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Synthesis Report

Anticipatory Action for Infrastructure Sectors in the Pacific Islands

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Key messages

This report draws on the findings from a regional overview and three case studies of ‘anticipatory action’ in infrastructure sectors in the Pacific Islands.

There is huge potential to improve anticipatory action for drought. Currently, when a severe drought is forecasted, it can take eight months for the drought response to begin. Finance can be triggered earlier based on seasonal forecasts.

For tropical cyclones, the window of opportunity for anticipatory action is much smaller, so planning is key. Private sector utilities companies have business continuity plans to protect their assets and ensure services can be quickly reinstated. State-owned enterprises and ministries need much more detailed plans, and clearer mandates for ensuring service delivery in outer islands.

Government agencies rely on recurrent budgets to pay for anticipatory action; and may be reimbursed later. They would benefit from more reliable and earlier reimbursement, which could be based on a forecast.

More detailed disaster impact assessments and vulnerability analysis is needed to design impact-based forecasts focussed on specific infrastructure sectors. These would allow for better operational decisions to be taken when a disaster is imminent.

Contents

Acronyms

BCM	business continuity management
CLEWS	NIWA's Climate Early Warning System
DMC	ADB Developing Member Countries
ENSO	The El Niño-Southern Oscillation
FbA	forecast-based early action
ICT	Information and Communications Technology
IOM	International Organisation for Migration
MWSC	Majuro Water and Sewer Company
NDMO	National Disaster Management Office
NECC	National Emergency Coordination Centre
NIWA	New Zealand National Institute of Water and Atmospheric Research
NMHS	National Meteorological & Hydrological Services
NOAA	US National Oceanic and Atmospheric Administration
PCRAFI	World Bank's Pacific Catastrophe Risk Assessment and Financing Initiative
PDNA	Post-Disaster Needs Assessment
PDRP	Pacific Regional Disaster Resilience Program
PEAC	Pacific ENSO Applications Climate
PICRIC	Pacific Catastrophe Risk Insurance Company
RMI	Republic of Marshall Islands
RO	reverse osmosis
SOE	state-owned enterprise
Solar PV	Solar Photovoltaic System
SOPs	standard operating procedures
TPL	Tonga Power Limited
VMGD	Vanuatu Meteorology and Geo-Hazards Department
VUV	Vanuatu Vatu (currency)
WASH	water, sanitation and hygiene sector
WRNs	Weather Ready Nations

1 Introduction

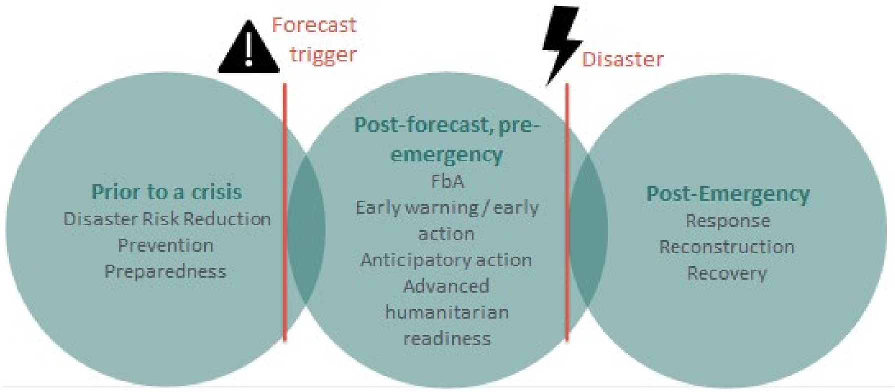
1.1 What is anticipatory action needed for infrastructure services in the Pacific islands?

1. ADB's Developing Member Countries (DMCs) in the Pacific face increasingly frequent and intense extreme weather events that cause significant damage and losses to these island nations. Climate change, environmental degradation and urbanization are all increasing disaster risks and threatening to undermine the viability of island communities. It is critically important to reduce these risks, but also to be well prepared, and a range of strategies and actions are needed that can help mitigate the impact of tropical cyclones, floods and droughts on communities.

2. The Pacific region has seen a marked shift in the uptake and use of disaster risk assessments, regional data and diagnostic risk assessment platforms in recent years, which can be used for development planning and disaster risk reduction, but also for forecasting disaster impacts. These so-called ‘impact-based forecasts’ can be used to fine-tune preparedness strategies and plans so that actions when a disaster is imminent are focused on those with the greatest potential to mitigate losses. This set of actions aimed at reducing or mitigating the impact of disasters and enhancing post-disaster response, using forecasts or early warnings of imminent shock or stress (Weingärtner and Wilkinson, 2019) is known as ‘anticipatory action’. The concept is being widely applied within the humanitarian sector with a focus on actions taken to help vulnerable individuals and communities likely to be affected by a disaster to take action to minimise the impacts and recover more quickly. The rationale derives from experience and evidence of humanitarian assistance frequently arriving too late to reduce some of the devastating effects of drought, flooding, tropical cyclones, heatwaves, and other hazards, despite the availability of forecast information and knowledge of how communities are likely to be affected.

3. Anticipatory action in the humanitarian sector has been advanced largely through relatively small-scale assistance projects, while acknowledging that to scale up these mechanisms and their benefits will require engagement with governments and their development partners. However, to-date the role of these development actors in anticipatory action has not been explored in any depth. Where exploratory work around state-led anticipatory action has taken place -for example in the Eastern Caribbean- the concept has met with some resistance (Wilkinson et al., 2020). This is partly because in the context of rapid-onset hazards in particular, anticipatory actions may look similar to ‘preparedness’ – hence it is difficult to see the added value. Anticipatory action is a sub-set of preparedness implemented in a time sensitive ‘window of opportunity’ after a forecast (see Figure 1), that can helping increase the resilience of services and the communities that rely on them, by reducing impact and time to recover after a disaster. Anticipatory action is made possible by the significant advances that have been made over the last decade in forecasting capacity, making it possible to improve the effectiveness and efficiency of preparedness systems and activities.

Figure 1. How anticipatory action fits in the disaster timeline



4. The scope for this enhanced preparedness to take place in the window between a forecast and a disaster, needs to be considered in relation to different types of shocks and stresses (especially rapid versus slow-onset weather events)[1]; and in particular, to the kinds of actions that can realistically be triggered using forecasts and targeted at specific geographies or communities using information of where and what types of impacts can be expected. Timing is critical for action to have a positive impact, and the 'window of opportunity' for action linked to a tropical cyclone forecast is very different than for drought (this is discussed in greater detail in section 2).

5. One typology of anticipatory action that is useful in considering 'what type', as well as 'when', anticipatory action may be required, has been developed by Levine et al. (2020) in relation to the protection of livelihoods in anticipation of drought impacts. A summary of the typology and examples for drought and for rapid onset events are highlighted in Table 1 (below).

Table 1. Types of anticipatory action for drought and rapid onset events.

Type of anticipatory action	Examples for drought	Examples for rapid onset events
Implementing an assistance project pre-shock or pre-crisis	Distribution of drought resistant seeds	Cash transfers to vulnerable communities, education and capacity building for communities
Surveillance/situational monitoring	Monitoring nutrition levels; water quality levels	Tracking of a cyclone/ weather system, from tropical depression level. Monitoring electricity supply to users
Accelerating regular work that needs to get done	Planned repairs of water tanks	Trimming of trees near electricity lines, repairing damaged equipment
Redirecting expenditure	Switching from water infrastructure investment in one location, to increasing supply to drought-prone areas	Switching from new road construction to gutter/culvert repairs in flood-prone areas

[1] Anticipatory action initiatives have also been developed for volcanic eruptions and for non-natural hazard related events such as conflict.

Getting ready to respond	Pre-positioning desalinization equipment	Pre-positioning building materials for reconstruction
Providing information and advice	Drought advisories/ text messages to farmers	Tropical cyclone alerts and advice for vulnerable households

6. This scoping study focuses on the potential and rationale of anticipatory action in infrastructure service sectors in the Pacific islands. This is important because of the significant impacts of extreme weather on service provision in these islands, and difficulties in 'climate proofing' or reducing risk across infrastructure because these structures and delivery networks are so geographically dispersed and because of the very high costs of retrofitting and rehabilitating infrastructure in the Pacific.

7. Some service providers will have preparedness plans – often referred to as standard operating procedures, or business continuity plans- to protect their assets, avoid service interruption and rehabilitate services quickly after a disaster. But very few will have considered the range of anticipatory actions that may be needed to reduce the impacts of extreme weather on vulnerable communities (as described in Table 1). Not all of these actions are the responsibility of utilities companies: some of the actions would fall under the mandates of national disaster management agencies (especially iii) and national meteorological services (vi), as well as line ministries and state-owned utilities companies responsible for delivering different kinds of public services (iv. and v., and ii. particularly for public health departments). In some cases, where public services are privatised, these anticipatory actions would be the responsibility of private entities.

8. The objective of this scoping study is to understand better the disaster impacts that could be mitigated through anticipatory action and the institutional arrangements and systems that are needed in Pacific islands to facilitate those actions in key infrastructure sectors, with a particular focus on the outer islands, where infrastructure may be weaker and access to services more easily disrupted. The study looks at disaster impacts related to infrastructure services experienced by both the service providers and users/ communities.

2 Methodology, case study approach and limitation

9. This synthesis report draws on the findings from a regional overview of anticipatory action in infrastructure sectors in the Pacific Islands and three case studies.

10. The regional review focusses on the institutions, policies and capacities in place to take anticipatory action across ten ADB Developing Member Countries (DMCs) participating in the Pacific Regional Disaster Resilience Program (PDRP), using a common analytical framework made up of four components (Wilkinson et al., 2018):

- Forecasts: If forecasts of extreme weather impacts in infrastructure sectors are being produced and being made available in a timely way for decision making;
- Planning: Status of specific plans for climate hazards with clarity on the roles and responsibilities of different sectoral stakeholders – public and private;
- Finance: Pre-arranged finance that can be made available to pay for actions after a forecast; and
- Delivery: Delivery mechanism, human resources and skills needed to carry out anticipatory actions.

11. Examining each of these for all infrastructure services across the ten countries was beyond the scope of this study, so the regional report concentrates instead on the institutions, policies and capacities in place in the electricity, transport and water, sanitation and hygiene (WASH) sectors. It undertakes a high-level assessment of these mechanisms and systems for their potential use in anticipatory action and highlights gaps and capacities that need to be strengthened to enhance the effectiveness of disaster preparedness in the delivery of energy, transport and WASH infrastructure services in the Pacific region.

12. To look in more detail at the potential costs and benefits of investing in anticipatory action to mitigate impacts in infrastructure sectors, three case studies were developed with local experts. The selection of countries and sectors was based on a number of criteria:

i. Countries experiencing disasters recently, where data not collected at the time can be more easily recalled through interviews;
ii. Sectors that we know to have been heavily affected by extreme weather, so there is an interest/rationale for avoiding losses through anticipatory action;
iii. Sectors that are vital to the effective delivery of other services (such as communications and transport) and which play a critical role in facilitating emergency response and recovery, and hence high priority for anticipatory action
iv. Countries or sectors where there is already interest in/use of impact-based forecasts, where this can be further augmented through analysis and planning;
v. Countries or sectors where ADB is already providing risk analysis

Three countries and sectors were identified for further analysis:

2.1 Water sector

13. The **Republic of Marshall Islands** (RMI) experienced drought from 2015-16 with the northern atolls being most severely affected. Getting water supplies to these islands was slow and costly, which highlights the importance of maritime transport for the effective delivery of

water supply and other basic services IOM coordinated a response. The drought was well forecasted but the response was slow and desalination plants were shipped many weeks after severe drought impacts were already being felt across the outer islands. Higher shipping costs were incurred by chartering vessels and flying the water in an emergency. Potential options for anticipatory action, particularly for the island of Majuro which is more reliant on rainwater harvesting, were explored, including: increasing storage and rainwater harvesting using seasonal forecast; shipping desalination units out earlier with flexible/mobile maintenance support; and shipping water earlier at lower rates. The case study also looks at the potential for making finance available earlier, before drought conditions deteriorate, to pay for anticipatory action.

2.2 Energy sector

14. **Tonga** is considered a regional leader in resilient energy production and distribution. It has benefited from investment in underground cabling and is a leader in solar energy. ADB projects assess the climate vulnerabilities and design features to minimise impacts – for example, to cables/power lines, PV plants and power houses (where batteries are stored). TPL is a state-owned enterprise (SOE) and has skilled staff in the capital, Tongatapu. A significant proportion of energy needs are imported (diesel-based) so logistics/transportation is important, and dependence on diesel for food and water supply makes anticipatory action in the energy sector a critical issue. When Tropical Cyclone Gita hit Tonga in 2020, the energy sector faced T$17.14 million in damages and losses (including major damage to the power network in Tongatapu and ‘Eua, with less known about damage and disruption in the outer islands), so understanding what TPL and the Energy Department did to prepare and to what extent this could have been improved, are critical questions for the energy sector.

2.3 Transport sector

All Pacific Island countries have a main international port, and although the outer islands do not tend to have a port, they often have jetties or wharves. In the outer islands, boats would usually be taken inland if adverse weather is expected (although some islands lack land that is safe from flooding), but the jetties themselves often get damaged. The scope for anticipatory action, and potential reduction in losses due to damage or interrupted inter-island navigation, is particularly significant for the main ports given the various assets that can be damaged (cargo, equipment), and the problems and knock-on effects that damage creates for delivery of water, diesel and other services. Ports are systems with many stakeholders and complex governance structures, so anticipatory action will need to be based on a model of shared investment and benefits. Based on an initial assessment of anticipatory action potential, severity of impacts, and alignment with ADB investments and practices, the Ports sector in Vanuatu was selected as the third case study.

15. Based on information from across the three case studies and the regional assessment, we first examine the types of disaster impacts that occur in infrastructure sectors related to different hazards. The report then reviews the forecasts that are available and how they are used by infrastructure service providers to take action, as well as the plans they have in place to prepare for -and respond after- disasters and how preparedness and response actions are financed. This analysis highlights some important limitations in terms of the usefulness of forecast information, understanding of community vulnerability and risks across infrastructure systems, and the skills, human resource and financing gaps that exist and need to be addressed in order to enhance preparedness for -and reduce the impacts of- extreme weather in the Pacific islands.

3 Impacts of Tropical Cyclones and Drought in the Pacific Islands on infrastructure Services

16. Anticipatory action and better preparedness for drought and rapid onset events requires an in-depth understanding of the impacts of extreme weather.

17. A review of the literature on recent disaster impacts on key infrastructure sectors in the Pacific Islands shows how types of impacts vary according to hazard type, but also look very different depending on the kind of services being delivered (see Table 1). Table 1 does not differentiate between state-owned enterprises, private utilities companies or community managed infrastructure, but this is important information to have in considering what anticipatory action should be taken and by whom (i.e., who has the mandate to do so) to reduce anticipated impacts.

18. The table demonstrates the wide range of direct impacts (damage and losses to the infrastructure itself, disruption to service delivery and additional costs of delivering services) as well as the indirect costs on communities of that damage and service interruption. But beyond these broad types of impacts very little information exists as to the relative impacts of similar strength of hazards on different islands, for different levels of preparedness or according to the extent of risk reduction measures that have taken place. The impacts are complex and interrelated, and hard to anticipate without more detailed analysis and information, making cost-benefit analysis of anticipatory action very difficult.

19. The next section compares some of the costs of disaster for different infrastructure sectors for recent disasters in the case study countries.

Table 3. Hazard impacts on water, electricity and transport sectors, and subsequently for communities

	Impacts on water and sanitation service delivery	Impacts on electricity service delivery[2]	Impacts on transport networks	Impacts on communities (related to service infrastructure damage and losses)
Flood	• Water supply pipes exposed to floodwater and flood-borne debris • Saline intrusion in water tanks or groundwater sources • Contamination of drinking water sources with wastewater or sewage • Flooding of household sanitation systems leading to discharge of raw sewage and pollution into the environment • Inundation of water utilities • Clean-up costs	• Solar PV generation: short-circuiting and damaging solar system electronics exposed to flood • Diesel generation: inundation of generation asset while still in operation, and fuel storage • Transmission and distribution: inundation of substations; short-circuiting power network before de-energising; damage or destruction of transmission towers and distribution poles; breakage of cables; damage to critical ICT systems. • Safety and public health of staff • Security of important information • Long-term power yield losses • Clean-up costs	• Damage to road and port infrastructure • Damage and destruction of boats and other forms of transport • Disruption to supply chains, logistic networks, and revenue losses • Disruptions to daily operations, mobility, delays in movement of goods and services	• Disruption to water supply • Increased time cost to fetch water • Increased expenditure for bottled water • Floodwater limiting mobility • Increase of water-borne diseases • Extra expenditure for families due to loss of clothing, hygiene products and other essentials • Loss of electricity services after disaster, especially on outer islands and atolls due to absence of transport, equipment and presence of emergency teams for rapid electricity recovery • Schools, businesses and roads closed down • People left homeless • Impact on agricultural production and loss of harvest • Clean-up costs • Lost income

[2] Diesel and solar power generation are included here as the two most common sources in the fuel mix of Pacific Island countries.

				• Sale of valuable assets and accumulation of high-interest debt
High windspeed	• Damage to water storage systems • Clean up and rehabilitation costs	• Solar PV generation: damage to solar panels • Destruction of transmission towers and distribution poles; breakage of cables; damage to critical ICT systems. • Damage to substations and generators	• Damage to road and port infrastructure • Damage and destruction of boats and other forms of transport • Disruption to supply chains and revenue losses • Damage to lose equipment and containers at the port • Fallen debris can cause disruption in mobility	• Disruption to water supply • Increased time cost to fetch water • Increased expenditure for bottled water • Extra expenditure for families due to loss of clothing, hygiene products and other essentials • Destruction of health facilities, equipment and supplies • Destruction of water supply systems and sanitation facilities, leading to increases in waterborne diseases • Psychological and mental distress
Drought	• Less rainfalls leading to decreased utility drinking water supply • Rapid depletion of household rainfall water catchment • Higher costs to deploy alternative systems (i.e., reverse osmosis) and distribute water, especially to outer islands and atolls • Higher utility abstraction costs from water catchment	• Solar PV generation: decreased operational efficiency due to higher temperature; lack of water to clean panels. • Hydropower generation: reduced water availability and generation output. • Diesel generation: decreased operational efficiency due to higher temperature; altered ramp-up and cool down times; insufficient water for operating needs • T&D: exceedance of operational limits due to higher temperatures; breakage of	Potential limitations to water transportation if routes are affected. High temperatures can damage roadways, rail lines, and other assets.	• Increased expenditure for bottled water • Increased time cost to collect water • Increased use of unsafe water • Increased harassment of women when collecting water • Decreased labour capacity and lost income • Loss in reproductive labour • Increased social tension and fighting • School absenteeism

		overhead and underground cables		• Deteriorating hygiene and increase of diseases (e.g., conjunctivitis). • Higher electricity consumption for fans, air conditioners and other appliances • Food shortages and reduced food security • Abandoning of traditional staple plants and diets • Growth of invasive species (e.g., invasive seaweed species in Tuvalu). • Loss of workdays and income due to drought-induced shift in production • Loss of employment

Source: Ebinger and Vergara (2011); Iese et al. (2021); Johnston (2012); Leenders et al. (2017); Woodruff (2008); key informant interviews

3.1 Counting the costs on infrastructure sectors

20. The cost of disaster is only partly related to the intensity of the drought or tropical cyclone. It also depends on which islands, locations and parts of systems are most affected. Also, critically, the costs are not just felt in terms of damage to infrastructure; with interruption and loss of revenue and additional costs of provision also creating difficulties for service providers. This is important in considering where additional or different preparedness action may be needed following a forecast.

21. The following tables summarise the extent of losses in infrastructure sectors for recent disasters. Much of the information comes from Post-Disaster Needs Assessments (PDNAs), which include more detailed information and a breakdown of losses and damage by sub-sectors, but not by assets or for different hazards (for example distinguishing between flood and high windspeed impacts of tropical cyclones). Of the total damage caused by Tropical Cyclone Harold (Table 4), for example, damage to the post infrastructure (Luganville wharf) is estimated at VUV 500,000 (USD 4,420). Most of the damage occurred in roads and bridges.

Table 4. Vanuatu – Costs of Tropical Cyclone Harold in the transport sector (Millions USD)

	Damage	COVID-19 losses	TC losses	Total
Transport	25.29	2.82	0.73	28.84
TOTAL all sectors	245.22	81.71	210.69	537.62

Source: Vanuatu Recovery Strategy 2020-2023 (Government of Vanuatu, 2020).

Table 5. Tonga – Costs of Tropical Cyclone Gita in the energy sector (Millions USD)

	Damage	Losses	Total
Energy	5.95	1.66	7.61
TOTAL all sectors	92.69	65.38	158.07

Source: Post Disaster Rapid Assessment (Government of Tonga, 2018).

Table 6. RMI – Costs of the 2015/16 drought in the water sector (Millions USD)

	Damage	Production disruption	Higher costs of production	Total
Water/ sanitation		0.16	0.73	0.90
TOTAL all sectors	0.01	4.04	0.88	4.94

Source: Post Disaster Needs Assessment (RMI, 2017).

22. Direct damage to infrastructure is the most significant cost for infrastructure sectors from tropical cyclones, whereas for drought, in the case of RMI, production disruption and subsequent revenue losses and higher costs of production experienced by the water service provider are relatively higher. This makes business continuity planning particularly important.

4 The Status of Anticipatory Action in Preparedness and Response Arrangements

23. This section assesses the extent to which anticipatory action is being considered and planned for within infrastructure sectors in the Pacific Islands, with examples from the three case studies in Tonga, Vanuatu and RMI.

4.1 Use of forecasts for preparedness

24. The use of forecasts to trigger action prior to a disaster is very different for drought than for rapid onset hazards, so the following analysis discusses the two separately.

4.1.1 Action based on tropical cyclone forecasts

25. Tropical cyclone seasonal outlooks in the Pacific are provided by regional and local meteorological agencies, such as the Vanuatu Meteorology and Geo-Hazards Department (VMGD) and Tonga Met. For short-range forecasts the local met services use forecast models to prepare and issue alerts to the government and general public with information on 'wind strengths around the systems, movement of the system and locations of the systems expected in specific areas (National Disaster Management Office, Government of Vanuatu, 2020). VMGD's forecast information is estimated to have around 85% forecast accuracy.[3]

26. VMGD, the National Disaster Management Office (NDMO), and other actors will be monitoring storms from when tropical depressions form in the South Pacific, but normally do not issue information until 72 hours before. In Vanuatu, an information bulletin is first produced when a weather system is approaching Vanuatu area but is not yet a threat to any islands (usually one week before it could reach Vanuatu depending on how quickly the tropical storm develops). The bulletins are issued twice a day. If the system is a Tropical Cyclone, the bulletin contains detailed information on its position, intensity, the distance from the centre to the nearest island of Vanuatu and a 72-hour forecast track. Advisory bulletins are issued every 6 hours at least 36 hours before the likely onset of gales or stronger winds to any islands of Vanuatu. Cyclone Warning bulletins are issued when Gale, Storm or Hurricane Force winds are expected to affect any islands of Vanuatu within 24 hours. The warning bulletin is issued every 3 hours.

27. These type of alert systems for tropical cyclones are common across all Pacific Island nations. They stipulate actions to be taken at each level of alert, but these are focussed on community-level action, assisted by NDMOs.

28. Interviews with actors in the Port of Luganville, Santo, Vanuatu explained that they had around a week to prepare for Tropical Cyclone Harold, as they started tracking the cyclone while it was still a depression. When asked if any of the damage could be prevented, they explained they did their usual preparation activities but had not expected the damage of a category 5 cyclone.

29. In terms of the quality and granularity of current forecasts, key informants have highlighted how these tend not to be detailed enough for operational decisions. The development of impact-based forecasts is happening across the region,[4] but we found only a

[3] Key Informant interview.
[4] The WMO is implementing the Weather Ready Nations (WRNs) programme to monitor rainfall shortages and issue bi-weekly warnings once a drought is identified. The World Bank's Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) is generating detailed country specific data on assets and populations' exposure to hazards and developing country risk atlases, as well as creating a risk information database (PACRIS). The Pacific

few examples of these products being developed for different sectors or specific users. For instance, rainfall forecasts for hydropower operation should be provided weekly as millimetres of rain per day, to be useful for decisions on water harvesting and storage. Moreover, verification of forecasts by meteorological agency personnel, local community representatives and private sector stakeholders in the Pacific islands is still rudimentary[5]. Further engagement with organisations working at the community level is needed to improve this.[6]

4.1.2 Action based on drought forecasts

30. Seasonal drought forecasts are provided at the start of the rainy season, 8-9 months in advance of a drought in the form of bulletins and regional climate outlooks. These forecasts are regularly updated and become more precise (in terms of stipulating which islands will be most affected) as information on actual rainfall informs the forecast. A range of agencies are involved in these including the New Zealand National Institute of Water and Atmospheric Research (NIWA), the US National Oceanic and Atmospheric Administration (NOAA), Pacific ENSO Applications Climate (PEAC) Center and the University of Hawaii - Joint Institute of Marine and Atmospheric Research (for more information refer to the Regional Assessment Report).

31. In RMI, for the 2015/16 drought, the seasonal, meteorological drought forecasts began in May, but most actions to mitigate the impacts were not carried out until a hydrological drought could already be detected in the form of reduced water levels in reservoirs and other catchments. RMI experienced high levels of rainfall in March and April 2015, which is typical of an El Niño year. According to the Pacific ENSO Update in May 2015, RMI would be at risk of severe drought in early 2016. By November 2015, the region was under an El Niño Advisory. The Climate Impacts and Outlook bulletin for Hawaii and U.S. Pacific Islands Region, 4th Quarter 2015, stated that "drought … will expand to include Kwajalein and Majuro in the RMI … by late in the quarter." No detail was given, however, of what kinds of impacts could be expected.

32. In late 2015, the International Organisation for Migration (IOM), the Marshall Islands Red Cross and NGOs operating in RMI began to undertake some preparedness, focussing on communication with communities in outer islands around cleaning pipes, handwashing and other measures related to hygiene and water conservation. Majuro Water and Sewer Company (MWSC) started checking assets, carrying out repairs and looking at manpower – making sure that they would have people on call especially key staff to help run the water treatment plant and for water delivery to tanks. In January 2016, the government conducted a series of rapid assessments, and on 3 February 2016 the President declared a state of emergency. By early March 2016 local government officials had reported that the majority of water tanks were almost empty and well water was undrinkable (i.e., a hydrological drought was occurring) and on 8 March 2016, the Government of RMI declared a national disaster. Drought response activities, including shipping of reverse osmosis equipment to the outer islands and setting up of water collection points in Majuro, were then implemented, eight months after the first ENSO update predicted that severe drought would occur in RMI, and three months after the onset of the meteorological drought (lower than average rainfall).

4.2 Preparedness planning

33. Many of the actions described above are carried out in an *ad hoc* way; they are not formalised in any kind of plan. Similarly, very limited records are kept on which actions were

Resilience Program is creating hazard models to forecast inundation from cyclone rainfall, cyclone wind damage and hazard modelling for tsunami induced landslides and is creating a multi-hazard risk information system to store LiDAR data. NIWA's Climate Early Warning System (CLEWS) provides seasonal sectoral forecasts for the agriculture, health, tourism and forestry sectors three months in advance to help them prepare.

[5] Key informant interview,

[6] Pacific Science Solutions, 'Pacific Roadmap for Strengthened Climate Services 2017-2026'.

implemented, and which were not – the authors did not come across any recent post-disaster evaluations of preparedness actions (the PDNA documents reviewed for this study do include some examples of actions taken before the disaster, but this is not a detailed or comprehensive assessment and actions are not analysed in relation to what was planned).

4.2.1 Standard operating procedures

34. Across the three case studies and in reviewing disaster plans more broadly across the Pacific Islands, we came across some examples of standard operating procedures (SOPs) for different hazards, but these are generally not being used by infrastructure sectors.

35. In Vanuatu, the Port of Luganville, Santo does not have SOPs. They have a set of standard practices that they carry out before a cyclone arrives, but these are not formalised in writing. These include putting up shutters to protect the building, removing solar lights, preparing and tying down equipment in case the roof is blown away, covering equipment and items that are not waterproof with tarpaulin, placing all light buoys inside the harbour, and removing all CCTV cameras around the Port Facility before the cyclone makes landfall. In terms of distribution of responsibilities, the port operators are responsible for the shutters while the other government offices are responsible for looking after the equipment.

36. Tonga's NEMO has developed SOPs for different hazards, which in the case of tropical cyclones, are triggered by receiving a warning from the Tonga Met Service. The SOPs involve establishing the National Emergency Coordination Centre (NECC) 48 hours before impact, ensuring emergency response plans are ready for activation (12-24 hours from impact), and then monitoring the event as it approaches (00-12 hours from expected impact). These are not focussed on any particular sector, and the Department of Energy does not have SOPs for any type of hazard. Tonga Power Limited is the only utilities company covered by this study that does have official SOPs (it has a business continuity plan).

37. In RMI, IOM has issued guidance on the preparation of SOPs for the different clusters, but the WASH cluster does not yet have SOPs for drought. The cluster is quite well organised and can put together a drought response plan quickly, with costings but, as mentioned in section 4.1, this precludes earlier actions when seasonal drought forecasts are issued.

4.2.2 Business continuity plans

38. State-owned enterprises and private sector look a bit different. In Tonga, Tonga Power Limited (TPL) has a Business Continuity Management System (BCM) that ensures action is taken in advance of disasters to safeguard the company's assets, activities, reputation and interests of stakeholders. The BCM includes seasonal preparedness actions like ensuring additional stock from suppliers for the cyclone period. TPL also has an Emergency Response Plan with recommended actions to be carried out according to the level of alert, to safeguard assets on TPL premises and ensure vehicles, generators etc are on standby to respond quickly; and protocols for shutting down power generation when certain thresholds are reached of likely flooding, strong winds that could trip main feeder lines and other criteria (TPL, 2021). They also include a 'systems recovery schedule' with plans for getting the power and IT systems back on.

4.2.3 Community preparedness plans

39. Community preparedness plans in the Pacific islands usually include some detail on what to do for each phase of the alert, and for post-disaster response. In Tonga, for instance, a typical village emergency management plan would start at 'yellow' alert when a hazard event is detected in the region as a potential threat. Appointed leaders and the chain of command are identified and their responsibilities and tasks assigned. Most of the anticipatory action is related to warning people in the village, ensuring evacuation centres are ready, and some

measures to avoid damage to houses (outing up window shutters). No mention is made of actions to safeguard public -or privately-owned infrastructure.

Table 2. Preparedness actions being taken (after forecast, before disaster*)

Tonga- energy sector (cyclones)	**RMI – water sector (and WASH cluster) droughts**	**Vanuatu – Port authorities droughts**
• TPL- business continuity plan activated (mainly to protect staff and offices); skeleton crew put on standby; power switched off. Action to protect assets not clear. • Department of Energy – checking solar panels and equipment in outer islands. Not clear how extensive that is.	• Communication with outer island communities on cleaning pipes, handwashing and other hygiene and water conservation measures. • MWSC - checking assets, carrying out repairs and looking at manpower, contracting additional staff to run water treatment plant and delivery to tanks.	• Putting shutters in place and removing the solar lights, diverting ships to seek shelter elsewhere, tying down loose equipment, and covering equipment that are not waterproof with tarpaulin. • Fuel and subsistence costs for 20 people assisting in round-the-clock pre-disaster operations (harbor master, assistant, port captains, engineers, external navigation, securities, linesmen). • Hiring a contractor to oversee preparations.

* Other activities were carried out after the hydrological drought had started, so these are classified as 'drought response' rather than preparedness. These include provision of water tanks in Majuro; procurement of RO units for Majuro Islets; education on safe drinking water; RO units and spare parts shipped to outer islands; provision of WASH kits.

4.3 Paying for preparedness

40. Most state-owned enterprises and government departments rely on their recurrent budgets to undertake anticipatory action when a disaster is forecasted, particularly for tropical cyclones; and then apply for additional resources for disaster response. For both, they often spend their own budget first and are then reimbursed by central government from a national contingency budget. This reimbursement is often delayed, however, and does not cover all the costs of anticipatory action and response.[7]

41. In Vanuatu, before Tropical Cyclone Harold made landfall, the Ports Authority coordinated a series of rapid anticipatory actions, including putting in place shutters and removing the solar lights – all paid from an operational budget. Expenditures included some cost of equipment and the hiring of a contractor to oversee preparations. Interviewees mentioned that the budget was quite limited, and they could have done more to prepare for the cyclone if they had adequate financing. The impacts amounted to VUV 5m, including from damage to 4 containers, clean-up costs from a fallen tank from a coconut oil company that fell into the port area; and a pilot boat stationed and docked at the port was lost during the cyclone as well.

[7] Interviews with stakeholders in Vanuatu and Tonga.

42. In RMI, line ministries would have to make a request, coordinated by the NDMO, to the Ministry of Finance once a disaster has been declared.

43. There are a range of disaster risk financing instruments available to Pacific Island countries, but currently only very few can trigger payments on the basis of a forecast; and a few more have the potential to do so (see Annex 1). Earlier release of funds would be useful for ministries and SOEs, as they often have to wait some time to be reimbursed and their budgets are limited, so they risk running out of resources to respond to disasters if they pay for anticipatory action. Even if the funds do not arrive before a disaster, some kind of pre-authorisation would give the right signal to agencies.

44. For drought, the costs of anticipatory action are more significant, and funding will need to be released several months before a hydrological drought occurs, in order to allow enough time for increased water collection and the delivery of water/equipment to outer islands at a lower cost (not in an emergency situation). Because of the longer lead time, developing drought forecast triggers for risk financing instruments make sense and could be considered by the Pacific Catastrophe Risk Insurance Company (PCRIC) and ADB's Policy-based Contingent Disaster Financing (CDF) (for further analysis of risk financing instruments and their potential to support anticipatory action see the regional assessment report).

4.4 Gaps and constraints for anticipatory action

Human resource and skills constraints

45. Anticipatory action for tropical cyclones in infrastructure essentially involves undertaking a range of activities in a very short space of time, and ultimately requires significant human resource capacity and specialist skills. In the Vanuatu Port of Luganville, expenditures incurred during disaster preparedness included all fuel and subsistence costs for 20 people assisting in round-the-clock pre-disaster operations (harbour master, assistant, port captains, engineers, external navigation, securities, linesmen). The port authorities were not able to do more to prepare when they were given 1-2 days' notice that the tropical cyclone would be a category 5 hurricane- they did not manage to take any further measures such as moving the pilot boat (that sank consequently) or ensuring that containers and tank (belonging to a coconut oil company) were tied down. Not having these actions formalised in plans, procedures, or regular training and exercises is a constraint; but so too is the lack of personnel available at short notice to assist in these activities. Similarly, in Tonga, the availability and skills of government staff to implement preparedness actions such as checking solar panels, diesel generators, and acquiring fuel, and for working closely with communities is a major gap.

46. Across all case studies, the number and distribution of many small islands across wide geographical areas means that there are very high fixed costs associated with sending out personnel and equipment to support anticipatory action in the outer islands. As highlighted in the Tonga case study, energy systems are widely distributed across many islands, so the Ministry's capacity to reach all islands in the 48 hours before a tropical cyclone will always be inadequate. However, the costs of responding after disasters with personnel and equipment are likely to be even higher, as more resources are needed to rehabilitate damaged infrastructure than repair infrastructure that needs maintenance, and the prices often go up after a disaster. TPL in Tonga, for example, has a contract in place with Transnet for sourcing equipment and supplies that could be on hand in case of unexpected damages.

Unclear mandates

47. An analysis of anticipatory action potential also raises issues of responsibility and mandates, of what anticipatory actions should be taken and by whom to reduce anticipated damage, interruption to services and impacts on communities? This is particularly an issue in the outer islands where household and communities manage the infrastructure services, not SOEs. Off-grid energy, household water tanks and jetties (not major ports) are the norm; and

while the government and NGOs will step in after a disaster to repair and provide humanitarian assistance to communities, they do not have a clear responsibility for anticipatory action. At the same time, communities do not focus on infrastructure in their preparedness plans and activities, so there is clearly a gap in terms of responsibilities, resources and incentives for them to do so.

48. During the 2015/16 drought in RMI, the most important response measure taken by government for the outer islands was to ship mobile desalination units. In 35 communities, temporary 360 GPD (gallons per day) reverse osmosis units were installed, which along with some supplies of bottled water, use of ground water and other limited local sources, provided families with drinking water, albeit less than the estimated 18 GPD (which is already low). These communities are not users or customers of MSWC, unlike many residents of Majuro; hence, delivery of RO units and other types of assistance is seen more in terms of additional services that need to be provided, rather than business continuity to protect assets and income streams. This may explain why anticipatory actions tend to be less comprehensive for the outer islands.

49. Overall, the scope for implementing anticipatory actions to reduce damage to infrastructure for rapid onset events is limited. For example, during Tropical Cyclone Gita, the grids that were not yet upgraded suffered most damage (45.9% of the grids that had not yet been upgraded in Tongatapu's outer islands were damaged during Tropical Cyclone Gita, compared to only 4.7% of upgraded grids). Little could have been done in 72 hours or even a week to avoid damage where network infrastructure was in need of upgrading. This is not true however for off grid solar panels and diesel generators, which can be detached, positioned and protected.

Inadequate data

50. In the regional assessment and across all three case studies, the lack of detailed data on disaster impacts or vulnerability data for communities in the outer islands were identified as being major challenges to enhancing preparedness and mitigating disaster impacts through anticipatory action. In RMI, for example, stakeholder noted that without information on the total capacity and quality of multiple sources of water that communities can access in a drought, it is difficult to estimate and anticipate when they will face acute water shortages and which communities will be most vulnerable. Similarly for tropical cyclone impacts on electricity networks, detailed damage information and risk assessment is needed at the asset level, to identify where critical failure points might occur. All this information can help in the development of sector-specific impact-based forecasts on which anticipatory action can be based.

5 Recommendations and next steps

51. The framework of anticipatory action used here to explore preparedness taking place in infrastructure sectors in the Pacific Islands has uncovered some critical gaps. The solution to many of the problems with preparedness is not so much in focusing only on what can be done between a forecast and a disaster, but rather in understanding what the residual risks are and what resources and capacities are needed to manage them better – through seasonal preparedness as well as more targeted actions based on impact-based forecasts.

5.1 Data for decision-making on anticipatory action

52. Further research will be necessary to isolate the potential for anticipatory action to reduce disaster impacts in different infrastructure sectors and for different types of hazards. Anticipatory action focusses attention on where and how preparedness can be improved, and some losses and damage avoided by using forecasts and risk information to take decisions. Importantly, different types of anticipatory action need to be planned and implemented according to how severe impacts are expected to be, with the acceleration of more routine tasks for less severe storms, and full implementation of SOPs and other plans for more severe disasters. All this relies on having good data on the structural weaknesses and other potential points of failure across energy, water, transport and other service delivery systems, and a detailed plan of measures that can be taken to address these residual risks.

53. Anticipatory action for drought will involve similar measures to those currently being taken when a drought is already happening. But with a better understanding of local vulnerabilities to drought and risks in the water infrastructure, and more accurate forecasts informed by local rainfall monitoring and data collection, these actions can be timelier and better targeted at particularly water-vulnerable communities (where storage capacity is less, water sources more contaminated etc).

54. There are different ways of identifying the residual risks in infrastructure. One would be to support sectors to collect more detailed spatial and temporal loss and damage data when disasters occur to feed into a better understanding of asset- and system- risk assessments. Post-disaster evaluations of how sectors prepared for and responded to disasters and how plans were implemented could help in identifying where the gaps are, and where additional capacities and resources are needed. Another way to identify where anticipatory action is most needed is to include this analysis in climate risk assessments for infrastructure and in the design of projects, identifying where expected losses and weak areas in infrastructure networks and services are, and deciding for each whether to reduce, or prepare better.

5.2 Formalised preparedness planning

55. This scoping study on anticipatory action in the Pacific Islands has uncovered a major gap in preparedness planning: beyond the plans that communities, NDMOs and their partners have developed, very few departments or sectors have SOPs, and few utilities have business continuity plans, so actions taken to prepare for different hazards (including for different hazard intensities) are *ad hoc*, incomplete and sometime poorly coordinated with other actors. No plan means it is unlikely that funds will be set aside to pay for preparedness actions. One major gap where ADB could usefully provide support is therefore around business continuity planning for utilities companies in urban areas, based on different scenarios and compounding effects.

5.3 Financing preparedness

56. One option for ensuring equipment and human resources are available for seasonal infrastructure preparedness and anticipatory action for rapid onset events, would be to include this as a cost in the operations and maintenance budgets that are sometimes built into ADB investments. Alternatively, in-kind contingency reserve of spare parts could be created to overcome logistical and access issues in the archipelagic island countries. This is already being discussed in the energy sector.

57. For drought, there certainly appears to be a case for further exploration and examination of the feasibility of setting up forecast-based triggers for the release of contingency funds to pay for preparedness actions. A feasibility study is recommended to look at the potential for a forecast-based drought product by PCRIC. Such a product would require localised data not only on the impacts of drought but the relative costs and benefits of taking action for different lead times.

5.4 Strengthening governance and coordination

58. One of the major issues raised by this scoping study is the lack of clarity over responsibilities and mandates for infrastructure maintenance and service provision and continuity in a disaster in the outer islands. A full inventory of these assets, responsibilities assigned to local actors is needed, alongside capacity development and other types of assistance that needs to be provided in advance so communities can take anticipatory action to protect the infrastructure and ensure services can be quickly restored following a disaster.

59. Given high costs of reaching outer islands with equipment, technical staff, and to pre-position supplies for rapid response, as well as the time limitations for rapid onset events, preparedness planning for infrastructure in the outer islands will need to be more decentralised. Local actors need formalised roles, responsibilities and resources for seasonal preparedness and for anticipatory action to reduce some of the impacts of extreme weather on infrastructure services. An infrastructure governance programme, focussed on strengthening municipal infrastructure preparedness could help overcome some of the time, logistics and cost issues with anticipatory action across the outer islands.

60. Greater coordination between met offices and ministries, SOEs and private sector utilities companies is also needed to enhance preparedness through anticipatory action. This is particularly important to the development of impact-based forecasting products and services, which are critical for targeting scarce resources in the short time frame that exists between a forecast and a disaster (for rapid-onset events).

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Annex 1. Disaster risk finance instruments available to Pacific islands and potential for supporting anticipatory action

Table 6. Disaster risk finance instruments in the Pacific Islands

Instrument	Type of instrument	When	Funders	Funding	Beneficiary country	Criteria for withdrawal	Used already for AA	Potential for AA
Disaster Assistance Emergency Fund (DAEF)	Contingency fund	Ex-post	National governments and USAID	$100,000 per event	FSM, RMI	Declaration of national emergency; showing disaster response exceeds country's capability and resources	No	Low
Tonga National Emergency Fund	Contingency fund	Ex-ante, ex-post	Government	$2 million	Tonga	National Emergency Management Committee	Yes	High
Tuvalu Climate Change and Disaster Survival Fund Act	Contingency Fund	Ex-post	Government and international donors	$3.6 million initial capitalization	Tuvalu	Declaration of national emergency; Citizen submission of 'Request for assistance'	No	Low
Fiji Climate Relocation and Displaced Peoples Trust Fund	Contingency Fund	Ex-ante	Government and international donors	3% revenues from Fiji's Environment and Climate Adaptation Levy (ECAL)	Fiji	Pre-emptively relocating communities and infrastructure deemed to be at severe risk due to climate change and disaster-related risks	Yes	High
Asia-Pacific Disaster Response Fund	Contingency fund	Ex post	ADB	Up to 3m per country	Pacific Islands	A disaster has occurred; an emergency has been declared that is of a scale beyond the government capacity to restore lifesaving services; the UN humanitarian/resident coordinator has confirmed scale of disaster and indicated general amount of funding necessary	No	Low

Fiji Disaster Rehabilitation and Containment Facility (DCRF)	Contingent credit	Ex-post	Central Bank	Maximum loan FJD500,000 ($238,698)	Fiji	Lenders can access funds from the Reserve Bank through this facility at a concessional rate of 1% per annum and lend to eligible business at a maximum interest rate of 5% per annum for a period of six months and possible extension up to five years	No	Low
ADB Policy-based contingent disaster financing (CDF)	Contingent credit and grants	Ex-post	ADB	Negotiated for each country and by phase. The Phase 3 total amount is $94 million	Cook Islands, FSM, RMI, Palau, Samoa, Solomon Islands, Tonga, Tuvalu	State of emergency declaration and after a disaster event has been confirmed/has made landfall; ADB developing member countries need to complete prior agreed policy actions to strengthen disaster and climate risk management	No	High
World Bank Catastrophe Deferred Drawdown Option (Cat DDO)	Contingent credit	Ex-ante	World Bank	Up to $500 million or 0.25% of GDP (whichever is less).	Pacific Island IDA countries	Declaration of state of emergency or another pre-specified trigger; country to have adequate macroeconomic policy framework and national DRR management programme	No	High
Pacific Catastrophe Risk Insurance Company (PICRIC)	Parametric insurance	Ex-post	Germany, Japan, UK, US, WB IDA (via Pacific Resilience Program)	$24.8 million capitalization, with a total coverage limit of $36.3 million; countries pay annual premium to take out policy. Pay out levels and parametric triggers are designed for each country based on needs and	Cook Islands, RMI, Samoa, Tonga and Vanuatu	Government sends 'Notice of Applicable Event' to PICRIC; PICRIC calculates impact of disasters based on predefined formula on physical variables that are strongly correlated to losses	No	High

				agreed level of annual premium				
Microinsurance for homes, individuals, families, communities and businesses	Micro insurance	Ex-post	Households, communities and businesses		Fiji, Solomon Islands, Vanuatu	Can be based on parameters for weather-based insurance, or other arrangements	No	Medium