Seqwater Winnovators 2024

Solve Submission

Our Brief

Coastal communities in Papua New Guinea, such as those on Tarawai Island, are grappling with the dual challenge of accessing clean water and coping with the escalating impacts of climate change such as rising sea levels and unpredictable weather patterns.

The Water Challenge

Devise innovative and sustainable solutions to address these pressing issues, with a focus on integrating climate resilience into the water supply systems of these vulnerable communities.

Our Solution

We have focussed on a multi-solution, staged approach to water sourcing and security, enhancing existing collection practices with innovative components and introducing alternate water sources to establish a stable supply of drinking water for the community.

Enhancing and Improving Rainwater Harvesting

The World Health Organisation (WHO) considers 50 L per person, per day, as intermediate water access, sufficient to meet drinking, cooking and basic hygiene needs[1]. For Tarawai Island, 12,500 L/day (380,208 L/month) is the intermediate supply requirement for sufficient drinking water (*Appendix 1*).

Since rainwater harvesting is well understood and accepted within the Tarawai community, we decided to consider enhancements to rainfall capture as part of our broader solution, focussing on improving the volume of water collected, water storage capacity, and storing water safely.

Our solution includes:

- Utilising existing roofing suitable for rain capture and a staged upgrade of selected communal dwellings to metal roofing.
- Installation of shared rainwater bladders throughout the community to increase water storage capacity.

Improving rainfall capture yield and storage capacity will help address irregular rainfall patterns experienced on Tarawai, ensuring water supply in drier periods. An additional benefit to improving rainwater capture is reduced localised flash flooding through capture of run-off.

The innovative element of our solution is the use of rainwater bladders for storage, over conventional metal, plastic or composite tanks. Bladders can be rolled up and transported to the island using existing transport options and come in a variety of sizes that can be customised to suit the under-floor storage availability of each chosen structure

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[1] "Domestic water quantity, service level and health", World Health Organisation (WHO), 2020.

(*Figure 1*). Their durability is a key advantage, ensuring long-lasting performance even in demanding climate-adverse conditions.

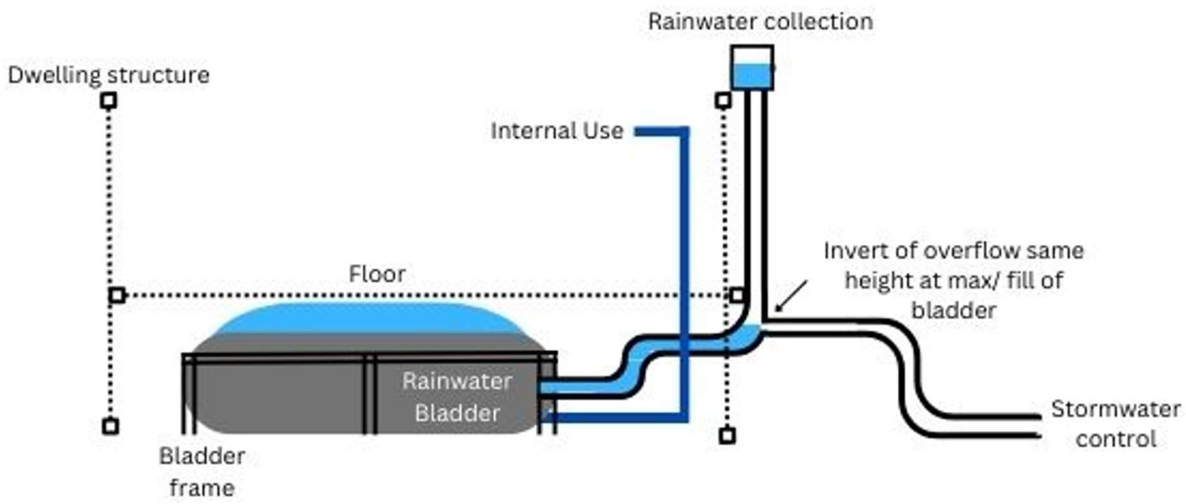

Figure 1: Proposed bladder system for use in rainwater collection and storage.

Satellite imagery (*Appendix 2*) indicated that approximately nine dwellings within the western village have metal roofing which could be suitable for safe rainwater capture, with an additional 17 dwellings targeted for conversion to metal roofing, to attain a target of 2,600 m^2 surface area of rainwater capture. The target roof surface area takes into consideration rainfall patterns[2] and estimated roof sizes of targeted dwellings, allowing for increased rainfall capture to supply WHO intermediate requirement levels. Rainfall calculations are outlined in *Appendix 1*.

Communal dwellings would be prioritised to take advantage of larger roof areas, lower risk from coastal sea level rise and to ensure equitable community access, whilst also attracting maintenance support from community and church groups. Private dwellings would be targeted for upgrades based on centralised location and total surface area, to attain the targeted 2,600 m^2 surface area of rainwater capture.

We calculated water supply balance based on utilising existing and upgraded roof capture capacity at both essential supply (10L) and intermediate supply (50L) per person, per day, in both average and reduced rainfall conditions. Our solutions provide sufficient rainwater capture for continued essential supply under reduced rainfall conditions and intermediate supply for most of the year under typical conditions. Alternate sources (see *Groundwater Harvesting*) would supplement rainwater supplies during dry periods or in the event of limited system failure (e.g., bladder puncture, contamination, etc.).

Groundwater Harvesting

Whilst our main climate-resilient solution to address water supply on Tarawai is to improve rainwater collection and storage, we acknowledge an additional supply is required to safeguard against longer and more frequent dry periods, especially with the predictions of a 50% chance of increase in drought conditions in the Pacific[3]. To achieve this, we

[2] “Pacific climate change site data [Summary Data]”, Bureau of Meteorology, 2024.

[3] “Climate Impacts on Pacific Water Security and Water Resource Management: A Stocktake of institutional settings and management challenges in eight Pacific Island countries”, Australia Pacific Climate Partnership, 2021.

propose to supplement rainwater capture with an alternate groundwater source. Resistivity surveys conducted in 2023 have found evidence of freshwater below the island[4]. Groundwater use is supported by the Water for Women fund, which acknowledges groundwater as a safe and reliable source of water on outer islands and in mainland coastal communities of Papua New Guinea[5]. We therefore eliminated the use of lakes near the community due to high sulphur content and potential for pathogenic contaminants.

Our approach is to draw groundwater to an elevated reservoir using a solar pump and then gravity feed the water to smaller storages around the island (*Figure 2*). Solar is the preferred option to pump groundwater due to the reliability of sunlight, especially during dry periods, allowing for a reliable and low maintenance power source (*Appendix 3*).

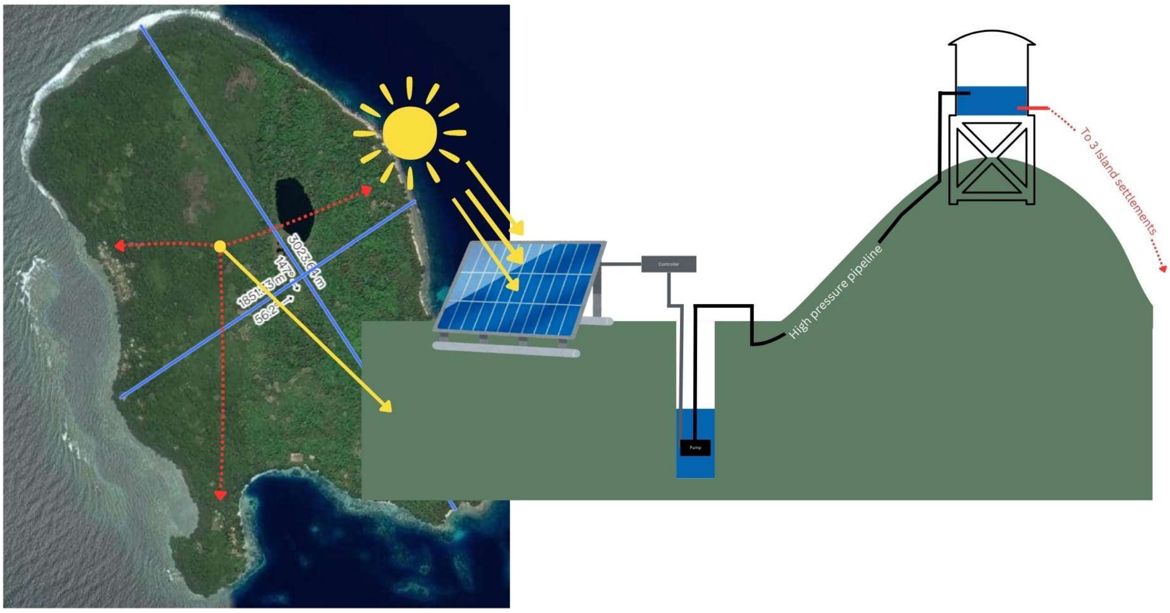

Figure 2: Proposed groundwater storage and distribution approach.

Addressing Climate Change Impacts

By maintaining a focus on durability, simplicity and adaptability, our integrated solution addresses Tarawai Island's water scarcity issues. Our solution provides a relatively low maintenance, low-cost, resilient water system that mitigates the effects of irregular rainfall patterns, rising sea levels, and the impact of salinity on shallow wells, therefore enhancing the resilience of the community facing climate adversity.

Community Engagement and Education

We are aware of the importance of "buy-in" from the local community to ensure any implemented solutions are a success. An important part of our solution includes working with the community to step through our proposed designs, enabling consultation and leveraging local knowledge to refine the solution within the local context. This process also provides opportunities to educate the community on smart water use, such as using the lake for agricultural uses, and reserving rainwater for drinking, food preparation and hygiene purposes.

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[4] "Mid-Program Solve Webinar 19th June 2024", WaterAid, 2024.

[5] "Inclusive WASH and climate adaptation in Wewak, Papua New Guinea", Water for Women Fund, 2022.

The consultation phase would include the creation of a community group who is responsible for the management of water resources, ensuring equitable access to water and continued community support of infrastructure on completion of the project.

The community will also be linked with organisations such as the Australia Pacific Training Coalition (APTC) to provide upskilling opportunities for the community to assist in maintaining infrastructure. Financial Assistance programs are also available through APTC to help pay for travel and training costs.

How will this be funded?

Cost estimates are outlined in *Appendix 4*. There are several local and international initiatives that provide funding to support water security projects in developing countries, including:

- Australia's Department of Foreign Affairs and Trade Water for Women program
- World Bank grants
- PNG Government
- Local community

Recommendations – Phase 2

While our solution prioritises providing the community with adequate water supplies, a future phase could focus on advancement in water treatment and drinking water quality, with cost-effective and resilient approaches, including:

- **Community shared Biosand Filtration (BSF) Systems**: BSFs are a simple, gravity-fed system formed from inexpensive, locally sourced, and sustainable materials and coagulants. As water flows through the filter, physical straining removes pathogens, odour and turbidity from drinking water. A flow rate of ~30L/hr, per unit, will ensure a stable supply of clean, safe water.
- **Ceramic Water Filters (CWF)**: CWFs are made from clay and sawdust, moulded, and painted with colloidal silver for bacterial protection. CWFs filter water at 1-2L/hr, sufficient for five people daily.

Appendix 1 – Climate and Rainfall Data and Calculations

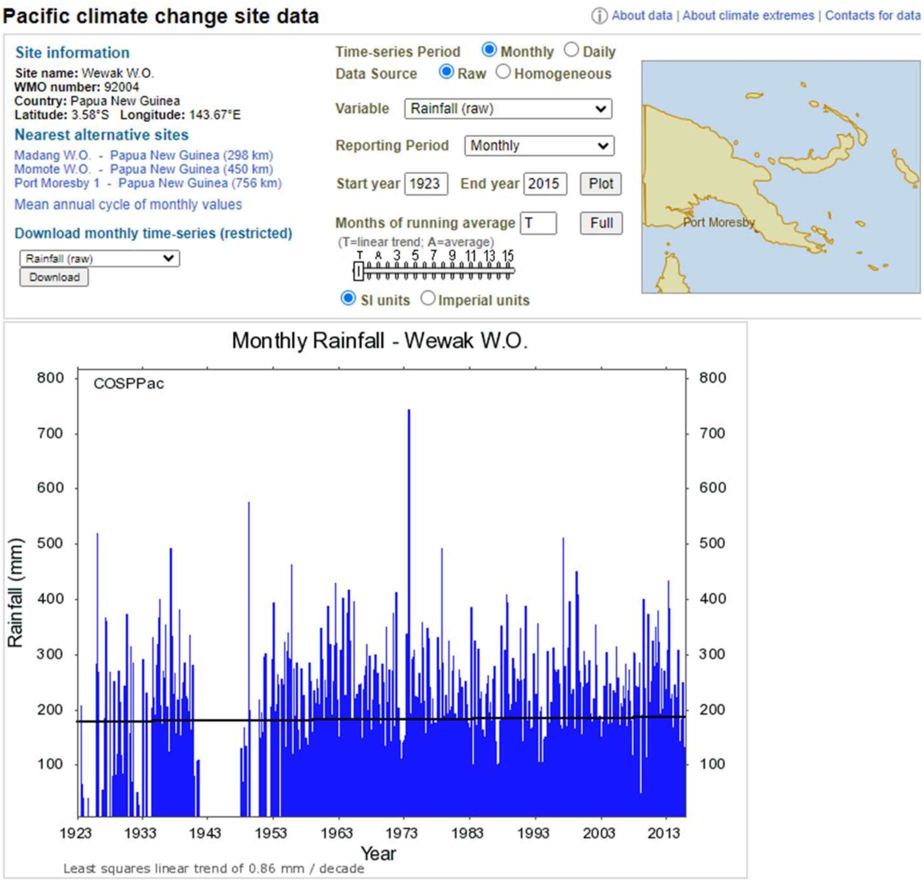

Figure 3: Climate and rainfall data for Wewak, closest data point to Tarawai Island[6]

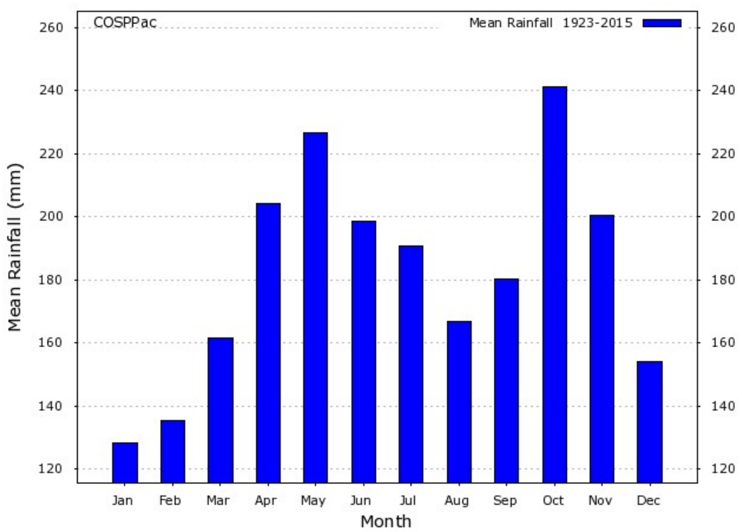

Figure 4: Monthly mean rainfall data for Wewak, closest data point to Tarawai Island[6]

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[6] "Monthly mean rainfall – Wewak W.O. [Summary Data]", Bureau of Meteorology, 2024.

Rainfall Capture Calculations

The following assumptions have been made to assess the amount of rainfall capture required to support the community:

- Water required for intermediate supply per person, per day = **50 L**
- Water required for essential supply per person, per day = **10 L**
- Estimated population (assuming population growth) = **250 people**
- Estimated safe water required per day for whole community = **12,500 L per day**
- Estimated average roof area of targeted dwellings = **100 m^2**
- Estimated safe water required per month for whole community = **380,208 L per month**
- Reduced rainfall scenario of 75% monthly rainfall. This scenario approach maintains seasonal rainfall patterns and is supported by over 100 years of rainfall data (*Figure 5*) that shows typical dryer years result in rainfall approximately 500mm less than the mean. A 75% rainfall scenario results in an annual reduction of 547mm.

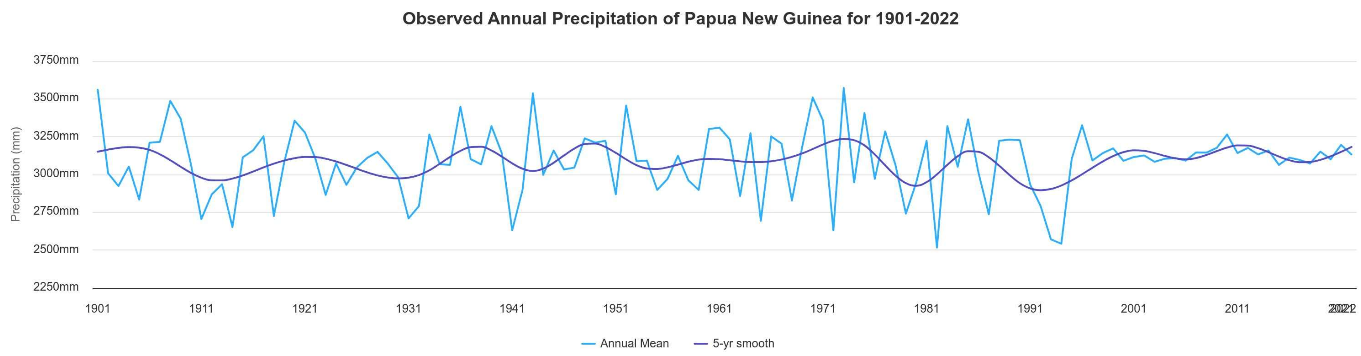

Figure 5: Observed annual precipitation of Papua New Guinea between 1901-2022[7].

Nine dwellings are estimated to have existing metal roofing and a further 17 communal dwellings would be targeted for metal roofing and rainwater bladder installation, to aim for total a target surface area of 2,600 m^2 of rainwater capture. *Figure 6* shows rainfall capture scenarios under typical and reduced rainfall conditions, in addition to proposed groundwater supply capacity.

[7] Climate Change Knowledge Portal, World Bank Group. https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/climate-data-historical

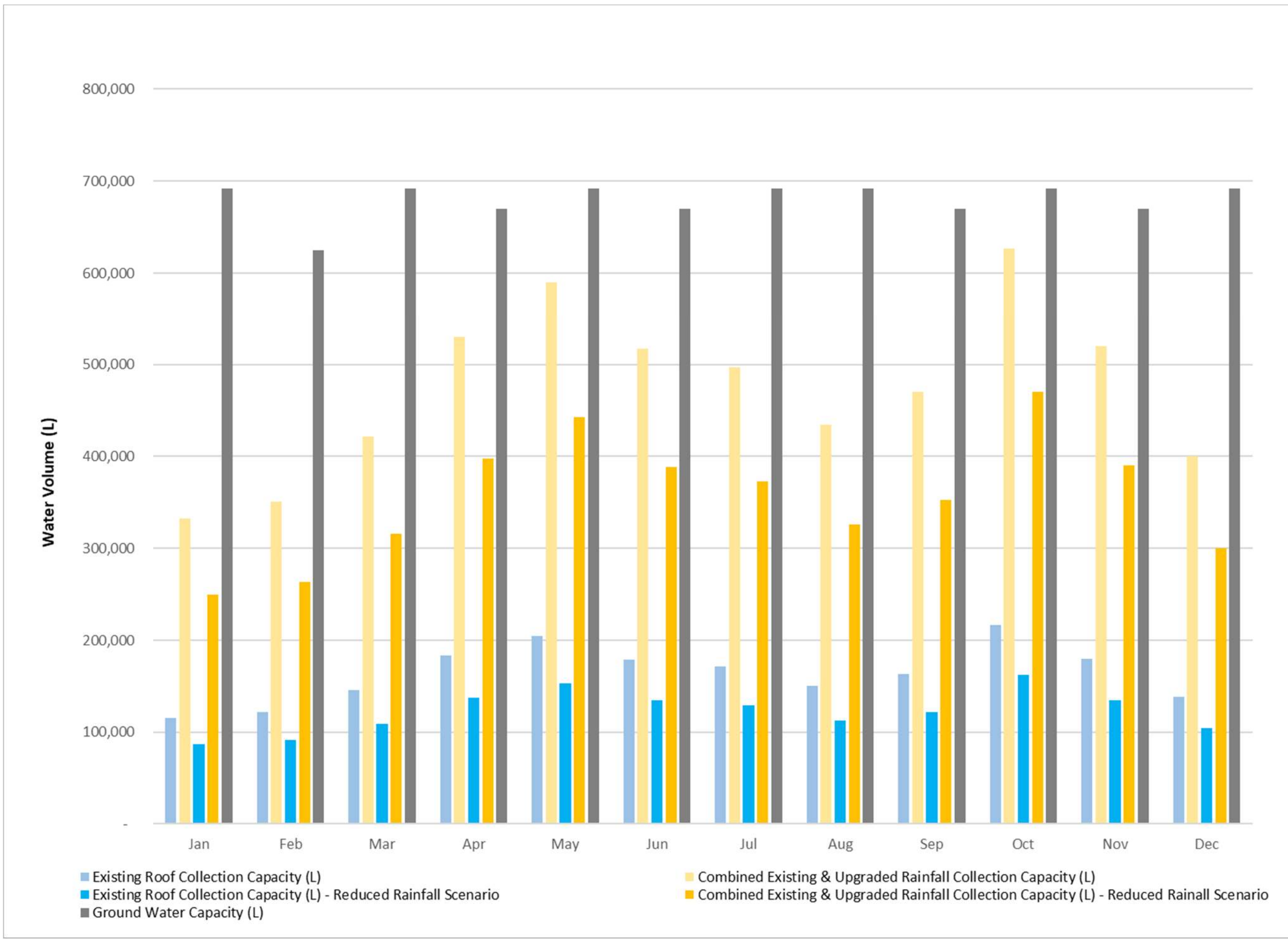

Figure 6: Potential collection capacities under different water sources and climate scenarios.

Figure 7 shows water demand balances under various demand and supply options during reduced rainfall conditions. At 10 L per person, per day demand, the existing roof capacity is adequate even under reduced rainfall scenarios. Under average rainfall conditions an upgrade of roofs is required to meet the 50 L per person, per day demand, however under a reduced rainfall scenario (75% rainfall) there is a deficit in water storage over the year. Therefore, supplementing rainfall capture with groundwater extraction will likely be necessary during the dry season to meet the shortfall in supply from rainwater collection. As part of progressing the groundwater solution, investigative works would need to take place to determine the suitability (quality and quantity) of groundwater as a viable water source. The targeted number of dwellings for roofing upgrades and rainwater bladder installation can be adjusted if the community is able to supplement rainwater capture with groundwater harvesting. It is recommended that both rainwater and groundwater solutions are implemented to enable system redundancy in the event of poor rainfall seasons or local system failures (e.g., bladder leaks or contamination events).

Given the information presented, our solution would suggest that priority should be given to utilising and enhancing existing roof collection capacity to meet 10 L per person, per day demand first, followed by the addition of a ground water supply that would allow the most cost-effective provision to meet a consistent 50 L demand under dry conditions.

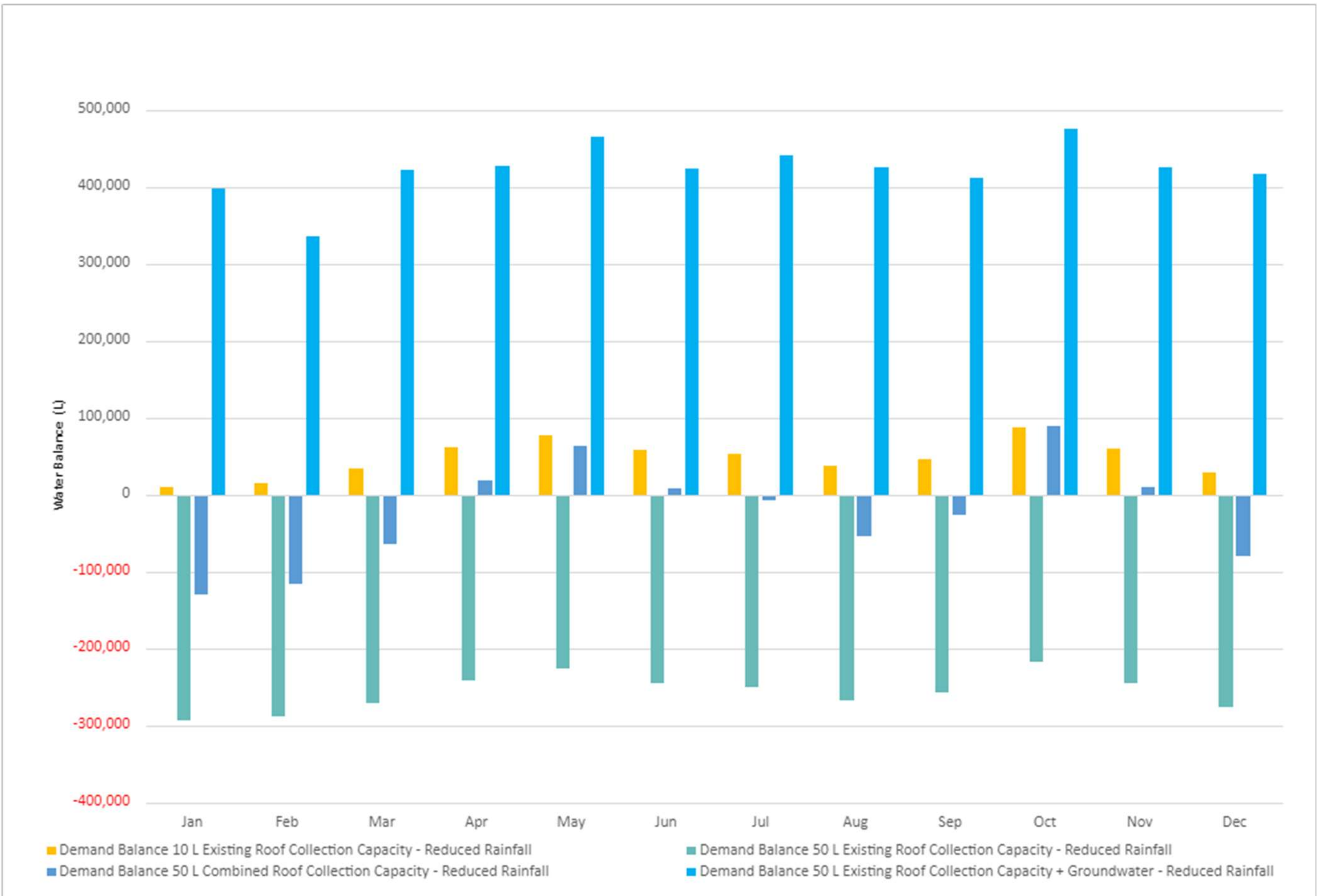

Figure 7: Water demand balance under various demand and supply options during reduced rainfall conditions.

Appendix 2 – Satellite Imagery of Western Village

Figure 8: Satellite imagery of western village on Tarawai Island.

Appendix 3 – Solar Power Justification

Table 1 outlines the benefits and limitations when choosing solar as a power source for pumping groundwater.

Table 1: Benefits and limitations of using solar as a power source for pumping water.

Benefits	Limitations
1. **Environmentally Friendly:** Solar pumps operate using renewable energy from the sun, producing no greenhouse gas emissions during operation. 2. **Reliability in Sunny Areas:** In regions with ample sunlight, solar pumps provide reliable and consistent water extraction. 3. **Low Maintenance:** Solar pumps have fewer moving parts compared to windmill pumps, resulting in lower maintenance requirements and costs. 4. **Scalability:** Solar pump systems can be easily scaled up or down by adding or removing solar panels as water demand changes. 5. **Remote Operation:** Solar pumps can operate independently from the electrical grid, making them suitable for remote locations.	1. **High Initial Cost:** While costs have decreased, solar pump systems still require a significant initial investment in solar panels and the pump system. 2. **Dependent on Sunlight:** Solar pumps require adequate sunlight to operate effectively, which may limit their functionality in cloudy or shaded areas. 3. **Potential for Seasonal Variability:** Seasonal changes in sunlight intensity can affect the pump's performance, especially in regions with distinct seasons. 4. **Limited Night Operation:** Without storage solutions or backup power, solar pumps cannot operate at night or during periods of low sunlight. 5. **Battery Requirements:** For off-grid applications or nighttime operation, solar pumps may require battery storage, adding to the initial cost and maintenance

Appendix 4 – Cost Estimates

Table 2 shows a breakdown of estimated costs to install rainwater bladders for enhanced rainfall capture, per dwelling, illustrating the cost estimate for 10 L and 50 L demands. Two scenarios are priced out:

- Upgrading 9 structures with existing metal roofs with downpipes and water bladders at ~$56,000 AUD.
- Additional upgrade of 17 structures with metal roofing, downpipes, and water bladders at ~$211,000 AUD.

Table 2: Rainwater Collection Solution Cost Estimate.

Rainwater Collection *(all prices in $AUD)*		Min 10L/person/day		Max 50L/person/day	
Item Description	Unit Cost	# units	subtotal	# units	subtotal
Metal Roofing	$2,050	0	$0	17	$34,850
Existing roof repair cost (i.e. patching, replacing)	$205	9	$1,845	0	$0
% new to fix existing	10%				
Roofing Screws	$90	0	$0	17	$1,530
Sealant	$133	9	$1,197	17	$2,261
PVC Guttering	$504	9	$4,536	17	$8,568
PVC Gutter Bracket	$124	9	$1,116	17	$2,108
PVC Gutter Stop End	$22	9	$198	17	$374
80mm x 3m Round Downpipe	$473	9	$4,257	17	$8,041
Various pipe fixings	$300	9	$2,700	17	$5,100
Rainwater Bladder (2 x 10,000L or similar volume)	$3,200	9	$28,800	17	$54,400
Transport of equipment (banana boat)	$1,000	9	$9,000	17	$17,000
Transport to north PNG from distribution hub (new roof)	$1,000		$0	17	$17,000
Transport to north PNG from distribution hub (existing roof upgrade)	$250	9	$2,250	17	$4,250
Estimated Total			**$55,899**		**$211,381**

Rainwater Collection Costing Assumptions

- Existing roofs do not have gutters, downpipes, etc., which would need to be installed to improve rain capture efficiency.
- Existing roofs may require repairs for optimal rainwater capture, estimated as % of new metal roofing.
- New AND existing roofs will require bladders, as current capture is primarily via small tanks and barrels (sub-optimal, limited volume).
- Labour/installation will be provided by charity/NGO e.g. Engineers without Borders Australia, WaterAid or WaterAid affiliates.
- Transport to north Papua New Guinea would be via ground (i.e. truck).

Table 3 shows a breakdown of estimated costs to locate, drill, line, and install a pumping system for bore water (underground aquifer) access. The proposed solution would address the needs of both the 10 L and 50 L per person, per day demands. There are several advantages to the system, including:

- Designed to access bore water up to a 100m depth, designed based on over-capacity (~10x required volume), to significantly lower system failure risks.
- Sufficiently sized to accommodate upgrades to a pumped and piped reservoir-based solution discussed in the main document.
- Double redundancy across all electrical aspects, to ensure continued operation during a single system failure, while also providing a hand pump as further backup in case of total failure.

Table 3: Groundwater Solution Cost Estimate.

Groundwater Pump (1x borehole up to 100m depth) *(all prices in $AUD)*	**Min 10L/person/day**	**Max 50L/person/day**
Remote well drill cost (max cost in QLD x 2)	$20,314	$20,314
Piping (PVC or Cement) (included in installation costs)		
Pump (electric) (500 kPA)	$4,843	$4,843
Housing for Pump (small shed)	$290	$290
Solar Panel (pump power) (1.5 kW required) (install 2x for redundancy)	$5,600	$5,600
Inverter (up to 3 kW) (install 2x for redundancy)	$918	$918
Backup Hand-Pump (Oxfam blue pump, up to 100m borehole compatible)	$2,982	$2,982
Remote installed hand pump (price estimate x 2)	$4,000	$4,000
Total	**$ 38,947**	**$ 38,947**

Groundwater Pump Costing Assumptions

- Groundwater is of sufficient quality and quantity to support the community as an alternative water source (further investigations to occur to confirm groundwater resistivity survey results).
- Single industrial grade pump at 10x indicated volume, oversized to run at low capacity (extend life) with built in electrical system redundancy.
- Borehole drill and lining costs are based on remote QLD install, at maximum of cost range, adding 2x remote install factor.
- Transportation is included in install cost, covered by remote factor, with borehole services provided by more local drill rig operators.
- Pump would only run on as needed vs. continuous cycle (i.e. button press to dispense standard volume).
- All systems are over-designed to improve operating life and lower maintenance requirements.
- Design includes robust hand-pump as backup if 2x redundancy fails on any system.
- Pump runs on 240V, 50hz, inverter from 12v solar required.

Reference List

[1] World Health Organisation [WHO] (2020). Domestic water quantity, service level and health [Second Edition]. World Health Organisation. https://iris.who.int/bitstream/handle/10665/338044/9789240015241-eng.pdf?sequence=1

[2] Bureau of Meteorology [The Bureau] (2024a). Pacific climate change site data [Summary Data]. Bureau of Meteorology. http://www.bom.gov.au/cgi-bin/climate/pccsp/site_data.cgi?download=%2Fweb01%2Fncc%2Fwww%2Fpccsp%2FPNG_000003_Rain.csv&ts_period=monthly&data_source=raw&variable=Rain&period=monthly&s_yr=1923&e_yr=2015&ave_yr=T&unit=A&nat_id=PNG&station=000003

[3] Dore, D. (2021). Climate Impacts on Pacific Water Security and Water Resource Management: A Stocktake of institutional settings and management challenges in eight Pacific Island countries. A report for the Australia Pacific Climate Partnership.

[5] Water for Women Fund (2020). Inclusive WASH and climate adaptation in Wewak, Papua New Guinea. Water for Women Fund. https://www.waterforwomenfund.org/en/news/inclusive-wash-and-climate-adaptation-in-wewak-papua-new-guinea.aspx

[6] Bureau of Meteorology [The Bureau] (2024b). Monthly mean rainfall – Wewak W.O. [Summary Data]. Bureau of Meteorology. PNG_000003_Rain_ave.26106.png (640×480) (bom.gov.au)

[7] Climate Change Knowledge Portal, World Bank Group. https://climateknowledgeportal.worldbank.org/country/papua-new-guinea/climate-data-historical