with more severity by residents. For example, in the flooding in Honiara in 2014, most of the 22 reported deaths were residents in highly vulnerable settlements along the Mataniko River (Government of Solomon Islands, 2014).

Relevant journal articles were reviewed to collate impacts to water and sanitation systems from these climate-related hazards. The climate hazards likely to be most common and cause the most significant impacts to informal settlements in Melanesia are:

- Floods (alluvial, pluvial), cyclones, storms, and heavy rain (related to increasing likelihood of heavy precipitation)
- Sea level rise and coastal erosion
- Drought and extreme heat

Table 2: Impacts to water systems from literature

Water systems	Impacts[5]		
	Floods (alluvial, pluvial), cyclones, storms and heavy rain	**Sea level rise and coastal erosion**	**Drought and extreme heat**
Utility metered connection - large piped systems	Damage to exposed pipes and taps Damage to meters Access to tap cut off by floodwaters if in yard or similarly exposed Ingress of floodwaters to damaged or leaking pipes leading to contamination Contamination of source Impacts to electrical supply and therefore conveyance pumping Water pressure can be reduced Additional burden on women and girls to collect alternative sources and/or treat contaminated sources	Erosion of buried pipes leading to damage and leakage Inundation of taps and infrastructure Corrosion of pipes and taps	Increased demand with reduced supply Increase water age in distribution systems, meaning a loss of disinfection residuals (lower treatment efficacy) and higher disinfection by-products Accelerated loss of disinfection residuals under extreme heat
Tankered supply	Road flooding reducing access for tankers. Direct damage to tankers or water source infrastructure No service during cyclones and sometimes recovery period	Road access reduced along coast Erosion of coastal roads	Increased demand with reduced supply and/or resources (staff and trucks) to service the demand.
Borehole / standpipe	Access to source cut off by floodwaters If borehole is unsealed or improperly installed, incursion of contaminated water causing water quality impacts Direct impacts to infrastructure Additional burden on women and girls to collect alternative sources and/or treat contaminated sources	Saline intrusion leading to poor quality water for long periods of time, sometimes permanently, particularly with improper installation Increased bromide levels, which can produce toxic brominated disinfection by-products Corrosion of infrastructure	Lowered water table leading to reduced water quantity available Lower recharge rates

[5] Sources include: (Bouzourra, Bouhlila, Elango, Slama, & Ouslati, 2015; Heath, Parker, & Weatherhead, 2012; Heisler et al., 2008; Howard, Charles, et al., 2010; Khan et al., 2015; Langridge et al., 2012; Luh, Royster, Sebastian, Ojomo, & Bartram, 2017; McTigue, Cornwell, Graf, & Brown, 2014; Singh & Singh, 2015; Wright et al., 2014; Zapata, 2021)

<table>
<tr><th rowspan="2">Water systems</th><th colspan="3">Impacts[5]</th></tr>
<tr><th>Floods (alluvial, pluvial), cyclones, storms and heavy rain</th><th>Sea level rise and coastal erosion</th><th>Drought and extreme heat</th></tr>
<tr><td>Shared shallow dug well, protected</td><td>Access to source cut off by floodwaters
Contamination by faecal pathogens in runoff or floodwaters (incursion of surface water)
Direct impacts to infrastructure</td><td>Saline intrusion leading to poor quality water for long periods of time, sometimes permanently</td><td>Reduced water quantity and drying</td></tr>
<tr><td>Shared spring, protected</td><td>Difficulty accessing spring location due to unstable ground in high rainfall
Direct impacts to infrastructure</td><td></td><td>Reduced flow and quantity</td></tr>
<tr><td>Rainwater tank</td><td>Floodwater ingress into tank including pathogens and other contaminants
Perceived contamination and reduced use
Floating or damage to tanks
Direct impacts to infrastructure, including from landslips</td><td>Direct damage to infrastructure or access
Corrosion of tanks</td><td>Reduced rainfall and quantity</td></tr>
<tr><td>Shared surface water source, - small piped systems</td><td rowspan="2">Contamination by faecal pathogens or other contaminants in runoff or floodwaters
Direct damage to surface water supply infrastructure or pipes
Changes to surface water recharge
Access to source cut off by floodwaters.
Short-circuiting of reservoirs leading to poor water quality outcomes because of reduced processing of dissolved organic carbon or variable salinity
Additional burden on women and girls to collect alternative sources and/or treat contaminated sources</td><td>Inundation of surface water source with saltwater
Corrosion of pipes and taps</td><td rowspan="2">Decrease of natural runoff leading to higher relative flow contributions from logging runoff, min runoff and wastewater discharge with increased ambient contaminant concentrations
Algal and cyanobacterial blooms
Increased survival and abundance of Vibrio spp bacterial, including cholera causing species.
Extreme heat can make carrying and carting household water dangerous, particularly for women and girls who bear the highest burden of water collection.
Increased evaporation leading to unreliable water sources</td></tr>
<tr><td>Private household direct from surface water</td><td>Inundation of surface water source with saltwater</td></tr>
<tr><td>Bottled water - water kiosk/ vendor</td><td>Access to kiosk cut off by flood
Damage to kiosk infrastructure
Reversion to unsafe or contaminated surface water source for kiosk if normal source is unavailable
Temporary (or long term) reduction in income leading to decreased ability to afford water at kiosks, particularly when coupled with GESDI vulnerabilities
Additional burden on women and girls to collect alternative sources and/or treat contaminated sources</td><td>Direct damage to coastal kiosk infrastructure</td><td>Increased heat and water demand leads to increase in water price from kiosks
Decrease in livelihood production and income leading to decreased ability to afford water kiosks</td></tr>
<tr><td>Bottled water - no kiosk</td><td>Increased demand leads to reduced or unavailable supply
Flooding of service chain routes
Temporary (or long term) reduction in income leading to decreased ability to afford water in bottles</td><td>Direct damage to retail outlets
Interruption of supply chain by damaged or inundation roads, stock supply etc.</td><td>Increased demand leads to reduced or unavailable supply
Temporary (or long term) reduction in income leading to decreased ability to afford water in bottles</td></tr>
</table>

Table 3: Impacts to sanitation systems from literature

Sanitation systems	Impacts[6] Floods (alluvial, pluvial), cyclones, storms and heavy rain	Sea level rise and coastal erosion	Drought and extreme heat
Centralised sewer network	Ingress of floodwaters to sewers, overloading pipes and conveyance infrastructure, particularly where stormwater is combined. Treatment facilities overwhelmed leading to untreated releases. Ground settlement or movement can crack pipes/infrastructure Backflow of sewerage into households.	Ingress of sea water to sewers, overloading pipes and conveyance infrastructure. Treatment facilities overwhelmed leading to untreated releases. Ground settlement or movement can crack pipes/infrastructure. Backflow of sewerage into households. Water levels in sewers rise as outfalls that discharge to sea are inundated	Reduced water for flushing leads to clogging and disruption of conveyance. Reduced capacity of water resources to absorb less treated wastewater. Non-functioning toilets can lead to higher rates of OD and risk of violence to women and girls.
Decentralised small sewer network (modified system e.g., small bore/ shallow/ simplified)	Typically shallower depth of pipework conveyance than centralised systems can lead to increased risk of pipe damage. Ground settlement or movement can crack pipes/infrastructure. Backflow of sewerage into households.	Ground settlement or movement can crack pipes/infrastructure Backflow of sewerage into households.	Should only carry effluent so shouldn't be significantly affected by blockages. Non-functioning toilets can lead to higher rates of OD and risk of violence to women and girls
Flush to septic tank	Inundation and flooding of septic tanks, including loss of containment of faecal pathogens. Inhibition of treatment capacity and degradation processes of septic tank and soakaway. Flooding of roads affecting ability to pump out septic tanks.	Saltwater inhibits treatment capacity and degradation processes of septic tank and soakaway. Inundation and flooding of septic tanks, including loss of containment of faecal pathogens. Coastal roads impacted affecting ability to pump out septic tanks.	Reduced water for flushing leading to clogging, though not as severe as networked sewers. Non-functioning toilets can lead to higher rates of OD and risk of violence to women and girls.
Low flush to septic tank			Additional water carting may be needed for flushing, women and girls bear the highest burden of water collection.
Pit toilet - improved	Inundation and flooding of pits, including loss of containment of faecal pathogens. Rising groundwater levels can infiltrate pits. Flooding of roads affecting ability to pump out pits.	Saltwater inhibits degradation processes in pit. Inundation of pit with seawater, including loss of containment of faecal pathogens. Coastal roads impacted affecting ability to pump out pits.	Reasonably low impacts - should still function as designed in periods of drought. Some additional odour concerns under extreme heat conditions.

[6] Sources include: (Howard, Bartram, & Organization, 2010; Tandon, Wallace, Caretta, Vij, & Irvine, 2022)

HOW CLIMATE-RESILIENT ARE THE WATER AND SANITATION SERVICE DELIVERY MODELS PREVELANT IN SETTLEMENTS TO LIKELY CLIMATE HAZARDS?

The resilience to climate hazards of eight water service delivery models and eight sanitation service delivery models (with some variants) were judged. Judgement based on literature about ways that climate hazards affect water and sanitation infrastructure, and expert opinion about how that applies to broader SDMs.

Climate resilience of water and sanitation infrastructure and services is a function of vulnerability and adaptability

For the purposes of this study, resilience was determined as a function of the vulnerability and adaptability of the service delivery model (see definitions below). Howard, Bartram, et al. (2010) suggested adaptative measures for water and sanitation technologies could include capital expenditure, operational expenditure, monitoring and socioeconomic tools, though the adaptability of services must be assumed because they are yet to be adapted (Fleming et al., 2019).

It is recognised that there are other areas of vulnerability and adaptability, including some of the behavioural dimensions of both, the social norms and user preferences with respect to WASH services, that are critical to understand when selecting appropriate water and sanitation service delivery models. This will be the focus of further work within this extended research study. Further, the influence of governance and management structures on water and sanitation resilience cannot be underestimated, though, as Howard, Bartram, et al. (2010) wrote, *"the resilience of sanitation is not as management-driven as the resilience of drinking-water supply"* pp20.

Vulnerability: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed and its sensitivity.

Adaptive capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Source: IPCC 2007

Climate resilience of service delivery models is relative

We followed Howard, Bartram, et al. (2010) and Fleming et al. (2019) to conduct the assessment aligned with vulnerability and adaptability. We assessed the service delivery models relative to each other for all topographical and hydrological settings for each hazard type, rather than assessing the absolute resilience of each model. Thus, the resilience of a water service in this assessment cannot be directly compared to a sanitation service.

Resilient service delivery models also mean people have the ability, resources and support to fix systems when they fail.

Climate hazards affect different types of topographies and geographies differently

Planning for WASH services increasingly needs to take climate hazard data into account, and to do this WASH practitioners need to become more cognizant of the range and scope of hazard data that is available to them. Notwithstanding, because detailed hazard mapping of Melanesia urban environments, including flood mapping and spatial sea level rise predictions is not yet widely available (though significant advancements are being made by, for example, the Pacific Secretariat (SPC) and others), environmental and geographical proxies can be useful for differentiating between different types of vulnerabilities. Thus, low-lying land or areas close to surface waters can be a coarse proxy for flood prone areas. Coastal areas are likely to be more affected by sea level rise, and hillside locations are faced with challenges during storms and cyclones due to their elevated positions. Hillside areas also shed water faster than flat areas, increasing resilience in flood times but potentially decreasing resilience during droughts as soils erode (Meaza, Abera, & Nyssen, 2022).

Thus, the following assessment of climate hazards and water and sanitation service delivery models also considers the topographical and geographical setting. A rating of "high" denotes a service delivery model with greater resilience and suitability under the conditions and likely hazards.

The most resilient water service delivery models to flooding and storms are likely to be individual household connections with inside access. Backup sources managed through functional community centres can also add to resilience to these hazards. The least resilience service delivery models are likely to be any that can be inundated, or access cut off by events – shared, offsite access, shallow groundwater, and surface water sources. This assumes that centralised sources have sufficient protection and adaptive capacities to withstand flood and storms, as the widespread consequences of damage to centralised networks can be more disruptive to more people than other service delivery models.

Table 4: Resilience of water service delivery models to storms (cyclones, rainstorms) and flooding

Resilience to storms and floods		Land type			
Type	**Water Service Delivery Model**	**Low-lying & close to surface waters**	**Coastal areas**	**Hillside areas**	**Other areas**
Type 1a	Individual private household water connections managed by utility (metered) (inside)	High	High	High	High
Type 1b	Individual private household water connections managed by utility (metered) (outside house)	Low	Medium	Medium	Medium
Type 2	Individual private rainwater tanks, with back-up tankered water provider	Medium	High	Low	High
Type 3	Shared private water connections (metered) using pay-as-you-go fee structures	Low	Medium	Low	Medium
Type 4	Water kiosk/vendor (private or public operator)	High	High	Medium	High
Type 5	Backup community sources at established community centres (e.g., rainwater tank at churches)	High	High	High	High
Type 6	Shared groundwater / tubewell source with container-based collection.	Medium	Low	High	High
Type 7	Private unprotected dug wells or springs (shallow groundwater)	Low	Low	Low	Low
Type 8	Household collection of surface water in containers	Low	Low	Low	Low

When sea levels rise, and associated coastal erosion and potential saline intrusion occurs, water service delivery models that rely on shallow groundwater or surface water are likely to be the least resilient. Private connections that are located in yards (rather than the house) have additional vulnerabilities when, for example, a tidal storm surge cuts off normal access or corrodes materials with less protection than connections inside houses. Rainwater and tankered backups have the potential to improve resilience however can be subject to access, quality, and maintenance issues if coastal roads are eroded or inundated.

Table 5: Resilience of water service delivery models to sea level rise and coastal erosion

Resilience to sea level rise and coastal erosion		Land type	
Type	**Water Service Delivery Model**	**Coastal areas**	**Other areas**
Type 1a	Private household piped connection, inside	High	High
Type 1b	Private household piped connection, outside	Medium	Medium
Type 2	Rainwater and tankered backup	Medium	High
Type 3	Shared pay-as-you-go piped connection	High	Medium
Type 4	Water kiosk/vendor	High	High
Type 5	Backup community resources	Medium	High
Type 6	Shared deep groundwater	Low-medium	High
Type 7	Private unprotected dug wells or springs	Low	Medium
Type 8	Household collection of surface water in containers	Low	Medium

During droughts, water kiosks or bottled water may be in high demand and sources for the water may be scarce, decreasing the ability of operators to maintain the quality or the quantity of the service. A centrally managed service can provide higher resilience to drought conditions, in that managers and operators can attempt to manage demand to maintain the equity of the service. In times of drought and extreme heat, having access to backup community resources can be vital to continuity of water use.

Table 6: Resilience of water service delivery models to droughts and extreme heat

Resilience to water scarcity (droughts and extreme heat)		Land type		
Type	Water Service Delivery Model	Low-lying & close to surface waters	Hillside areas	Other areas
Type 1a	Private household piped connection, inside	High	High	High
Type 1b	Private household piped connection, outside	Medium	Medium	Medium
Type 2	Rainwater and tankered backup	Medium	Low	Low
Type 3	Shared pay-as-you-go piped connection	Low	Low	Medium
Type 4	Water kiosk/vendor	Medium	Medium	High
Type 5	Backup community resources	High	High	High
Type 6	Shared groundwater	High	Medium	High
Type 7	Private unprotected dug wells or springs (shallow groundwater)	Medium	Low	Low
Type 8	Household collection of surface water in containers	Medium	Low	Low

Applying the service chain concept to exploring the vulnerability of water service delivery models

As noted in the definitions of service delivery models above, assessing the resilience of such models are not just about the core infrastructure. When we refer to resilience, we mean the resilience of the service including the human resources and systems to operate, transport, and manage it. To only consider damage, inaccessibility, or inoperability of primary pieces of infrastructure is unlikely to be sufficient to maintain resilience of water and sanitation services. Looking beyond this requires a systems perspective.

Water service delivery models of all types have different points of vulnerability along the service delivery chain. A water service delivery chain can be described to include the distribution, access and post-use waste, and points along that chain can be impacted differently by climate-related (and non-climate related) hazards. Examples of this are shown below, including a piped water supply from a water utility (Figure 5) and a household rainwater supply (Figure 6). For example, a centralised service will have a range of vulnerabilities and adaptation measures, which will affect the flow of water to this connection during climate hazards (including staff continuity of service during extreme events).

Figure 2: Exposed water pipes

Figure 3: Rainwater collection and guttering

Figure 4: Stagnant water

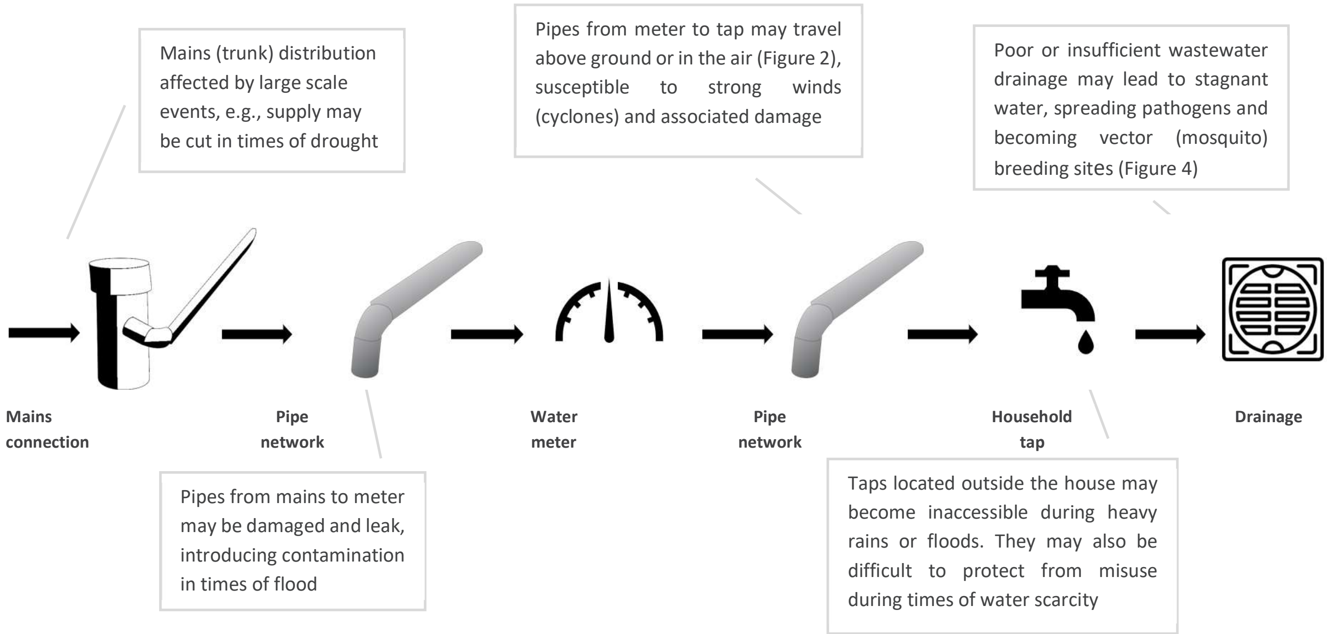

Figure 5: Example of climate-related impacts along a water service delivery chain (piped water supply)

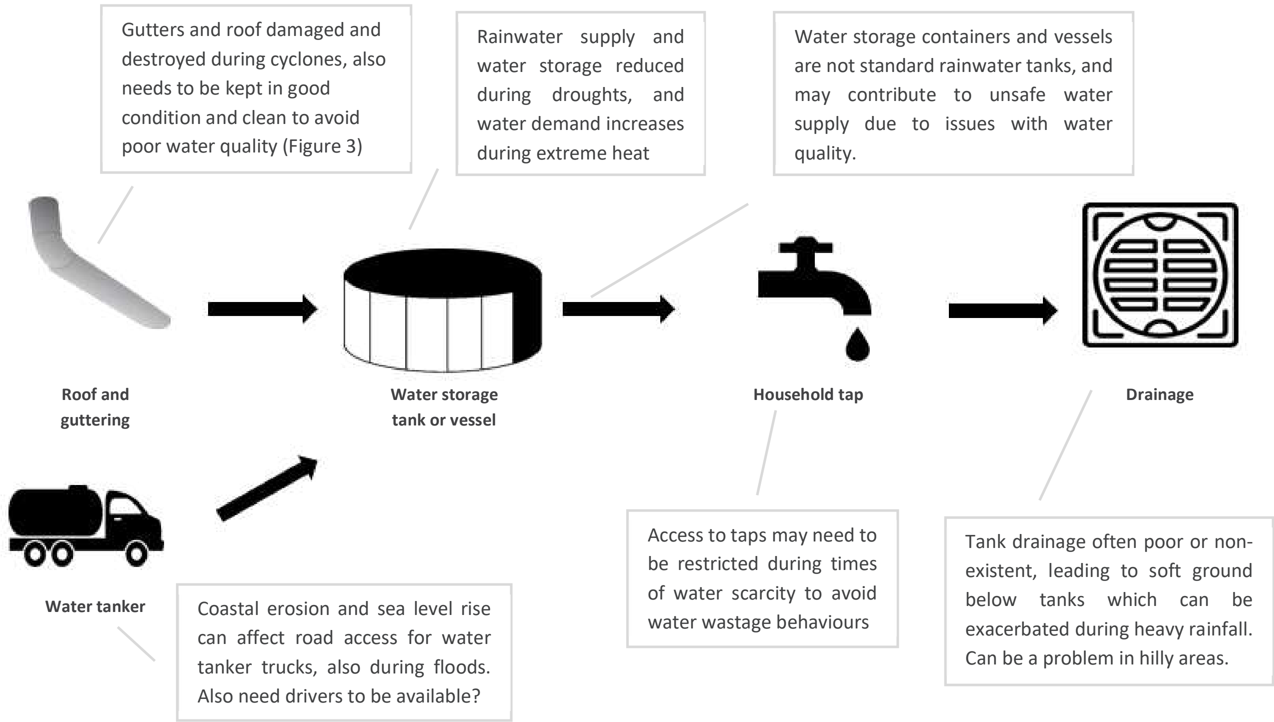

Figure 6: Example of climate-related impacts along a water service delivery chain (rainwater supply)

Applying the service chain concept to exploring the vulnerability of sanitation service delivery models

Sanitation service delivery models can broadly be classified as onsite or offsite, in terms of the ways in which wastes are contained and managed. However, for most of the service delivery models in urban areas, the conveyance and treatment of wastes offsite could be expected to be required at a point in time, though that time period will vary depending on subsurface conditions and infiltration levels. In these situations, twin-offset pits may allow for safe onsite management, and the rate of filling of such pits may be slow so as to not require desludging for 10 years or more. Notwithstanding, in most situations some emptying will be required, particularly in areas prone to flooding, and this preferably occurs prior to a flood to avoid the pit or tank filling and overflowing. Similar to water service delivery models, different points of risk are present along different sanitation service chains, with examples shown in Figure 7 and Figure 8.

It is acknowledged that in Table 7, no sanitation service delivery model rates "high" for resilience to flooding and storms in low-lying areas or close to surface waters. In these settings, it must be acknowledged that the vulnerabilities are difficult to properly overcome and multiple service delivery options or support mechanisms may be required in times of extreme weather.

Table 7: Resilience of sanitation service delivery models to storms (cyclones, rainstorms) and flooding

Resilience to storms and floods		Land type			
Type	**Sanitation Service Delivery Model**	**Low-lying & close to surface waters**	**Coastal areas**	**Hillside areas**	**Other areas**
Type 1a	Individual private household toilets (flushed, piped, central sewerage managed by utility)	High	Low	High	Medium
Type 1b	Shared toilet blocks (flushed, piped, central sewerage, utility managed)	Low	Medium	Medium	Medium
Type 2a	Individual private household toilets (flushed, piped, fully serviced septic tanks)	Low	Medium	Medium	High
Type 2b	Low flow household to flush to septic	Low	Medium	High	High
Type 3	Simplified / decentralised sewer systems	Medium-High	Medium	High	High
Type 4a	Pour flush pit toilets, fully serviced, twin offset	Low	Low	Medium	Medium
Type 4b	Raised Pour flush pit toilets, fully serviced, twin offset	Medium	High	High	High
Type 4c	Pour flush toilets, not serviced	Low	Low	Medium	Medium
Type 5a	Ventilated Improved Pit (VIP), fully serviced, single or twin offset	Low	Low	Medium	Medium
Type 5b	Raised Ventilated Improved Pit (VIP), fully serviced, single or twin offset	Medium	High	High	High
Type 6	Above-ground sanitation (container-based, fully serviced, or composting, maintained[7])	Medium	Medium	High	High
Type 7	"Bush toilets" – unimproved pit toilets	Low	Low	Low	Low
Type 8	Hanging or floating toilets	Low	Low	N/A	N/A

Some sanitations service delivery models that rely on onsite treatment or volume reduction for containment can be significantly affected by the introduction of salt water into the pit or tank. Centralised or piped sewer networks, including simplified sewers, are regarded as having higher resilience under increased sea level scenarios. However, it is recognised that significant outlay of resources is often required to implement or extend sewered systems, and thus in coastal areas subject to sea level rise, where migration inland is possible, safe sanitation service delivery models that are more adaptably, such as above-ground sanitation or raise VIPs, may present a more appropriate option.

[7] (Leney, 2017)

Table 8: Resilience of sanitation service delivery models to sea level rise and coastal erosion

Resilience to sea level rise and coastal erosion		Land type	
Type	**Sanitation Service Delivery Model**	**Coastal areas**	**Other areas**
Type 1b	Household flush to sewer	High	High
Type 2a	Shared toilet block, flush to sewer	High	Medium
Type 2b	Household flush to septic	Medium	Medium
Type 3	Simplified sewer system	High	High
Type 4a	Pour flush pit, twin offset	Low	High
Type 4b	Raised pour flush pit, twin offset	Medium	Medium
Type 4c	Pour flush pit, not serviced	Low	Low
Type 5a	Ventilated Improved Pit (VIP), single or twin offset	Low	Medium
Type 5b	Raised Ventilated Improved Pit (VIP), single or twin offset	Medium	Medium
Type 6	Above-ground sanitation	High	High
Type 7	"Bush toilets" – unimproved pit toilets	Low	Low
Type 8	Hanging or floating toilets	Low	N/A

Areas prone to drought must consider low-flow or waterless toilets to improve resilience. User preference is always an important consideration, and in settings where flush toilets may be less resilient there will be necessarily community engagement and sanitation behavioural considerations to be made. Commonly, flush toilets are regarded as higher standard across Melanesia, however there are examples of composting or low-flow technologies and demonstrations that may address some of the perceived issues of cleanliness, waste handling and safety (Integre, 2017).

Table 9: Resilience of sanitation service delivery models to droughts and extreme heat

Resilience to water scarcity (droughts and extreme heat)		Land type		
Type	**Sanitation Service Delivery Model**	**Low-lying & close to surface waters**	**Hillside areas**	**Other areas**
Type 1a	Household flush to sewer	Low	Medium	Low
Type 1b	Shared toilet block, flush to sewer	Low	Medium	Low
Type 1c	Household flush to septic	Medium	Medium	Low
Type 2b	Low flow household to flush to septic	High	High	High
Type 3	Simplified sewer system	Medium	High	High
Type 4a	Pour flush pit, twin offset, serviced	Medium	Medium	Medium
Type 4c	Pour flush pit, twin offset, not serviced	Low	Low	Low
Type 5a	Ventilated Improved Pit (VIP), single or twin offset	High	High	High
Type 6	Above-ground sanitation	High	High	High
Type 7	"Bush toilets" – unimproved pit toilets	Low	Low	Low
Type 8	Hanging or floating toilets	Low	N/A	N/A

Sanitation service delivery models have vulnerabilities and opportunities for resilience

From user interface, containment, conveyance, treatment and end use or disposal, a sanitation service delivery model may be subjected to different impacts along that service chain. In the following figures, examples of different points of vulnerability are presented. In some cases, the service chain has a lower number of links in the chain, and thus both points of vulnerability, but also opportunities for adaptation, are reduced.

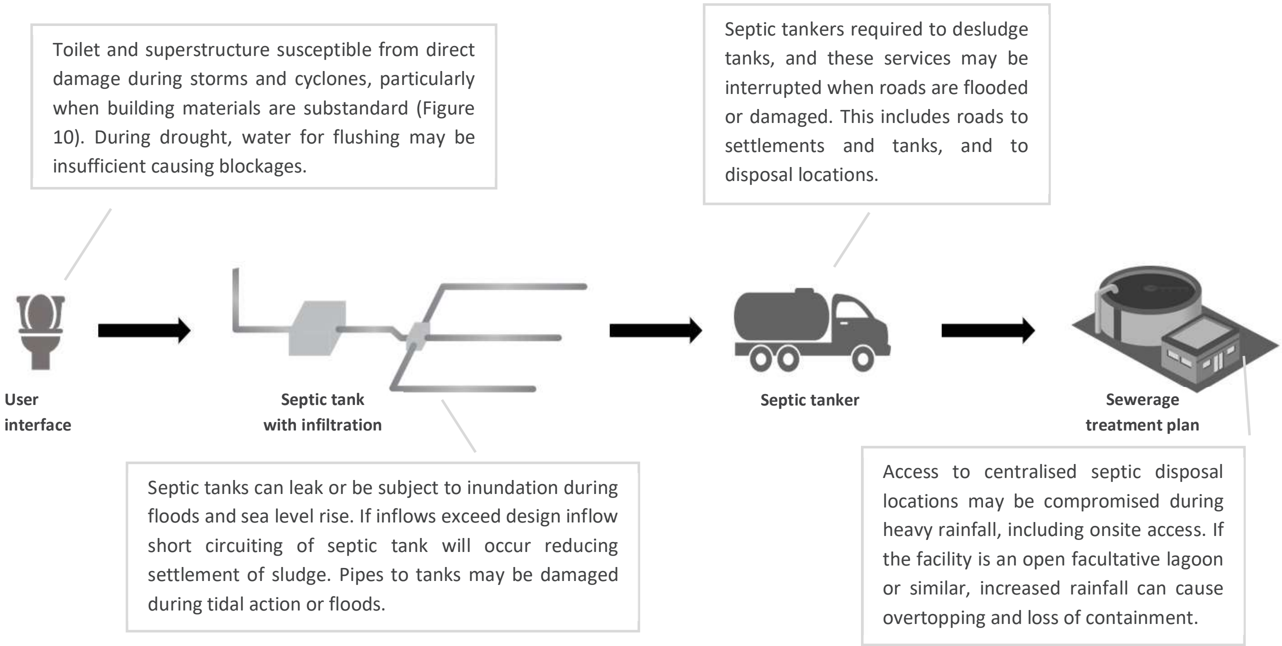

Figure 7: Example of climate-related impacts along a sanitation service delivery chain (serviced septic tank)

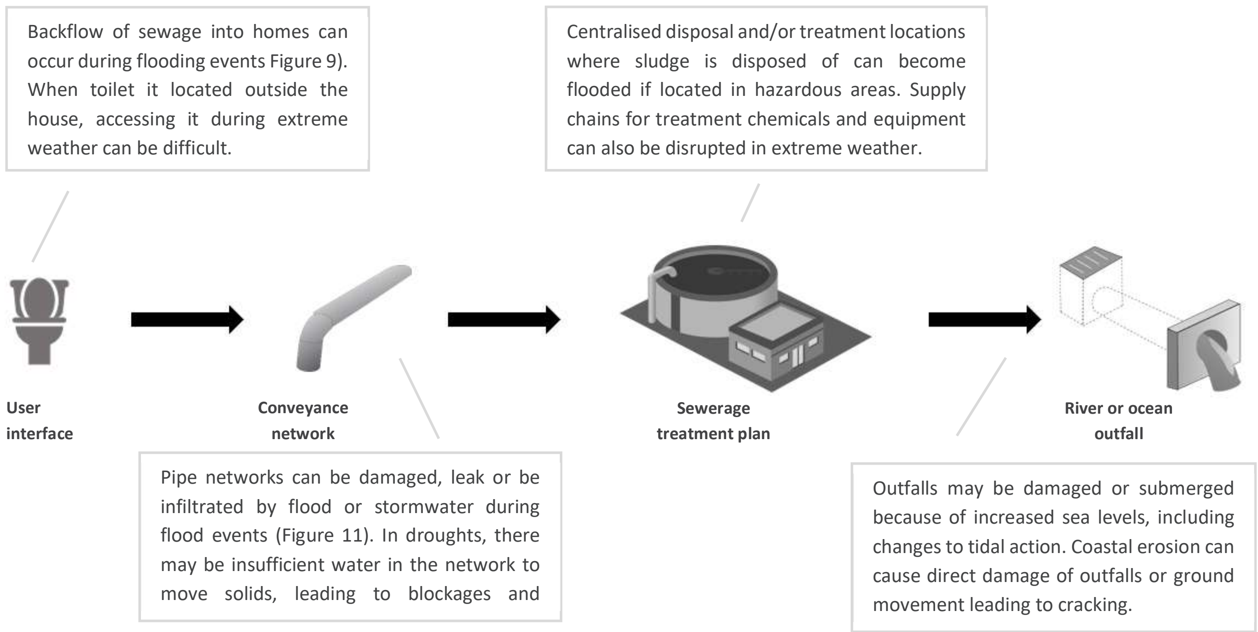

Figure 8: Example of climate-related impacts along a sanitation service delivery chain (centralised sewer network)

Figure 9: Superstructure and latrine showing water level encroachment of water (dark water marks on right)

Figure 10: Substandard superstructure materials

Figure 11: Exposed sewerage pipes

WHERE DO WE GO FROM HERE?

Urban informal settlements across Melanesia are diverse socially, culturally, and geographically, however many residents of informal settlements face challenges with respect to insecure tenure, substandard housing, and limited representative for service improvement. These existing characteristics affect the vulnerability and adaptive capacities of residents, particularly with respect to water, sanitation, and hygiene services. As well as being integral to overall health and wellbeing, it is well accepted that strong ongoing access to WASH services increases overall resilience of individuals, households, and communities in times of disaster and shock. The variety of different water and sanitation service delivery models in Melanesian urban informal settlements have different levels of resilience to the range of climate-related hazards currently affecting and likely to increase in severity across the Pacific, depending on different topographies and hydrogeological settings. At present, residents are relying upon many service delivery models that do not offer resilience to the most likely climate hazards for settlements, or rather, the service delivery model chains are incomplete, increasing the vulnerability of that service to climate hazards at many distinct points along a service delivery chain.

Service organisations, providers and CSOs can consider the sorts of support they provide along the service delivery chain, not just at the main infrastructure end. Thus, support with better quality materials and installation for piping, or access to toilets to facilitate emptying when required can help support resilience. Resilient service delivery models also mean people have the ability, resources, and support to fix systems when they fail.

Use of data and planning tools to understand the extent and likely impact of climate hazards across areas is required to properly assess and plan for risks to water and sanitation service delivery. Integrating urban planning approaches and climate hazard data, including spatial and GIS tools, with WASH service provision planning should be a priority for governments and utilities. Even in settings with poor adherence to the core elements of urban planning such as building approvals, standards and codes, integration and collaboration across these areas will lead to more resilient outcomes.

Notwithstanding other factors that affect the feasibility and authority to implement different service delivery models, a mix of service delivery models that includes completed service chains and consideration of user preferences is needed to offer climate resilience to everyone across the urban environment. Greater consideration of decentralised services, supporting private operators to play roles along the service chain, and facilitating safe and equitable sharing of services could all be considered within the context of overlapping urban, climate change and WASH service provision and planning.

ACKNOWLEDGEMENTS

The authors would like to thank those individuals and organisations who provided information and insight into this work, including The Fijian Government, The Vanuatu Government, and numerous other organisations who made this research possible. In particular, we thank the staff from the following organisations and departments who constructively participated in project meetings and stakeholder workshops and interviews: Fiji Roads Authority, Ministry of Health and Medical Services - Environmental Health Department, Department of Water and Sewerage, Suva City Council, Water Authority of Fiji, Ministry of Lands and Mineral Resources, Port Vila Municipal Council, Ministry of Health, Department of Urban Affairs and Planning, Ministry of Lands and Natural Resources, Public Works Department and UNICEF. We also acknowledge the contributions of our excellent research assistance team including Grace Ratidara, Emali Turaga, Aline Watt, Precila Wells and White Tougen.

This project was supported by the Australian Government Water for Women Fund and implemented by the International WaterCentre at Griffith University, Australia from 2021 to 2022.

Water for Women is the Australian Government's flagship WASH program and is being delivered as part of Australia's aid program.

Disclaimer: This publication was funded by the Australian Government through the Department of Foreign Affairs and Trade. The views expressed in this publication are the contributing authors' alone and are not necessarily the views of the Australian Government.

ADDITIONAL RESOURCES

The project has produced other publicly available resources, including:

- Research report – Policy review – water, sanitation, and hygiene (WASH) and climate change in urban planning systems in Melanesia (October 2022) https://www.watercentre.org/wp-content/uploads/2022/10/Report_WASHCC-and-urban-planning-in-Melanesian-cities_FINAL_31Oct2022.pdf
- Technical brief – Pilot study – autonomous identification of informal settlements in Pacific Islands using machine learning and satellite imagery (July 2022) https://www.watercentre.org/wp-content/uploads/2022/10/Report_WASHCC-and-urban-planning-in-Melanesian-cities_FINAL_31Oct2022.pdf

Other resources of interest include:

- Research Brief: Investigating the transmission of faecal pathogens in urban informal settlements in and around Port Vila, Vanuatu, recognising biophysical and demographic diversity: https://www.watercentre.org/wp-content/uploads/2021/08/Sanderson_MIWM_Vanuatu_WASHResearchBrief_V2_.pdf
- Research Brief: Investigating the transmission of faecal pathogens in urban informal settlements in and around Port Vila, Vanuatu, recognising biophysical and demographic diversity: https://www.watercentre.org/wp-content/uploads/2021/08/Sanderson_MIWM_Vanuatu_ResearchBrief_V1_Nov2020.pdf
- Project Synopsis: Planning for Climate-resilient Urban WASH in Pacific Islands: https://www.watercentre.org/wp-content/uploads/2021/08/PlanningforClimateResilientUrbanWASHinPIC_project-outline.pdf
- Working Paper for the World Bank: Water and Sanitation Services for Informal Settlements in Honiara, Solomon Islands, by Dr Regina Souter and Pablo Orams: https://documents1.worldbank.org/curated/en/514751574138362122/pdf/Water-and-Sanitation-Services-for-Informal-Settlements-in-Honiara-Solomon-Islands.pdf

SUGGESTED CITATION

Sanderson, R., Kotra, K.K., Koto, C., Molitambe, H., and Souter, R. 2022. "Climate-resilient and climate vulnerable water and sanitation service delivery models in urban informal settlements in Melanesia" International WaterCentre, Griffith University. Nathan: Australia.

Cover image: resident in Nanuku settlement (flooded access to residences in settlement in Suva).

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SUPPORTED BY

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