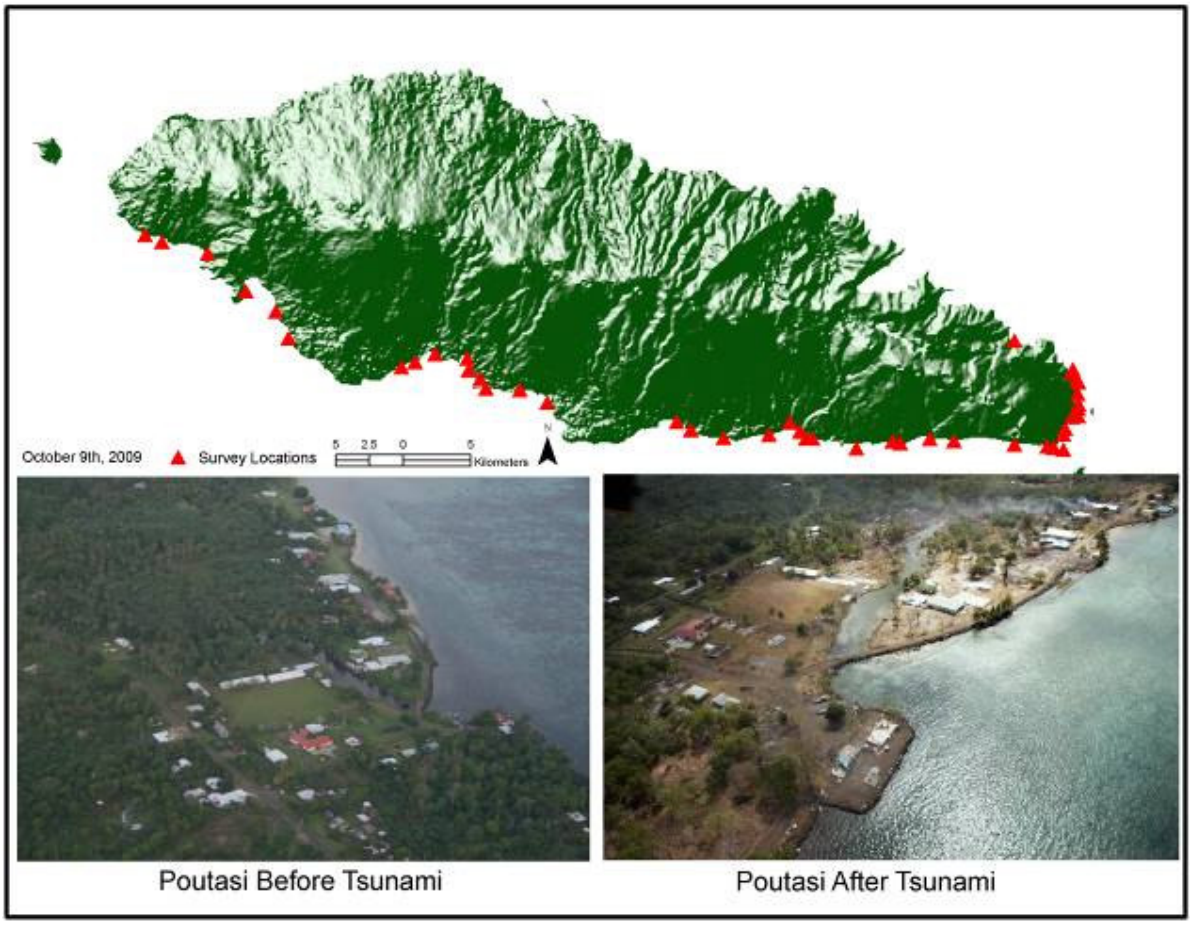
Samoa Tsunami Rapid Environmental Impact Assessment Report

DRAFT

October 14th 2009



Acknowledgements

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Samoa Tsunami rapid environmental impact assessment report

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1. Executive Summary

A rapid assessment of the environmental impacts of the 29 September tsunami was conducted by a multi-agency team from 3 to 14 October, 2009.

Fourteen “green” and 10 “brown” environmental variables were selected and measured based on the experience of the survey team and similar reports from elsewhere. During a tour of the affected area on Upolu by car and on foot those “assessable” variables were scored “high” (over two thirds affected), “medium” (over one third, less than two thirds affected), “low” (less than a third affected) or zero (unaffected). Manono and Savaii were surveyed by air with the former showing evidence of some damage and the later apparently none or very little. The most affected areas in Upolu were villages in the Aleipata, Lepa and Falealili districts with the most obvious indicators of the tsunami’s impact being solid waste (sometimes resulting from the complete destruction of a village), erosion of the beach and fore-shore and the (expected) impact on marine resources. Other environmental variables assessed also showed similar patterns. Impacts on a wharf/dry dock facility are also described (including lost fuel drums) as are the possible environmental implications of new settlements created by displaced persons (mainly revolving around sanitation, drainage and water supply).

A number of recommendations were identified and categorized as being needed in the short (<3 months) or medium to long term (> 3 months).

Strategically the key recommendation for marine habitats is to implement actions that foster the natural recovery and resilience of these areas.

Strategically the key recommendation for terrestrial habitats is to implement actions that focus on restoration based on ecological and resilience principles eg replanting with native wave resistant species on the foreshore and ensuring that human developments, rebuilding and associated infrastructure (eg villages, tourism) are undertaken cognizant of both the ongoing tsunami risk and minimizing the environmental impact to both terrestrial and marine habitats.

GENERAL RECOMMENDATIONS:

- Where possible there should be clear coordination over the implementation of the recommendations dealing with marine and terrestrial habitats
- Those recommendations endorsed by the Government of Samoa should identify clear decision making lead agencies, develop clear and costed terms of reference and invite partnerships for resourcing and needed expertise in these from local and overseas organizations.
- Work carried out in the recommendations above should follow normal protocols in Samoa for village and district approvals and participation. Existing governance structure eg MPA District Committees, CIM committees should be used effectively.

- Every effort should be made to capitalize on local expertise and supplement with overseas expertise where needed.
- Coastal Infrastructure Management Plans for affected districts should be revised to include a specific tsunami vulnerability layer and then fully implemented
- New settlements for displaced communities should be planned in a participatory manner and implemented carefully to mitigate potential environmental impacts
- Every effort should be made to collaborate with related activities in American Samoa to maximize benefits and sharing of knowledge
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Specific recommendations for marine and terrestrial habitats follow:

MARINE SPECIFIC RECOMMENDATIONS

Short term:

- **Clean up activities:**
  - Undertake offshore aerial check of debris and removal of any items posing risk to shipping or the coast.
  - Undertake lagoon debris removal manually in impacted areas. Do not use dredging as this will cause further impact. Find and remove lost diesel fuel drums in the vicinity of the Aleipata Wharf.
  - Beach and foreshore area clean ups are required in partnership with communities and after salvage of useful materials by owners.
  - Stabilization of immediate beach and foreshore areas and associated infrastructure eg roading to prevent further impact to the marine environment eg from sediment run-off.
  - Mangrove and wetland clean up of debris including solid waste required.
  - Aleipata Wharf clean up and immediate stabilization of sources of further pollution eg sediment run off.
- **Potential food source contamination**
  - As a precaution, warn local villages of potential food source contamination particularly shellfish, sea slugs and other near shore species in highly impacted areas including in marine areas surrounding the Aleipata wharf.
  - Assays of key food species eg shellfish in heavily impacted areas to assess safety for consumption. Based on results advise villagers accordingly.
- **Marine Rapid Assessment (MRA)**
  - Undertake an in-water marine rapid assessment with focus on expected highly damaged areas and those where previous information exists eg Aleipata and Safata MPAs.
  - As part of the MRA:
    - assess impact/vulnerability of key coastal features eg channels and embayments
    - identify sites for longer term recovery monitoring
    - assess loss of ecosystem function and impact on services eg food sources for people in affected areas
  - A joint team should be lead by MNRE/Fisheries combined with local and overseas expertise where needed. Expertise should include resource economist and at least one marine surveyor with marine tsunami impact experience.
- **MPA and Fisheries no take zones**
  - Undertake more detailed impact assessment of MPA and Fisheries no take zones and their potential for recovery and/or need for relocation. Note pre impact information for many of these sites is available (MNRE, Fisheries)
  - Based on consultations and agreement with villages and districts remark no take zones.
- **Marine Food Source Supply**

- Using the results from the above undertake an assessment for marine food source supply including specific recommendations for possible substitute sources and rebuilding fishing capacity in a manner that does not significantly compromise marine area recovery eg first focus on rebuilding offshore capacity that can benefit entire village, ban outside commercial fishing in an offshore area to maximize local access.

- **Aleipata Wharf**
  - Detailed assessment of tsunami impact and the ongoing risk, costs and benefits of the wharf and its widened channel to nearby coastal villages.
- **Other marine stressors**
  - Remove/reduce other stressors and impacts to the coastal marine systems eg ban on sand mining, commercial fishing, and new reclamations to allow the best chance for recovery.

Medium- long term:

- **Other marine stressors**
  - Remove/reduce other stressors and impacts to the coastal marine systems eg ban on sand mining, commercial fishing, new reclamation to allow best chance for area recovery.
- **Aleipata Wharf**
  - Comprehensive assessment of long term risk, costs and benefits of rebuilding the wharf assessed, including with local community input, before wharf rebuilding actioned beyond the immediate stablisation and clean up recommended above.
- **Recovery Monitoring**
  - Based on the MRA results institute a monitoring programme to understand recovery of marine habitat from tsunami impacts.
  - Include in the recovery work monitoring of fishing capacity and ongoing need for any substitution measures for marine food supply that were used in the short term.

TERRESTRIAL RECOMMENDATIONS

Short term:

- **Clean up activities**
  - Undertake clean up and removal of solid waste from terrestrial, wetlands, river habitats and village areas.
  - Maximize reusing and recycling materials and sort and remove remaining material into disposable and hazardous rubbish. Link with JICA Clean Up project.
  - Specific focus on clean up and proper disposal of waste from illegal/improper dumps exposed by tsunami eg Tuialemu, Lalomanu.
  - Review and update plan for effective local waste collection.
- Stabilization of land based sources of sediment from wetlands, streams, infrastructure eg roading to prevent further impact to the marine environment eg from sediment run-off.
- **Terrestrial Impact and Restoration Assessment**
  - Perform a comprehensive assessment of impacts on sensitive coastal habitats such as marshes and swamp areas and environmental impacts of new settlements
  - Assess restoration options for key terrestrial habitats made with costs clearly identified.
  - Build into these assessments a recognition of the ongoing tsunami risk and related coastal area vulnerability/hazard zones eg from channels and embayment areas. This should inform patterns of rebuilding.

Medium- long term:

- **CIM Plans – Updating and Implementation**
  - Update and implement CIM (Coastal Infrastructure Management) for coastal areas
    - Ensure that findings from incoming geo-science teams are fed into planning processes including revision of CIMP plans as required. Include specific tsunami risk layer.
    - Seawall rebuilding to proper standards according to codes of environmental practice as appropriate – in some areas natural alternatives may be preferable.
    - Restoration actions identified above should be included into CIM planning and implementation.
    - Replanting of areas should focus on native salt tolerant species and species that are able to hold the coastline together.

2. Introduction

The Cabinet of the Government of Samoa commissioned this rapid Environmental Impact Assessment two days following the 29 September 2009 Tsunami. The Tsunami was triggered by an 8.3 earthquake centred on the Tonga Trench about 220 miles south east of Samoa. Two waves, up to 8m in some locations, caused localized devastation over the eastern and southern coast of Upolu Island with generally less severe impacts further west. Detailed accounts of the seismological and physical statistics of the Tsunami will be reported by others elsewhere. A rapid EIA team was established under the United Nations "Cluster" system of disaster management and reporting to the Government of Samoa/UN Disaster Advisory Committee. The EIA team comprised staff from the Ministry of Natural Resources and Environment (MNRE, Government of Samoa), Conservation International Pacific Programme (CI), the Secretariat for the Pacific Environment Programme (SPREP), UNESCO (Apia) and UNEP (Apia). The team members have co-authored this report and are listed in the acknowledgements.

The objective of the assessment was to rapidly assess the impact of the Tsunami on the coastal habitats of the south and eastern coast of Upolu, Aleipata Islands (offshore of the south Upolu coast), Manono Island, and southern coast of Savai'i. Based on these assessments the team was requested to make recommendations for further detailed investigations of the most affected assets and areas and associated expertise required.

Field work was undertaken from 2-8 October with initial findings and recommendations presented to the Government of Samoa on the 9th of October and the full report presented on the 14 October to the Government of Samoa/UNDAC.

3. Methods

At each site tsunami impact on coastal terrestrial and marine habitat was rated ("green issues") and impact to environmental parameters ("brown issues") of pollution, water, sewage and impact to roading assessed. Selection of these variables were made after reviewing other EIA's following disasters and judging which would be relevant for Samoa based on the team's prior knowledge of the affected areas. Appendix 1 gives the format of the survey sheets used.

The same information was gathered from 44 localities on Upolu Island from Tiavea Village (Aleipata District) as the northern most site through to Samatau (Falelatai District) in the west. Site units were mostly villages although other key sites were also visited eg Aleipata Wharf, tourist resorts. Aerial photographs were used to assess impacts on sites which were not visited.

For each impact variable the following impact rating was used:

High – at least two thirds of the area or resource being considered was damaged beyond normal functionality.
Medium – as above – between one third and two thirds
Low – as above – up to one third
Zero – no observable affect from the Tsunami
Assessed – variable was systematically assessed in the locality visited
Not assessed – for some reason the variable was/could not be assessed
Expected – while the variable was not observed, common sense or prior information meant the variable was able to be estimated.

Photographs illustrating each of the categories were taken and are included in Appendix 2.

At each site photographs at a grid-referenced point (Garmin GPS 60CSX; latitude/longitude in degrees to five decimal points) with a recorded direction (photo-points) were taken to enable future comparisons. These images are not included in this report and are available separately. Significant photographic resources were obtained and are available of sites, impacts, aerial photography and pre impact shots from team members' photo libraries.

Data were compiled by site and analyzed for degree of impact and summarized in Appendix 3 and in maps with relative rating indices given.

Key limitations of this rapid EIA are:

- The report is a preliminary assessment that does not comprehensively assess and cost tsunami impacts and mitigation measures. Rather, the report identifies the extra investigations needed for a comprehensive impact assessment to be undertaken.
- This assessment does not account for impacts on agriculture because these are reported elsewhere (e.g. MAF report to the Government of Samoa)
- Direct impacts from the earthquake itself were not assessed.
- Impacts to the marine habitat beyond the immediate beach and intertidal zones are inferred and rated relative to the adjacent coastal impact. In-water assessments were not completed.
- Some areas of the Upolu coastline and three offshore islands (Manono between Upolu and Savai'i, and Nu'utele and Nu'uloa in the Aleipata District) were not visited. However, these were inspected from a New Zealand Army Iroquois helicopter by two of the survey team and photographed. The NZ Airforce had already inspected the exposed coasts of Savaii from about fifty feet above sea level and could not detect any Tsunami damage.

4. Findings

4.1 Spatial Patterns of Impacts

Impacts were not evenly spread across the tsunami impact zone for each type of impact- some areas were impacted much more than others. A number of maps have been generated to show the spatial distribution of the following observed impact parameters: septic tank pollution (figure 1); foreshore and beach erosion (figure 2); impacts on village areas (figure 3); expected impacts on MPA and Fisheries no take zones (figure 4); impacts on wetland areas (figure 5); expected impacts on coral reef areas (figure 6); solid waste pollution (figure 7); salinisation (figure 8) and a map showing the route of the aerial photo survey of October 9, 2009 (figure 9). All maps have been colour coded to show impacts in the three major categories- high, medium and low impact for each parameter at each observation point.

The general spatial patterns of the impact of the tsunami are summarised below (see also Figures 1 to 8):

- On Upolu the impacts were generally highest in the south and eastern end of Upolu in Aleipata, Lepa and Falealili districts and diminished westwards towards Falelatai;
- On Manono island the south and eastern coasts were most seriously impacted;
- Impacts on Savaii were minimal;
- Impacts on marine systems beyond intertidal areas are inferred by damage to the adjacent coast. No in-water assessment was completed and a more detailed marine impact assessment will be required.
- Marine habitats that are or expected to be highly impacted by the Tsunami are beaches and foreshore, lagoon habitat (seagrass, patch reefs, shellfish beds), coral reefs and channels, and mangrove areas;
- Channel or ava areas and associated embayments clearly funneled the wave in to the coast causing greater damage whilst areas that had extensive lagoon and offshore reef were clearly more protected from the tsunami force;
- Terrestrial habitats most severely impacted were beach and coastal vegetation, riverine systems and marsh and swamp areas;
- Impacts to village areas range from minimal to severe devastation;
- Ten to 15 metres of coastline has eroded inland and beach profiles have dropped up to 1.5m in some areas, especially in Aleipata. This means significant sand and sediment has been washed into the lagoon and reefs causing further impact.

Figure 1: Septic Tank Pollution

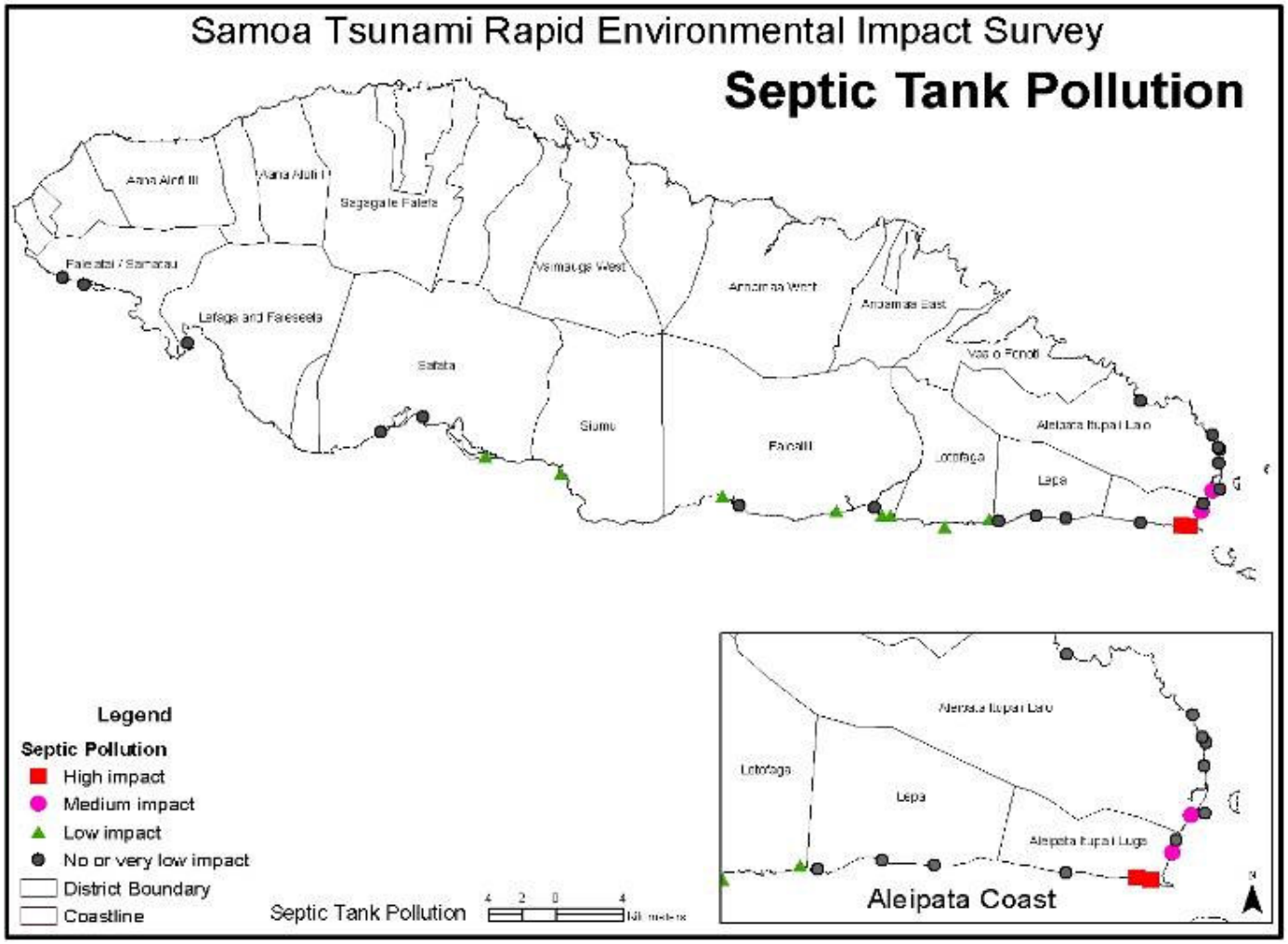


Figure 2: Foreshore and Beach Erosion

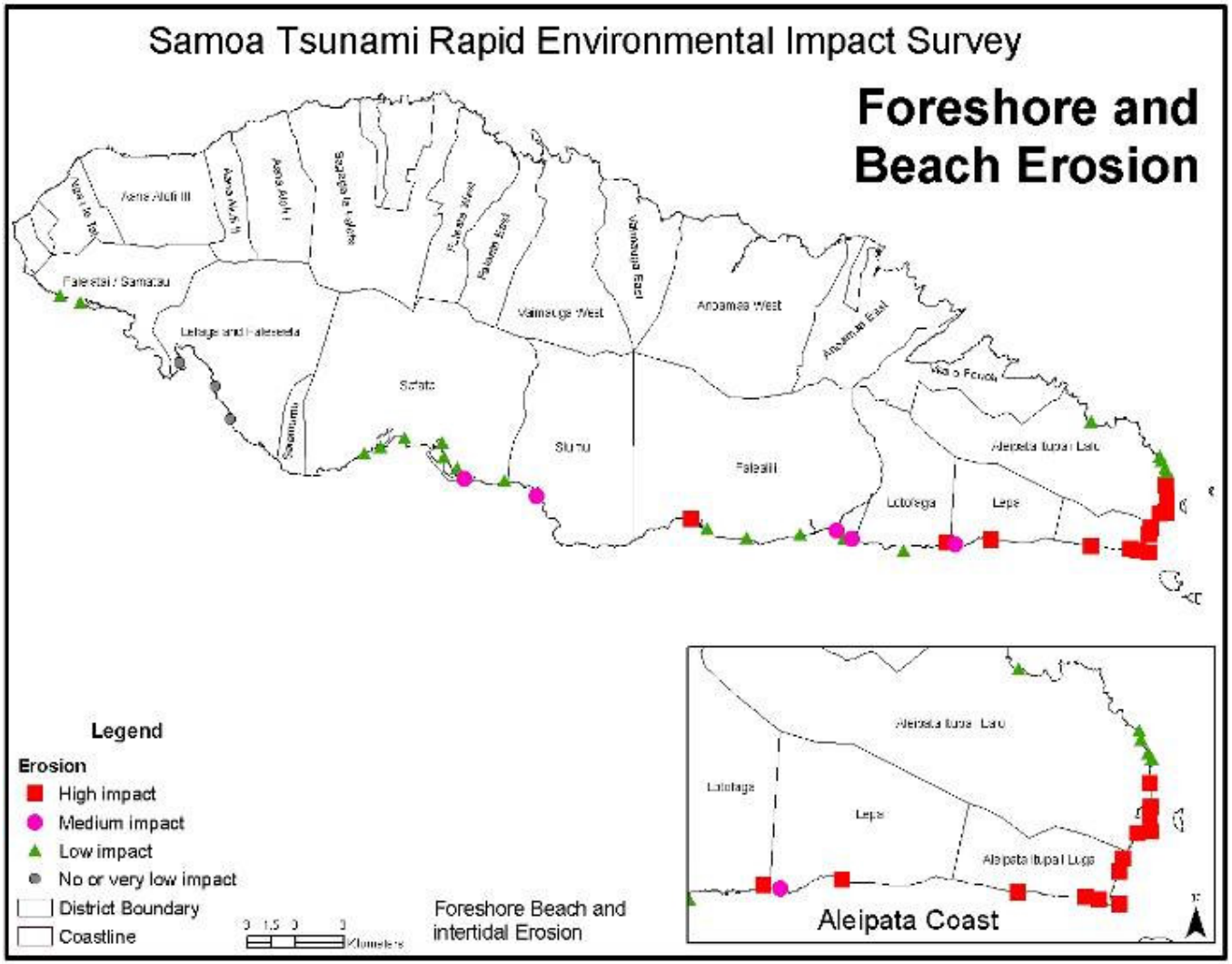


Figure 3: Impact to Village Area

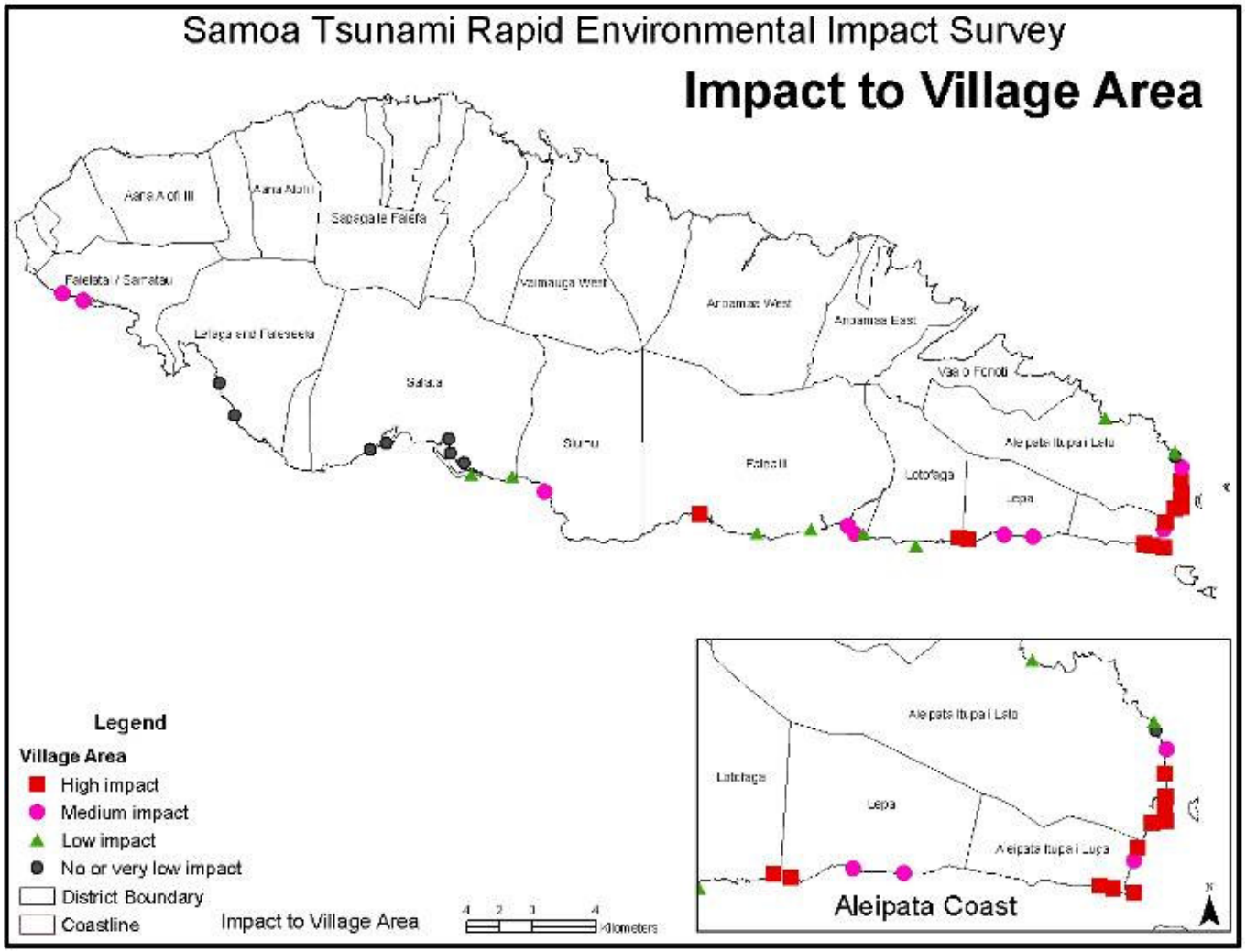


Figure 4: Expected Impact to MPA and Fisheries No Take Zones

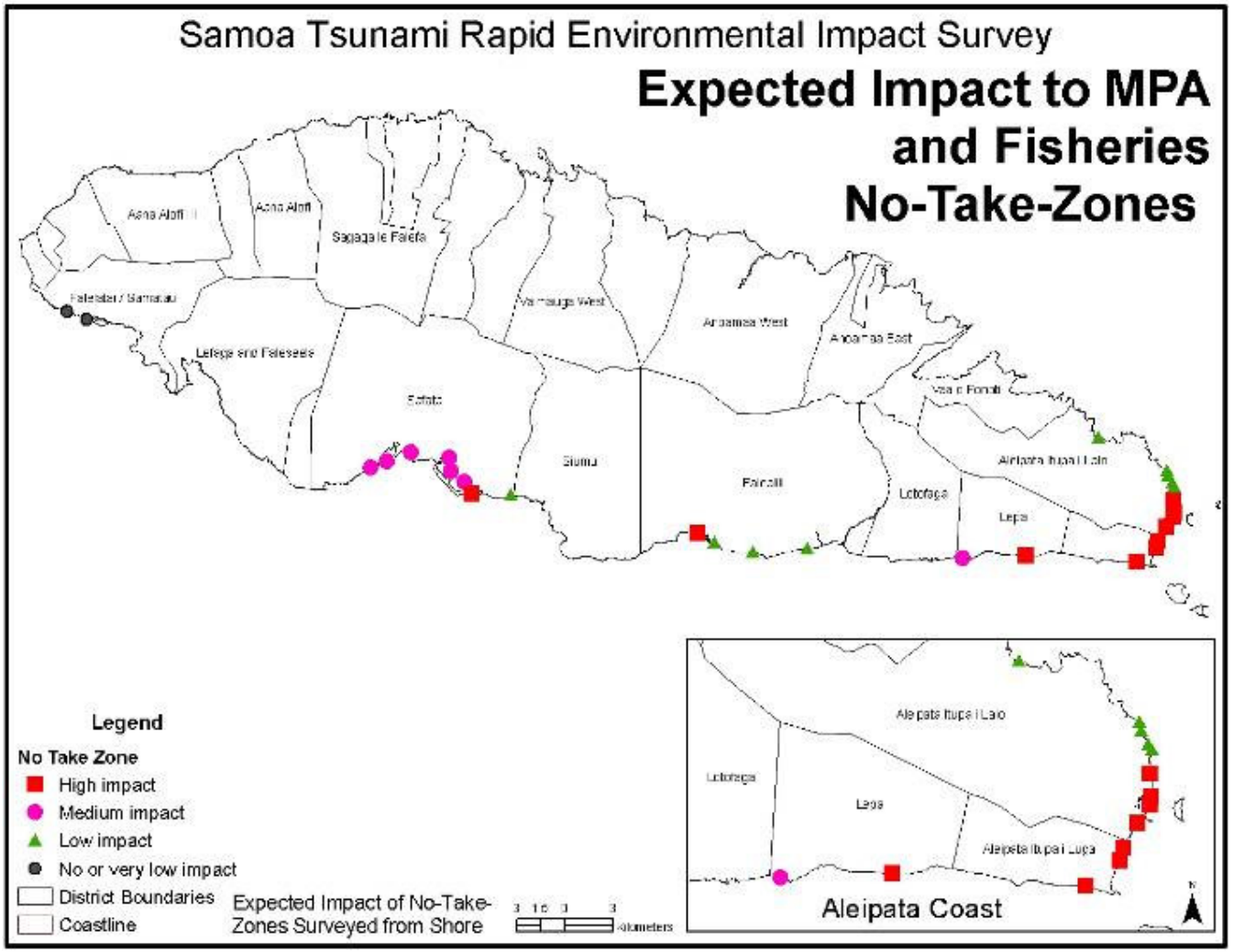


Figure 5: Impact on Wetlands

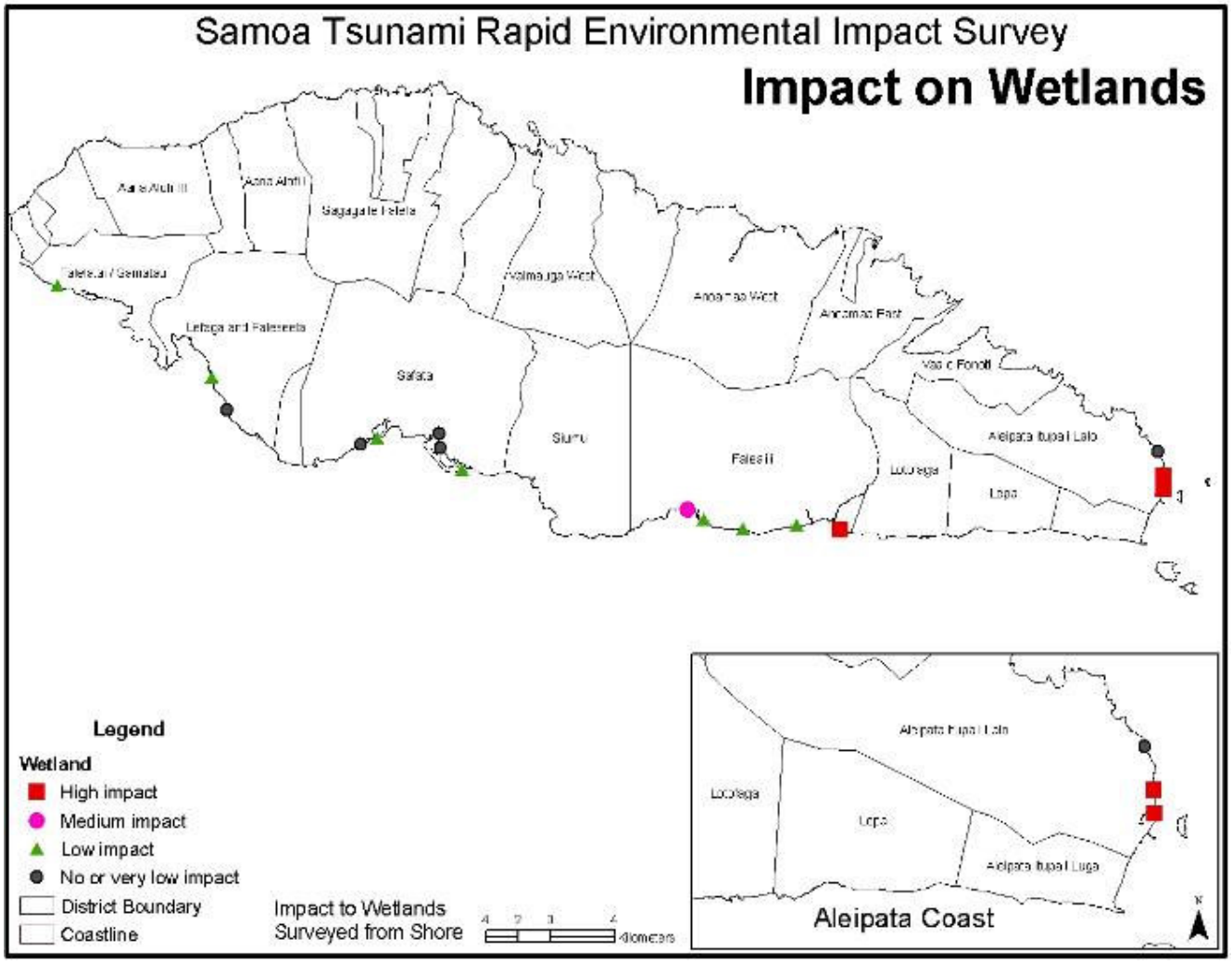


Figure 6: Expected Coral Reef Impacts

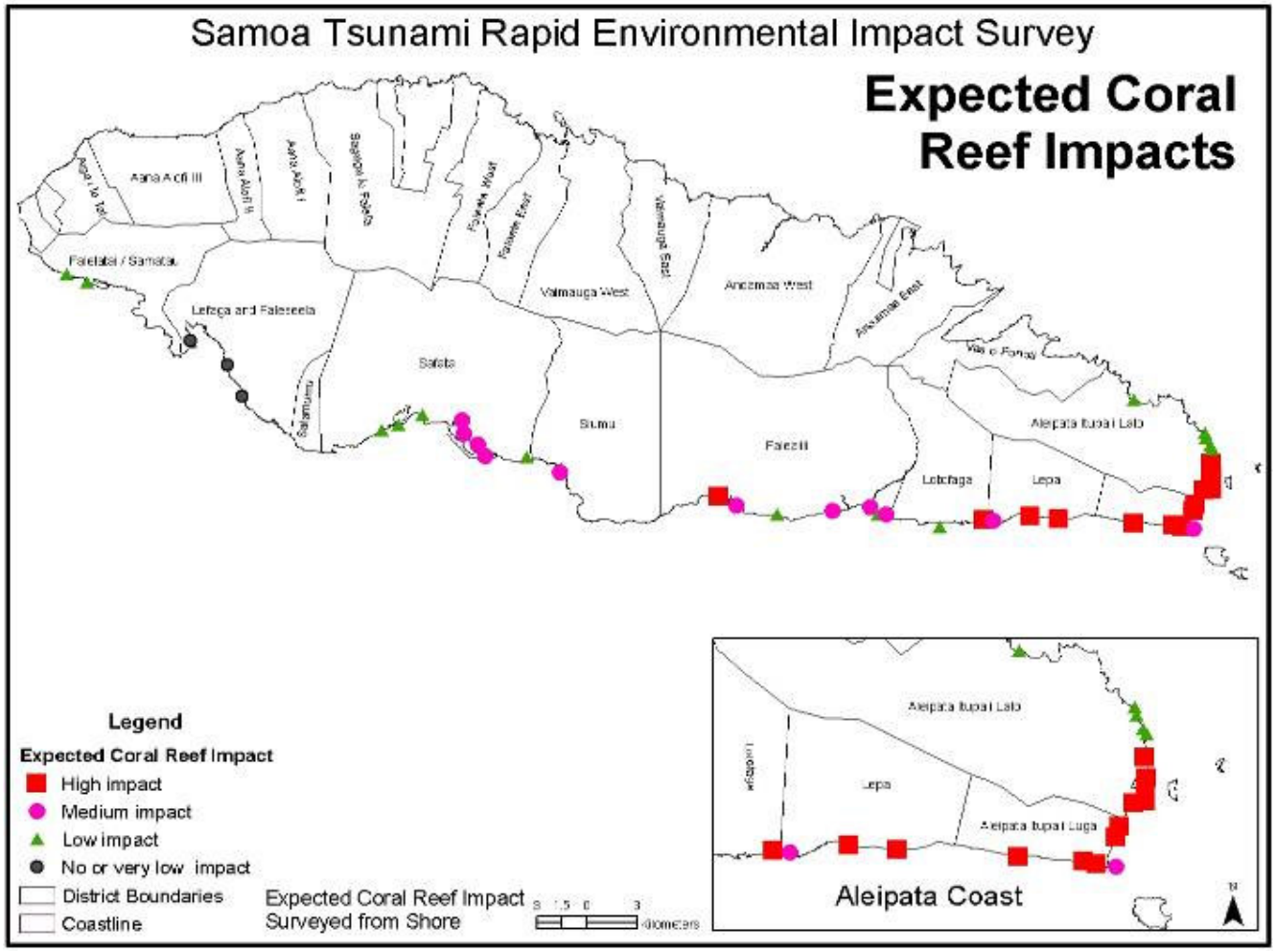


Figure 7: Solid Waste Pollution

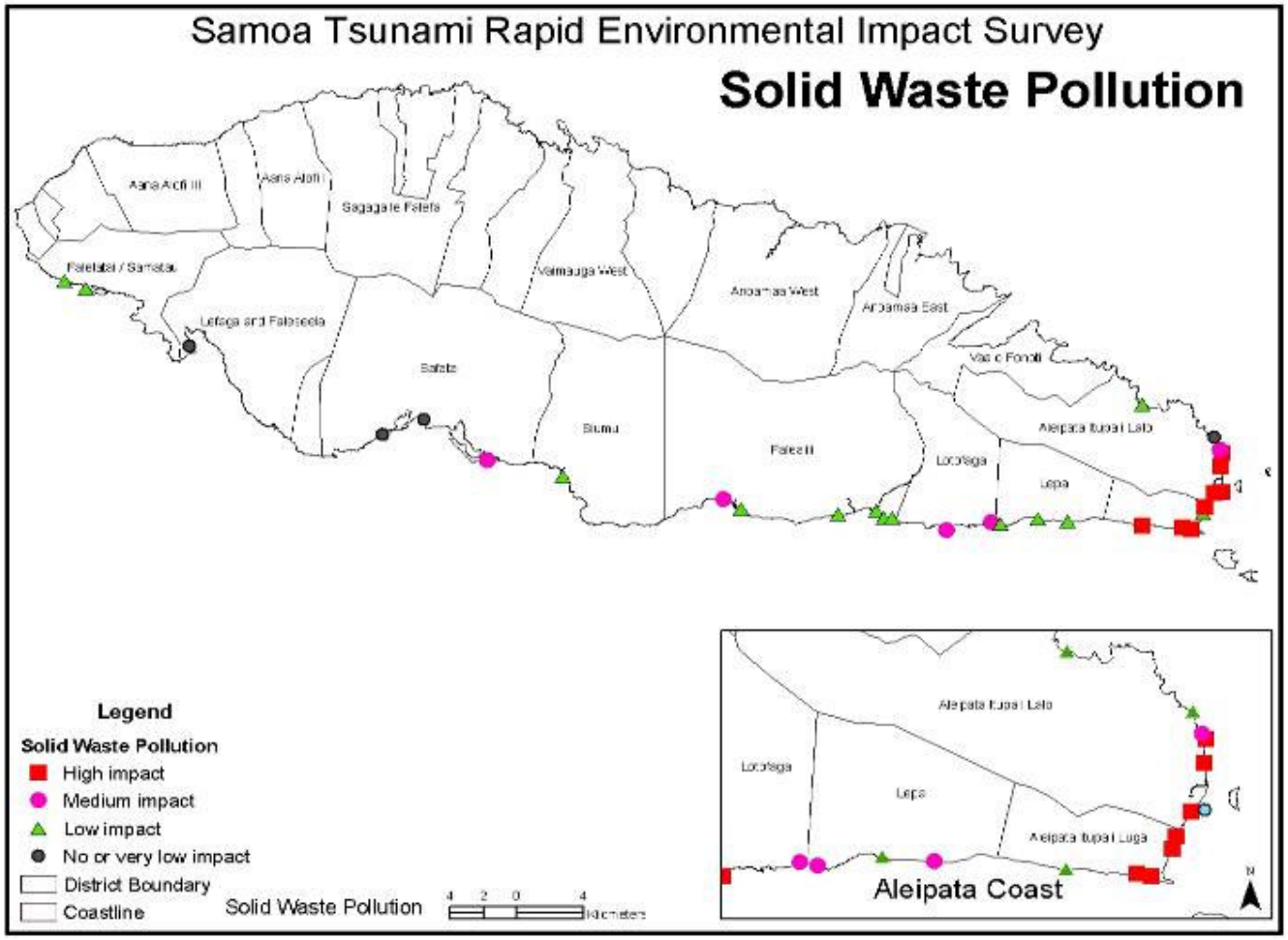


Figure 8: Salinisation

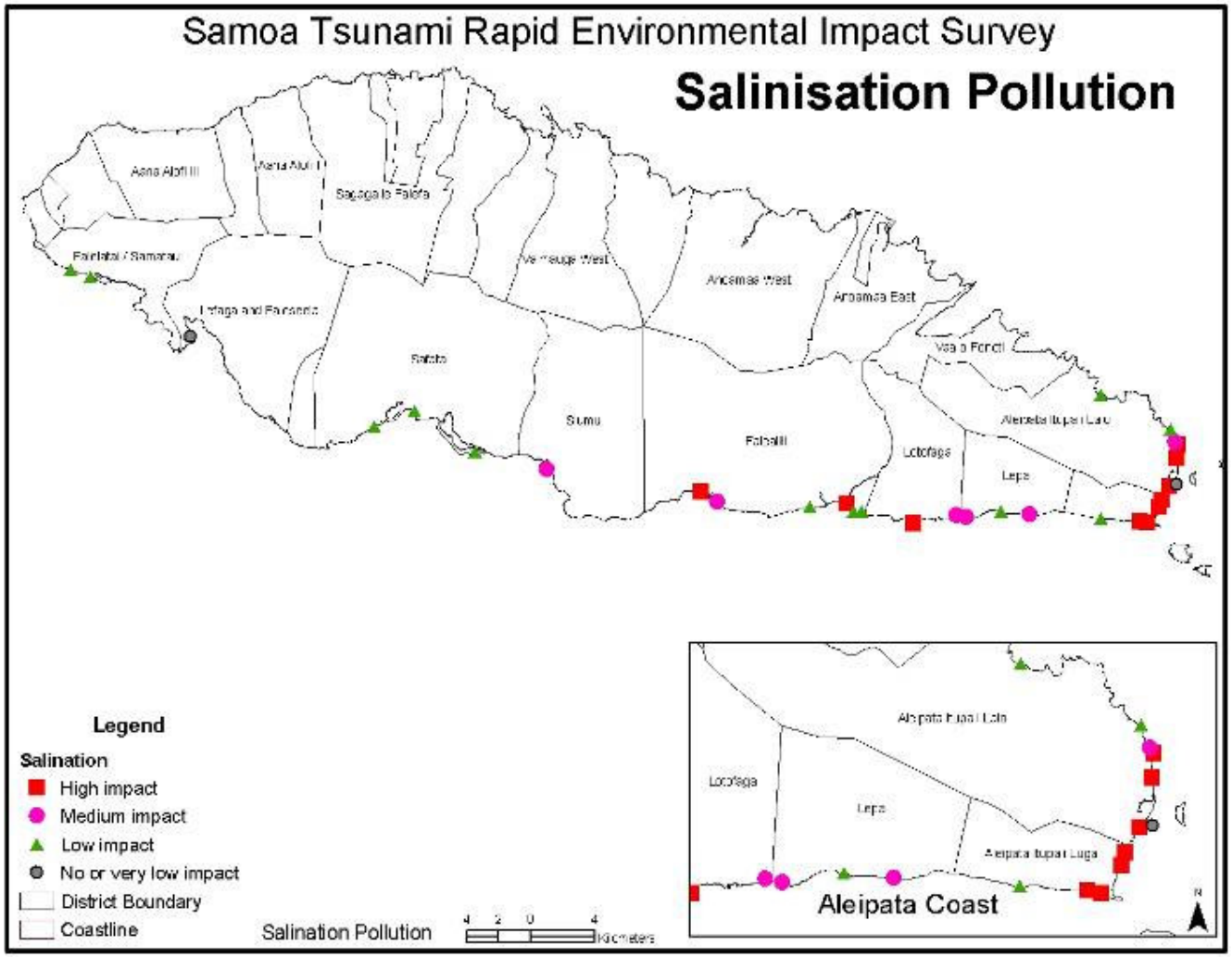
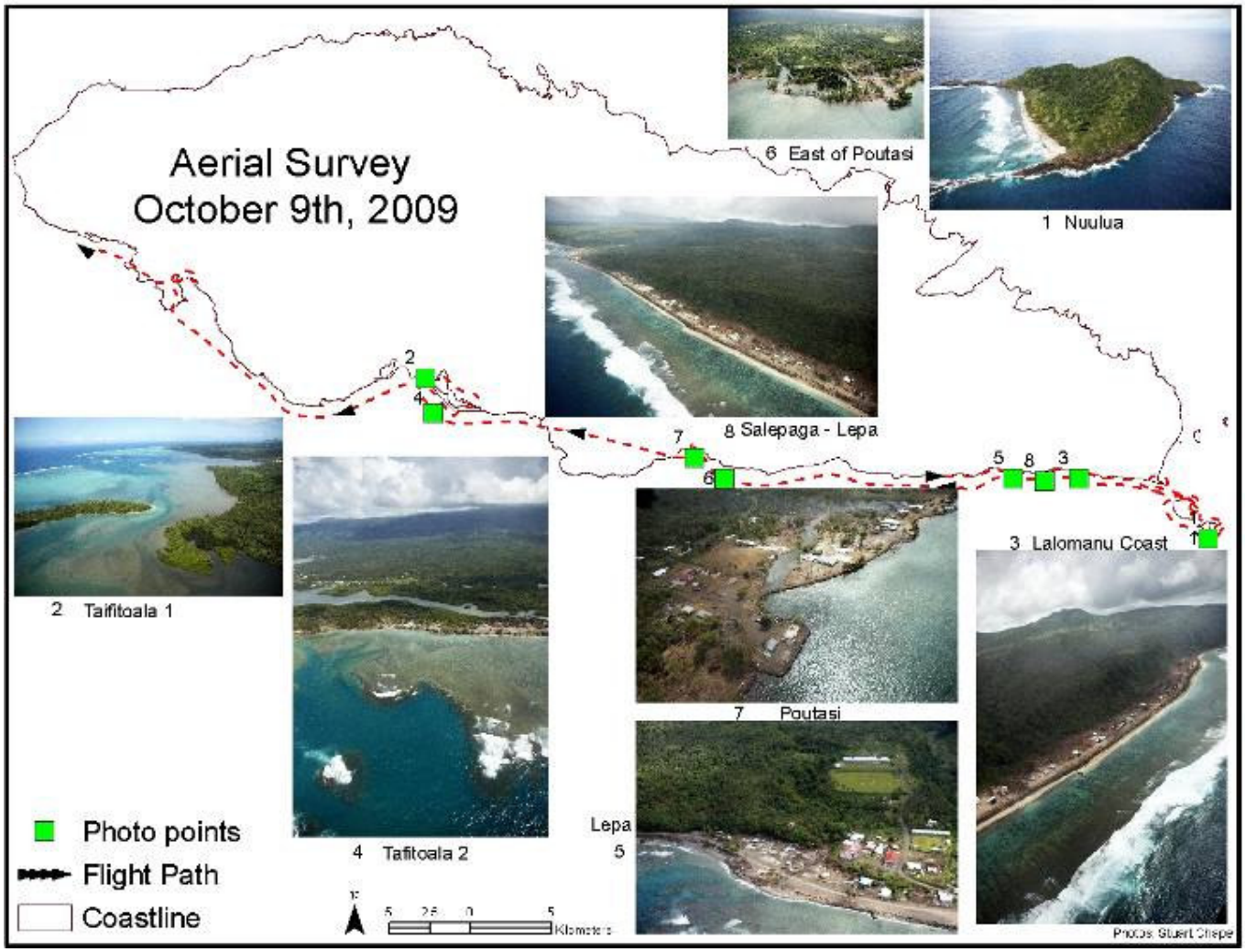


Figure 9: Aerial Survey Route



4.2 Impacts, consequences and recommendations for each habitat category – tabulated information with commentary (interpretation, summary, explanation)

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
Offshore (outside the reef)	Pelagic, open sea	Floating debris fields, localized sediment plumes of mainly marine and partially terrestrial sediment origin, extending up to 1 km from the coastline were observed during the first 3 days after impact.	Sediment plume impact is expected to be short term and quickly dispersing in offshore areas. Larger floating debris will either disperse or drift ashore in the short to medium-term.	Within the first 1-2 weeks after the Tsunami marine transport and fishery vessels must be warned of large floating debris in offshore areas
Outer Reef	Reef slope	Expected impact from quake and tsunami waves causing physical breakage, smothering by sediments, as well as damage from land-based sediment, pollutants and moving debris. Note no in-water marine assessments were complete in this rapid EIA. Due to decreased coastal vegetation increased coastal run off may be experienced in some affected villages during the next rainy season. In many villages unquantified amounts of reef fish were washed onshore by the waves.	Reduction in reef quality and its ability to support marine life including food sources and coastal protection values. Increased vulnerability of damaged corals, potential medium- to long-term impacts from coral diseases may be caused by terrestrial pathogens in the terrestrial sediment plumes. Due to the combined factors causing stress and damage to slow-growing corals, there is a risk that some affected coral reef areas will experience a benthic community shift from coral to algal dominance. Strongly affected coral communities may require 5-10 years for natural recovery in the case of *Acropora* - dominated communities, which are common on much of the affected shallow reef areas. Damage to communities dominated by larger massive corals such as *Porites* may require several decades or more to recover.	A comprehensive Marine Survey is required and could be carried out late October/November to quantify impacts on reef structure, live coral cover and associated reef biota/food sources, such as reef fish communities, mollusks, echinoderms, sponges and crustaceans. Based on the survey results a monitoring program based on permanent transects may be required to document reef recovery and to determine community shifts and coral disease impact. Reduce other impacts or stressors on reefs as much as

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
			Most affected villages, which rely on outer reef areas for subsistence fisheries, may experience a short-term decrease in catch.	possible e.g. destructive and commercial fishing to support the natural recovery process.
	Ava/channels	Higher degrees of damage to coastal infrastructure and an increased amount of broken coral and coral rubble were associated in several cases with the presence of reef channels (Avas). These channels and their related embayment areas funneled the wave energy and caused higher damage to lagoon and coastal areas. In the vicinity of channels higher expected sand scouring of corals and other sedentary organisms.	Lagoon and inshore areas in the vicinity of these channels are at a consistently higher risk of tsunami impact.	Marine Survey of tsunami damage in key channel areas. Rebuilding of coastal infrastructure, such as roads and housing should be cognizant of channel locations and the associated risk. A cost-benefit and environmental impact analysis may be of value in cases where widening of avas may be considered, such as near the Aleipata wharf.
Back reefs	General observations	Not directly assessed yet there was significant coral rubble in these areas e.g. from impact by cyclone Heta. It is evident that coral rubble has been washed inshore and also may have been washed down the outer reef slope.	Movement of preexisting coral rubble has added to damage inshore in the lagoon and possibly the outer reef slope. There is a risk that back reef areas undergo a shift to algal dominance.	Marine Survey of Tsunami damage in back reef areas.
Lagoon areas	General observations	Not directly assessed yet except for near-shore areas. Sediment plumes, solid waste	All affected villages rely to a significant extent on lagoon areas for subsistence food resources. Physical damage, sand scouring, sediment and	Removal of marine debris may need to be carried out manually, dredging to remove debris in the lagoon is likely to cause further

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
		and debris accumulation, as well as physical wave damage and removal of sand are the main impacts in nearshore lagoon areas. Patches of mainly land-based sediment plumes, consisting of sand, mud and silt were observed on the Upolu east coast between Samusu and Satitoa, as well as on the South coast near Vailoa, Poutasi, Maninoa and Saanapu.	localized impact of contaminants such as diesel fuel and sewage impact may have decreased the capacity of lagoon resources to support human needs. Filter feeders may be contaminated in areas impacted by sediments, fuel or oil spills.	damage. Contamination assays of key lagoon food species to ensure safety for human consumption. Marine Survey of tsunami damage in lagoon areas.
	Seagrass	Seagrass has a limited distribution in Samoa. The largest seagrass bed on the Aleipata east coast adjacent to Malaela and Lotopue was already impacted by wharf construction. The tsunami caused a sediment plume, debris and likely scouring and physical damage to this important seagrass bed.	Seagrass is a rare habitat in this area, important for feeding green turtles, as a nursery area for fish species, as well as providing lagoon fisheries resources including shellfish and edible algae.	Increased protection for remaining seagrass areas to facilitate recovery.
	Soft coral beds	The Aleipata east coast had significant soft coral beds (e.g. inshore form Namua Island) which are likely to be extensively damaged from wave action, sand and sediment.		
	Patch reefs	Patch reefs were mainly		The construction of any form of

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
		dominated by branching *Acropora* and less frequently massive *Porites*. Significant physical damage is expected as evidenced by the amount of *Acropora* fragments washed ashore. Remaining patch reefs may be vulnerable to infection, disease and smothering from sediments.		artificial reefs is not recommended. A common sense approach to remove stressors to the lagoon and reef systems is likely to support the highest rate of recovery.
	Shell fish beds	Shellfish beds - likely erosive impact, sand scouring and possible contamination.		
Marine Protected Areas, No Take Zones and Fisheries Reserves		Aleipata and Safata MPA 'No take' zones are likely significantly impacted by physical damage, rubble and smothering sediments and possible other pollutants. Other Fisheries and MNRE 'no take' zones e.g. in Poutasi were also heavily impacted. Many 'no take' zones have lost 100% of the marker buoys in heavily impacted areas. Based on marker buoy loss 11 of the 12 no take zones in Aleipata MPA are thought to have had strong impact. Two of the 9 Safata MPA 'no take' zones are thought to be heavily impacted on basis of buoy loss (Mulivai,	The no take zones will have lost some or all function in terms of providing the spillover effect to support subsistence fishing by the villages. Recovery will vary. Depending on the type and severity of tsunami impact these functions are likely to take significant time to recover (2-5 years). If coral areas are largely smothered by sand or sediment, these areas may not recover and of MPA relocation may need to be considered.	More detailed 'no take' zone survey as part of marine impact assessment, assess potential for natural recovery and recommend MPA relocation, where needed. With village, and for the MPAs District, consultation and agreement, remark and reinstitute 'no take' zones as soon as possible.

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
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Beaches and foreshore	General observations	Impact severe in many areas with significant removal of sand, deposit of solid waste and debris. Wave impact and associated erosion carried marine sediments inland and transported land-based sediments out into lagoon and reef areas, likely leading to scouring and smothering of coral and associated benthos.	Beaches and foreshore areas of much of the south coast, especially Aleipata District, have been severely impacted. Damaged coastal infrastructure e.g. roads, buildings have been the subject of other surveys and are not summarized here.	Allow villages/owners time to remove materials of value to them followed by a more general and comprehensive clean up of all debris. Recovery and restoration of beaches and foreshore is important and should be guided by ecological and restorative principles e.g. planting of robust plants e.g. 'talie' which are resilient to wave damage. Serious consideration required in the rebuilding phase on how much and what kind of infrastructure is required adjacent to beaches/foreshore/ coast.
	Coastal Infrastructure	See summary by village ranging from low to high impact. Includes road, housing and other buildings, power, phone lines etc.		Stabilize roads and other coastal infrastructure quickly to minimize further run-off of sediment and other pollutants to the coastal areas, especially before advent of rainy season.
	Previous land reclamation sites	Reclamation has previously occurred in several areas, especially Aleipata District. This has reduced productivity of the already limited lagoon area. These reclaimed areas are highly vulnerable to tsunami	Further erosion of beaches, foreshore areas and adjacent inland areas may pose a significant risk to the natural recovery process in lagoon and reef areas, especially with advent of the rainy season.	New reclamation proposals should undergo a comprehensive EIA. Reclamations often have a 'groin' effect, which can increase erosion as well as sand and sediment deposition in adjacent areas

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
		impact as they extend into the lagoon and are low-lying.		relative to current flow.
	Previous sand mining sites	Significant sand mining has previously occurred in different areas, especially in Safata District. This increases vulnerability of nearby land to marine erosive impacts, including tsunami.		Any new sand mining proposals should undergo a comprehensive EIA.
	Seawalls	Evidence of both protective and destructive impact of seawalls.		Care taken in the rebuild or construction of new seawalls is advised and not to be used as a basis for reclamation. Investigation into stabilizing seawalls to prevent rocks acting as 'missiles' needs to be looked at.
	Septic tanks	A significant number of septic tanks were observed to be damaged or emptied by the wave, dispersing sewage to adjacent areas on land and in the sea, posing a low to medium risk of contamination of groundwater lens and food sources.		Serious consideration may be required in the rebuilding phase on how much and what kind of infrastructure is required adjacent to beaches/foreshore/ coast. Septic tanks should not be replaced in these areas but further inland and/or other technologies e.g. composting toilets used.
	Rubbish dumps	An illegal rubbish dump was exposed by the waves on the Tuiolemu Peninsula near Lalomanu, comprising mainly plastic and glass bottles		Illegal dumping of rubbish needs to be stopped. Awareness of proper waste management needs to be improved. Clean up needs to be instituted and fines e.g. through MPA need to be

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
				implemented.
	Aleipata Wharf	The widening of the channel for the wharf may have reduced tsunami coastal protection and funneled the wave in. Significant loss of sediment and some fuel (40x44 gallon drums of diesel) Significant damage to the wharf has been sustained. The wharf poses an ongoing risk to the marine environment including through acting as an ongoing source of sediment and pollutants.	Clean up of the wharf to reduce ongoing risk to marine environment is needed. Serious consideration given to the ongoing risk and increased vulnerability of this type of infrastructure in a high tsunami and other coastal hazards zone.	Wharf clean up should operate to minimize any further environmental damage to adjacent lagoon and reefs. Wharf channel should not be widened as increases risk to coastal areas. Pollutants eg diesel drums should be searched for and removed from lagoon/reefs. Serious consideration should be given to whether there should be this type of infrastructure in a high coastal hazard zone.
Intertidal vegetation	Mangroves	In highly impacted areas large amounts of large debris and damage to mangroves. However affected mangrove areas are most likely to recover in the short to medium-term and may not suffer long-term damage. Mangroves clearly had a protective function in several areas, e.g. in Safata.	Recovery potential post clean up of mangroves is high. Protective values of mangroves should be promoted e.g. as in Safata MPA .	Mangrove clean up once villages have had the needed time to salvage items. Possible restoration of some areas with replanting, checks for invasive species etc. Villages should be strongly encouraged to conserve mangrove areas as cost effective coastal protection.
	Coastal Marshes	Damage to marsh areas from wave action, sediment loading, salinization, contamination with		Possible restoration of some areas with replanting, checks for invasive species etc.

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
		polluted water and debris, solid waste and general pollution		Villages should be strongly encouraged to conserve marshland areas as cost effective coastal protection.
Terrestrial Vegetation	Shrub communities and freshwater swamps	Damage to swamp areas from wave action, sediment loading, salinisation, contamination with polluted water and debris, solid wastes and general pollution	Loss of habitat for valuable marsh plants (e.g. 'lauieie') and animals (e.g. feeding grounds for reef heron & grey duck). Continued demise of marshes may increase exposure of coastal communities to the risks of severe wave actions and strong winds.	Assess impacts on all sensitive coastal habitats & recommend recovery and restoration options for heavily impacted habitats Clean-up all debris from coastal marshes especially that which may cause long term pollution (e.g. from vehicles) Protect coastal marshes from further degradation and development so they can continue to act as a buffer against tsunami and storm surge
	Riverine Systems & Water Courses	Significant erosion of river banks and water courses	Increased vulnerability of riverine communities & infrastructures to future flooding risks – erosion & landslide.	Review and update the natural disaster risk vulnerability of all affected areas for future planning (e.g. CIM plans and coastal hazard zone mapping). Replant river banks with appropriate native plants
	Littoral Vegetation	Damage to littoral vegetation from direct wave action and from salinisation The role of coastal vegetation,	Increased vulnerability of coastal infrastructures & communities to the risks of severe wave actions and strong winds.	Review and update the natural disaster risk vulnerability of all affected areas for future planning (e.g. CIM plans and coastal hazard zone mapping).

General Habitat/Site	Specific Habitat	Impact Summary	Consequences	Recommendations
		especially large coastal trees such as fetau and talie in reducing coastal erosion and holding together the foreshore was obvious in many places		Replant the coastline with appropriate native coastal plants to act as a buffer for coastal hazards and to reduce coastal erosion
Species of Special Consideration	Sea turtles	Reports of numerous turtles washed ashore and villagers returning them to the sea.	Damage and potential loss of only significant green turtle feeding area. For green turtles the loss in area and quality of the seagrass bed north of the Aleipata wharf is of concern as this is the only bed of its size in the area and a vital green turtle feeding habitat. This seagrass bed has suffered impact from the Aleipata wharf development.	Increased protection for seagrass beds and investigation into recovery options.

4.3 Summary of impacts and consequences on impacted areas

Appendix 4 summarises impacts and consequences on affected communities and provides specific recommendations for these communities including recovery, rehabilitation and medium to long-term solutions.

4.4 Tsunami settlement survey

A visit was made to two areas where new settlements have been established by persons displaced by the tsunami. Details are reported in Appendix 5. Most of the recommendations centre on sanitation, water supply and access, and integrating all these issues into a single planning process.

4.5 Photo review and collation of qualitative comments

Photographs were taken from the ground and the air to illustrate the damage to the various habitats and the environmental problems created by the tsunami (Appendix 2). These include examples of the various categories of damage (high, medium, low). Photographs were taken facing a fixed direction were also taken for future comparisons. These positions were all recorded with a Geographic Positioning System.

During the course of the survey, team members recorded qualitative observations as they passed through the impact zone (e.g. wash zone, miscellaneous impacts, occasional accounts from individuals etc).

Both of the above categories of information will be compiled onto an excel spreadsheet so that the images may be accessed directly from the comment relating to a known point. Scanned images of the original data-sheets and field maps will also be included. This database can be made available to readers on request.

5. Recommendations

These are listed specifically for marine and terrestrial habitats and categorized as being needed in the short (<3 months) or medium to long term (>3 months. General recommendations are also listed.

Strategically the key recommendation for marine habitats is to implement actions that foster the natural recovery and resilience of these areas.

Strategically the key recommendation for terrestrial habitats is to implement actions that focus on restoration based on ecological and resilience principles, such as replanting affected coastlines with native wave resistant species and ensuring that all developments, rebuilding and associated infrastructure (eg villages, tourism) are undertaken cognizant of both the ongoing risk from tsunami, cyclones, sea level rise and other coastal hazards and follow appropriate planning processes and codes of environmental practice to minimize environmental impact to sensitive terrestrial and marine habitats.

MARINE

Short term:

- **Clean up activities:**
  - Undertake offshore aerial check of debris and removal of any items posing risk to shipping or the coast.
  - Undertake lagoon debris removal manually in impacted areas. Do not use dredging as this will cause further impact. Find and remove lost diesel fuel drums in the vicinity of the Aleipata Wharf.
  - Beach and foreshore area clean ups are required in partnership with communities and after salvage of useful materials by owners.
  - Stabilization of immediate beach and foreshore areas and associated infrastructure eg roading to prevent further impact to the marine environment eg from sediment run-off.
  - Care taken in the clean up of debris including solid waste in sensitive areas such as mangrove and wetlands so as not to damage these sites.
  - Aleipata Wharf clean up and immediate stabilization of sources of further pollution eg sediment run off.
- **Potential food source contamination**
  - As a precaution, warn local villages of potential food source contamination particularly shellfish, sea slugs and other near shore species in highly impacted areas including in marine areas surrounding the Aleipata wharf.
  - Assays of key food species eg shellfish in heavily impacted areas to assess safety for consumption. Based on results advise villagers accordingly.
- **Marine Rapid Assessment (MRA)**
  - Undertake an in-water marine rapid assessment with focus on expected highly damaged areas and those where previous information exists eg Aleipata and Safata MPAs.
  - As part of the MRA:
    - assess impact/vulnerability of key coastal features eg channels and embayments
    - identify sites for longer term recovery monitoring
    - assess loss of ecosystem function and impact on services eg food sources for people in affected areas
  - A joint team should be lead by MNRE/Fisheries combined with local and overseas expertise where needed. Expertise should include resource economist and at least one marine surveyor with marine tsunami impact experience.
- **MPA and Fisheries no take zones**
  - Undertake more detailed impact assessment of MPA and Fisheries no take zones and their potential for recovery and/or need for relocation. Note pre impact information for many of these sites is available (MNRE, Fisheries)
  - Based on consultations and agreement with villages and districts remark no take zones.

- **Marine Food Source Supply**
  - Using the results from the above undertake an assessment for marine food source supply including specific recommendations for possible substitute sources and rebuilding fishing capacity in a manner that does not significantly compromise marine area recovery eg first focus on rebuilding offshore capacity that can benefit entire village, ban outside commercial fishing in an offshore area to maximize local access.
- **Aleipata Wharf**
  - Detailed assessment of tsunami impact and the ongoing risk, costs and benefits of the wharf and its widened channel to nearby coastal villages.
- **Other marine stressors**
  - Remove/reduce other stressors and impacts to the coastal marine systems eg ban on sand mining, commercial fishing, and new reclamations to allow the best chance for recovery.

Medium- long term:

- **Other marine stressors**
  - Remove/reduce other stressors and impacts to the coastal marine systems eg ban on sand mining, commercial fishing, new reclamations to allow best chance for natural recovery.
- **Aleipata Wharf**
  - Comprehensive assessment of long term risk, costs and benefits of rebuilding the wharf assessed, including with local community input, before wharf rebuilding actioned beyond the immediate stabilisation and clean up recommended above.
- **Recovery Monitoring**
  - Based on the MRA results institute a monitoring programme to understand recovery of marine habitat from tsunami impacts.
  - Include in the recovery work monitoring of fishing capacity and ongoing need for any substitution measures for marine food supply that were used in the short term.

TERRESTRIAL

Short term:

- **Clean up activities**
  - Undertake clean up and removal of solid waste from terrestrial, wetlands, river habitats and village areas. Care to be taken in clean up so that sensitive ecosystems are not damaged eg by earth moving equipment
  - Maximize reusing and recycling materials and sort and remove remaining material into disposable and hazardous rubbish. Link with JICA Clean Up project.
  - Specific focus on clean up and proper disposal of waste from illegal/improper dumps exposed by tsunami eg Tuialemu, Lalomanu.
  - Review and update plan for effective local waste collection.

- Stabilization of land based sources of sediment from wetlands, streams, infrastructure eg roading to prevent further impact to the marine environment eg from sediment run-off.

- **Terrestrial Impact and Restoration Assessment**
  - Perform a comprehensive assessment of impacts on sensitive coastal habitats such as marshes and swamp areas and environmental impacts of new settlements
  - Assess restoration options for key terrestrial habitats made with costs clearly identified.
  - Build into these assessments a recognition of the ongoing tsunami risk and related coastal area vulnerability/hazard zones eg from channels and embayment areas. This should inform patterns of rebuilding and new development.

Medium- long term:

- **Replanting coastlines and river banks with native plants**
  - Plant buffer zones of native salt resistant trees (eg niu, talie, fetau, milo, pu'a, mangrove tree species etc) along the impacted coastline to reduce coastal erosion, hold together the foreshore and protect infrastructure
  - Plant buffer zones of native salt resistant trees along impacted river banks to reduce river bank erosion and protect infrastructure

- **Restoring and conserving sensitive coastal habitats**
  - Sensitive coastal habitats (swamps, mangrove areas etc) should be restored and protected from development and further degradation. Such areas provide multiple ecosystem services including the protection of the coastline from erosion and adjacent settlements from wave damage.

- **CIM Plans – Updating and Implementation**
  - Ensure that findings from incoming geo-science teams are fed into planning processes including revision of CIM plans as required.
  - Add a specific tsunami risk layer to the existing coastal hazard zone maps.
  - Seawall rebuilding should follow proper standards according to codes of environmental practice as appropriate – in some areas natural alternatives may be preferable.
  - Restoration actions identified above should be included in a revision of the CIM plans
  - Ensure that a mechanism for implementing CIM plans including partner roles and identification of resources needed is developed and then fully implemented

GENERAL RECOMMENDATIONS:

- The existing district Coastal Infrastructure Management Plans developed in full consultation with village governance systems (eg village fono) are an appropriate planning mechanism for participatory planning of the restoration of villages on the impacted coast.
- Consideration should be made to revise the Coastal Infrastructure Management Plans to include the management of coastal natural resources such as coral reefs, lagoon, seagrass beds, beaches, swamps, mangrove areas, etc as well as built infrastructure. Such CIM plans could be rephrased "Coastal Asset Management Plans" to reflect the fact that all coastal assets are included.
- The national coastal hazard zone maps and the CIM plans for affected districts should be revised to include a specific tsunami vulnerability layer and the likelihood of a repeat tsunami and areas most at risk from it must be factored into all planning
- Relevant planning processes and codes of environmental practice should be followed for all rebuilding and restoration work including new developments.
- Those recommendations endorsed by the Government of Samoa should identify clear decision making lead agencies, develop clear and costed terms of reference and invite partnerships for resourcing and needed expertise in these from local and overseas organizations.
- Work carried out in the recommendations above should follow normal protocols in Samoa for village and district approvals and participation. Existing governance structure eg MPA District Committees, CIM committees should be used effectively.
- Every effort should be made to capitalize on local expertise and supplement with overseas expertise where needed.
- Development of new settlements for displaced communities should follow relevant codes of environmental practice and be planned in a participatory manner to mitigate potential environmental impacts.
- Every effort should be made to collaborate with partners in American Samoa to maximize benefits and sharing of knowledge and experiences

References (incomplete)

Ministry of Natural Resources and Environment. (2000) Coastal Hazard Zone Mapping Stage II Report. Report prepared for Government of Samoa by Beca International consultants, Apia, Samoa.

Ministry of Natural Resources and Environment. (2006) Coastal Infrastructure Management Plan Aleipata Itupa i Lalo District. *Implementation Guidelines*

Ministry of Natural Resources and Environment. (2006) Coastal Infrastructure Management Plan Aleipata Itupa i Luga District. *Implementation Guidelines*

Park, G. Hay, J. Whistler, A. Lovegrove, T. and Ryan, P. (1992) *The Ecological Survey of Western Samoa: The Conservation of Biological Diversity in the Coastal Lowlands of Western Samoa*. Report by the NZ Department of Conservation for the Ministry of External Relations and Trade.

Pearsall, S. H. and Whistler, W. A. (1991) *Terrestrial Ecosystem Mapping for Western Samoa.* A report prepared for the Government of Western Samoa, South Pacific Regional Environment Programme and East-West Center and Policy Institute, Honolulu, Hawaii, U.S.A.

Whistler, W. A. 2002. *The Samoan Rainforest. A Guide to the Vegetation of the Samoan Archipelago*. Isle Botanica, Hawaii.

Appendix 1: Survey sheets

Environmental Assessment of Samoa Tsunami- Green Impacts

Village/Site Name:			**Date:**		**Observers:**		
Lat:		**Long:**		**Elevation (m)**			
IMPACTS		**Impact Level***	**Erosion Level**	**Ass./NotA/Exp.**	**Notes:**		
MARINE		(circle response)	(circle response)	(circle response)			
	Coral Reef						
	Lagoon						
	MPA NTZ						
	Seagrass						
	Beach/intertidal						
	Foreshore						
	Mangrove						

			Ass./NotA/Exp.	**Notes:**			
TERRESTRIAL	**Wetland**	H M L U 0	A NA E				
	Forest	H M L U 0	A NA E				
	Freshwater/stream	H M L U 0	A NA E				
	Pastoral	H M L U 0	A NA E				
	Agricultural (crops)	H M L U 0	A NA E				
	Village Area	H M L U 0	A NA E				
	Invasive Risk	H M L U 0	A NA E				
		Photos Taken		Y/N	Photo Numbers:		
		Video Taken		Y/N			

**Impact levels:*	*High (H)*	*Medium (M)*	*Low (L)*	*U (Unknown)*	*0 (zero impact)*
Further Observations					

Environmental Assessment of Samoa Tsunami- Brown Impacts

Village/Site Name:		**Date:**		**Observers:**	
Lat:	**Long:**			**Elevation (m)**	
Max Wave Height:		**Max distance of wave from shore:**			
IMPACTS			**Impact* Level**	**Ass./NotA/ Exp.**	**Notes**
	Pollution	Solid Waste			
		Hydrocarbons			
		Toxins (pops/non-pops)			
	Water	Water Courses			
		Water lense			
		Salination			
	Sewage	Effluent/Contamination			
		Septic Tanks			
	Roading	Roading / rerouting			
		Environmental impact			
	Documentation				
		Photos Taken		Photo Numbers:	
		Video Taken			
**Impact levels:*		*High (H)*	*Medium (M)*	*Low (L)*	*U (Unknown)*	*0 (zero impact)*
Further Observations						

Appendix 2. Photographs of habitats and variables assessed

Plate 1: Damaged wetland area, Utulaelae (High impact)

Plate 2: Damaged wharf, Satitoa (High impact)

Plate 3: Coastal erosion, Vaovai (High impact)

Plate 4: Damaged petrol station, Vailoa

Plate 5: Septic tank pollution, Vailoa

Plate 6: Coastal erosion, Satitoa (High impact)

Plate 7: Solid waste impact on mangrove habitat, Lotopu'e

Plate 8: Solid waste and complete village destruction, Lalomanu (High impact)

Plate 9: New settlement, Lepa

Plate 10: Unaffected coast, Matautu, Lefaga

Plate 11: Coastal erosion, Tafatafa (Low impact)

Plate 12: Coastal erosion, Lotofaga, Safata (Medium impact)

Plate 13: Old solid waste dump-site exposed by tsunami, Tuialamu, Lalomanu

Appendix: 3 Impact assessments for all sites surveyed

A. Green variables

	Count of High	Percent High	Count of Medium	Percent Medium	Count of Low	Percent Low	# observations
Coral Reef	13	36	11	31	12	33	36
Lagoon	14	39	6	17	16	44	36
MPA NTZ	9	36	7	28	9	36	25
Seagrass	4	80	0	0	1	20	5
Beach/intertidal	14	39	5	14	17	47	36
Foreshore	15	41	5	14	17	46	37
Mangrove	3	27	3	27	5	45	11
Wetland	3	30	1	10	6	60	10
Forest	0	0	0	0	16	100	16
Freshwater/stream	1	9	3	27	7	64	11
Pastoral	0	0	0	0	1	100	1
Agricultural (crops)	6	25	2	8	16	67	24
Village Area	12	43	8	29	8	29	28
Invasive Risk	1	50	0	0	1	50	2

B. Brown variables

	Count of High	Percent High	Count of Medium	Percent Medium	Count of Low	Percent Low	# Observations
Solid Waste	8	33	5	21	11	46	24
Hydrocarbons	1	17	1	17	4	67	6
Toxins (pops/non-pops)	0	0	1	100	0	0	1
Water Courses	4	33	4	33	4	33	12
Water lens	0	0	1	33	2	67	3
Salination	10	37	6	22	11	41	27
Effluent/Contamination	2	14	2	14	10	71	14
Septic Tanks	2	17	2	17	8	67	12
Roading / rerouting	2	14	4	29	8	57	14
Enironmental impact	4	27	0	0	11	73	15

Appendix 4: Summary of Marine & Terrestrial Impact Characterisation (Magnitude & Areas Affected) – Brown variables

TYPE OF IMPACTS	NO OF OBSERVATIONS	IMPACT MAGNITUDE AVERAGE FOR ALL OBSERVATIONS H=High, M=Medium, L=Low	VILLAGES AFFECTED	IMPLICATIONS FOR DETAIL ASSESSMENT & COMMUNITY REHABILITATION PROGRAM
Solid Waste	24	H=33%	Lalomanu, Ulutogia, Satitoa, Mutiatele, Saleaumua,	Explore effective management measures
		M=21%	Tafitoala, Poutasi, Lotofagá, Vavau, Utufaalalafa,	for waste & pollution control and sound
		L=46%	Samatau, Siufaga, Virgin Cove, Siumu, Vaovai, Satalo, Salani, Utulaelae, Sapo'e, Aufaga, Lepa, Saleapaga, Vailoa, Tiaveatai,	disposal in consulation with severely affected communities.
Hydrocarbons	6	H=17%	Satitoa,	Investigate the potential effects of toxins
		M=17%	Lalomanu, Vailoa,	and hydrocarbons on food and water source
		L=67%	Vaovai, Salani, Lotofaga, Vavau,	and appropriate mitigation measures.
Toxins	1	H=0%		Investigate the potential effects of toxins
		M=100%	Satitoa	and hydrocarbons on food and water source
		L=0%		and appropriate mitigation measures.
Water Courses	12	H=33%	Salani, Aufaga, Saleapaga, Ulutogia,	Investigate potential contamination and loss
		M=33%	Poutasi, Lotofagá, Vavau, Lepa,	in capacities of water supply and measures for immediate and long term restoration.
		L=33%	Virgin Cove, Siumu, Vaovai, Tiaveatai	
Water Lens	3	H=0%		Investigate potential contamination and loss
		M=33%	Poutasi,	in capacities of water supply and measures
		L=67%	Siumu, Vaovai,	for immediate and long term restoration.
Salinization	27	H=37%	Poutasi, Salani, Lotofagá, Lalomanu, Vailoa, Ulutogia, Satitoa, Mutiatele, Saleaumua,	Investigate nature of productivity loss
		M=22%	Siumu, Vaovai, Vavau, Aufaga, Saleapaga, Utufaalalafa,	in affected agricultural lands due to
		L=41%	Samatau, Siufaga, Saanapu, Lotofaga, Tafitoala, Satalo, Utulaelae, Sapo'e, Lepa, Tiaveatai, Savaia-Faleseela,	salinization and measures for restoration in

TYPE OF IMPACTS	NO OF OBSERVATIONS	IMPACT MAGNITUDE AVERAGE FOR ALL OBSERVATIONS H=High, M=Medium, L=Low	VILLAGES AFFECTED	IMPLICATIONS FOR DETAIL ASSESSMENT & COMMUNITY REHABILITATION PROGRAM
				consultation with affected communities.
Effluent/ Contamination	14	H=14%	Lalomanu,	Investigate extend and levels of potential contamination with hazardous effluents and
		M=14%	Vailoa, Satitoa,	clean-up / restoration measures in
		L=71%	Tafitoala, Siumu, Poutasi, Satalo, Utulaelae, Sapo'e, Lotofagá, Vavau, Utufaalalafa, Tiaveatai	consultation with all affected communities.
Septic Tanks	12	H=17%	Lalomanu,	Explore effective short and long term
		M=17%	Vailoa, Satitoa,	sewerage in constuation with all affected
		L=67%	Tafitoala, Siumu, Poutasi, Satalo, Utulaelae, Sapo'e, Lotofagá, Vavau, Aufaga,	communities.
Roading/ rerouting	14	H=14%	Ulutogia,	Investigate public infrastructural restoration
		M=29%	Poutasi, Vaovai, Lalomanu,	and rebuilding that are enviornmentally
		L=57%	Virgin Cove, Lotofagá, Saleapaga, Vailoa, Mutiatele, Saleaumua, Tiaveatai,	sound and more resilient to future coastal
Environmental impact	15	H=27%	Saleapaga, Lalomanu, Ulutogia, Satitoa,	natural hazards impacts in consultation
		M=0%		with all affected communities.
		L=73%	Saanapu, Lotofaga, Poutasi, Vaovai, Sapo'e, Lotofagá, Vailoa, Mutiatele, Saleaumua,	

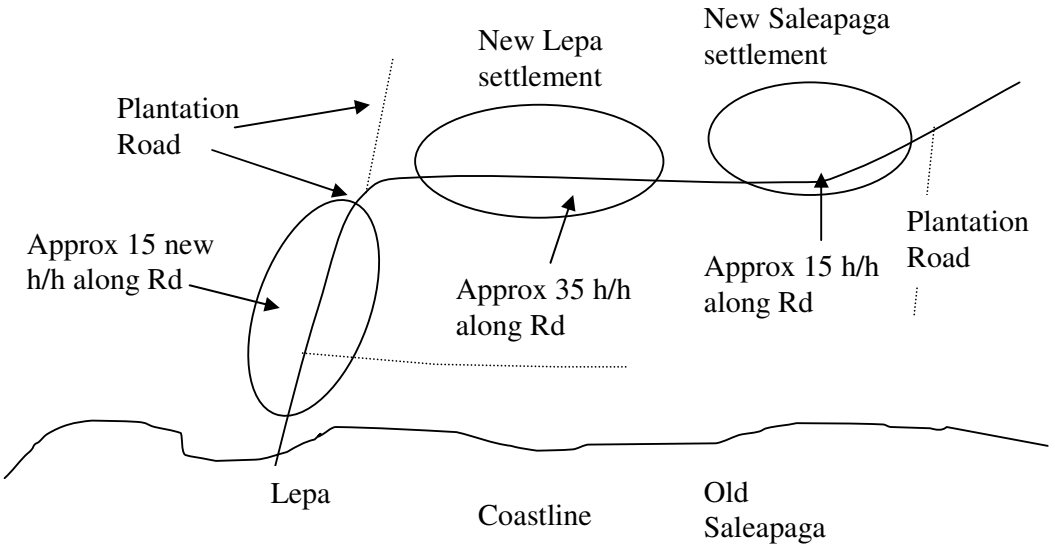
Appendix 5: Survey of new settlements post-tsunami

Two of the survey team (James Atherton and Greg Sherley), accompanied by Charmina Saili (RC's Office, UNDP) visited the area newly settled after the Tsunami on 10th October 2009. They spent about an hour driving the road slowly, observing and taking images. About five people in three groups were casually interviewed. The traffic was heavy including heavy vehicles installing new power lines. There was no other evidence of infrastructural development apart from some rudimentary clearing of land for building sites and (dirt) roading.

New settlements (in effect following an existing access route into plantations) were observed along the Lepa and Saleapaga plantation road (14.02852E; 171.49579N; 243m elevation highest point). While driving the road groups of tents and shelters (including utility shelters such as latrines, storage etc – termed here as "households") belonging to the same extended family were scored and plotted roughly on a schematic map (below). On the day of the survey (Saturday 10th October) approximately 65 households were seen – 35 from Lepa,15 from Saleapaga and another 15 spread out along the lower reaches of the road above the coastal village of Lepa. Each household may have accommodated between 6 to 12 people. Note that further households almost certainly occurred out of sight – well back from the road edge and along the dotted plantation road partly drawn into the diagram. Hence the above figures are certainly an underestimate.

Power was being connected to the road using permanent materials and high voltage cable. Pit latrines have been built (some to a standard specification) and "Portaloos" were also seen. There is no water reticulation and women were seen walking containers down the road for filling at the coast (another colleague pers.comm).

Figure 10: Sketch map showing new settlements behind Lepa and Saleapaga as at 10th October 2009 ("h/h" = "households")



The access road to the bat crater at Luo-o Fafine (inland from Lalomanu) was driven to check the new settlements there. Two resettled households were seen but the larger settlements in the area were not visited.

Surveyors considered that the main environmental issues which faced the new settlements were –

- sanitation in the absence of proper septic tanks (including for "grey" waste/water) – likely to be compounded during heavy rain with spill over
- the absence of reticulated water compromising the consumption of potable water, hygiene standards in washing up clothes and kitchen ware, and personal hygiene
- many of the roads and tracks to households were little more than cleared dirt access ways. These will be come extremely muddy and possibly impassable with the advent of wet weather. The mud may compound sanitation issues
- new habitations will inevitably result in more solid waste which will need to be managed so that further solid waste (and possible POP's and hazardous waste) is not aggravated.
- land clearance may impact some native trees with flow-on effects to native wildlife
- new settlement may result in a new focus towards harvesting traditional food such as pigeons, doves and bats

Many of the above issues will be exacerbated with either or some of the following and other factors not identified –

- heavy rain – almost certainly due soon with the advent of the rainy season
- water storage and reticulation issues

- managing sewerage disposal either through septic tanks or a reticulated service
- planning the above using standard methods well known to practitioners

Recommendations explicit to the new settlements

.

- create a planned approach to the new settlements as soon as possible to accommodate the issues described above and avoid establishing settlements which will create issues in future
- consider supplying water tanks supplied by either or both a reticulated scheme or roof-fed rain water as soon as possible
- stabilize the road with compact roading material as soon as possible
- set up monitoring of variables as described above – including those relating to the environment and human welfare (i.e. done in tandem)
- proper environmental impact assessments should be completed for any major developments in the new settlement areas- such as tapping nearby crater lakes for water supply. Such crater lakes harbour sensitive crater marsh ecosystems and can be easily destroyed or damaged
- codes of environmental practice should be followed for all major developments