THE VANUATU CLIMATE RESILIENT ROAD STANDARDS PROJECT



An initiative funded by the PACCSAP Program, Australian Department of Environment, in cooperation with the Government of Vanuatu

Australian Aid

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CONTENTS

ACRONYMS

ARI	Annual Return Intervals
Ausaid	Australian ODA Program
C-CAP	Coastal Communities Climate Adaptation Program - USAID funded Program
CRRS	Climate Resilient Roads Project
GIS	Geographical Information System
GPS	Global Positioning System
IDF	Intensity – Duration – Frequency curves for rainfall
LiDAR	Light Detection and Ranging
MIPU	Government of Vanuatu Ministry of Infrastructure and Public Utilities
NAB	National Advisory Board on Climate Change and Disaster Risk Reduction
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning
PWD	Public Works Department
RCP	Representative Concentration Pathways (Climate Change Emission Scenarios)
US NOAA	United States National Oceanic and Atmospheric Administration
VMGD	Vanuatu Meteorological and GeoHazards Department
VRRM	Vanuatu Resilient Roads Manual

PACIFIC-AUSTRALIA CLIMATE CHANGE SCIENCE AND ADAPTATION PLANNING (PACCSAP)

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program commenced in 2011 and ran up until June 2014. With total funding of AUD$32 million, PACCSAP has been used to assist Pacific island countries better understand and respond to climate change impacts, particularly in relation to infrastructure, coastal zone management and cross sectoral planning. The program aims to:

- Improve scientific understanding of climate change in the Pacific;
- Increase awareness of climate science, impacts and adaptation options; and
- Improve adaption planning to build resilience to climate change.

PACCSAP in Vanuatu

Cooperation between the Government of Vanuatu and the Australian Government has been imperative in the success of PACCSAP in Vanuatu. The aims of PACCSAP are being realised in Vanuatu through the following projects:

1. **Scientific understanding of Climate Change**
    - Improving National Climate Change Projections (Meteo).
2. **Awareness of Climate Science**
    - Cloud Nasara and the Climate Change (VMGD-Red Cross); and
    - Action Against Climate Change (A2C2 – PACMAS).
3. **Adaptation Planning in Key Development sectors**
    - Climate Resilient Road Standards (PWD);
    - LiDAR & coastal inundation modelling (VMGD-Lands); and
    - Cost-Benefit Analysis for adaptation (NAB).

Through these projects, the Vanuatu Government with the assistance from the Australian Government and other groups, will continue to educate its people by making them aware of the changes to come and training the communities to better manage the effects.

Snapshot of Vanuatu

The island formation of Vanuatu lies between 13°S-21°S and 166°E-171°E and includes over 80 islands. Port Vila is the capital of Vanuatu and is located on the Island of Efate. Efate is also where the Vanuatu Government offices have been established. Vanuatu has an Economic Exclusion Zone of 710,000km^2 which encompasses Vanuatu's total land area of 12,190km^2.

The largest island in Vanuatu is Espiritu Santo. Vanuatu's larger islands are characterised by rugged volcanic peaks and tropical rainforests. The highest peak, Mount Tabwernasana on Espiritu Santo is 1,877m above mean sea level.[1]

Vanuatu's climate is tropical, moderated by southeast trade winds from May to October. There is moderate rainfall from November to April and may be affected by cyclones from December to April.

Vanuatu's population in 2012 was estimated at 247,262 of which 80% live in rural areas. The majority of Vanuatu's population relies on subsistence agriculture. Its main sources are cocoa, copra and coffee exports. These contribute to Vanuatu's economy along with tourism, logging and fishing. More recently, revenue from mineral extraction may provide significant future revenue.

[1] Climate Change in the Pacific: Scientific Assessment and New Research | Volume 2: Country Reports

CLIMATE RESILIENT ROAD STANDARDS (CRRS) PROJECT OVERVIEW

The Climate Resilient Road Standards (CRRS) Project was funded directly by a grant from the Australian Government (under the PACSSAP Program) to the Government of Vanuatu. It commenced in December 2013 and was completed in July 2014. This document is a summary for policy makers and provides a snapshot of the main achievements of the project. It aims to raise awareness of the project both within Vanuatu and in the region and provide momentum for future engagement of other communities facing similar issues.

The CRRS Project forms part of a response by the Government of Vanuatu to address the current poor quality, unreliability and high cost of basic transport in Vanuatu. The project was specifically aimed at addressing ways to improve the climate resilience through adaptation options for road infrastructure across the Islands of Vanuatu.

A variety of activities were undertaken by the project team including a **review of current legal and institutional framework** for road construction across the Islands, with the aim of identifying a regulatory avenue that would ensure a standard practice for future road construction.

A number of tools as part of a **climate risk screening methodology** were developed to assist with assessment, identification and mapping of priority risk areas of the national road infrastructure network.

A set of sub national climate risk profiles were also developed detailing expected changes in key climate factors relevant for transport infrastructure design and planning. Four sites across four islands were also examined as case studies, and climate risk and adaptation assessments were carried out. The sites are detailed in this document and a range of design variables were examined including; road pavement surface types, drainage structures, coastal protection measures and bridge design.

Lastly, a set of national climate resilient road standards and construction guidelines for Vanuatu – the "Vanuatu Resilient Roads Manual" - was developed. This is a significant achievement for the CRRS project providing a manual with climate screening tools that ensures climate risk is taken into account in road project identification, formulation and execution.

Key Steps in CRRS Project

SUB NATIONAL CLIMATE PROFILES

The Sub National Climates Profiles were prepared as part of the CRRS Project for four islands of Vanutau - Ambae, Pentecost, Malekula and Tanna. The profiles provide background information on climate covering rainfall, temperature, relative humidity, and wind speed.

Separate climate projections are included for each island; with climate projections performed utilising PACSSAP Data; Pacific Climate Futures (for risk assessments); RX1Day data; Intensity – Duration – Frequency (IDF); Return Periods; Downscaling; Daily Rainfall; and Hours of Bright Sun.

A thorough analysis of the observed and projected climate variables was an essential component of the Sub National Climates Profiles. These profiles will serve as guidelines for planners and decision makers in planning for and implementing projects for the four islands, particularly those involving infrastructure development.

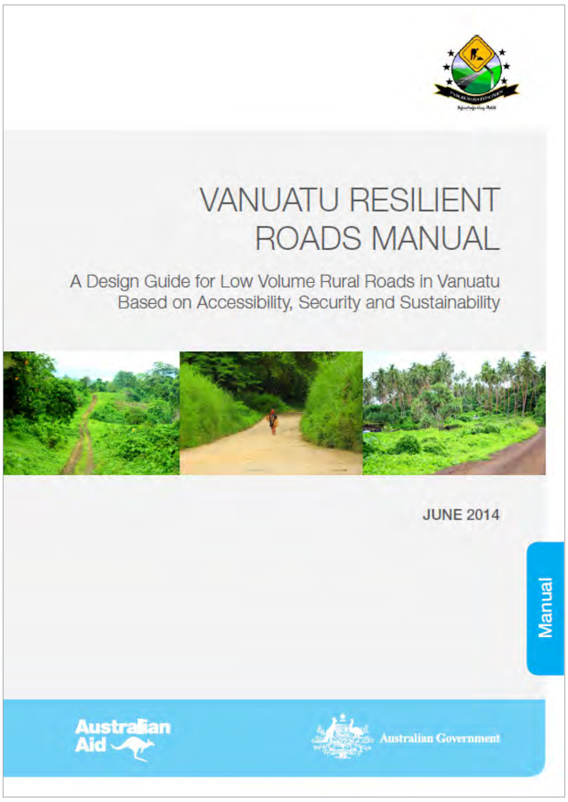
VANUATU RESILIENT ROADS MANUAL

In Vanuatu, there are just over 2,500 kilometres of public roads with 83% (around 1800 km) spread over 8 main islands. Most of the public roads network already exists and there is a low demand for new roads.

The Government of Vanuatu Ministry of Infrastructure and Public Utilities (MIPU), Public Works Department (PWD) have responded to the need to develop and promote appropriate methods of road engineering that give the best possible access to communities at minimum cost through the Vanuatu Resilient Roads Manual (VRRM). This manual has been developed with assistance from the Australian Government, and is an initiative of the Australian Aid funded Vanuatu Transport Sector Support Program Phase 2 (VTSSP2) and PACCSAP funded Climate Resilient Road Standards Project.

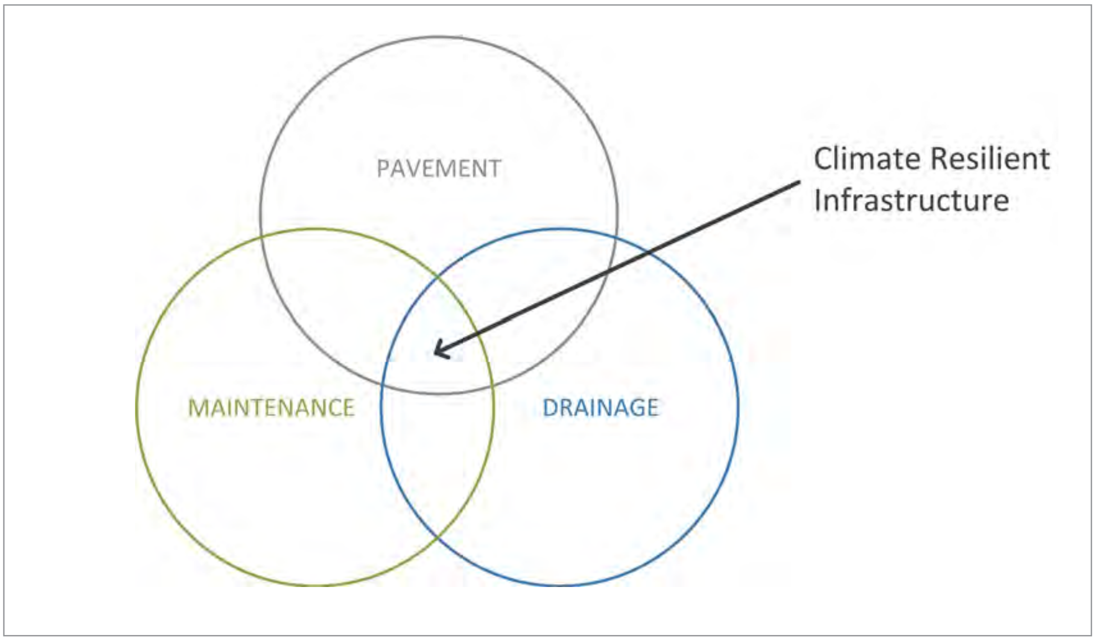
The VRRM addresses the current situation, where there was previously no unified standard for road design work in Vanuatu, as well as a lack of attention to climate resilient design. As Vanuatu is vulnerable to extreme weather, it is critical that its road infrastructure is more climate resilient.

The VRRM is a significant step forward to addressing issues in future road design and maintenance.



The Vanuatu Resilient Roads Manual (VRRM) provides a set of national climate resilient road standards and construction guidelines.

This VRRM has been prepared for use by PWD across the rural road network in Vanuatu. Standard specifications are included in the VRRM which will be made available to private sector design consultants.



A NEW APPROACH

The traditional approach for road design generally considers traffic parameters (volume and type) to address security and sustainability aspects. However, for low-volume roads such as those in Vanuatu, innovative solutions or a new approach are needed to challenge the conventional assumptions regarding road design criteria.

Low-volume roads are more affected by rainfall (erosion, landslide, overflows, etc) than by traffic.

The VRRM addresses the concept of an appropriate, or locally environmentally optimised design approach, providing a practical way forward. Low volume road standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms.

The approach in VRRM considers:

- Availability of funds;
- Local technical capacity; and
- Social impacts.

The Government of Vanuatu Public Works Department is responsible for significant lengths of low volume roads. On this basis, a Road Classification System for Vanuatu is proposed to ensure consistency in the management (design, maintenance, etc.) of the road network across the range of roads on all islands. This is complemented by:

- The VRRM with Standard Drawings and Standard Specifications;
- Procedures to monitor the performance of road conditions for the various road types and appropriate intervention levels to set priorities for scheduling road maintenance works; and
- Periodic training for local contractors and inspectors in order to allow the implementation of all the above.

Design Approach for Road Classification System

The key principles for the classification and design approach proposed are summarised in the table below.

	Based On	To Achieve	Design Parameter
Accessibility	Road function, climate	The right management of accessibility and mobility to communities and users	River crossing, all design aspect (for all weather roadway access)
Security	Traffic of vehicles and pedestrians, slope, climate	Security for all users (geometry)	Geometry, pavement, drainage design
Sustainability	Traffic of vehicles, slope, climate	Resilient when flood or other environmental event occurs, and better value for money	Geometry, pavement, drainage design

CLIMATE SCREENING

A screening process for ‘Climate Resilience’ was included in the VRRM which considers the following key design aspects of a road:

- **Fit for Purpose** - given the low number of vehicles using roads in Vanuatu, and the low axle weights, in most cases roads will be unsealed.
- **Extreme weather events and over design** - this may require some overdesign (and increased costs) now but this is offset against potentially higher costs avoided later.
- **Existence value** – in most cases in Vanuatu it is hard to justify expenditure on roads based on present and future traffic volumes. A conventional economic appraisal would return a negative value. However, in Vanuatu roads perform many functions other than for vehicles. While the social value of roads is difficult to quantify, the VRRM acknowledges that there are both social and economic benefits in having communities interconnected to key community infrastructure (e.g. schools, hospitals, markets) as well as job opportunities to reduce poverty alleviation.
- **Alternative Alignments** - even if it involves longer travel time an alternative route will still provide access for a medical emergency or for disaster relief.
- **Pedestrian Bridges** - If temporary road closure for vehicles is anticipated due to flooding, a combination of a pedestrian bridge in the vicinity of a stream crossing may be viable. Signage will act as a warning, but a footbridge will still allow connectivity in an emergency without entailing excessive additional cost.

Ambae

Malekula

Tanna

Tanna

A CLIMATE RESILIENT ROAD

The figure below shows what can be considered a "good" design for a climate resilient road. In an "ideal world" this is the design that would be followed. However, in Vanuatu the situation is far from ideal.

"A climate resilient road correctly designed now is no different to a climate resilient road in 2050.[2]

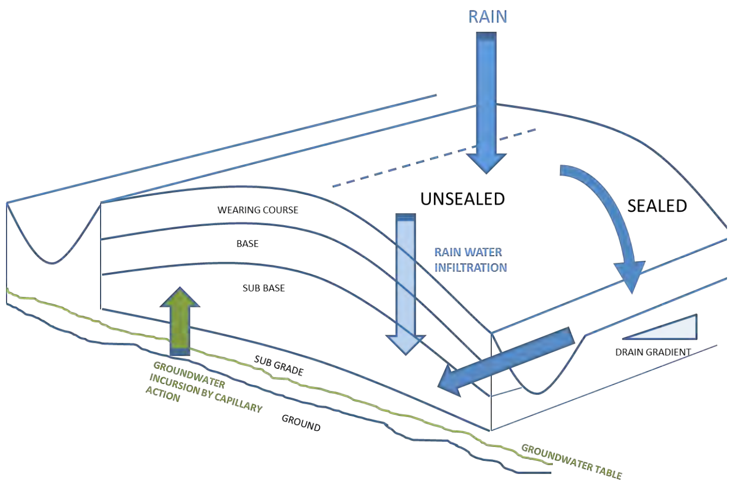
It is generally accepted that "$1 of preventive maintenance equals $5 of repairs".[3]

The performance of a road can be defined in terms of its connectivity. Ideally a road should be an all-weather road, passable in all weathers, including extreme weather events. In Vanuatu, at present, this is an unrealistic expectation. Given the present constraints in Vanuatu it was accepted that roads may be closed at times. If this closure time is limited to a few hours, this should be acceptable to the community.

If a road is permitted to be closed for a short period of time due to flooding, it must be structurally sound when the floodwaters recede.

The other main considerations for climate resilient infrastructure are vulnerability to:

- **Sea level rise –** in Vanuatu this is currently measured to be 6 mm per year and this will probably continue at, or around, this rate in the future.
- **Time horizon -** due to the permanent nature of coastal infrastructure such as walls or jetties, a life cycle of 50 years should be considered. For coastal roads a life cycle of at least 20 years should be considered.
- **Storm surges –** these are a common occurrence in Vanuatu resulting in overtopping of coastal roads. Wave heights are driven by wind speed and "fetch" so are hard to predict but any coastal locations currently experiencing flooding during storms will experience more severe events in the future.
- **Rainfall –** in Vanuatu this will become more intense, of shorter duration but may happen more often.
- **Temperatures -** will increase in Vanuatu with longer periods of drought also expected.



The above figure shows what can be considered a "good" design for a climate resilient road in an "ideal world"

[2] World Bank "Making Transport Climate Resilient" Country Report: Ethiopia, August 2010
[3] Infrastructure Maintenance in the Pacific, Pacific Region Infrastructure Facility, 2013

CLIMATE SCREENING TOOLS

1. Vulnerable Areas Screening

Vulnerability maps were produced under the CRRS project to enable calculation of run off in a quick and easy manner, identification of flood prone areas, steep slopes and areas close to eroding coastlines.

The VRRM also sets the following guidance for identifying vulnerable roads:

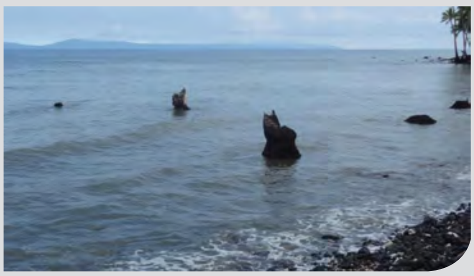
- Close proximity to shoreline where erosion is self-evident;
- Close proximity to shoreline where overtopping by storm waves is known to occur;
- Flat areas prone to flooding which take a long time to dry out;
- Steep gradient > 10%;
- Road below steep slopes prone to landslides; and
- Roads crossing water courses.

A vulnerable steep muddy road

A climate resilient road in Tanna

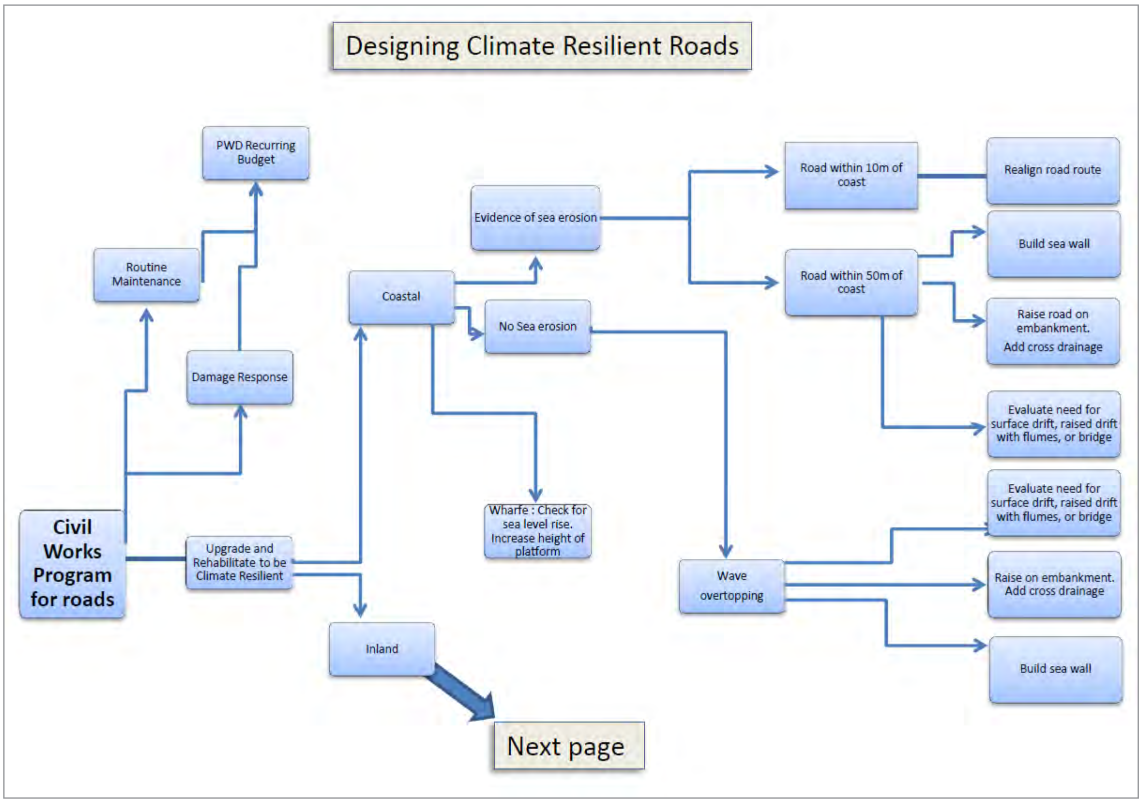
Evidence of Coastal Erosion

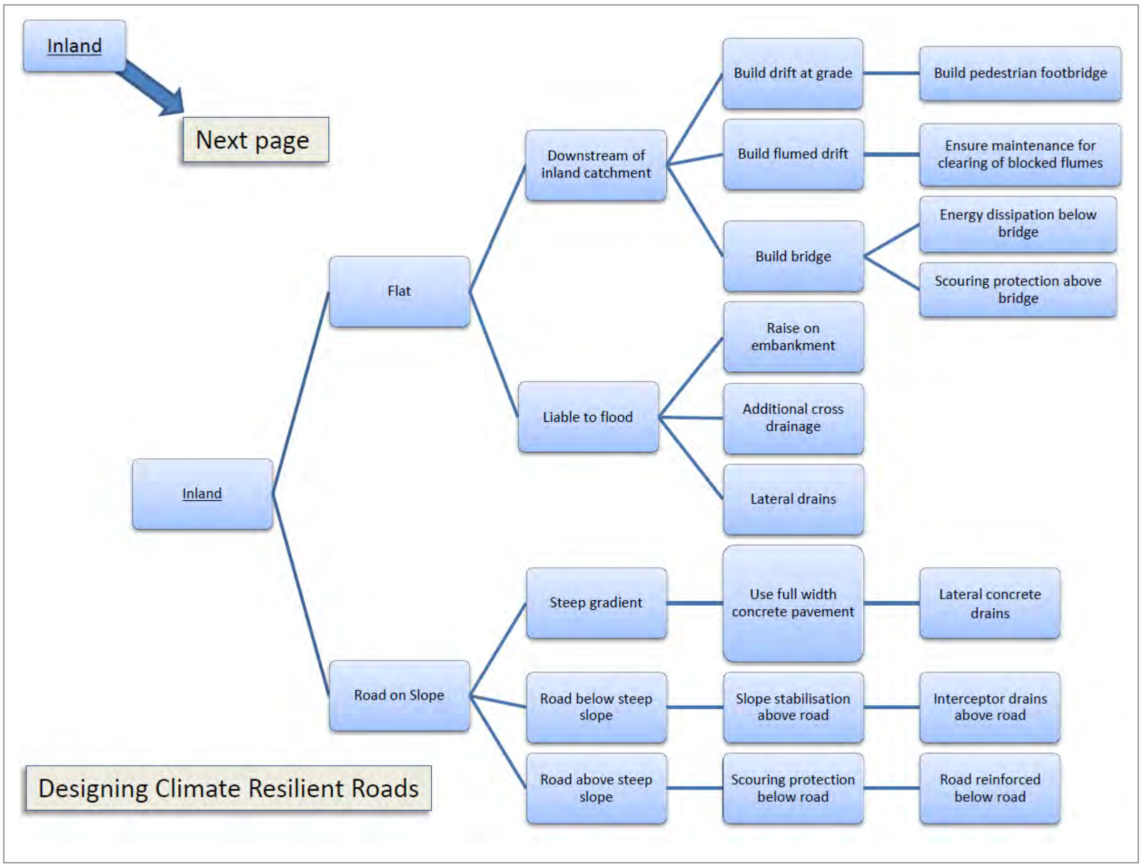
Although coastal erosion is not necessarily attributable to climate change it makes coast lines more vulnerable to sea level rise and wave overtopping.



2. Decision Tree Analysis

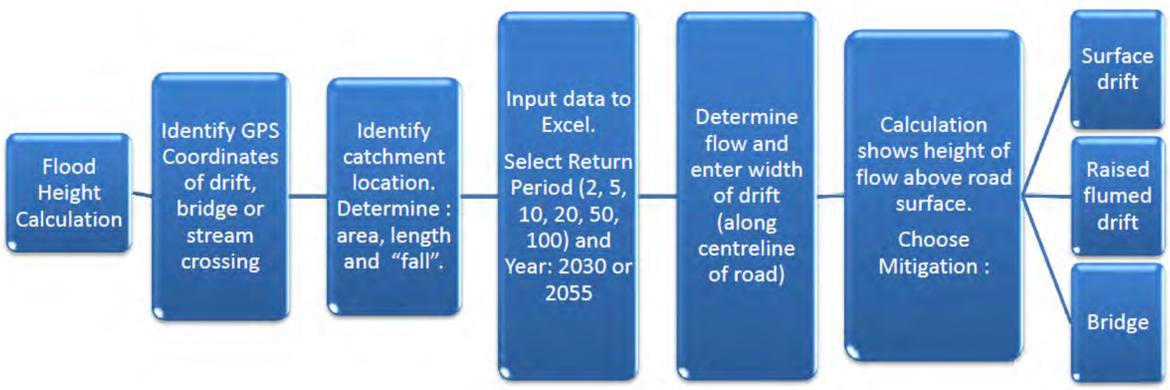
Climate risk screening steps are included in the VRRM and were developed by the CRRS Project. They were developed to provide guidance for planners, engineers and decision makers. Using a simple tool, they provide an effective guide and checklist when designing resilient new roads, or rehabilitating existing roads, to be climate resilient.





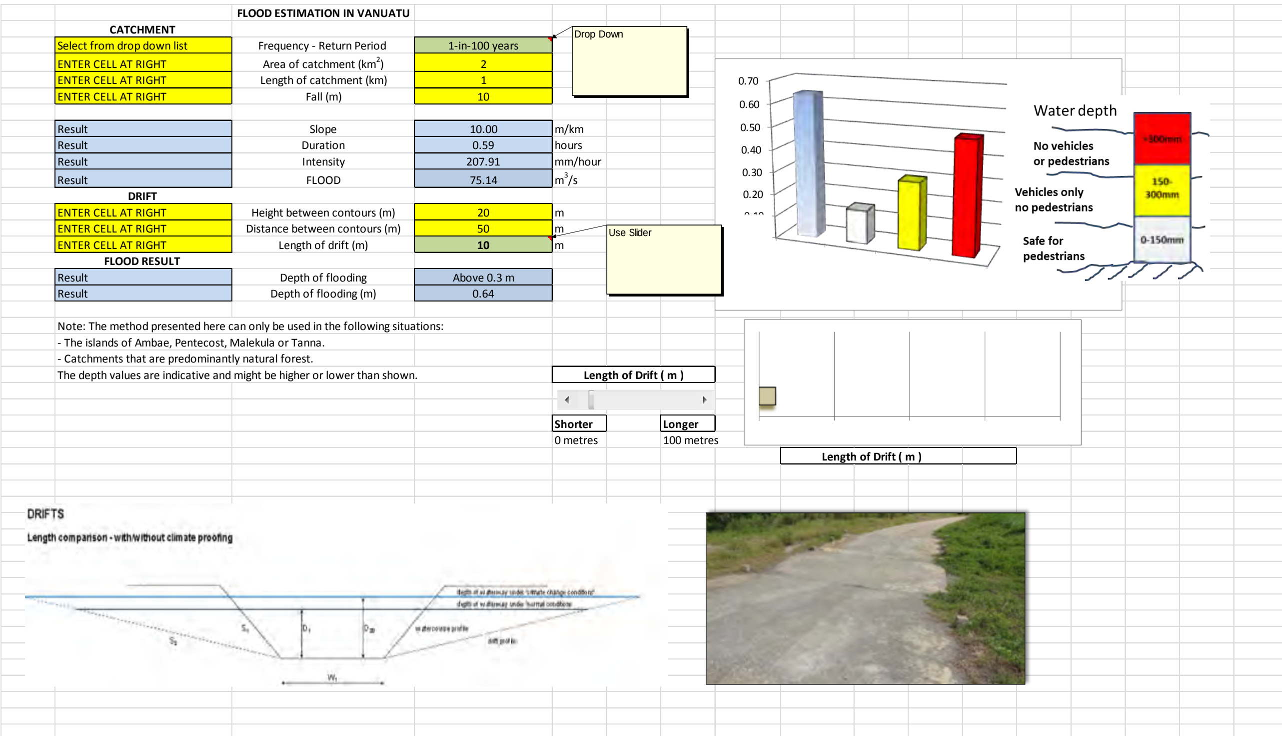
3. Flood Height Calculator

A tool for calculating flood height across a drift was also developed by the CRRS Project and included in the VRRM. The model is a simplified version of the rational method of calculating the Intensity, Duration and Frequency (IDF) curves for the Vanuatu context. This tool is linked to the Geographic Information System (GIS) that was also developed in PWD as part of the CRRS Project.



Flow chart for calculating height of flood over drift

A screenshot of the EXCEL file is shown below. Varying the length of the drift will alter the flood height and this, combined with the selection of various Return Periods, will allow "What-if" Scenarios to be simulated.



FLOOD ESTIMATION IN VANUATU

CATCHMENT			
Select from drop down list	Frequency - Return Period	1-in-100 years	
ENTER CELL AT RIGHT	Area of catchment (km^2)	2	
ENTER CELL AT RIGHT	Length of catchment (km)	1	
ENTER CELL AT RIGHT	Fall (m)	10	
Result	Slope	10.00	m/km
Result	Duration	0.59	hours
Result	Intensity	207.91	mm/hour
Result	FLOOD	75.14	m^3/s
DRIFT			
ENTER CELL AT RIGHT	Height between contours (m)	20	m
ENTER CELL AT RIGHT	Distance between contours (m)	50	m
ENTER CELL AT RIGHT	Length of drift (m)	**10**	m
FLOOD RESULT			
Result	Depth of flooding	Above 0.3 m	
Result	Depth of flooding (m)	0.64	

Note: The method presented here can only be used in the following situations:
- The islands of Ambae, Pentecost, Malekula or Tanna.
- Catchments that are predominantly natural forest.

The depth values are indicative and might be higher or lower than shown.

PRACTICAL APPLICATIONS OF CLIMATE RISK SCREENING AND CLIMATE CHANGE ADAPTATION

The following case studies are examples of how the climate risk screening assessment tools developed by the CRRS Project have been used across Vanuatu.

Case Study 1 - Wiana Village, Emao Island

Background

The villagers of Takara are a common community that actually live in two villages – Takara on Efate and Wiana on Emau island 5kms offshore from Takara. During public consultation for a proposed geothermal project in Takara, the villagers of Takara raised what they considered to be a climate change issue, coastal erosion.

Assessment

There is strong evidence of coastal erosion on the beach facing Takara. Erosion rate is high, possibly 0.5 metres per year and this is encroaching on the village, including the graveyard and key community infrastructure, a cyclone shelter, built by villagers.

Based on data obtained from US NOAA, Vanuatu is in an exposed position receiving extreme waves from a southeast direction. The erosion being experienced at Emao Island, is also known to be occurring elsewhere in Vanuatu.

The response to this issue was multi-agency. Resources from PWD, PWD Shefa and Shefa Provincial Council engaged with the local community to develop a coordinated response and action plan. As a result Emao Island is now included in the USAID funded C-CAP Program. Funding and assistance is being given to the village to reinforce infrastructure and coastal defences. The local community are participating in the process and will provide labour and materials for the seawall construction.

This is an excellent example of multiple stakeholder interaction and engagement with the community to tackle climate change issues. This example has provided PWD with a community engagement model, which it intends to replicate in other coastal communities in Vanuatu affected by coastal erosion.

Areas in Wiana Village encroached by the sea

Case Study 2 - Ambae Island – Manifold GIS

Background

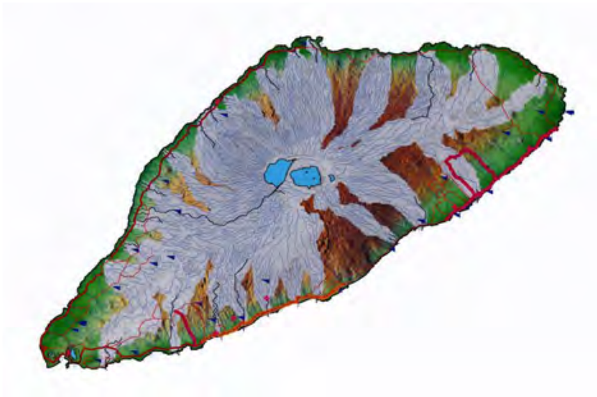
A number of road upgrades are planned for Ambae Island, specifically on the northern shoreline roads. (See orange line in the map below) Ambae is characterised by mountainous terrain and as a result many streams cross roads.

Assessment

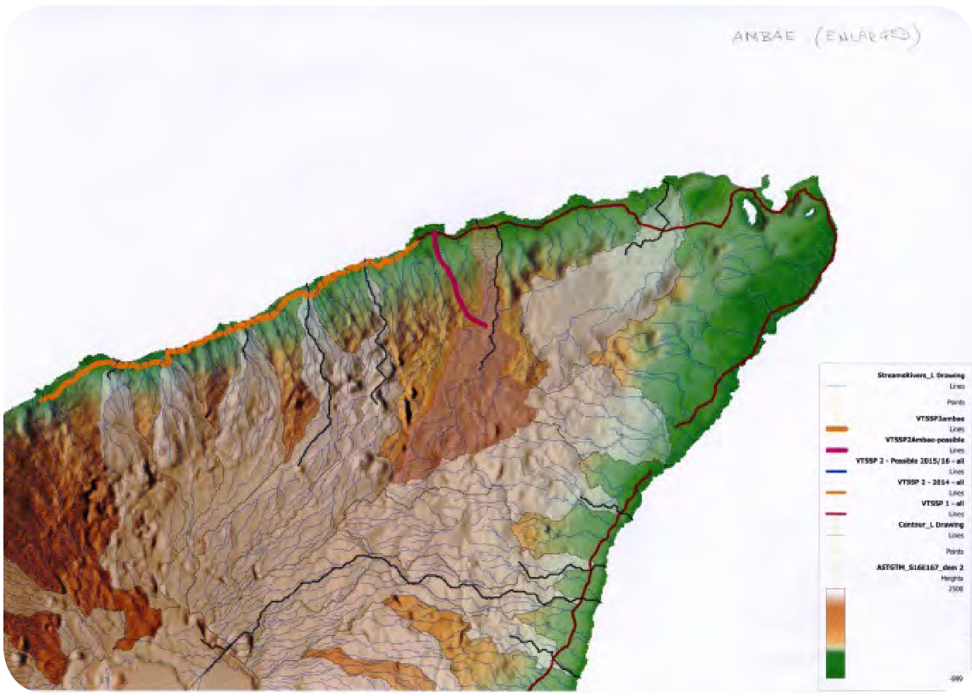
A number of crossing points are subject to flash floods with rising flood waters making the roads impassable.

For road planning purposes, the height of a flood that is likely to occur both now and in the future under different climate change scenarios was modelled.

Normally this would require complex hydrological calculations but this has been simplified so that planners and engineers can make assessments that are rapid yet based on good science and robust assumptions.



In this instance screening for climate change impacts used in-house “Manifold” GIS software. The topographical map of Ambae has been divided into catchments and the areas of these catchments calculated. This allows major streams to be identified (shown by thick black lines on the map) and the exact point where they intersect the road to be specified in terms of GPS coordinates. Rainfall data for future climate change scenarios (RCPs) and projected years (2030 and 2055) has been calculated with ARIs (Annual Return Intervals) of 1 to 100 year events. ARIs can be selected in the model and the dimensions of the crossing varied to show different flood heights using the Flood Height Calculation Tool also developed by the CRRS Project.



Northern shoreline of Ambae Island

Case Study 3 - Mangaliliu Village, Efate

Background

Mangaliliu is a small coastal village northwest of Port Vila. It is connected to the Efate Ring Road by a short spur road of about 2 kilometres in length. The road is in poor condition and is very steep. Access to the main ring road in poor weather is difficult, especially for village children who have difficulty crossing the stream to get to school during heavy rain.

Assessment

A feasibility assessment was undertaken to identify how the standard of the road could be improved.

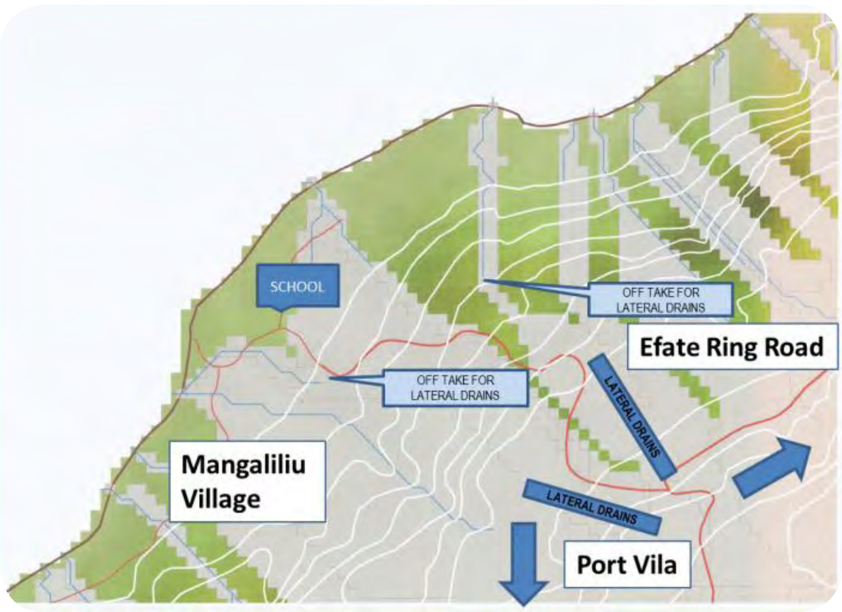
Digital Elevation Model (DEM) data was used to establish contours and from this the gradient of the roads sections was determined. A detailed examination of the contours aided in the design of the drainage system, as it identified offtakes from the road drainage. This avoided designing a road that directed flood waters to the village school.

Ground truthing was also carried out to confirm the veracity of the GIS data.

The design solution was that where gradients were in excess of 8% concrete slabs were to be used. The use of textile reinforced concrete rather than steel reinforced concrete, reduced costs by 50%.

Twin lateral drains were considered essential but costly. An alternative option using hand grouted stones placed by local labour again reduced costs.

The use of DEM data enabled a more focussed approach to the site survey, identified off take drains and quickly gave indicative costs.



Mangaliliu is a small coastal villa northwest of Port Vila

Case Study 4 - Manples Junction, Efate

Background

The junction at Manples, the main road to the airport in Port Vila, is prone to regular flooding. Flooding has become a nuisance to residents and often the subject of media attention in Vanuatu.

Assessment

To assess this issue more fully, Light Detection and Ranging (LiDAR) data was used. LiDAR surveys provide high resolution elevation data for low lying areas of Efate, Malekula and Santo. This technology was funded by the Australian Government and will become a significant asset for Vanuatu to improve coastal planning and management.

It has multiple applications, including:

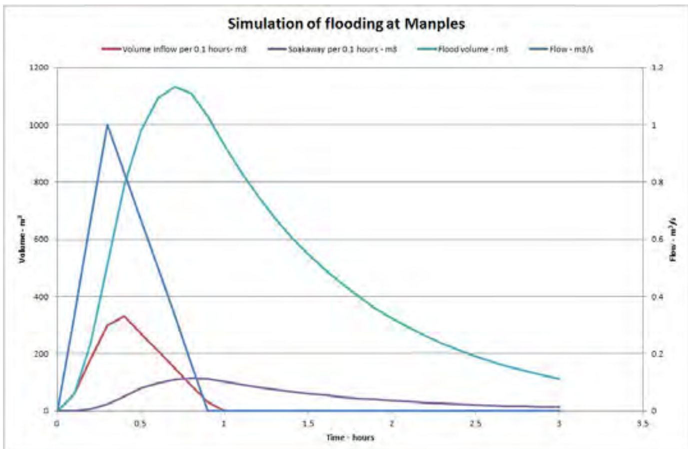
- Coastal flooding, tsunamis, and sea-level rise;
- Land administration;
- Disaster preparedness and planning; and
- Marine, transport, and commercial development.

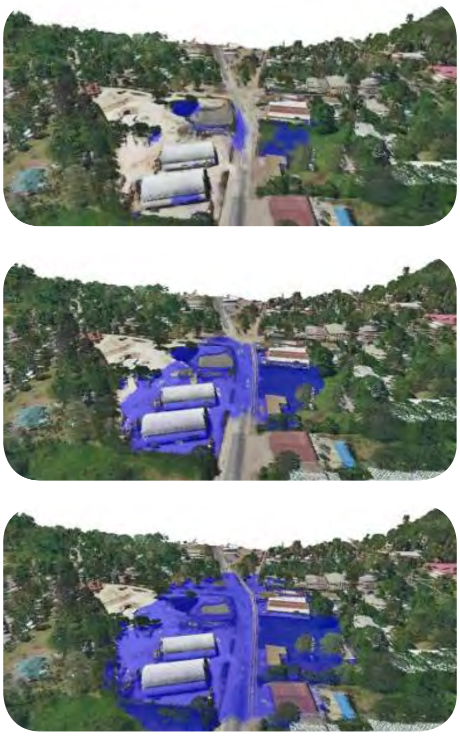
Under the Port Vila Urban Development project, options to alleviate flooding on the road to the airport are being examined. Options studied included soakways, pumping stations and a tunnel costed at US$3 million.

The road profile was established and low lying areas identified. Hydrological calculations provided rain water inflows and outflows plus ground infiltration rates. These gave the peak flow values.

PWD downloaded the LiDAR data which provided vertical elevation contours at 0.5 meter intervals. A 1 in 50 years flooding event was simulated.

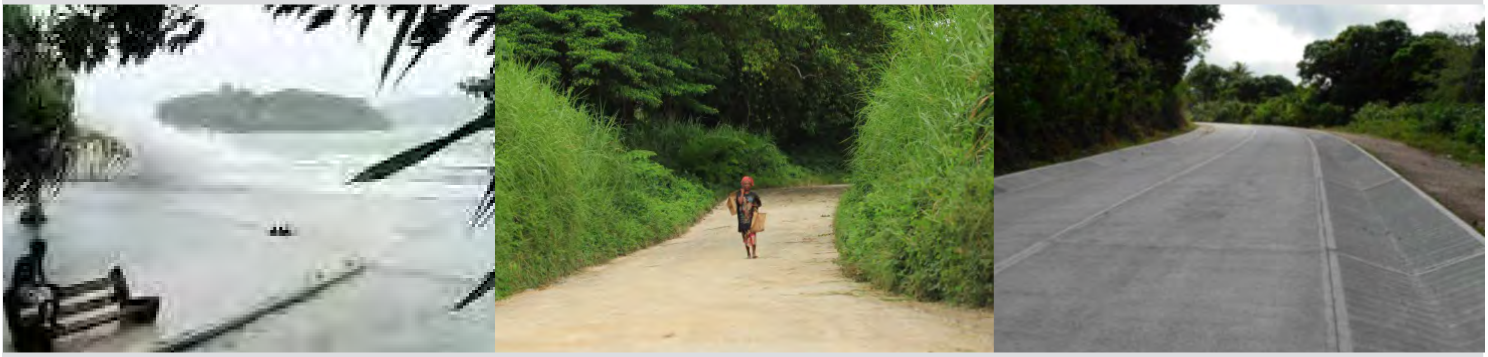
This showed that the extent of flooding along the road would be around 200 metres in length to a depth of half a metre. It was concluded that the road should be lifted 0.5 to 1.0 metres.





Flooding simulation of Manples Junction, Efate

Local People. Global Experience.



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