

Monitoring of coastal hazards zones in Samoa

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Samoa islands will continue to be subject to significant adverse effects from coastal hazards and an increase in the frequency and magnitude of tropical cyclones from time to time. Coastal hazards such as landslip, erosion and flooding from the sea mostly occur and affect the coastal areas of Samoa (CMCL, 2001).

There have been significant climatic events that have occurred since the study in 2000 for instance, flooding from heavy storms in April 2002 and cyclone Heta in January 2004. The 'Very High' sensitive areas to coastal hazards identified in the 2000 study noted severe impacts as a result of those events.

The Ministry of Natural Resources and Environment (MNRE) was directed and engaged to revisit and monitor the coastal areas of Samoa to identify changes and significant effects since the last five years. The result and findings from this survey will be reported to the Steering Committee of the World Bank's Second Infrastructure Asset Management Project as part of sub component on Environmental Risk and Resources Management.

Background

In the year 2000, the Coastal Management Consultancy Ltd were engaged by BECA International Consultants Ltd (BICL) to produce Coastal Hazard Zone (CHZ) Maps for the whole of Samoa, inclusive of the islands of Manono and Apolima. One of the major outputs from this project was the development of the Coastal Hazard Database (CHDB) and the Coastal Sensitivity Indices (CSI) now available for the Government of Samoa.

In the CHZ Mapping Final Report (Ibid) one of the recommendations stated that there is a need for a monitoring programme to track the changes on coastal areas from erosion, flooding and landslips.

The first study conducted in the Infrastructure Asset Management Project Phase 1 (IAMP1), there were 276 CHZ stations established for the entire 573 kilometers of the coastline of Samoa. Because of limited resources and constraints for this study, 50 Stations from 'High' to 'Very High' sensitive areas were selected to identify changes on an estimated length of 103 km.

Purpose

The main purpose of this study was to revisit and monitor areas of the coastal hinterland that have relatively high sensitivities and have been subjected to natural coastal hazards over the last four years.

Objectives

The primary objectives of this monitoring study are to:

- identify and quantify effects since the first study conducted under IAMP1 in 2000, and

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- to provide quantitative data to review the Samoa CHZs constructed and established in 2000

Table 1: Summary of the monitoring programme conducted in 2004 in comparison to the previous study in the year 2000

Study	Length of coastline (km)	Islands visited	Number of stations	Village interviews	Staff involved
Year 2000	573	8	276	347	13
Year 2004	103	4	50	24	9

Methodology

The methods adopted for Coastal Hazard Zone Monitoring programme in this study involved 2 main steps:

- Data collection of 50 stations
- CHDB assessment

The CHDB methodology used in this study was primarily developed by Dr Jeremy Gibb of the Coastal Management Consultancy Limited in 2000 (CMCL, 2000a). The CHDB provides the starting point from which the coast at each of the 50 Stations is ranked by CSI according to its sensitivity to coastal hazards. The 2000 Samoa CHZ Stations were then compared against findings of this Coastal Hazard Zone Monitoring Programme 2004. The methods have proved to be appropriate for the coastal environment and provide consistent results, moreover it will be treated as an MNRE model to continue with the implementation and monitoring works of the coastal hazards in Samoa.

In the execution of field data collections involving 24 people interviewed, an opportunity was taken to both accept the observations of reliable observers and raise public awareness in the villages on CHZ issues.

Data collection

With respect to the 276 CHZ Stations identified in the CMCL Report (2001), only 50 CHZ Stations were selected for purposes of this study.

The Stations selected ranged from 'Medium' to 'Very High' sensitivities. This ensured that the monitoring programme acquires broad coverage of areas likely to be affected by climatic events and to provide the Team with a general understanding of the coastlines surveyed. Generally the Stations provide a general and reasonable representation of the coastal areas. The selection of CHZ Stations predominantly focused on 'High' and 'Very High' sites. The selection process included B12 Utualii (Malua, Upolu) despite its 'Medium' CSI value. The justification for this inclusion is based on the concern that road infrastructure at this Station is a vital lifeline for the country and according to reports this segment of coastal infrastructure sustained significant impacts from cyclone Heta. Generally, continued uses such as road and utility infrastructure along the North Western Upolu corridor require special attention.

Table 2: Percentage of CSI classes selected for this study

CSI	Very Low	Low	Low	High	Very High
Totals	0%	0%	0%	36%	62%

Data on 50 Stations were collected in this study from the combination of field surveys, village interviews (anecdotal information) and analysis of survey data. Field data were

collected between 29 July and 3 September 2004 at the 50 Stations, the locations of which are given in Appendix I.

Given this programme is a general monitoring study of the coastal environment the hazards that were given priority was CEHZ and CFHZ. Areas Sensitive to Coastal Hazards (ASCH or multi-hazard (sea cliff retreat, landslip, and storm tide overtopping) areas and CLHZ were considered beyond the scope of this study largely due to resource constraints.

Field observations

The field team comprised 3 to 5 persons at all times and was led by Jude Kohlhase and Leoo Polutea. The MNRE staff involved in this study included Petania Tuala, Nomeneta Saili, Margret Rimoni, Kirisimasi Seumanutafa, Stephanie McCarthy, Seiuli Ueligitone and Malaki Iakopo.

During the 5-week period, 50 selected Stations were surveyed and 24 interviews were conducted at the 18% representative areas of Upolu, Savaii, Manono and Apolima Islands. The field monitoring programme commenced on Thursday 29 July on Upolu Island and was completed on Wednesday 3 September 2004 on Apolima Island.

Field techniques

Elevations were measured at each 50 Stations of the berm crest of the primary beach ridge and where possible, the heights reached by storm tides generated by the tropical cyclone of January 01-05 2004 Heta, the effects of which were clearly recalled by many villagers. A Zeiss Ni2 level, tripod and 5m survey staff were used together for field data collection.

The leveling survey adopted in this survey was based on the previous method used in the study conducted in 2000 where the survey datum used for each station was the intersection of the actual sea level at the time with the coast. Due to the long distances of survey bench marks allocated around the island, most of fixed origins were tied onto a permanent objects such as cemented buildings, telephone and power poles before reducing to mean sea level height.

All levels were reduced based on the Apia Tide Gauge zero of 2.0229 below bench mark 201 as a predicted tidal curves for Samoa for 2004, published by the National Tidal facility at the Flinders University of South Australia and was used to normalize all levels to Chart Datum which is the Lowest Astronomical Tide.

Orthophotomap base

Rectified contour orthophotomaps at 1:5,000 prepared in 1999 by Airesearch Mapping Pty Ltd were used for field work for this study. These rectified orthophotomap series were used as a backdrop to all the coastal hazard zone mapping.

Village interviews

A total of 24 interviews were conducted with between 1 to 3 persons at each Station during the 5-week field monitoring programme. The primary objective of the interviews was to elicit accurate information on site specific coastal hazards such as erosion and flooding from the sea which could be quantified. Some interviews provided other information on long-term changes in shoreline and coastal mitigation issues of concern to each village.

The Ministry of Women, Community and Social Development's Seiuli Eneliko Seiuli alerted pulenu'u and sui-o-le-malo at their July monthly meeting that the field monitoring programme would be undertaken. In addition, a formal letter written by Seiuli Eneliko Seiuli to all pulenuu and sui-o-le-malo was carried at all times by the survey team in the event a village or person was not prepared for the survey team conducting site investigations. In all cases the community was well warned of the survey team's visit.

The interviews were informal and usually took place around the Station where the effects of coastal hazards from cyclone Heta and past events could easily be recounted. The questions probed the interviewees for accurate accounts of erosion and flooding particularly as a result of cyclone Heta. All of the interviews were conducted in Samoan. The responses were translated into English and recorded by team members.

Case study

A 'Very High' sensitivity station at Manase was selected and revisited by the team and presented in this document. C5 station is 10m away from bridge at Saleia, Savaii [and a hard structural option was selected for this area to protect the coastline].

Details of C5 Station as previously surveyed in 2000 are outlined as follows:

According to the interviews held with the people from Manase and Saleia, this station was found severely affected by waves during the most recent cyclone Heta in 2004 and river flooding from the streams nearby in 2001.

Figure 1: Leveling work carried out at L19 station. This image illustrates part of the vertical seawall severely damaged during cyclone Heta in 2004. Petania Tuala, Senior Mapping Officer has the instrument and the chainmen with the staff. Photo taken at Vaiala Beach, Upolu.



One other significant change discovered in this area was the position of high tide which has been shifted to almost two meters inland.

During this study the nearby vegetation (coconut) used to cover the area as seen in the photographs in 2000 has been removed and sand continue eroded inland (retreat) and replaced the small swamp area used to be at this place (refer to photograph taken in 2000 and 2004).

Figure 2: CHZD data of C5 Station at Manase, Savaii

Island:	Savaii	
Village:	Manase	
CSI station:	C5	
Sheet No:	12	
Grid reference:	659909E, 5512549N	
Data collected:	21 June 2001	
Collected by:	Coastal Management Consultancy Ltd	
Variable class:	Data:	CSI
Elevation above MHWS:	1.24 m	5
Max. storm wave run-up at MWHS:	4.50 to 6.00 m	5
Gradient:	-5 to -5 degrees	5
Max. tsunami wave run-up at MHS:	4.9m in 1960	4
Lithology	Coral sand	5
Natural landform:	Barrier ridges	5
Long-term trend:	0.18 to 0.18 m/y	2
Max. short-term fluctuation:	+/- 10.00 to 15.00 m	4
	CSI =	35
	Rating =	Very High

Findings

The following is a summary of the findings during this study which indicates a total of five weeks spent in the field gathering data. The main purpose of the field programme was to monitor CHDB Stations already carried out in IAMP1. The survey focused on the Stations ranging from 'High' and 'Very High'. The actual coastline surveyed was about 18% of the total coastline length of Upolu, Savaii, Manono and Apolima Islands equating to about 103km.

Table 3: Summary of major outputs achieved during the CHZ station monitoring programme between August and September 2004

	Length of coastline surveyed	Field surveys (weeks)	Islands surveyed	CSI stations	Village interviews	Staff input
Totals	103km	5	4	50	24	9

CSIs

1. Discrepancies with some of the previous data in the past survey were found for instance:
2. Confusion over the coordinates and grid references for N1 Tiavea-tai Station which was found at Amaile Station (that was not included in this study);
3. B3 CSI class total was miscalculated therefore rated 'Low', it should have now read 'High'. This has been corrected and reflects field observations.
4. Of the 50 Stations surveyed, their CSI ranged from 'Medium' which is characterised by moderately hard rock platforms with very low erosion rates (-0.03 to -0.49m/y) to 'Very High' which in turn are characterised by low-lying sand barriers (beaches, dunes and

spits) with relatively medium rates of long-term erosion ($>2.00\text{m/y}$) and high short-term shoreline fluctuations ($>30\text{m}$), that are over topped by heavy seas (CMCL, 2001).

Figure 3: C5 station at Manase with significant vegetation growth in 2000. Note: The 8 mature coconut palms. Photo taken July 2004 by MNRE CHZ Survey Team



Coastal hazards

1. Significant coastal erosion and impacts on infrastructure is being experienced at various Stations. Equally the landward retreat is placing public services such as roads and utility extremely vulnerable particularly in areas where lithology generally includes beachrock and unconsolidated sediments (sands) for example Vaisala, Savaii.
2. Of the 50 Stations surveyed around Upolu, Savai'i, Manono, and Apolima, 62% recorded signs of significant erosion.
3. Flooding from the sea is a complex process and is the resultant of storm surge, storm wave run-up, wave overtopping of barriers, and ponding in flood basins enhanced by fresh water flooding.
4. Developments (such as low-value assets and infrastructure) in numerous high coastal sensitive (risk) areas surveyed continue to be sited within the CHZ for example tombs, residential dwellings, and carriage ways.
5. General erosion evident by the exposure of beach rock, vegetation loss and exposure of root systems indicating landward retreat.
6. Property owners within the CHEZ faces as large a risk from erosion as they do from flooding.

Geomorphology

1. Approximately 10% of the Stations indicated minor sand accretion/accumulation (Saleaula and Falealupo, Savaii and Leusoalii, Upolu). Sale'aula reveals significant build-up and accretion of coral. Study conducted in 2000 indicated a Northwest growth since 1991 of a 50 to 130m-wide by 1,570m-long free form spit at a net 17.6m/y , along the crest of the fringing reef. Since 1954, the pit tip has grown 250m at 5.6m/y (CMCL, 2001). This is a very rare occurrence for Samoa.

2. Significant losses from coastal erosion are occurring substantially at 66% of the stations which surveyed in this study.

Figure 4: Image of the CHZ Station at Manase. Note: In comparison to the image above only 1 coconut palm is firmly supported in the dune while the other coconut palm's support is clearly eroded. Photo taken July 2004 by MNRE CHZ Survey Team.



Anecdotal observations

1. Anecdotal observations at the Station particularly and generally on coastal hazards and their effects were recorded from 24 interviews. Focused discussion emphasized the effects of Heta as a starting point. Although Heta was not as severe as it passed 80km west of the islands it did damage trees, crops and coastal infrastructure. Observations included elevation and distance inland reached by storm tides, the duration of flooding, and the damage sustained from cyclonic waves and inundation by the sea.
2. In areas sheltered by wide fringing reefs and not directly facing the full assault of cyclone Heta much lower impacts were observed, e.g. Fagaloa Bay, Uafato (Upolu).
3. The Faleolo Stations are in an area of national significance due the proximity of the Faleolo International Airport. The B4 Station recorded minor erosion along the coastline parallel to the runway. However, B1 Station further west depicted significant changes as a result of erosion and land clearing for the new resort development.
4. Not all areas experienced significant short-term changes. The field data collection and comparisons made with images collected during CHDB assessments in 2000 against current images taken during this study showed 22% of the Stations having relatively stable coastlines with very minor erosion evident. Generally where lithology has been formed from relatively stable basaltic lava flows it is patently stable (Falelima, Savai'i).
5. General flooding experienced within immediate 5-10m of coastline resulted in families moving temporarily inland to higher elevations (Solosolo, Upolu).
6. Implementation of hard-planning options to protect coastlines (for example rock sea-walls) has taken away from the aesthetics of coastal beaches. The poor designs have led to slumping which subsequently appears to accelerate the erosion effect (Fasitoo, Upolu).

Conclusion

1. A total 103km of Samoa's coastline encompassing Upolu, Savaii, Manono, and Apolima islands are and will continue to be subject to significant adverse effects from the identified natural coastal hazards of erosion and flooding from the combination of sea and rainfall.
2. Within the CHZ infrastructure, property and assets have a high probability of being damaged or destroyed during future significant cyclonic events.
3. Where practicable high value infrastructure should be sited primarily beyond the CHEZ to mitigate and avoid the costs associated with damage and destruction that occurs during natural hazards such as cyclones, erosion, landslip, or flooding.
4. Correct positions and coordinates of the stations with some discrepancies have been corrected and geographically corrected and use to update and revise the existing Coastal Hazard Database for further study to be conducted in the future.

Recommendation

For on-going monitoring it is recommended that:

1. all 276 Stations be studied for accuracy with respect to each: Station's coordinates; and CHDB variables, data, CSI class and ranking.
2. all 276 Stations be monitored and the CHDB be updated by the MNRE following the above recommendation.
3. the use of the data found in this study to be a preliminary analysis for Coastal Infrastructure Management Plans and Sustainable Management Plans to investigate the need for regulatory measures such as site specific set-backs from the shoreline to reduce damages within CHZ. In addition, require development regulators, communities and villages to impose building standards (development practices) and landscaping for future flood conditions and erosion.
4. capacity building of staff be conducted in all aspects of CHZ identification, surveying and mapping, CHDB management and CHZ strategic planning, management and implementation.
5. for any future monitoring work to be carried out, the use of the Global Positioning System to be employed to give accurate position and reduced level base on the center of mass of the earth. This technology will reduce timeframe for traversing from any survey benchmark located around the country and accurate level of the coast will be identified.
6. with existing data available for the coastal hazard zone starting to be out of date and changes have been found at some areas, future aerial survey should be considered to update the existing coastal hazard zone maps. Any new photography shall be conducted and flown at the low level flight plan in order to obtain high resolution and accurate large scale orthophotomaps to replace the existing CHZM.

References

- CMCL, 2000a. Assessment of coastal hazard zones for Samoa – Stage I. Consultancy report (C.R. 2000/3) prepared by Dr. J. G. Gibb (Director, CMCL) for the Department of Lands, Surveys and Environment, Government of Samoa. September 2000. Coastal Management Consultancy Limited, Tauranga, NZ: 26p + Appendices.
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of Lands, Surveys and Environment, Government of Samoa. May 2001. Coastal Management Consultancy Limited, Tauranga, NZ: 81p (with Appendices).

Appendix 1

The 50 stations CHDB 2000

Upolu/Manono/ Apolima	Code	Village	CSI	Savaii	Code	Village	CSI
	C3	Fagalii	H		D4	Asaga	VH
	C22	Faleapuna	VH		M1	Asau	VH
	J7	Falelatai	H		C6	Avao	VH
	B1	Faleolo	H		F1	Faaala	VH
	B3	Faleolo	H		D10	Faga	VH
	B4	Faleolo Teminal	H		D11	Faga	VH
	G5	Iliili	H		D12	Faga	VH
	F8	Saleapaga	VH		A6	Falealupo	VH
	C10	Leusoalii	H		A7	Falealupo	VH
	C11	Luatuanuu	VH		J2	Falelima	H
	B12*	Utualii	M		G3	Gataivai	H
	A4	Manono- uta	H		C4	Manase	VH
	A2	Samatau	H		C5	Manase	VH
	C20	Saoluafata	VH		D1	Puapua	VH
	Q5	Sataoa	VH		D2	Puapua	VH
	I7	Savaia	H		D9	Saasaai	VH
	C16	Solosolo	VH		C2	Safotu	VH
	H5	Tafitoala	VH		I2	Salailua	H
	N1	Tiavea-tai	VH		C11	Saleaula	VH
	D5	Uafato	VH		B3	Sataua	VH
	L19	Vaiala	H		A1	Tufutafoe	VH
	E6	Vailoa	H		A2	Tufutafoe	VH
	MN1	Faleu	H		A3	Tufutafoe	VH
	MN5	Salua	H		B5	Vaisala	VH
	AP1	Apolima- tai	H		B6	Vaisala	VH

Note: This site was included due to the severity that was experienced during cyclone Heta along this area of coastal infrastructure.