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# Climate Impact Report

## Madang Provincial Hospital Eye Clinic: Papua New Guinea (PNG)

THE FRED HOLLOWS FOUNDATION NZ | FEBRUARY 2025

## PROJECT DELIVERED FOR

**Madang Provincial Hospital Eye Clinic**

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# Contents

# 1 Executive Summary

The Fred Hollows Foundation NZ (The Foundation) is a non-profit organisation with the mission of ending avoidable blindness in the Pacific. Founded by eye surgeon Fred Hollows, The Foundation now focuses on four main pillars of work: restoring and preserving sight, training and supporting doctors and nurses, strengthening health systems, driving innovation and research. There are eight eye clinics located across seven countries (Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Tonga, Samoa, Kiribati).

The Foundation, in partnership with Pacific eye clinics and Ministries of Health has contracted Edge Impact to support the completion of a Climate Impact Assessment (CIA) at three Foundation-supported clinics, aligning with WHO guidelines to assess sites for Climate Resilience and Environmental Sustainability interventions. This report focuses on the assessment of the Madang Provincial Hospital (MPH) Eye Clinic in Madang, Papua New Guinea (PNG), as part of the "Building Community-Level Climate Resilience in the Pacific" (BCCR) project, supported by the New Zealand Ministry of Foreign Affairs and Trade's (MFAT) Climate Finance for Community Resilience Programme. The aim is to identify climate risks and propose adaptation strategies to strengthen the resilience of healthcare facilities and the communities they serve.

By the end of the century, climate projections for the PNG indicate a 3.2°C increase in daily maximum temperatures in a high emissions scenario (The World Bank Group 2021). Projections for a high emissions scenario also include a significant rise in the frequency of heatwaves and extremely hot days, more intense and frequent heavy rainfall events with increased variability through the wet season, an overall decrease in dry season rainfall, and a sea level rise of up to 88 cm, along with increased impacts from tropical cyclones (CSIRO and SPREP 2021). These changes pose risks to the MPH Eye Clinic in Madang, and to the outreach services they provide.

The MPH Eye Clinic's resilience and sustainability measures enhance operational reliability, improve patient care, and optimise cost efficiency, effectively addressing local climate challenges. Solar power, natural ventilation, and rainwater harvesting reduce reliance on external resources, reducing costs and most significantly, minimising service disruptions. Specifically, the Net Present Value (NPV) of electricity cost savings from the solar PV and battery installations between 2023 and 2040, discounted at 5%, is estimated at $153,267 USD. This also provided an estimated 1273 additional medical interventions per year for community members of PNG attending the MPH Eye Clinic and approximately 50 extra operational training days. The facility's climate resilient adaptation measures offer protection against climate risks like extreme heat, storms, cyclones, and drought, specifically through improving the ability of the facility to stay operational during acute or chronic climate and weather conditions. These strategies collectively ensure that the MPH Eye Clinic can provide consistent, climate-resilient eye care for the community as well as suitable training centre for healthcare professionals.

The key findings of this assessment provide an understanding of the risks identified in this CIA and opportunities associated with climate change and are used to inform tailored adaptation strategies that prioritise the climate resilience of each asset. The following are the key findings from the CIA for the MPH Eye Clinic in PNG:

- **Heat Impacts:** Temperature fluctuations significantly impact the province's energy supply, with frequent micro-blackouts disrupting services. Drought conditions during the dry season further challenge water availability. While the MPH Eye Clinic's infrastructure handles heat impacts effectively, rising temperatures are increasingly affecting the health workforce, patients, and community members. These stressors, combined with cumulative climate change effects, are placing greater demands on infrastructure systems. A comprehensive assessment of the current systems' capacity to cope with these challenges, both now and under future climate scenarios, is essential to mitigate heat-related risks effectively.
- **Flooding and Sea Level Rise:** The MPH Eye Clinic's location, approximately 300m from the coast 3m above means sea level (MSL), makes it vulnerable to flooding and sea level rise, however other natural factors such as the soil profile - limestone dominant, porous horizon - limit the immediate risk. As such, the MPH Eye Clinic remains vulnerable to inundation-related climate hazards.
- **Storm and High Wind Impacts:** Storms and strong winds pose a risk to outreach activities, limiting accessibility and reducing the effectiveness of eye care services in remote areas. The MPH Eye Clinic itself is resilient to the impacts associated with storm-related climate hazards.
- **Cumulative Climate Change Impacts:** The interaction of multiple external factors exacerbating the ability to mitigate and adapt to climate change poses a risk to the MPH Eye Clinic and its operations. A diverse range of impacts including, but not limited to, adverse sea conditions, Provincial and National Government instability, and lack of understanding among the health workforce of climate hazards, have the potential to limit adaptation capacity.

Recommended adaptation actions were generated throughout the report. All are collated in Appendix E. Collated recommendations, with key findings including:

- Infrastructure Adaptation: The greatest risk to the continuous operation of the MPH Eye Clinic lies in the reliable and consistent supply of critical resources, namely power and water. Recommendations therefore prioritise upgrading water capture and treatment infrastructure and ensuring energy systems can meet both current demands and projected future usage. Additionally, the follow-up phases of the BCCR Project present valuable opportunities to advocate for infrastructure improvements at community healthcare facilities. Such enhancements would directly benefit the outreach clinics conducted by the Eye Clinic workforce, strengthening service delivery and resilience across the broader healthcare network.
- Operational and Staff Preparedness: Develop and implement heat protocols utilising apparent temperature of a heat index in standard operating procedures (SOPs) to minimise exposure risks. Improve staff training on emergency procedures and climate-related hazards to enhance response capabilities. Revise outreach checklist criteria to ensure that outreach centres are equipped with appropriate ventilation systems to accommodate increasingly hotter days. Collaborate with community healthcare facilities through provincial and local level government agencies to advocate for implementation of appropriate climate resilience infrastructure and strategy. Develop contingency plans to adjust outreach schedules or clinic hours during extreme heat events to minimise exposure and ensure safety.
- Capacity Building of the HealthCare Sector: There is a significant opportunity to strengthen the broader healthcare system by leveraging the insights and expertise developed at the MPH Eye Clinic. The facility's operational success, despite the numerous challenges facing the healthcare sector in Madang and across PNG, creates pathways for enhanced resilience-building initiatives with the Clinic's partners. Additionally, efforts to improve the health workforce's understanding of climate change risks—to themselves, their communities, and healthcare systems—are crucial. The advanced knowledge and experience of the MPH Eye Clinic workforce should be harnessed to advocate for improved climate resilience planning in healthcare infrastructure and to support the professional development of healthcare staff, thereby enhancing community resilience, particularly in the WASH sector.

To safeguard the resilience of the MPH Eye Clinic and its operations, a phased adaptation strategy is recommended. This approach should address immediate risks through targeted actions while incorporating long-term infrastructure and operational adjustments informed by evolving climate projections. Collaboration with local stakeholders - including the hospital, various levels of government, and community organisations - is essential to support these efforts and ensure the MPH Eye Clinic continues to provide effective health services in the face of future climate challenges.

# 2 Project overview

## 2.1 Project context

The Fred Hollows Foundation NZ (The Foundation) is a non-profit organisation dedicated to reducing avoidable blindness and vision impairment across the Pacific. Through the strengthening of Pacific-led eye health systems and advocating for equitable access to high-quality, affordable eye care, The Foundation's mission supports some of the most climate-vulnerable communities.

With a strong commitment to environmental sustainability, The Foundation has worked with partners to strengthen climate resilience into the facility. The MPH Eye Clinic operates on solar power, rainwater harvesting, and utilises an integrated sewerage system. The Clinic acts as an exemplar of what can be achieved through mitigation and adaptation measures in the face of a changing climate. Other notable facilities include the Vanuatu National Eye Centre and the Solomon Islands Regional Eye Centre, both of which utilise solar power, low-carbon building materials, and cyclone- and earthquake-proofing design elements. These developments underscore The Foundation's forward-thinking approach to integrating climate-proofing within infrastructure and operations.

In February 2024, The Foundation secured funding through the New Zealand Ministry of Foreign Affairs and Trade's (MFAT) Climate Finance for Community Resilience Programme to further its climate adaptation work. This funding supports the "Building Community-Level Climate Resilience in the Pacific" (BCCR) Project, which seeks to enhance the resilience of health care facilities and surrounding communities to climate change impacts.

As part of this initiative, The Foundation and its Pacific partners have engaged Edge Impact to perform Climate Impact Assessments (CIA) at three Foundation-supported eye clinics in PNG, Solomon Islands, and Vanuatu. These assessments aim to identify climate risks, evaluate on-site mitigation measures, and link these interventions to health and community resilience outcomes. The findings will inform tailored adaptation strategies and be shared with key health and climate stakeholders through a Knowledge Share session, ensuring widespread dissemination and engagement with the results.

## 2.2 Introduction

This technical report presents the findings of the Climate Impact Assessment for the MPH Eye Clinic located in Madang, a central northern Province of Papua New Guinea (PNG). PNG faces considerable climate-related challenges, including rising sea levels, more frequent extreme weather events including cyclones, intensifying wet season rainfall patterns, and extended dry season(s), all of which pose risks to critical infrastructure like the MPH Eye Clinic and its operations.

In this report, we first outline the methodology used to assess the site's climate risks and resilience measures. Next, we provide an overview of the broader climate context for PNG, followed by an in-depth analysis of our key findings. Finally, the report offers a series of recommendations aimed at strengthening the resilience of the MPH Eye Clinic and the community it serves.

### 2.2.1 Objectives

- Understand the exposure and vulnerability of the MPH Eye Clinic to the impacts of climate change.
- Assess climate risks at the MPH Eye Clinic to develop a high-level understanding of how these risks may affect its operations.
- Evaluate the MPH Eye Clinic and its operations in alignment with World Health Organization (WHO) guidance for climate-resilient and environmentally sustainable healthcare facilities, where applicable.
- Analyse the connections between community health outcomes and climate risk mitigation initiatives.
- Develop a suite of recommendations, including adaptation measures, to enhance the climate resilience of the MPH Eye Clinic and its operations to improve community outcomes.
- Identify key learning points to be shared with stakeholders in future workshops, contributing to the BCCR Project's objectives.
- Ensure that the communication of findings is aligned with the broader objectives of The Foundation within the BCCR Project.

## 2.3 Site details and location

The Eye Clinic is situated at the Madang Provincial Hospital (MPH) in Madang, PNG (Figure 1). This facility is a key healthcare asset dedicated to providing specialized eye care services. The MPH Eye Clinic consists of two main buildings, the Clinic, which was constructed as part of the main hospital in approximately 1962 and has undergone extensive upgrades, and the Eye Surgery Unit, completed in late 2014. The Eye Surgery Unit has a gross floor area of 160 square meters and features a concrete and timber pile foundation, timber wall and roof framing, aluminium window systems with louvres, plasterboard linings, long-run metal cladding, and long-run metal roofing.

Madang, located on the northern coast of Papua New Guinea, is the capital of Madang Province. The region experiences a tropical climate, with a wet season from November to April and a drier season from May to October, consistent with other parts of the country. The MPH Eye Clinic's construction reflects considerations for local environmental conditions, with its climate-proofing measures likely aligned with the region’s climatic challenges. The MPH Eye Clinic's position within the Provincial Hospital underscores its critical role in providing advanced eye care services to the local population and surrounding areas.


Figure 1: MPH Eye Clinic location within the Madang Provincial Hospital (MPH). Note, the MPH Eye Clinic is outlined in RED.

## 2.4 Methodology

Edge Impact employed an adapted risk-based methodology for this climate impact assessment, drawing on its extensive experience with traditional risk-based approaches. This method aligns with the Australian Standard 5334-2013: Climate Change Adaptation for Settlements and Infrastructure and utilises the *WHO guidance for climate resilient and environmentally sustainable health care facilities.* The approach aims to assess climate resilience and environmental sustainability while also capturing social and community outcomes.

The methodology was reviewed following the completion of the Solomon Islands Climate Impact Assessment. Minor adjustments were made to Task 2 (subsection 2.4.2 below), specifically regarding the stakeholders engaged. These adjustments aimed to ensure that further information and data was captured to develop a deeper understanding across the four WHO guidance areas, enabling the effective comparison of external challenges across these areas at The Foundation-managed facilities.

The risk and adaptation assessment included the three key tasks outlined below (summarised in Figure 2).

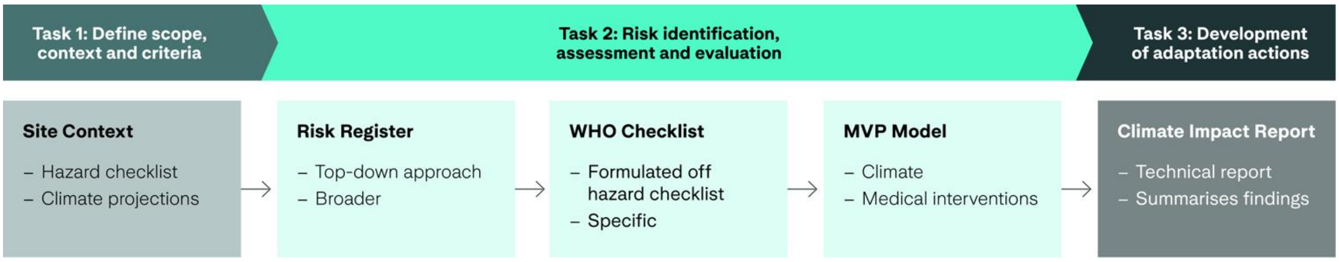


Figure 2 Summary of project approach (adapted from ISO31000:2018).

### 2.4.1 Task 1 - Define scope, context and criteria

Location-specific climate projections were gathered employing the RCP 8.5 high emissions scenario. This was combined with a review of documentation provided by The Foundation to inform a preliminary risk assessment aligning to The Foundation Risk Management Policy (refer to Appendix A). Preliminary risks were based on a review of key themes identified through an assessment of the *WHO guidance for climate resilient and environmentally sustainable health care facilities*.

### 2.4.2 Task 2 - Risk identification, assessment and evaluation

From November 17th to November 23rd, 2024, Matthew Peck from Edge Impact conducted a series of stakeholder meetings to identify and evaluate risks related to local climate hazards and their impacts on healthcare facilities. The sessions commenced with an introduction to the project and were tailored based on the stakeholders' understanding of climate and community health outcomes relevant to the MPH Eye Clinic. Risk identification and assessment were customized for each meeting to ensure comprehensive coverage of the key themes identified in Task 1. A climate lens was applied throughout the discussions to capture key insights and potential changes under future climate scenarios. A list of all stakeholders engaged is presented in Appendix B. (Table 7). Following the site assessment, identified risks were evaluated across specified timeframes (2050 and 2090), in alignment with available projection data for the Western Pacific for the location (PNG). Additionally, climate hazards with the highest associated risk ratings were identified by assessing exposure versus vulnerability and then evaluating likelihood against consequence. These hazards were then compared with medical intervention data collected during the site assessment to evaluate the impact of climate on The Foundation's work across PNG. This assessment, referred to as the 'MVP Model' in this report, involved modelling clinic and outreach performance data to identify instances where climate impacts likely reduced performance. Performance data included visits, consultations, doctor screenings, total referrals, and spectacles dispensed.

### 2.4.3 Task 3 – Development of adaptation actions

A combination of identified risks captured through the risk register and the WHO checklist, and modelled data, were used to identify high priority risk areas that require adaptation actions. Adaptation actions included both design and operational initiatives that aimed to reduce either the likelihood or consequence of risks.

The outcomes of the above tasks were reviewed and incorporated into an assessment tool. The key findings are summarised in this report.

# 3 Climate change summary: PNG / Madang Province

## 3.1 Historic climate

To establish a comprehensive understanding of climate change impacts in PNG, specifically in the Madang Province, it is essential to examine projected climate data alongside shifting trends under a changing climate. This assessment focuses on primary climate hazards, including temperature trends, rainfall patterns, and sea-level rise, as well as secondary effects such as relative humidity, flooding, wind patterns, and heatwaves. These elements are categorized to align with *WHO guidance for climate-resilient and environmentally sustainable healthcare facilities*, ensuring that the project objectives are met.

Extreme climate phenomena relevant to this study are detailed in Table 1. Historical climate information was sourced from regional climate databases, including the Pacific Climate Change Data Portal, the *PNG Climate Risk Country Profile* and the *NextGen' Projections for the Western Tropical Pacific: Current and Future Climate for PNG Technical Report*. This data provides essential insights into past weather events and their potential implications for the MPH Eye Clinic facility.

Table 1 Key extreme climate phenomena and related risks.

| Hazard | Description and potential impacts |
|---|---|
| Extreme Heat | Hot days and heatwaves in PNG may include periods of unusually high temperatures and humidity levels that exceed normal seasonal averages. They pose risks to health, agriculture, and infrastructure, and can be intensified by climate change. These events increase the frequency and severity of extreme heat conditions. |
| Precipitation changes | Changes in rainfall patterns in PNG refer to shifts in precipitation amounts and distribution over time. These changes can lead to water scarcity, affect agriculture and water supply, and disrupt ecosystems, potentially exacerbated by climate change. |
| Floods | Floods in PNG refer to instances of excessive water overflow, often caused by heavy rainfall or river overflow. They can lead to widespread damage, affecting infrastructure, agriculture, and communities. For this assessment, they include the following types: riverine, coastal, and flash, as well as the secondary hazards they contribute to, such as landslides and erosion. |
| Storms | Storms in PNG refer to severe weather events characterized by strong winds, heavy rainfall, lightning, storm surges and potential flooding. They include tropical cyclones and other intense systems that can cause widespread damage to infrastructure, ecosystems, and communities. |
| Sea-Level Rise | Sea level rise in PNG refer to the increase in average ocean levels due to global warming. It threatens low-lying islands and coastal areas, including Madang, with flooding, erosion, and saltwater intrusion. Regional factors can exacerbate these impacts, affecting ecosystems and communities. |
| Droughts | Droughts in PNG refer to areas with below-average rainfall, stressed vegetation and dry forecasts. They reduce the resilience of populations due to increased heat stress, affecting wildlife and human wellbeing. These changes may impact water accessibility, agricultural productivity, air quality and other health factors. |

Note: Earthquakes, volcanic activity and tsunamis are not covered by this assessment. Although the assessment may be applied to these hazard types, they were not considered for direct assessment as they did not fit within the guidance framework of climate risk assessment for healthcare facilities.

## 3.2 Future climate

### 3.2.1 Climate Projections

Table 2 below summarises the key projected climate changes under the Representative Concentration Scenario (RCP) 8.5, which represents a high greenhouse gas emissions climate change future (IPCC 2021). The climate projections are based on an average of the CMIP5 climate projections data from IPCC and looks specifically at current and future climate for PNG.

Table 2: Summary of key climate changes projected for PNG.

| Climate Impact Description | | Data | | | | | |
|---|---|---|---|---|---|---|---|
| Icon | Description | Historic | Baseline period (years) | 2030 | 2050 | 2090 | Trend Summary |
| | Increased average temperatures | 24.7 °C | 1991-2020 | +0.8 | +0.5 | +3.3 | Projected to increase. |
| | Increase in daily maximum temperature | 30.5 °C | 1991-2020 | +0.7 | +1.4 | +2.8 | Projected to increase. |
| | Increased maximum duration and temperature of heatwaves | NA | 1986-2005 | More heatwaves | More heatwaves | Many more heatwaves | Projected to increase. |
| | Increase in frequency of very hot days (above 35°C) | NA | NA | More very hot days | More very hot days | More very hot days | Projected to increase. |
| | More frequent and severe droughts (rainfall average months below 10th percentile) | NA | NA | NA | NA | NA | No projections were found to show drought in future. |
| | Reduced average annual rainfall | 3076 mm/yr | 1991-2020 | -4 to +6% | -14 to +14% | -21 to +16% | High variability, projected to decrease |
| | Increased annual rainfall, days of heavier rainfall intensity and potential resultant flooding | NA | NA | Heavier rainfall events | Heavier rainfall events | Much heavier rainfall events | Projected to increase. |
| | Sea level rise | 0.69 m | 1986-2005 | +0.13 | +0.27 | +0.73 | Projected to increase. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Increased intensity of storm events, tropical cyclones, and lightning | 65 to 200 km/hr cyclone winds | NA | Greater tropical cyclone impacts | Greater tropical cyclone impacts | Greater tropical cyclone impacts | Projected to **increase.** |
| | Cumulative climate change impacts | NA. Not data available. | | | | | Projected to **increase.** As other hazards are projected to increase, cumulative hazards are likely to increase |

*Climate projections data was sourced from the 2021 *'NextGen' Projections for the Western Tropical Pacific: Current and Future Climate for PNG Technical Report,* or where not available the *Papua New Guinea Climate Risk Country Profile* was used. Historic climate data was sourced from the 2021 *Papua New Guinea Climate Risk Country Profile*.

### 3.2.2 AR6 update

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), published in 2021, builds on the findings of the Fifth Assessment Report (AR5) from 2014, which coincided with the construction of the MPH Eye Clinic. For Papua New Guinea (PNG), AR6 underscores heightened vulnerabilities due to more pronounced warming trends, increased variability in rainfall, and accelerated sea-level rise compared to AR5. These changes are particularly critical for coastal regions like Madang, which face compounded risks from severe flooding, saltwater intrusion, and coastal erosion.

AR6 also highlights the intensification of extreme weather events, including tropical cyclones and heatwaves, which pose significant threats to infrastructure, public health, and local livelihoods. For regions like Madang, where communities often rely on subsistence farming and fisheries, these climatic shifts could exacerbate food insecurity and economic instability.

In response to these evolving challenges, AR6 emphasises the necessity of context-specific adaptation measures. For PNG, this includes leveraging traditional ecological knowledge, strengthening climate-resilient infrastructure, and enhancing early warning systems for extreme events. It also stresses the urgency of global and local mitigation efforts, advocating for collaborative approaches to address the interconnected challenges of climate change, biodiversity loss, and human well-being.

# 4 Key findings & recommendations

This section summarises the key findings of the climate impact assessment of the MPH Eye Clinic and its operations.

## 4.1 Climate Resilience and Capacity-Building Initiatives

This subsection examines the resilience and sustainability measures implemented at the MPH Eye Clinic, along with the clinic and outreach performance metrics (including visits, consultations, screenings, and surgeries).

The resilience and sustainability initiatives at the MPH Eye Clinic have notably enhanced operational continuity, patient care, and cost efficiency. These improvements are particularly evident when compared to the broader Madang Provincial Hospital site. Key measures include:

- Solar PV Panels: The Solar PV system reduces reliance on both grid power and diesel generators (Appendix C - Figure 6 & Figure 7), providing a stable power source amidst frequent outages in the Madang province (approximately 1680 hours annually). The Net Present Value (NPV) of electricity cost savings from solar PV installations between 2023 and 2040, discounted at 5%, is estimated at $153,267 USD. Calculations for the NPV of electricity cost savings are provided in Appendix D.
    - According to hospital administration staff and PNG Power representatives, the broader Madang Provincial Hospital site experiences approximately 10 weeks of power supply disruptions annually. This equates to 50 full 9-hour business days or a total of 450 hours without consistent power. The MPH Eye Clinic serves an average of 551 patients per month, which is approximately 2.83 patients per operating hour. Therefore, these 450 disrupted hours could affect up to 1,273 medical interventions annually for community members relying on the Clinic in Madang.[1] The additional operational capacity served by the resilience of the MPH Eye Clinic provides not only additional medical interventions to community members, but additional support through resourcing capability to training healthcare professionals.
- Natural Ventilation and Adjustable Flaps: Passive ventilation is incorporated into the older Eye Clinic building through louvred walls, while low ceiling heights, insulated walls and HVAC-considered design elements enhance the capacity of the air conditioning systems in the operating theatre. This approach aims to optimise energy efficiency, reduce maintenance costs, and ensure suitable conditions for patients and staff during high temperatures, all while minimising reliance on mechanical cooling.
- Insulated Roofing and Exterior Shading: Light-coloured insulated roofing and exterior shading reduce internal heat gain, decreasing cooling demands and electricity costs for the surgery clinic.
- Infrastructure Design: The MPH Eye Clinic's infrastructure has been designed with resilience to climate change impacts in mind. The operating theatre is elevated 40cm above ground level at the highest point of the site, while the energy supply systems are raised 10cm above ground level. Although the likelihood of these systems being impacted by fluvial or coastal flooding under current conditions is low, a thorough assessment of the positioning of all critical infrastructure and equipment across the facility relative to ground level is recommended. Taking a proactive approach to identifying vulnerabilities will support effective planning and help minimise operational downtime during potential inundation events in the future.
- Water Accessibility: Rainwater harvesting using storage tanks provides a sustainable and efficient solution, reducing reliance on municipal water supplies while enhancing water security and cost efficiency. Currently, the Eye Clinic is equipped with two 5,000L sealed plastic water tanks, which do not include filtration. These tanks are connected to isolated pumps that service the Eye Clinic, with water sourced from both rainwater and town water (Water PNG). The operating theatre is supported by two 9,000L sealed plastic water tanks, equipped with dual filtration (without UV treatment) (Appendix C - Figure 8). One pump delivers water through the filtration system into the operating theatre. The rainwater system at the MPH Eye Clinic addresses concerns round supply and water quality, providing a safer, more consistent, and operationally efficient water supply.

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[1] Statistical assumptions were made in this analysis. Specifically, it was assumed that collecting a representative sample of 40 hours per week (8 hours per day over 5 days) may not fully reflect the actual timing of historical power outages. Unfortunately, historic data on outage timing was not available from PNG Power.

- Waste Management: The MPH Eye Clinic employs advanced waste storage protocols to ensure the safety of both staff and patients, minimising exposure to medical and general waste at the site. Staff follow detailed policies to store waste securely in designated areas at the rear of the MPH Eye Clinic.
- Beyond the Eye Clinic, waste is stored near the facilities management area at the top of the MPH site and is collected three times a week. Waste is segregated into yellow bags (for clinical, chemical, and biological waste) and black bags (for general waste) (Appendix C - Figure 9 & Figure 10). No waste is incinerated on site; however, plans are in place to install a new incinerator in 2025, funded by The World Bank and executed by the PHA.

The Madang Provincial Hospital (MPH) Eye Clinic demonstrates significant sustainability advantages, providing a more stable and cost-effective model compared to the main hospital facilities.

The main hospital faces critical challenges with water and power. It consumes approximately 300 kWh daily and relies on 20 drums (4,000 litres) of diesel fuel monthly. Water supply is particularly strained during both the dry (drought) and wet seasons (increased turbidity from rainfall causing filtration issues/delay), with the hospital depending on 22,000 litres of stored water. Trauma cases, predominantly from tribal conflicts and road based incidents, account for 80% of emergency admissions. Waste management is another significant issue, with the hospital generating 90 bags of clinical waste and 180 bags of general waste each month (Appendix C - Figure 9 & Figure 10). This waste is collected by the Madang Urban Local Level Government (MULLG) three times weekly and disposed of at a single landfill site, raising concerns about land contamination, environmental degradation, and community exposure to hazardous materials.

The hospital's energy infrastructure depends on PNG Power and manually activated diesel generators, of which there are minimal for the site, with the ICU and operating theatre given priority. Fuel supply for these generators is a significant concern, with government funding and accounting issues often leaving the hospital unable to purchase fuel. Extended power outages occur approximately four times annually, typically lasting weeks, while micro-blackouts - up to 30 daily during peak periods - are commonplace. The water supply, reliant on Water PNG, is frequently disrupted by heavy rainfall or drought conditions, necessitating the use of the hospital's 22,000-litre holding tanks.

In contrast, the MPH Eye Clinic has implemented resilience strategies that address these challenges more effectively. Its measures promote operational stability, long-term cost savings, and environmental sustainability. For instance, the clinic's approach to energy and water management ensures a more reliable supply and reduces dependency on external systems prone to disruption. These strategies are well-suited to the region's climate and infrastructure conditions. The benefit of these climate proofing measures is most apparent at this site, providing a highly resilient facility in comparison the broader provincial hospital, district hospitals and community health care centres.

To further evaluate the effectiveness of the Eye Clinic's resilience measures, it is recommended to develop a baseline performance model. This analysis could provide insights into the clinic's sustainability and operational efficiency, offering a roadmap for broader adoption of similar strategies across the hospital precinct. Additionally, this would enhance decision-making processes using cost-benefit scenario analysis and by identifying capacity limits when assessing the need for an additional water tank, as well as additional solar PV panels and battery storage.

## 4.2 Climate Change Risk Assessment

Priority areas have been developed that focus on key risks (including both high risks), their current controls and proposed intervention actions in relation to specific climate change impacts. Proposed adaptation actions aimed to reduce the residual risk rating and were developed in consultation and should be reviewed for feasibility by both The Foundation team as well as the on-ground team and PHA Eye Clinic staff where appropriate.

The risk assessment process identified a total of 29 risks for the site, formulated using the WHO checklist and adopting a broad approach to capture impacts across multiple areas. These risks span a range of asset and operational components influenced by various climate variables. Risks with a rating of "25 Very High" for future time horizons have been prioritised and are included in this Climate Impact Report, with a summary presented in Table 3. Detailed assessments for each climate impact or hazard area are provided in the subsections below. For every risk with a "Very High" rating, a tailored suite of proposed interventions has been developed. These interventions aim to mitigate the risks, reducing the residual risk rating associated with each hazard from its original inherent rating. Additionally, the proposed interventions align with the broader objectives of enhancing site resilience and operational sustainability under future climate scenarios.

### 4.2.1 The impacts of heat

Extreme heat was identified as having significant impacts on the health workforce, patients, and community members, more so than on the physical structure of the MPH Eye Clinic itself. This pattern is consistent across all assessed site locations. While trends indicate increasing average temperatures, high temperatures are already experienced at the MPH Eye Clinic and throughout its operational jurisdiction in PNG. Humidity levels, particularly during the wet season, are also notably high, exacerbating health impacts through both primary mechanisms (e.g., direct heat exposure) and secondary mechanisms (e.g., increased mould growth).

The facility is generally well-designed to manage rising temperatures; however, continuous monitoring is essential, with infrastructure upgrades implemented as needed. For instance, the installation of an additional split-system in the operating theatre demonstrates a proactive approach to maintaining operational functionality. To ensure long-term resilience, it is critical that physical infrastructure continues to be maintained at a high standard to cope with increasing heat.

Although the MPH Eye Clinic operates as a standalone facility, it is closely integrated with the broader MPH health system. This integration includes shared medical resources such as laboratories, radiology, wards, and the pharmacy, as well as key infrastructure elements like wastewater, sewage, and general waste management. As such, any protocols developed for climate resilience and operations should align with existing MPH procedures while being tailored to the unique requirements of the MPH Eye Clinic and its workforce.

### 4.2.2 The impacts of drought

Drought presents a significant threat to the operational functionality of the clinic by limiting access to reliable and clean water sources. During the dry season (April/May to September), the facility experiences prolonged periods without rainfall. This reliance on the existing four water tanks (2 x 5,000L and 2 x 9,000L), which store rainwater and captured town water, can result in insufficient water supply to meet operational demands during this period. Current mitigation measures include the use of distilled bottled water in the operating theatre and efforts to minimise water usage in the older building.

To enhance resilience, it is recommended that an additional water tank be installed to increase storage capacity and mitigate the residual risk of water shortages. Furthermore, the installation of a water distiller could improve filtration processes, ensuring a consistent and adequate supply of clean water during periods of reduced availability. Collaboration with the on-site team, particularly Dr. Pahau, will be crucial to implementing these improvements effectively.

### 4.2.3 The impacts of flooding

An exposure assessment of the site and the surrounding hospital precinct indicates that flooding, primarily fluvial and coastal, poses a likely risk to the Madang Provincial Hospital Eye Clinic. However, a physical assessment of the site revealed that environmental factors, such as the predominance of limestone horizons in the soil profile, facilitate effective water infiltration to the water table. Consequently, the likelihood of pluvial flooding following extreme rainfall is low. Despite this, the risks associated with coastal inundation and fluvial flooding remain significant. Coastal erosion in the region was assessed as extreme, driven by the dynamic geomorphological characteristic of the area and projected sea-level rise.

Flooding consistently receives high consequence ratings under future projected climate scenarios, primarily due to the site's location, which significantly exacerbates flood risk. While the operating theatre at the Eye Clinic is elevated 40cm above ground level at the highest point of the site, critical energy infrastructure is only elevated 10cm above ground level, and water tanks remain at ground level or on similar 10cm slabs.

### 4.2.4 The impacts of sea level rise

Sea level rise has been identified as a high-risk hazard to the site over the long term, posing both direct impacts, such as storm surges and rising mean sea levels, and secondary impacts, including coastal erosion and saltwater intrusion, which can lead to groundwater contamination. These threats significantly jeopardise the clinic's infrastructure integrity and operational continuity.

All five assessed areas received a "High" risk rating for 2050 projections, underscoring the severe consequences of potential inundation at the site. Sea level rise is classified as a chronic, long-term concern, with projections indicating at least a 27cm increase above the baseline (69cm) by 2050.

### 4.2.5 The impacts of storms

Storms and storm-related weather have been identified as significant risks across all four assessed impact areas for the period up to 2050. While the direct impacts of storm activity on the MPH Eye Clinic remain relatively low currently, due to its robust design, engineering, and well-maintained surroundings, high-wind events present operational challenges. These conditions significantly limit the ability to conduct outreach clinics, a recurring issue across Pacific Island nations where air and sea travel face heightened risks during the wet season, further complicating the delivery of essential services.

To address these challenges, it is recommended that planning and operational procedures be strengthened to improve resilience during storm events. Comprehensive staff training should ensure a clear understanding of protocols that support operational continuity, including securing and transporting resources and equipment for outreach activities. Strengthening partnerships with local communities and healthcare providers could also enhance logistical preparedness and communication during severe weather events.

For outreach clinics, contingency planning should continue to prioritise capacity building in eye care among local healthcare staff to ensure a level of service continuity during disruptions. Additionally, exploring telemedicine solutions, where feasible and culturally appropriate, could provide an alternative method for delivering care in adverse conditions.

#### 4.2.6 Cumulative climate change impacts

Cumulative climate change impacts refer to hazards arising from the interaction of two or more climate-related factors. The assessment identified a total of 10 such impacts, including risks associated with climate-related health issues, governance, government responses to climate change, inundation, overcast conditions, and general climate-driven asset deterioration. Risk ratings varied significantly, with accessibility emerging as one of the highest risks to the MPH Eye Clinic's service capacity. This is characteristic of PNG's geography and rugged terrain, where patient accessibility to outreach clinics can be inhibited.

The greatest threat to operational functionality, however, was identified as government instability and policy changes, which received a "Very High" risk rating across all time horizons. The somewhat volatile nature of the three systems of government could adversely affect the health workforce and government funding mechanisms for the Eye Clinic.

Proposed interventions were diverse and tailored, requiring a range of strategies to enhance the resilience of the MPH Eye Clinic and its operations.

Table 3: Summary of sources of "Very High" risk ratings for the MPH Eye Clinic and its operations. RR – risk rating.

| Climate Change Impact | Risk Description | The Foundation Risk | WHO Intervention Sector | The Foundation Impacts | RR Current | RR 2050 | RR 2090 | Baseline Controls | Proposed Intervention |
|---|---|---|---|---|---|---|---|---|---|
| Heat | Increased heat stress on staff | Health and Safety | Health Workforce Interventions | Heat stress may lead to reduced efficiency of staff throughout the MPH Eye Clinic. This may impact work quality. | 21 High | 23 High | 25 Very High | Multiple HVAC systems are present across the facility. The power supply to them is primarily off-grid, captured by the 59.2kW/h solar system, with battery storage up to 92.4kW/h. Critical infrastructure (operating theatre) within the facility is supported by a larger HVAC system with split systems now in place.<br><br>The laundry facility is not air conditioned. Staff working in these areas may be impacted by heat stress. All other areas appear to be well ventilated. | Ensure continual power supply where possible. Investigate installing additional solar panels as outlined by Dr. Pahau, following Henry Cassin projected usage profile model, to meet energy supply needs. This will ensure a continuous energy supply for HVAC systems, likely reducing heat stress conditions in the clinic in particular.<br><br>Investigate elements of the emergency response plan. Aim to include hazard management into this where appropriate for extreme heat events to minimise the impact(s) on staff and patients. Conduct qualitative surveys of the impact of heat on stress and clinic performance (e.g. are there any procedures hampered by heat stress in the clinic)? |
| Drought | Reduced water availability; due to a longer dry season; affecting water supply & storage for essential functions and operations. | Health & Safety | Water, sanitation and health care waste interventions | Water shortages impacting the ability of the MPH EYE CLINIC to operate and function. | 23 High | 25 Very High | 25 Very High | 2 * 5,000L sealed plastic water tanks in place for eye clinic (no filtration). Both tanks have isolated pumps which service the eye clinic. They are a mix of both rain and town water (Water PNG).<br><br>2 * 9,000L sealed plastic water tanks with dual filtration (no UV). One pump runs water through the filtration system into the operating theatre. | Investigate installation of an additional water tank. Consult with Dr. Pahau on best location for this.<br><br>Assess current issue with UV filter. If necessary, replace or alternatively, repair and regularly maintain to avoid further issues. Alternatively, look to install water distiller to ensure water quality meets the needs of the operating theatre. |
| Sea level rise | Building foundations and structural elements damaged due to prolonged water exposure. | Health and Safety | Infrastructure, technology and products interventions ions | Prolonged exposure to water could lead to structural damage, making parts of the facility | 14 Medium | 24 High | 25 Very High | No historic flooding events noted by staff from SLR. Facility is in a low-lying area close to Coast.<br>The Eye Clinic is level with the highest local point of the area, | Assess long-term feasibility of site location, particularly towards the end of the century. |

| Climate Change Impact | Risk Description | The Foundation Risk | WHO Intervention Sector | The Foundation Impacts | RR Current | RR 2050 | RR 2090 | Baseline Controls | Proposed Intervention |
|---|---|---|---|---|---|---|---|---|---|
| | | | | unusable. There is an additional threat of coastal erosion further into the future. | | | | the rest of the facility is raised to approximately 120mm above ground level. The operating theatre is 400mm above ground level at this high point, and up to 1000mm above ground level for the rest of the site.<br><br>Building conditions are monitored continually, including on weekends, by senior staff (Dr. Pahau and Agnes Mor). | Advocate and work with local, provincial and national researchers and policy makers to ensure coastal erosion processes are understood, and efforts to mitigate the impacts along the Madang coastline are forthcoming. |
| Storm | Electrical components damage and power outages due to strong winds and severe storms | Clinical / Reputationa l | Energy | Power outages caused by storms could halt surgeries and emergency care services. | 18 Significant | 21 High | 25 Very High | Electrical components:<br>- Batteries, generator (Kohler DEC1000) & fuel are built on a 100mm slab above ground level at the highest point.<br>- Electrical wiring linking the water tanks to the pump for the operating theatre run underneath the operating theatre.<br><br>Gen set is a Kohler DEC1000, this system has an internal 180L fuel tank which is supported by a direct fed 200L auxiliary tank. Consumption @ 100% capacity = 16L/h. Thus, at a 100% capacity the gen-set provides 11.25 hours using the internal tank, plus an additional 12.5 through the direct fed auxiliary tank with an additional 200L of fuel stored on-site. Totalling a capacity of 36.25 hours under 100% load (approximately 4.5 days of back-up power generation). | Introduce training sessions alongside health and safety briefings to ensure more MPH Eye Clinic staff are aware of key system functionality.<br><br>Prepare contingency plans for these systems - i.e. outline roles and responsibilities.<br><br>Develop SOPs for asset management and maintenance and ensure these are recorded electronically. |
| Cumulative Climate Change Impacts | Increased frequency and intensity of adverse weather conditions impacting transportation | Clinical | Infrastructure, technology and products interventions | Inability to conduct outreach clinics due to accessibility issues impacting | 14 Medium | 23 High | 25 Very High | Outreach activities are aligned with seasons and are conducted in accordance with | Investigate coordination opportunities with other third-party health providers / NGOs. |

| Climate Change Impact | Risk Description | The Foundation Risk | WHO Intervention Sector | The Foundation Impacts | RR Current | RR 2050 | RR 2090 | Baseline Controls | Proposed Intervention |
|---|---|---|---|---|---|---|---|---|---|
| | | | | attendance as well as supply chain.<br><br>Reduction in attendance numbers of scheduled outreach appointments. | | | | local knowledge across multiple areas.<br><br>Although the reliability of services is impacted by climate/weather (storms, etc.). This is not seen as an issue impacting the capability of the team to conduct outreach. | Engage Mr. Rudolph Mongallee (MP Administration for Disaster Management) to assist in adaptation plans/planning for the MPH EYE CLINIC. |
| Cumulative Climate Change Impacts | Changes in Government policy, funding and approach to climate resilience | Fiduciary / Clinical | Health workforce interventions | Changes to government or localised leadership may impact staffing and policy directly impacting the MPH EYE CLINIC function and operations. | 25 Very High | 25 Very High | 25 Very High | The Eye Clinic is governed by staff employed by both PHA and The Foundation NZ. This mitigates against government change of power and policy reform. Challenges still do exist with government changes impacting the PHA, notably a change in power for the MPH (interim CEO), however the impacts on the Clinic are significantly reduced as a result of its governance structure. | Supply chain management is critical to ensuring continuity of operation at the Eye Clinic. It is recommended that localised or provincial reliance for supplies be minimised, with continual supply via The Foundation for medical supplies.<br><br>Conduct a stocktake of arrangement with the PHA in relation to the agreement of PHA-employed staff at the Eye Clinic. Ensure where possible that either government or policy changes have minimal impact on their continuity at the Clinic. |

## 4.3 WHO Checklist

This section provides a summary of the results of the modified WHO checklist (Table 4). The low, medium, or high represent the level of completion or integration of each intervention. Low indicates limited progress or lack of data. Medium represents partial implementation or ongoing efforts. High denotes full integration and successful completion of interventions.

Approximately a quarter of the assessed interventions were classified as high, completed, or achieved, with many falling under the category of Infrastructure, Technology, and Product interventions. An identical proportion were rated as low, unavailable, or unable, with only the Energy category performing well. This outcome reflected the limited understanding among staff of services extending beyond their technical expertise.

There was minimal awareness of climate, sustainability, and environmental principles and their relevance to healthcare. This gap was attributed to a lack of professional development training provided by the PHA.

Notably, in comparison to the broader hospital staff, those at the MPH Eye Clinic demonstrated a significantly higher level of training and comprehension of these principles and their applications. This was directly linked to the governance and leadership structure at the clinic and, more broadly, to the support provided by The Foundation.

The findings are summarised below across the four key intervention sectors as defined by the WHO.

Table 4: Summary of WHO checklist results, low indicating limited progress or lack of data, medium indicating partial implementation or ongoing efforts, and high indicating full integration and successful completion of interventions.

| Intervention Sector | Description | Low, unavailable, unable | Medium, in progress, incomplete | High, completed, achieved | TOTALS |
|---|---|---|---|---|---|
| Health workforce interventions | Training, capacity building, and management of health staff to ensure they are prepared for climate-related impacts and can maintain healthcare services. | 9 | 15 | 3 | **27** |
| Water, sanitation and health care waste interventions | Management of water resources, sanitation, and healthcare waste systems to maintain hygiene and operational continuity during climate events. | 9 | 12 | 7 | **28** |
| Energy | Ensuring a reliable and sustainable energy supply to support healthcare operations, including backup power and energy efficiency measures. | 1 | 7 | 7 | **15** |
| Infrastructure, technology and products interventions | Physical infrastructure, technology systems, and healthcare products necessary for resilient healthcare service delivery, including building integrity and technological tools. | 15 | 25 | 17 | **57** |
| TOTALS | | **34** | **59** | **34** | **127** |

### 4.3.1 Health workforce interventions

Assessment using the WHO checklist highlighted areas for improvement in the management of the health workforce, with only 3 of 27 checklist items rated as high, completed, or achieved (Table 4). The workforce demonstrated strong training in medical and clinical governance, surpassing the levels of PHA staff outside the Eye Clinic.

However, their understanding of how medical operations could be affected by both chronic and acute climate change was limited. Similarly, knowledge of how to implement contingency, disaster management, and emergency response plans was concentrated among a select few individuals. It was evident that cross-sectional training in these areas would be highly beneficial to broaden understanding and enhance preparedness.

For most clinical staff, personal development is managed by the PHA, resulting in a limited understanding of concepts beyond their acquired skill set. However, it was evident that the training and competency of the health workforce within the MPH Eye Clinic surpassed that of PHA staff working in other hospital wards.

Although some deficiencies were noted, it is clear that external procedural guidance from The Foundation has had a positive impact on patient health outcomes, particularly in relation to WASH (Water, Sanitation, and Hygiene) initiatives.

There is a clear opportunity within the MPH Eye Clinic to engage individual team members in discussions to coordinate Personal Development (PD) initiatives. These efforts aim to enhance the diversity of knowledge about climate threats, which could extend beyond the MPH Eye Clinic, contributing to broader community resilience against health-related climate impacts.

#### Recommendations

- Coordinate PHA staff PD to ensure breadth of additional learning across multiple other areas (e.g. climate and public health relationship, community engagement, etc.).
- Advocate for integration of procedural practices and policies implemented at the Eye Clinic to be extended to the broader hospital workforce to enhance capacity development. There are opportunities to share knowledge on supply chain management and WASH principles across the hospital precinct.
- Conduct information sessions on key operational systems function. Ensure understanding of these elements is engrained across workforce.

### 4.3.2 Water, sanitation and health care waste interventions

The MPH Eye Clinic has established various management systems for water, sanitation, and healthcare waste. Consequently, only 9 of the 28 assessment items in this category were classified as low, unavailable, or unable (Table 4).

A significant area for improvement is wastewater management. Currently, tanks are emptied reactively - only when they reach capacity - resulting in frequent backflow into the Clinic, which occurs approximately every six months (Appendix C - Figure 11). These incidents disrupt standard operating procedures (SOPs) and often lead to Clinic closures.

Additionally, there is an overreliance on assumptions regarding the functionality of sanitation equipment. For instance, water quality testing is not routinely conducted. Small, cost-effective adjustments could be implemented to enhance preparedness and resilience to acute climate hazards while ensuring that sanitation and waste management systems remain functional during such events.

#### Recommendations

- Advocate and work with the PHA to proactively empty wastewater tanks. Ensure waste management plan is in place.
- Investigate the need for replacement of UV filter for water quality treatment.
- Add additional filtration elements to water storage system prior to capture – retrofit water supply to tank systems to pass through course filtration system.
- Invest in water quality testing kit to ensure filtration system is functioning, particularly during a hazard/event.

### 4.3.3 Energy

The energy system at the MPH Eye Clinic achieved very high scores when evaluated against the WHO checklist for climate resilience and environmental sustainability (Table 4). While the solar power system demonstrates strong climate resilience, it is insufficient to meet the clinic's current energy demands. Frequent and prolonged power disruptions have affected the durability of critical components, including surge protection mechanisms. Further, the limited on-ground availability of suitable technicians increases the demand on external support to ensure function. Collaborating with the energy consultant, Henry Cassin, is recommended to explore opportunities for increasing solar capacity, enhancing battery storage and build capacity of Clinic-based staff to install, maintain and fix, energy system componentry. Additionally, a risk exists concerning the supply chain reliability of diesel for the backup generator. Although the on-site team reported no present or historical disruptions, regional fuel shortages have been documented and could pose future challenges.

#### Recommendations

- Look to install additional solar PV cells and additional batteries, aligning with Henry Cassin's updated usage profile.

- Determine the impact of periods with insufficient sunlight on solar energy capture and the resulting changes in the usage profile of the energy system.

- Investigate the potential to obtain and store an additional barrel of diesel. Thus, decreasing the risk likelihood associated with supply chain disruption.
- Train additional staff in how the energy system is managed, monitored and maintained to ensure contingency is in place in the event of staff unavailability.
  - This includes developing an understanding of how the online monitoring portal operates. Assign a role to a local staff member, who will be responsible for ensuring that data is uploaded to the cloud for monitoring purposes. This responsibility also includes overseeing the continual and timely payment of the data SIM card associated with the system.
- Investigate energy system(s) at the provincial level. Understand their limitations to chronic and acute climate hazards and how this would impact operation function during outreach clinics.
  - Work with them to understand planned works to upgrade the system in other provinces where outreach clinics are planned.

#### 4.3.4 Infrastructure, technology and products interventions

Approximately half of the interventions assessed within this sector were categorised as medium priority, in progress, or incomplete. This outcome is largely attributed to the specific requirements outlined in the WHO checklist, with many interventions only partially met. For example, while contingency planning is in place, it has not been formalised into official documentation.

From an infrastructure perspective, the facility and its operations were found to be broadly climate resilient and environmentally sustainable, achieving 17 of the 34 total high scores across the guidance framework (Table 4). However, the integration of technological systems requires significant improvement, particularly concerning patient record management (Appendix C - Figure 12). Although online storage solutions ensure data security through server distribution across multiple countries, accessibility to stored information remains constrained. Additionally, the communication and translation of technical infrastructure information to the workforce is insufficient and warrants focused attention.

Recommendations

- Investigate infrastructure at the Provincial level, particularly at the MPH. Understand their limitations to chronic and acute climate hazards and how this would impact operational function for:
  - Outreach clinics, and
  - General operation and integration of health services across the broader MPH precinct.
- Ensure accurate upkeep of maintenance records to key infrastructure elements.
  - Increase general monitoring of the main Clinic building due to its age, ensure this is recorded in maintenance records.
- Investigate whether an increase in access and understanding to infrastructure and key operational elements is needed for contingency planning purposes.
- Invest in training of staff at MPH Eye Clinic to reduce reliance on external contractor(s) for equipment assessment and upkeep where possible.

## 4.4 Modelling of Climate Change Impacts on MPH Eye Clinic and Outreach Clinics

In the model below, the performance metrics were referred to as “encounters”. The analysis focused on correlating clinic and outreach performance metrics (total visits, consultations, screenings, surgeries) with climate data to understand the impact of climate events on clinic and outreach performance. The analysis relied on seasonal trends, historic climate data, and local news reports. The findings indicate that extreme climate events likely contributed to reduced patient attendance in a number of instances for both the clinic (Figure 3) and the outreaches (Figure 4). However, implemented control measures have contributed to improved performance metrics for the MPH Eye Clinic. The key findings are:

- Heavy rainfall and flooding likely impacted patient attendance and disrupted clinic operations, particularly during the wet season (November to April). Flooding could have caused road blockages, power outages, and transportation disruptions, leading to lower patient turnout and cancellations of scheduled surgeries.
- Businesses in Madang have reported continuous outages, with a climate-event example being the February 2024 heavy flooding which led to a 96-hour blackout in the region (Post Courier 2023). It was also reported that in

December 2018, Madang experienced power disruptions caused by system tests and deteriorating infrastructure (Power Outage Live 2018). As conditions worsen due to increased intensity and frequency of extreme weather events, infrastructure will deteriorate e more and more power disruptions will occur. However, the installation of solar panels and battery systems at the MPH clinic assists with maintaining operations during power disruptions.

- Rough seas, strong winds and unique geography likely affect patient accessibility, limiting access to outreach clinics in remote areas especially during the wet season. Locations such as Karkar Island and Simberi required inter-island travel, and attendance numbers were likely impacted by adverse weather conditions. For example, Karkar Island recorded 369 encounters in May 2018 during the transition to the dry season, where residual wet conditions likely impeded access.
- Extreme heat has likely not directly impacted attendance numbers; however, it poses increasing operational challenges. These include risks of equipment overheating, heightened building maintenance needs, increased humidity leading to mould growth, and discomfort for both patients and staff. Outreach locations, often lacking the air conditioning and ventilation systems available at the MPH clinic, are particularly vulnerable, making these challenges even more pronounced in remote settings.
- Seasonal trends and remoteness of outreach locations also played a role in attendance variability. Locations requiring significant travel, such as Kiunga and Buka, had attendance numbers that fluctuated based on seasonal accessibility and logistical challenges. For instance, Buka recorded moderate attendance (547 encounters) in March 2023, aligning with wet season travel disruptions.
- The implementation of control measures, such as solar power backup systems and strengthened building infrastructure, has enabled the MPH Eye Clinic to maintain operations during extreme climate events. This likely contributed to the highest average total encounters per month at 684 encounters in 2024, which is up from 551 encounters in 2023, and 432 encounters in 2020. However, this is recognising that there were gaps and other influences throughout the years, such as COVID-19 in 2020.

Recommendations

- Raise critical infrastructure and improve drainage systems to mitigate flooding risks and ensure continuity of operations. Ensure solar power and batteries have sufficient surge protection and capacity to handle the frequent power disruptions.
- Plan outreach activities in periods of reduced climate impact, avoiding the wet season and transition months. For remote locations like Karkar Island and Simberi, consider climate forecasting tools and other methods of improving logistical readiness.
- Building local capacity in the energy infrastructure space, pertinent to improving technical capabilities for the installation and maintenance of solar and battery storage systems.
- Enhance staff knowledge and preparedness for climate-related disruptions to minimise operational impacts. This includes across infrastructure and technological systems (energy, internet, water).
- Monitor and adapt scheduling of outreach programs by integrating seasonal climate data and historic attendance trends to predict and mitigate climate-related impacts more effectively.
- Coordinate with hospital or clinics to ensure outreaches have appropriate ventilation and cooling prior to the outreach occurring. Improve transportation resilience by coordinating with local authorities to ensure reliable travel routes to outreach sites.

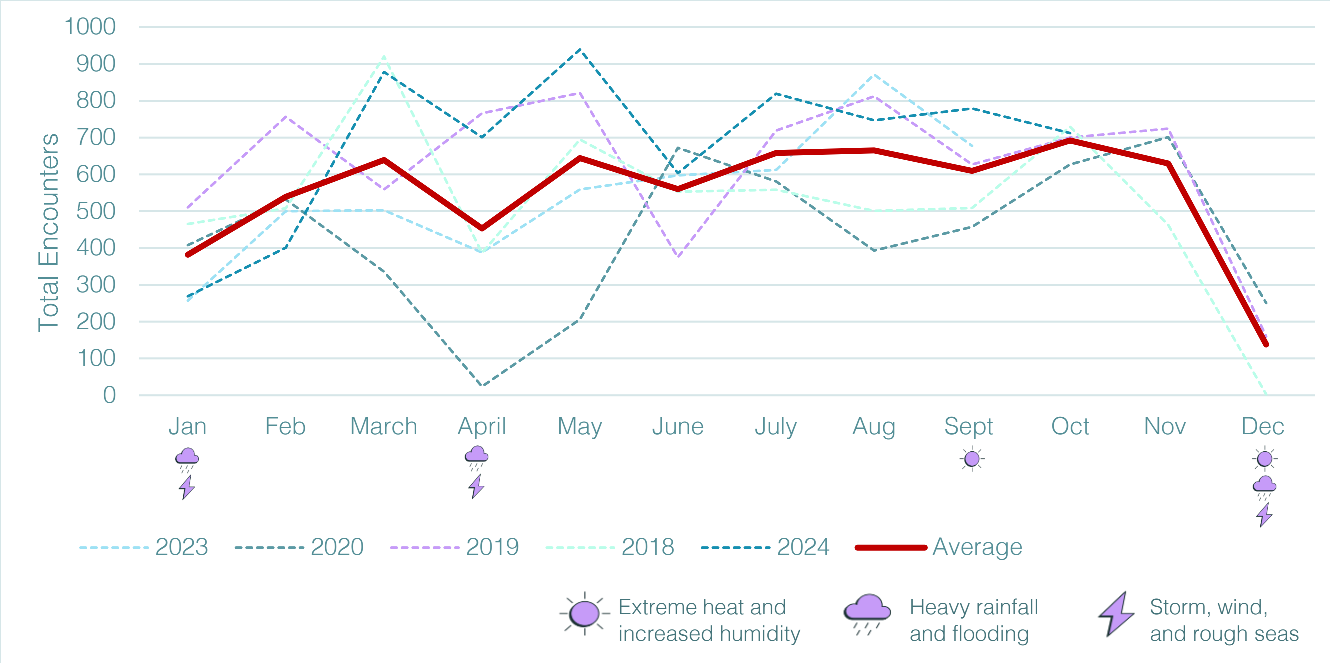


Figure 3 Total encounters and likely climate impacts for the PN Eye Clinic (The Foundation 2024).

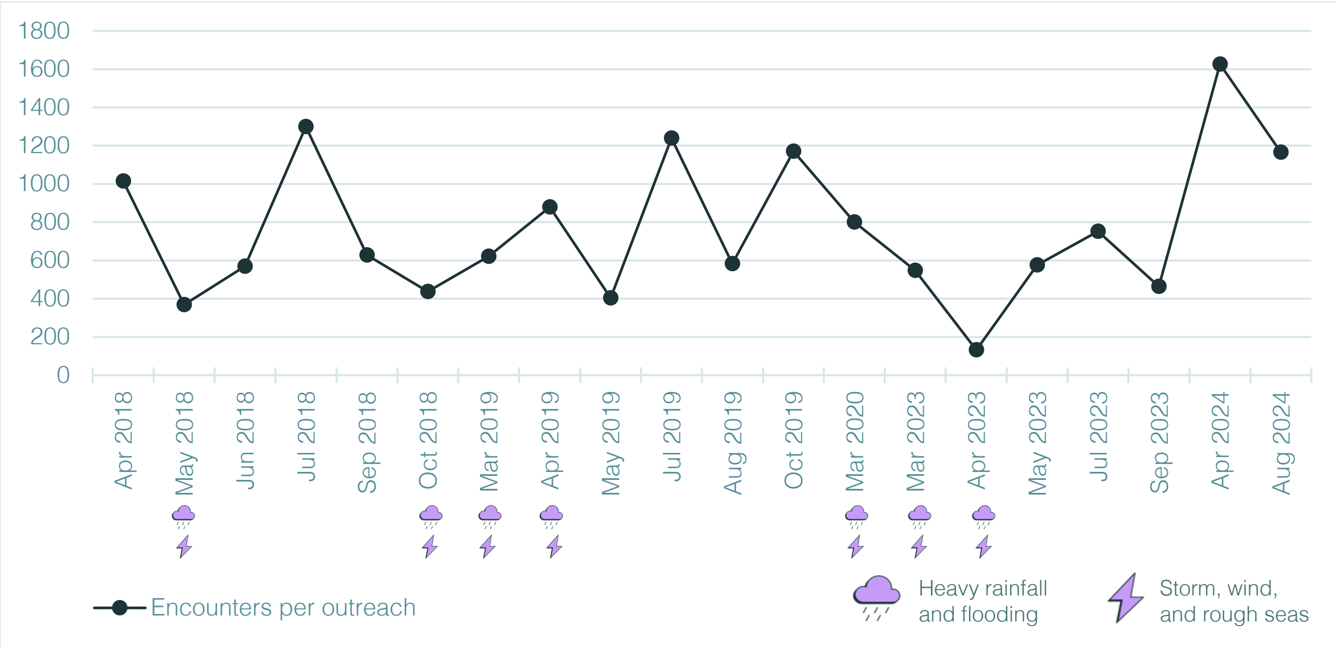


Figure 4 Total encounters and likely climate impacts for PNG Islands outreaches (The Foundation 2024).

# 5 Conclusion

This assessment identified a range of significant climate-related risks to the MPH Eye Clinic site and its operations. It is recommended that these are carefully considered by The Foundation team in conjunction with the broader team at the MPH Eye Clinic and implemented where appropriate to build resilience to the impacts of climate change. The recommendations provided in the above section (4) relate to adaptation planning strategy, ongoing risk management, as well as addressing broader climate-related risk at the organisational level. This section provides a summary of recommendations as well as guidance on implementation. Further, key insights from the assessment are also described with all recommendations displayed in Appendix E. Collated recommendations.

## 5.1 Adaptation implementation

Importantly, the risk ratings developed in this assessment are based on the prescribed climate scenario eventuating in both 2050 and 2090 timeframes and do not necessarily represent current risks. The adaptation actions identified for the very high risks above should be considered for implementation, with a focus on addressing the short-term, current risks as a priority. Importantly, the scale and timing of adaptation implementation requires careful consideration, remaining cognisant that risks have been identified for both current and future time periods.

It is important that the adaptation action hierarchy (refer to Figure 5 below) is considered, recognising that engineering and infrastructure investments to mitigate climate risks may usefully be preceded, in the short term, by management approaches including updated communications and operational guidelines. Importantly, the optimal scale and timing of adaptation measures should also be considered, noting that actions should only be implemented once defined triggers or thresholds are reached. This approach, termed Adaptation Pathways, facilitates a more strategic and cost-effective approach that responds to issues once they become material.

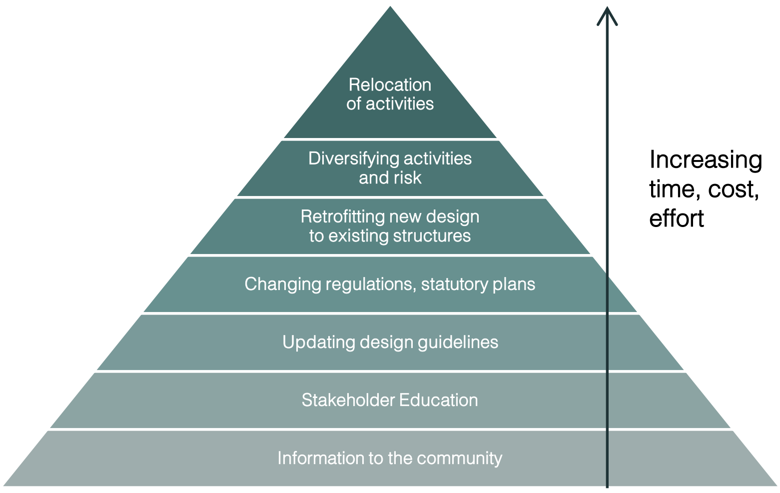


Figure 5: Adaptation action hierarchy.

## 5.2 Ongoing climate risk management

The risks identified in this assessment should be included as a climate change specific annexure to the existing risk management framework for the MPH Eye Clinic to ensure that risks can be monitored and reviewed as the impacts of climate change unfold. It is suggested that climate risks are reviewed on an annual basis by The Foundation team both on-ground and based in NZ to identify any changes in the climate risk profile as a result of significant events.

## 5.3 Key insights and broader community implications

The recommendations presented in Section 4 above address specific climate risks identified through the assessment and align with the *WHO guidelines for climate-resilient and environmentally sustainable healthcare facilities*. The following summary highlights key insights from the risk assessment, WHO checklist, and MVP model, offering a consolidated overview of critical findings.

Recommendation: Strengthen integration and understanding of climate risk planning documentation

- There is a general lack of integration and understanding of key planning documents (e.g., contingency, emergency, and disaster plans) related to mitigating climate risks at the MPH Eye Clinic. Currently, knowledge of these documents and their implementation is concentrated among a few key staff members. While this centralisation can streamline communication, it leaves the MPH Eye Clinic vulnerable if those staff members are unavailable.
- Furthermore, the health workforce is unclear about the direction of communication and the development of procedures in this area. It would be beneficial to engage the Provincial Disaster Management Officer, as well as the PHA, to coordinate documentation and develop a localised, site-specific climate resilience plan.
  - For example, implementing a comprehensive business continuity plan could serve as a unifying framework, aligning these individual plans and ensuring that critical knowledge and procedures are accessible to all staff members across the MPH Eye Clinic.
- It is further recommended that The Foundation incorporates temperature thresholds into SOPs to activate extreme heat protocols. These thresholds should use an apparent temperature or heat index measure to account for the combined effects of heat and humidity. The overarching aim of these protocols should be to minimise exposure to extreme heat for staff, patients, and visitors.

Recommendation: Enhance future climate resilience of the MPH Eye Clinic

- While the MPH Eye Clinic is currently resilient to climate change impacts, projections indicate that future climate scenarios will exacerbate risks across all assessed areas. The greatest emerging threats are related to flooding and sea level rise, with severe coastal erosion occurring along the southern coastline of the Madang urban area. Currently, the most significant operational disruptions stem from energy supply issues with the grid. A myriad of factors contribute to these challenges, including extreme heat, fuel supply shortages, storm activity, landslides, and aging infrastructure. These issues trigger a range of flow-on effects, such as internal temperature fluctuations, water supply disruptions (due to electric pumps), and the inability to use specialised equipment. Despite these challenges, existing systems and protocols have proven effective in managing these conditions, ensuring positive patient outcomes.
- To ensure long-term resilience, it is crucial to proactively strengthen infrastructure and adapt protocols to address the anticipated increases in climate-related risks. In the short term, enhancing climate resilience can be achieved by expanding the photovoltaic (PV) system and battery storage, ensuring adequate surge protection, installing an additional water tank for storage, and investing in a water distiller to maintain water quality.

Recommendation: Advocate for enhanced WASH management across the broader hospital precinct.

- There is an opportunity to enhance capacity development in WASH (Water, Sanitation, and Hygiene), particularly by advocating for the alignment of MPH & PHA protocols with the more advanced understanding and implementation of WASH protocols demonstrated by the Eye Clinic's workforce. This alignment will ensure consistent and effective implementation by staff, while maintaining cohesion with the broader MPH health system.
- The same approach applies to clinical governance protocols. The Director of Nursing Services noted that ongoing and continuous training for WASH is currently lacking across the health workforce servicing the Hospital, resulting in a noticeable decline in the proper application of these protocols.

Recommendation: Advocate for the inclusion of climate change into professional coursework and qualifications

- A valuable opportunity exists to partner with Divine Word University, the PHA, and the federal Department of Health to advocate for the integration of climate resilience and environmentally sustainable coursework into the development of future health-related qualifications. Such coursework would address critical gaps in understanding the linkages between environmental systems and healthcare within the current healthcare workforce.
- Both the Director of Nursing Services and the Director of Environment and Public Health at Divine Word University have highlighted the limited awareness among healthcare professionals regarding the connections between climate, the environment, and public health. Additionally, the Director of Environment and Public Health noted that Divine Word University is collaborating with the University of Technology Sydney to develop a new curriculum for their nursing programs. This presents a timely opportunity to advocate for the inclusion of climate-related content, ensuring healthcare workers are better equipped to understand and address the complex interplay between climate change, environmental systems, and public health.

Recommendation: Continually explore collaboration opportunities for outreach clinics

- Opportunities exist to enhance community impact by integrating with other organisations during outreach clinics, particularly in remote communities. Climate shifts are reducing the seasonal window for these clinics, making it imperative to coordinate efforts with partners. Such collaboration can ensure that community members in outer provincial areas not only receive improved health outcomes but also gain a better understanding of how climate and weather changes may affect their health in both the near and distant future.

Recommendation: Conduct stocktakes with outreach centres to determine operational capacity

- Advocate for the expansion of the current program investigating the climate resilience of community health care facilities across the Madang Province. Look to incorporate learnings of resilience planning and strategy from the Eye Clinic to these other, community level, healthcare facilities.
- Collaborate with local healthcare facilities to advocate for improvements to existing infrastructure. Develop contingency plans to adjust outreach schedules or clinic hours during extreme heat events to minimise exposure and ensure safety.

Recommendation: Ensure outreach scheduling aligns with periods of minimal climate disruption

- Plan outreach activities primarily during the dry season when the risks of heavy rainfall, high winds, flooding, and rough seas are lower, ensuring better accessibility and higher patient turnout. Implement a flexible schedule that can be adjusted and provide staff with short-term weather forecasts and early warning systems for adverse conditions. Collaborate with local communities and stakeholders to align outreach schedules with local climate and/or seasonal pattern knowledge and integrate climate forecasting tools into planning to avoid periods of anticipated severe weather, such as tropical cyclones or heatwaves. Further explore the use of data insights, including weather patterns and historical attendance records, to optimise the planning of outreach activities

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# Appendix A. Risk Management framework

Table 5: The Foundation Risk Management Framework and Overview of Incident Levels and Response.

| Risk Type | Substantive policy | Procedures | Committee |
|---|---|---|---|
| | Risk Management Policy<br>Code of Conduct | Incident Management Procedures<br>Country Security and Safety Protocols | Risk Management Committee |
| **Risk Type** | **Associated policies** | **Procedures** | **Committee** |
| Clinical | Clinical Governance Policy | Numerous Clinical procedures | Clinical Governance Committee |
| Fiduciary | Credit & Debit Card Policy<br>Investment Policy<br>Prevention of Wrongdoing and Terrorism Policy<br>Reserves Policy<br>Treasury Policy | Numerous Fiduciary procedures | |
| Health and Safety | Health & Safety Policy<br>Whistleblower Policy | Health & Safety procedures | Health & Safety Committee |
| Information Security | Cyber Security Policy<br>Privacy & Information Handling Policy | | |
| Legal/Compliance | Child Safeguarding Policy | | |
| Reputational | Content Gathering and Use Policy<br>External Complaints Policy | | |
| Security | Crisis Management Policy<br>Travel Policy<br>Vehicle Policy | Vehicle Inspection checklist | |

Table 6: The Foundation overall risk rating matrix.

| Risk Rating | | Consequence | | | | |
|---|---|---|---|---|---|---|
| | | Negligible (1) | Minor (2) | Moderate (3) | Major (4) | Catastrophic (5) |
| Likelihood | Almost Certain (5) | 11 Medium | 16 Significant | 20 High | 23 High | 25 Very High |
| | Likely (4) | 7 Low | 12 Medium | 17 Significant | 21 High | 24 High |
| | Moderate (3) | 4 Low | 9 Medium | 13 Medium | 18 Significant | 22 High |
| | Unlikely (2) | 2 Low | 5 low | 10 Medium | 14 Medium | 19 Significant |
| | Rare (1) | 1 Low | 3 Low | 6 Low | 8 Low | 15 Medium |

# Appendix B. Engaged stakeholders

Table 7: Stakeholders engaged through assessment.

| Stakeholders | | | |
|---|---|---|---|
| Area / Position | Organisation | Name | Date |
| General Manager | The Foundation NZ (PNG based) | Anges Mor | 18/11/2024 |
| Programme Manager | The Foundation NZ (PNG based) | Lydia Seta | 18/11/2024 |
| Nursing Unit Manager | The Foundation NZ (PNG based) | Sr Getruth Bare | 18/11/2024 |
| Madang Disaster Coordinator | Madang Provincial Administration (Disaster Management) | Mr. Rudoplh Mongallee | 19/11/2024 |
| Infection Control Officer | Madang Provincial Health Authority | Suzanne | 19/11/2024 |
| Occupational Health & Safety Officer | Madang Provincial Health Authority | Paul | 19/11/2024 |
| MPH Pharmacist | MPHA | Grace | 19/11/2024 |
| Environmental Health Officer | Madang Urban Local Level Gov (MULLG) | Stacey | 20/11/2024 |
| Hospital Manager | MPHA | UNKNOWN | 20/11/2024 |
| Director | PHA - Environmental Health | Dr. Martin Daimen | 20/11/2024 |
| WASH Officer | PHA - Environmental Health | Paul Sikoso | 20/11/2024 |
| EHO | PHA - Environmental Health | Benny Yaruman | 20/11/2024 |
| HoD - Ophthalmology | The Foundation NZ (PNG based) | Dr. David Pahau | 20/11/2024 |
| Director Nursing Services - MPH | MPHA | UNKNOWN | 20/11/2024 |
| PNG Power Team | PNG Power | Entire Provincial Team (~20) | 22/11/2024 |
| Water PNG Team | Water PNG | Entire Madang office-based team (~15) | 22/11/2024 |
| HoD - Env Health | Divine Word University | Mr. Alphonse Begani | 22/11/2024 |
| General Manager | The Foundation NZ (PNG based) | Anges Mor | 22/11/2024 |
| Programme Manager | The Foundation NZ (PNG based) | Lydia Seta | 22/11/2024 |
| Nursing Unit Manager | The Foundation NZ (PNG based) | Sr Getruth Bare | 22/11/2024 |

# Appendix C. Site photos

Figure 6: Installation of and location of solar panels at the Eye Clinic (The Foundation NZ).

Figure 7: Power supply system, including gen-set and solar system.

Figure 8: Water filtration system, internally located within operating theatre building.


Figure 9: Wider view of waste storage facility at the MPH.


Figure 10: Waste storage and separation at the MPH.

Figure 11: Wastewater/sewage treatment tanks at the front of the Clinic.

Figure 12: Historic patient records stored in the entranceway to the Clinic.

# Appendix D. Net Present Value (NPV) of cost savings from solar panels

The electricity data used actual data for the past 6 months from 21-06-2024 to 18-12-2024 which is 180 days (6 months) of usage that covers periods of the dry and wet season. As full data from solar energy usage was not available for all years, this 6-month was extrapolated to a 12-month period and is assumed to be the baseline average usage for a year.

For modelled data the average use in a year was applied along with a degradation rate of 0.07% for solar panel efficiency.

Total kWh of electricity usage was 40,325 kWh for the 6-month period[2], with the usage profile breakdown equating to 40.5% from direct solar, 13.3% from stored solar via the batteries, 1.3% from generator power, and 44.9% from the grid.[3]

The formula used to calculate the Discounted Cost Savings for each year was the Net Present Value (NPV) formula:

$$Discounted\ cost\ savings = \frac{Cost\ savings}{(1 + discount\ rate)^{(year - base\ year)}}$$

Average cost of electricity is 0.7379 toea per kWh in 2024 (PNG Facts, 2024). This is about 0.28 USD with an exchange rate of 1 Kina (PGK) = 0.28 USD.[4]

The total energy usage over the period from 2023 to 2040, accounting for a 0.07% annual decrease in solar panel efficiency, is approximately 770,223.64 kWh.

With a 5% discount rate the total discounted cost savings is approximately:

Total discounted cost savings (USD) = $153,267

[2] Note limited data availability was due to only 6 months of data being available online. However, it is assumed the solar panels and batteries were still operating during the prior 6 months, as the reason for no data availability was network issues and not with the solar panel operations.

[3] This represents the percentage of power consumption as a usage profile but does not differentiate the power source. Battery consumption is categorised under solar energy when referencing power source.

[4] The calculations for the total discounted cost savings exclude the initial capital expenditure of the solar system, based on the assumption that this cost has already been incurred. Consequently, the energy generated by the system is considered to contribute directly to net energy savings.

# Appendix E. Collated recommendations

| | Section/Sub-Section Number | Section/Sub-Section Name | Recommendation |
|---|---|---|---|
| Sector / Intervention-specific recommendations | 4.3.1 | Health workforce interventions | Coordinate PHA staff PD to ensure breadth of additional learning across multiple other areas (e.g. climate and public health relationship, community engagement, etc.). |
| | | | Advocate for integration of procedural practices and policies implemented at the Eye Clinic to be extended to the broader hospital workforce to enhance capacity development. There are opportunities to share knowledge on supply chain management and WASH principles across the hospital precinct. |
| | | | Conduct information sessions on key operational systems function. Ensure understanding of these elements is engrained across workforce. |
| | 4.3.2 | Water, sanitation, healthcare waste interventions | Advocate and work with the PHA to proactively empty wastewater tanks. Ensure waste management plan is in place. |
| | | | Investigate the need for replacement of UV filter for water quality treatment. |
| | | | Add additional filtration elements to water storage system prior to capture – retrofit water supply to tank systems to pass through course filtration system. |
| | | | Invest in water quality testing kit to ensure filtration system is functioning, particularly during a hazard/event. |
| | 4.3.3 | Energy | Look to install additional solar PV cells and additional batteries, aligning with Henry Cassin's updated usage profile.<br>Determine the impact of periods with insufficient sunlight on solar energy capture and the resulting changes in the usage profile of the energy system. |
| | | | Investigate the potential to obtain and store an additional barrel of diesel. Thus, decreasing the risk likelihood associated with supply chain disruption. |
| | | | Train additional staff in how the energy system is managed, monitored and maintained to ensure contingency is in place in the event of staff unavailability.<br>This includes developing an understanding of how the online monitoring portal operates. Assign a role to a local staff member, who will be responsible for ensuring that data is uploaded to the cloud for monitoring purposes. This responsibility also includes overseeing the continual and timely payment of the data SIM card associated with the system. |
| | | | Investigate energy system(s) at the provincial level. Understand their limitations to chronic and acute climate hazards and how this would impact operation function during outreach clinics.<br>Work with them to understand planned works to upgrade the system in other provinces where outreach clinics are planned. |
| | 4.3.4 | Infrastructure, technology and products interventions | Investigate infrastructure at the Provincial level, particularly at the MPH. Understand their limitations to chronic and acute climate hazards and how this would impact operational function for:<br>Outreach clinics, and general operation and integration of health services across the broader MPH precinct. |

| | Section/Sub-Section Number | Section/Sub-Section Name | Recommendation |
|---|---|---|---|
| | | | Ensure accurate upkeep of maintenance records to key infrastructure elements.<br>Increase general monitoring of the main Clinic building due to its age, ensure this is recorded in maintenance records. |
| | | | Investigate whether an increase in access and understanding to infrastructure and key operational elements is needed for contingency planning purposes. |
| | | | Invest in training of staff at MPH Eye Clinic to reduce reliance on external contractor(s) for equipment assessment and upkeep where possible. |
| Modelling Recommendations | 4.4 | Modelling of Climate Change Impacts on MPH Eye Clinic and Outreach Clinics | Raise critical infrastructure and improve drainage systems to mitigate flooding risks and ensure continuity of operations. Ensure solar power and batteries have sufficient surge protection and capacity to handle the frequent power disruptions. |
| | | | Plan outreach activities in periods of reduced climate impact, avoiding the wet season and transition months. For remote locations like Karkar Island and Simberi, consider climate forecasting tools and other methods of improving logistical readiness. |
| | | | Building local capacity in the energy infrastructure space, pertinent to improving technical capabilities for the installation and maintenance of solar and battery storage systems. |
| | | | Enhance staff knowledge and preparedness for climate-related disruptions to minimise operational impacts. This includes across infrastructure and technological systems (energy, internet, water). |
| | | | Monitor and adapt scheduling of outreach programs by integrating seasonal climate data and historic attendance trends to predict and mitigate climate-related impacts more effectively. |
| | | | Coordinate with hospital or clinics to ensure outreaches have appropriate ventilation and cooling prior to the outreach occurring. Improve transportation resilience by coordinating with local authorities to ensure reliable travel routes to outreach sites. |
| Overall Recommendations / Key Findings | 5.3 | Key insights and broader community implications | Strengthen integration and understanding of climate risk planning documentation |
| | | | Enhance future climate resilience of the MPH Eye Clinic |
| | | | Advocate for enhanced WASH management across the broader hospital precinct. |
| | | | Advocate for the inclusion of climate change into professional coursework and qualifications |
| | | | Continually explore collaboration opportunities for outreach clinics |
| | | | Conduct stocktakes with outreach centres to determine operational capacity |
| | | | Ensure outreach scheduling aligns with periods of minimal climate disruption |