Many efforts have been carried out by South Pacific island countries affected by conventional or traditional means to protect their coastal areas against the alarming and increasing rate of natural disasters such as hurricanes, tsunamis, and coastal inundation. However, these efforts are not enough, since the problems are further compounded with changes in global climate systems and natural disasters associated with global warming and sea level rise. The study carried out a technology assessment of the present situation of coastal protection systems (CPSs), followed by analysis of the problems. It discusses appropriate solutions to the problems and concludes with the result of the nature of present CPSs using a proposed technology assessment table.

Key Word: Coastal protection systems, seawalls, climate change, sea level rise, erosion, hurricanes, waves, coastal inundation.

1. Introduction and Objectives

In the Pacific studies have shown increased incidences of coastal inundation, flooding and erosion (SOPAC 1991, 1994). Fenney (1989) and Carter (1990) reported that the occurrences of cyclones over the past century are to average about one cyclone per year with a severe cyclone once every four years. Incidences have been also reported such as loss of mangroves (Fujimoto et.al.1989), increased bleaching of coral reefs (Wilkinson 1998, Hori 1980) and melting of ice caps in the Atlantic and Greenland (IPCC 1996). Wigley and Raper (1992) predicted sea level rises to be from 15cm to 90cm with the best estimate of 48cm by 2100, if global warming continues at its current pace. Small island nations such as Samoa, Kiribati, Cook Islands, Tuvalu, Solomon Islands, Federated States of Micronesia (FSM), Marshall and Tonga, with almost 90% or more of the vital social, economic, and political zones located in vulnerable low-lying coastal areas, adaptation options to sea level rise is a very important issue.

The study carried out a technology assessment of CPSs with three objectives. The first objective is to review past practices of coastal protection systems and to identify major constraints of their effectiveness.
It outlines how effective these structures are in the wake of past and recent natural disasters such as high waves, hurricanes and tsunamis in the region. Second, to suggest relevant system (structures) for such constraints using available local knowledge combined with civil engineering methodologies that are predominantly lacking in many of the structures in terms of material, design and placement.

The study suggested that new innovations should be imported from successful projects in similar coastal settings along with more complex technological methods from developed countries that could suit the local environment and nature of the South Pacific coastlines. An example is combining existing natural coastal protection systems such as mangroves and coral reefs, with artificial structures to obtain optimum advantage of coastal protection. Third, to develop guidelines and criteria for assessment of existing technology in order to facilitate a common platform and methodology in implementing appropriate technology, since there are no i) systematic and scientific assessment criteria, and ii) a civil engineering manual guideline for CPSs in the South Pacific region.

2. Present Situation of Coastal Protection

The efforts of protecting coastal areas against natural disasters are very limited from the view point of civil engineering in the South Pacific. These problems occur in four main areas, i) lack of scientific qualitative background knowledge of coastal areas, ii) material weakness, iii) placement and misplacements, and iv) design failures. The lack of scientific knowledge in the locals regarding wave properties, wave forces on the structures, currents and sand movement, and the effect of high waves during hurricanes on coastal areas is reflected in the narrow life span of most of the CPSs in the South Pacific (Mimura and Nunn 1998), because many CPSs are constructed without taking into consideration these natural elements. For example, breakwaters built in areas that experiences strong wave energy and current flow, sand build-up or erosion can occur immediately behind or away from breakwaters (Solomon and Kruger, 1996). This is also a common problem for groins, since it disrupts natural flow of sand and current movements and redirecting them. For example (plate 1), a locally made groin in Kiribati causes an accumulation of sand on the updrift side and causing shoreline erosion on the downdrift side which can also be seen in other similar cases in the Cook Islands and Fiji (Solomon and Kruger, 1996).

![Plate 1. Coral Rumble Mole Groin in Kiribati (SOPAC 1996)](image)

Most of the materials used in the region to protect coastal areas against strong waves, hurricanes and
tsunamis are inadequate. For example, iron materials used in gabion nets and 44-gallon drums are easily corroded in salt water, because of the absence of anti-corrosive substances (like epoxy tar, galvanized wires, marine varnish and teak oil) in the drums and nettings. This leads to their total breakdown, which causes quick and easy dispersion of fill materials. Another common material problem is the type of cement used for matrix binding and concrete slabs. In Fiji, most of the CPSs are made from Portland cement type 1, which is the ordinary cement commonly used for general construction of infrastructures on dry land. This accounts for almost 90% of the total CPSs in Fiji (Dau, 1996). Those that are located in shallow and deep waters easily corrodes and breakdown due to the constant pounding of strong wave actions during hurricanes and tsunamis and also from the hydraulic pressures occurring at low and high tides (Dau, 1996). This occurs mostly at the toes of vertical seawalls from strong reflected waves. The result is usually seen in stones, rocks, gravels, sands or even old tires and tin cans materials strewn in all directions in front of ruined structures. In other cases in Fiji, crude materials such as discarded refrigerators, rotten woods, old electrical posts, old tires and household garbage, are also used as CPSs. These structures are very vulnerable to even lesser natural disasters such as high tides and flooding. This is linked to the above problem regarding current and wave movements in coastal areas. Most of the CPSs are not resilient to strong wave attacks and therefore a failure in the first place. It also presents a sore eyesight to the coastal landscape that characterizes island ecosystems of the South Pacific.

The problems associated with placement occur in cases where toe stones are placed in front of seawalls and other CPSs. This becomes a threat during strong wave attacks since it usually washes back onto seawalls behind, causing concrete blocks to crack and breakdown (Sherwood, 1994). It is also observed that due to the weaknesses of concrete structures and the lack/or no matrix binding of CPSs made from cement and rock boulders, structural breakdown often takes place, which is compounded by the increase rate of CPSs failures. Another problem is misplacement. Structures are sometimes wrongly placed in coastal settings in regards to the capacity to cope with strong wave-energy, winds and other natural forces. In Fiji vertical seawalls are built almost everywhere, from exposed to protected coastal areas. The problem occurs mostly when vertical seawalls are constructed in high wave-energy coastal areas. Many case studies in the South Pacific region have reported that vertical seawalls constructed in high-energy wave areas compounded existing problems such as depression of gravel in front of structures, increase of soil and sand erosion in front of seawalls due to reflected waves, back and base scouring, and final collapse of seawalls (Sherwood, 1994). On the other hand vertical seawalls that are built in protected harbors and coastal areas have greater lifespan and are more effective because wave condition is mild in these areas.

Final problem is associated with structural design. Most of the design pattern of CPSs in the South Pacific Region lacked fundamental civil engineering standard in terms of firm foundation, drainage systems, shape of structures in regard to its immediate surroundings (slope or vertical) and protective covers such as toe footing and solid frontal mortars. In Fiji, for example, there are many seawalls crudely made from 44-gallon drums, old tires, and hand-placed rock boulders. These seawalls due to the deep spacing between the structures are too porous and offer no resistance to waves, thereby causing back scouring and settling of backfilled materials. This in turn leads to leaning of structures and final failure of seawalls. In Fiji, about the majority (51%) of the seawalls is a vertical wall (Dau, 1996). The designs of vertical seawalls in high wave-energy areas are inadequate. Therefore sloping seawalls are better options to construct in such places to alleviate direct action of strong waves and overtopping that causes soil erosion, and back and base scouring of seawalls. Another example is the construction of high technological engineering CPSs imported from developed countries to the local environment without consideration of the environmental and
ecological nature of the local area. In Kiribati, a causeway linking two coral atolls has blocked a natural flow of seawater during high tide from the ocean to the lagoon and vice versa during low tide. As a result, the lagoon was deprived of its natural drainage flow of seawater, causing seawater stagnation, this in turn lead to two main problems. The first is the water built up during high tide in the lagoon, which leads to inundation of the immediate low-lying coastal area (SOPAC, 1992). The second is the negative effect of stagnant seawater on coral communities and many other marine organisms such as fish, crabs, seaweeds, etc. Even though the causeway has contributed positively to the transportation system between the two atoll islands, it would have been more appropriate if water drainage was installed under the causeway to allow the natural flow of seawater between the lagoon and the open sea in the first place.

So far very little focus has been put by small island nations to address the importance of existing CPSs from an engineering point of view. For example, Dau (1996) reported that lack of monitoring has led to massive losses of seawalls incurred all over Fiji especially in the area of management and repair works, where very little governmental financial commitment has been allocated.

Some of the problems associated with coastal protection are also direct or indirect consequences of prevailing external social and political issues apart from natural elements and ineffective engineering techniques. Another crucial factor is the lack of coastal zone management (CZM) policies, especially on issues relating to i) national environmental legislation, ii) planning of national environmental protection, and iii) disaster mitigation plans. This is compounded by the lack of institutional and human resource capacity in the area of management, repair and maintenance in responsible governmental institutions such as Public Works Department, Department of Environment and the Department of Town and Country Planning or related governmental and non-governmental bodies in the region.

Apart from the above problems related to CPSs, many South Pacific island countries are poor developing countries, which primarily depend on agriculture or fisheries. An average of poverty rate is 15%, and GNP is less than US $96-$1,748 (Maharaj, 2000). Many of these small island nations do not have necessary financial means to carry out mitigation and adaptation work in the area of coastal zone management, including construction of proper CPSs, repair and management of CPSs, and installation of new CPSs. In Fiji, another problem is the complexity of land tenure system. Often this makes maintenance and repair works of CPSs in rural areas difficult, due to the conflicting views and interests between the landowners and the government.

Regarding the problems associated with technology, this paper identifies the following similarities of problems that commonly prevail across the South Pacific islands countries. These are: i) little or no toe protection of CPSs; ii) no filter clothes, and improper or no drainage systems at the back and front of CPSs; iii) weak and insecure foundations; iv) inappropriate or too expensive materials; v) lack of maintenance and management of damaged CPSs; vi) lack of historical data of credible information; vii) undesirable designs such as, vertical designs and rusted materials; viii) little or no standard and systematic design for height, weight, etc of the structures and concrete production, and: ix) unaesthetic sights and landscaping.

3. Solutions to Problems

In defining solutions to the problems of CPSs in the South Pacific Region, three main areas can be
suggested; a) institutional, b) planning and c) engineering. Many South Pacific island countries lack institutional capacities to address vulnerability of coastal areas through appropriate legal tools. It is evident that policies safeguarding coastal zone and development are not well structured and inappropriate. In Fiji, setback policies regarding construction of infrastructure on vulnerable coastal areas are inconsistent, ineffective and confusing. Due to this discrepancy, very little institutional arrangements and monitoring are carried out for coastal development such as construction of tourism infrastructures, road and ports facilities, sand mining, and waste disposal. Proper Environmental Impact Assessment (EIA) from responsible governmental bodies has seldom been performed.

The study proposes three areas that are to be incorporated into the main institutional framework of Fiji’s coastal zone management (CZM) and policy framework. The first is creation of a new integrated environmental and resource management legislation as a legal tool to safeguard against adverse effect of coastal developments. The second is the establishment of a coastal resource management body, comprising of key management personnel from governmental, non-governmental and private bodies empowered to legally review the performance of existing legal bodies regulating CZM. This should overcome overlapping, duplication and inconsistency of coastal protection and management, since currently too many bodies are involved in so many diversified goals and objectives. Finally to facilitate institutional capacity building in empowering existing monitoring bodies. Special acts should be developed to carry out environmental impact assessments (EIA) and to carry out fines and penalties for offenders.

In terms of planning, three main areas identified are i) land-use plan, ii) environmental protection plan and, iii) natural disasters mitigation plan. Land-tenure systems are very complex issues in the South Pacific Region, compared to many of the western countries, where the majority of land is owned by indigenous people and their communities. For example traditional community units in Fiji own the majority of the land area (87%). This makes the work of the central governments difficult when it negotiates about governmental induced coastal developments and mitigation options in areas affected. An integrated approach is needed with a bottom-up approach that includes landowners and stakeholders as vital players in governmental planning schemes. This would allow greater participatory efforts by locals.

4. Identification of the Nature and Problem of Existing Engineering Technology

In the engineering field, the problems identified for the structures in the South Pacific region are shown in Table 1.

<table>
<thead>
<tr>
<th>PROBLEMS OF CPSs</th>
<th>CORRESPONDING NATURE OF EACH PROBLEMS</th>
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</thead>
<tbody>
<tr>
<td>i) Structural/Design</td>
<td>Strength of CPSs</td>
</tr>
<tr>
<td>a) Corrosive Materials</td>
<td>- 44 gallon drums corrode easily, - iron strengthening, elastic/plastic sand bags easily deteriorated causing of dispersion of sand/gravel materials, - gabion baskets eroded too easily once plastic covering is scratched away and gabion nets broken into pieces</td>
</tr>
<tr>
<td>b) Material Strength</td>
<td>- cement blocks broken into pieces when big toe boulders washed onto them during strong wave attacks, - toe of vertical CPSs are vulnerable to strong pressure from deflected waves pounding and may eroded very quickly, - combination of weak/strong boulders together makes the...</td>
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</table>
structures weak overall

c) Matrix Binding
- no matrix binding leads to backfilling and settling, - piled stones have no concrete binding matrix, vulnerable to strong wave actions, - local designs like tire seawalls are not well bounded and thus strewn in all directions due to strong wave actions, - rocks inside gabion baskets are not well bounded thus movements of rocks inside break gabion netting, - local responses too porous from frontal onslaught of storm waves & etc. due to use of shrubs, rubbish, leaves and logs.

d) Flaw in design
- deep spacing renders no protection from saltwater intrusion, - defense mechanism such as no toe footing lead to face break-up, - overtopping of waves mostly experienced due to vertical designs, - introduced CPS not suitable for exposed conditions (e.g. Causeway in Kiribati), - breakwater constructed in too deep coastal waters, thus costing too much since no feasibility study in the first place (Breakwater in Onotoa, Kiribati)

ii) Placement

Effect on Coast and Human

a) Base & foundation scouring
- due to base underscoring this lead to mass silt concentration in front of sandbags, - no firm foundation lead to front deeply scoured and failure of face leads to siltation pollution

b) Back scouring
- backfill is of fine grain soil, loose gravel and sand or sand stones and thus too porous to backscourings causing erosion of backfill offering little back and face support of seawalls and revetments.

c) Erosion
- washing out of rocks from rear of CPS due to back settlement, - erosion causes immediate silt pollution to immediate peripheral areas, - protects only land immediately behind it, while renders erisions to those nearby, - washing out of rocks from rear shoulders of breakwater crest this exposes smaller secondary armors

d) Leaning of Structures
- leaning of structures indicates no solid backfill or erosion of backfill due to little or no drainage system at the back.

e) Hydraulic characteristics change
- blocking water draining into lagoons decreases water quality affecting marine biotic and abiotic materials, - causes accumulation of sand on the updrift, while causing erosion on the down-drift side, - wave set-ups due to introduction of Breakwater in a lagoon channel, - blocking of natural current and sediment transport through the channel, very fined grained sediments have accumulated in the still water zone causing undesirable condition for recreation, broken or damages rock boulders are hazards to out boat motoring & etc

f) Social and Cultural
- unequal distribution of benefits, that only economical regions benefited while less imported areas are totally ignored, - traditional coastal sacred grounds are affected due to erosion of brought about by seawalls and breakwaters, - cause of conflict of interest if serves only a specific household around a wider community

g) Landscape
- absence and erosion of sandy beaches, coastal vegetables and mangroves are unaesthetic

h) Human Health/Safety
- broken or damages rock boulders are hazards to out boat motoring & etc, - local CPS response and practices of constructing with rubbish, rusted old refrigerator and etc lead to pollution

i) Recreational purposes
- immediate access from land to sea is difficult due to awkward design patterns e.g. access to coastal areas are sometimes cut off from vertical structures, very fined grained sediments have accumulated in the still water zone causing undesirable condition for recreation

iii) Cost

Construction, Management & Repair

a) Type
- too expensive CPU in Cooks and Tonga, Breakwater and Causeway in Kiribati, - basic building materials such as cement, concrete and iron materials are very expensive, - cheap materials are very easily damaged on the other hand.

b) Machinery/labour
- too costly needing heavy machinery to construct, - high cost & high level of specialized and technical labour input.
Apart from the hard structures, the majority of the coastlines are protected with coral reefs, mangroves and coastal vegetations. Many of the problems that resulted from coastal erosion are also due to the following factors: i) mangrove swamps are used as rubbish dumps, source of firewood, cut down for reclamation; ii) coastal vegetations are used for medicinal purposes, housing materials, reclamation due to rapid expansion of urbanization and industrialization, historically depleted due to human activities on coastal areas such as road and housing infrastructures; iii) coral reefs are very fragile to climate change such as increases in seawater temperature and sea level (Mimura and Harasawa, 2000). Other factors are dumping of toxic and polluted waste from industries sewerages, human interferences from diving, snorkeling, extractions and boat anchorage.

5. Guideline to Choose Appropriate Engineering Options

Since there is little or no understanding of the natural environment and the effect of engineering options to the surrounding environment, a guideline is proposed for assessment and evaluation of many of the coastal protection system in the South Pacific Region. The study proposed a modified Environmental Technology Assessment Manual (EnTA) (Hay and Hoonan, 2000) as a guideline manual, i) to state the environmental nature of a construction site, ii) to choose appropriate engineering options applicable to the nature of a coastal area. The steps taken are: i) technology description which reviews existing CPSs; ii) identifying pressure and impacts of major weaknesses and major strengths; iii) evaluation of impacts on environmental, social and economic issues; iv) comparison of options and execute changes, and v) conclusion and recommendation. From the EnTA manual, the study finalizes a technological assessment table (Table 2) which incorporates a selection criteria based on function, cost, suitability and people’s acceptance in the assessment of existing and envisaged CPSs. The criteria are discussed below in detail.

The first Criterion is function of CPSs. When specific CPSs are constructed, it is important to understand whether it serves only one purpose or many purposes. For example, if a seawall is chosen, it serves not only to protect the coast from the sea, but also serves as an erosion protection system, an asset to beautiful landscape and a place of recreation for locals. This serves three functions at the same time. The problem in Fiji is that too many CPSs are built with only one purpose in mind, which is to keep the sea from encroaching upon dry land. Most of these CPSs, especially vertical seawalls, do not take into consideration the landscape perspective. That is why inappropriate design of seawalls compounded existing problems such as soil and sand erosion. Therefore careful engineering options should be selected including sloping seawalls on high wave energy coasts, drainage systems of seawalls to reduce water pressures build-up at the back, and better concrete to bind rocks in the seawalls. The functions of CPSs should reflect its design characteristics and framework. In designing a seawall, it is necessary to assess and evaluate its function to a particular space and setting.

The costs criterion should reflect structures that are affordable and less expensive but also strong and durable to protect coastal areas. In many rural settlements located in low-lying coasts in Fiji, the work of constructing coastal protection systems is mostly carried out by communal and individual initiatives. In remote small islands, construction of smaller CPSs such as seawalls and revetments is more favorable than expensive structures such as breakwaters and coastal protection units (CPU’s) since the materials are readily available, and they are easier to construct. Results have shown that vertical designed seawalls in Fiji constructed in protected coastal areas with low-energy waves tend to be very effective in protecting the
<table>
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<tr>
<th>Structure</th>
<th>Cost</th>
<th>Impact on local Natural Env</th>
<th>People's Acceptance</th>
<th>Suitability</th>
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**Table 2: Technology Assessment Table**

- **Design and Cost = Y/N- Yes /No,**
- **People's Acceptance = A. Acceptance NA - Not Acceptable**
- **Degree of threat = D-Dangerous S - Safe**
immediate dry land from the waves (Solomon S., Kruger J., 1996).

The design suitability criterion is also linked to the function criterion. Four criteria identified are stability, flexibility, durability, and maintenance in the South Pacific region (Hassan, 1999). Most of the CPSs that are locally made have very little or no engineering features. Therefore CPSs should be stable and tough against the hydraulic loads of waves and other natural forces, and it should be able to keep the foundational subsoil from erosion (Hassan, 1999). For example, toe-protection rocks and boulders are necessary in exposed and high wave-energy areas.

CPSs should be flexible to accommodate changes occurring to its structural make-up (Hassan, 1999). Good drainage system such as ducts should be incorporated into the initial design, through the layers of the seawalls to ease the pressure of the water pressure that build up behind CPSs during heavy rains, floods, sea sprays and storm. Durability of CPSs depends on the ongoing processes of aging, in its design life (Hassan, 1999). When chemical weathering of concrete do occur, it should still be functioning. The non-corrosive substances such as ordinary tar paint used in the construction of tar sealed roads or resin paint could be utilized to paint iron bindings of CPSs.

Lastly stabilizing and reinforcement of existing damaged or partially damaged CPSs is a complex task that requires constant financial, infrastructural and human resource needs, which many of these Island countries could not afford. Due to lack of monitoring and maintenance of CPSs it has lead to massive losses being incurred all over Fiji, where seawalls have fallen and rebuilt only to fail again, when lessons could have been learnt much earlier to prevent events repeating itself (Dau 1996). Another problem is construction of very expensive and large seawalls that cannot be maintained by relatively cheap materials. Once damaged it will require expensive construction materials, heavy supporting infrastructures and machineries that are not locally available. Therefore design of CPSs should feature maintenance factors that include easily renewable materials such as rocks and boulders that are easily available and accessible in the area, less support infrastructures and machineries. For example gabion baskets are ideal CPSs since they are strong, easy to maintain and easy to deployed anywhere with minimum support infrastructural system and availability of construction materials.

The final criterion is the people’s acceptance of a CPS to its surroundings. This includes the structure should reflect the decision and acceptance of the community as a whole against individual needs. Culturally the people of the South Pacific have very strong social and intricate communal bond, and if CPS reflects the will of the majority, it should be installed. This will create less diversity and friction amongst villagers and locals. It will also promote togetherness to form alliances and locals are better equipped to solve problems more easily as a group. Also structures should protect not only areas of concern regarding erosion and wave attacks, but areas of important cultural sites such as sacred burial grounds, religious grounds, and recreational playgrounds. Another important factor includes total integration of a CPS into the social and cultural attachment of the locals to the sea. Many of the vertical and high seawalls do not allow easy access to the sea, therefore considerations should be accommodated to allow easy access to the sea and to provide available resting or meeting place for locals to enjoy the spectacle of sunrise and sunset.

6. Conclusions
In this paper, present situation of the coastal protection systems were examined to reveal prevailing problems from engineering viewpoints. Results of the assessment are:

i) Approximately 80% - 90% of active CPSs are in the form of coral reefs, mangroves and coastal vegetation, while only 10-20 % are artificial CPSs. The major artificial options in the South Pacific are the cheapest and locally manufactured structures, while expensive modern technology are applied in some places including coastal protection units, causeway, groins, and gabion baskets.

ii) Rusted 44 gal drums, gabion PVC and iron netting, local seawalls consisting of rubbish (hard, soft) are not effective, and often cause adverse environmental effects on the surrounding coasts.

iii) Local materials are more acceptable to local situation due to availability, cheap cost, and familiarity to the local people.

iv) Most local CPSs have no design standards, and do not last for a long time. Approximately 90% of CPSs suffered from some form of structural breakdown like leaning, toe erosion, loss of back fill, and total failure.

Since the natural coastal protection, such as mangroves, coral reefs, and coastal vegetation, is prevailing and heavy engineering is not necessarily suitable to the coasts in the South Pacific island countries, careful development is necessary on how to combine such natural and artificial elements to obtain optimal coastal protection. The criteria for this development are multi-faceted including cost, environmental consideration, and people’s acceptance, in addition to the structural viewpoints of function, durability and flexibility of the structures. This is a new challenge to the people in the South Pacific, where there has been no such development in the coastal engineering.

References


Dau E., 1996 A review of Coastal Protection Structures with Comments on their Structures and Effectiveness. Mineral Resources Department, Engineering Geology Unit, Suva.


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