COASTAL AREA PLANNING AND MANAGEMENT USING FORESTS AND TREES AS PROTECTION FROM TSUNAMIS

Jane Preuss AICP
Planwest Partners
Kirkland, Washington 98033
USA

Integrated Disaster Management to Maximize Protective Role of Trees in Coastal Zone

Immediately after the December 26, 2004 tsunami, extensive efforts were mobilized to identify, characterize, and map the devastating losses and impacts. The recovery process continues to generate awareness of the need for an integrated approach to decision making in coastal regions that balances the need to accommodate seemingly conflicting objectives such as ecosystem management, housing, and economic development. To date however a model for this integration does not exist. Analysis of communities that have experienced disasters reveals that too often in the rush to return to "normal" rebuilding occurs in such a way as to recreate, and often increase exposure to repeat hazards while not taking into consideration lessons learned from the event such as the protective role of forests and dense vegetation buffers.

The Background Information for the Regional Coordination Workshop entitled *Rehabilitation of Tsunami-Affected Forest Ecosystems: Strategies and New Directions* (FAO 2005) clearly defined the fundamental requirements for the integrated approach:

> Rehabilitation and management of forests and trees are components of an integrated approach to coastal zone management in which the needs of people in urban and rural development need to be balanced with environmental considerations and natural resources management. Issues in forestry can not be addressed in isolation of those in fisheries, aquaculture, agriculture, infrastructure, industry, tourism and residential development. Conflicts arise when different stakeholders lay claims on land and resources when not appropriate institutional frameworks and policy and strategic planning mechanism are not in place to balance trade offs between different interests. There is an opportunity in the reconstruction, rehabilitation and restoration processes to promote multi-disciplinary and inter-sectoral approaches to coastal zone management. However this will require close collaboration and coordinated efforts between stakeholders from community levels to work with Government (local, provincial national), funding and technical agencies, NGOs and the private sector. (FAO, 2005)

Multiple geological and atmospheric hazards tend to occur in the same places and exacerbate the effects of each other, thus increasing the risk of repetitive loss from all hazards. For individual communities vulnerability to large scale disasters such as tsunamis or earthquakes is rare; however medium and localized small scale disasters such as from floods, landslides and drought reoccur frequently. Cumulatively these annual events result in significant losses. Reduction of this complex exposure can only be achieved through an integrated approach to coastal zone management. As integrated intersectoral approach consists of three primary phases:

- Phase I — Hazard, Vulnerability and Risk Assessments
- Phase II — Mitigation Strategy Planning
- Phase III — Institutional Issues to encourage planting of forests and trees as part of coastal management

Phase I: Hazard Vulnerability and Risk Assessment

Phase I establishes the baseline context for integrated decision making. It consists of four components

1. Define boundary of area (entire country, one community, etc)
2. Hazard Identification
3. Vulnerability Assessment
4. Risk Assessment

Part I: Define Boundaries of Project Area

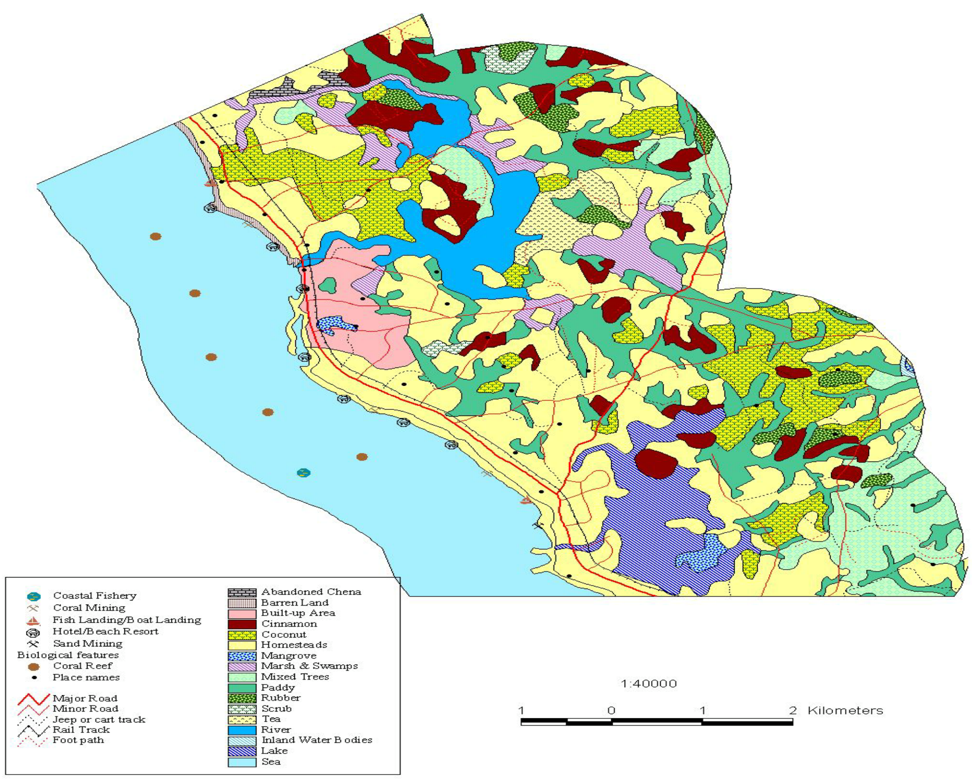
Objectives

The coastal hazards assessment will be used as the foundation for long term coastal management planning. Because of the multi-purpose, multi sectoral uses to which the assessment will be applied a map of the study area is important.

Define mapping protocols

Define scale and reconcile data sets for baseline variables and features for orientation which could include:

- Coast line and off-shore limits of interest
- Water bodies (rivers, lakes, other inland water bodies)
- Topography
- Major ecosystem features (forests, dunes, others)
- Major transportation linkages that may constrain area available for planting
- Land uses that impact (or possibly encroach into) ecosystems



A base map defines key features that will be addressed in detail through the planning process (Hikkaduwa Sri Lanka)

Source: USAID Sri Lanka Tsunami Reconstruction Project

Part II: Hazard Identification

Objectives

Threats vary within comparatively short geographic distances and not all hazards constitute important threats to each community. It is therefore necessary to define hazards for further analysis and characterization.

Identify Key Hazards

On a national basis the probability of specific hazards occurring in individual communities will differ depending on such variables as climate, geology, bathymetry/topography, coastal geometry, and land use patterns. For some hazards the entire community will have similar susceptibility such as from a cyclone. For others, such as flooding, some portions of the community may be impacted more than others, e.g. low lying areas are more susceptible to inundation. For this reason it is important to obtain maps for as many types of hazards as possible and to clearly delineate the specific characteristics and small scale location based variables that will become important considerations when developing a mitigation strategy.

Table 1
Key Hazard Identification
Countries Have Different Exposures to Hazards

Major Hazard	Indonesia	Sri Lanka*
Earthquake (ground motion, landslides and/or subsidence	X	
Tsunami	X	X
Severe Storms	X	X
Floods	X	X
Cyclones		X
Landslides	X	X
Coastal Erosion	X	X

** Identified by the Sri Lankan Parliament Select Committee on Natural Disasters*

Define incidence of previous disasters and document impacts

There is extensive data on damage from the December 26, 2004 tsunami. In addition to the tsunami it is important to analyze damage from lesser, but more frequent events to begin assessing cumulative past losses. An electronic version of data sets will facilitate correlation of multiple variables using GIS. In some cases GIS maps may not be available in which case it will be necessary to rely on "qualitative information such as "oral histories". For each hazard variables could include but not be limited to:

- Inundation boundaries
- Other location indicators
- General characteristics including but not limited to secondary effects such as location of scour, sediment transport and others

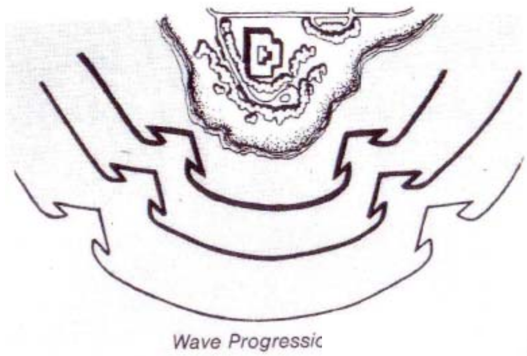
Part III: Vulnerability Assessment

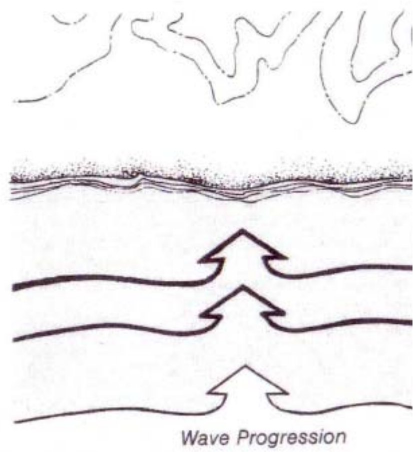
Objectives:

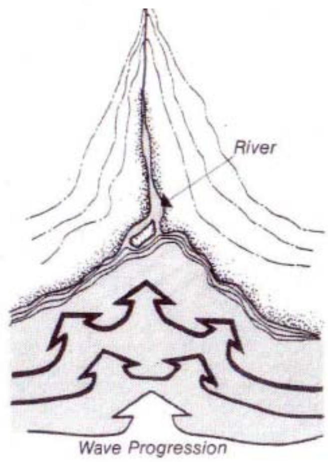
The vulnerability assessment identifies features that are susceptible to damage including ecosystems, and manmade structures. Societal variables including demographic profiles and sites of potential life loss such as hospitals and schools are also defined.

Identify and Characterize Impacts from Prior Events
Within the area identified during the *Hazard Analysis* identify and characterize damages and impacts of prior disasters as well as those impacts that can be expected from future events such as coastal flooding riverine flooding, landslides, cyclone, and/or tsunami.

Correlate Effects with Coastal Geometry
Tsunami behaviour varies in relation to topography, location (especially with respect to islands) and coastal geometry. In areas where the coast line is relatively even vegetation can buffer effects of the wave; in areas where there is considerable articulation wave forces can be considerably higher.







Wave intensity and inundation area may vary significantly depending on whether the coastal area is relatively straight, or whether waves are refracted off of points or headlands, or funnelled into narrow bays.

Some harbours may be in protected locations from the standpoint of wind energy because they are in narrow bays and/or have headlands that break up wind energy. On the other hand, such features can also focus or amplify the wave in which case tsunami energy is focused against the infrastructure causing extensive damage to harbour facilities and boats such as appears to have been the experience of Hamatsumae on Okushiri Island, Japan in 1993. Tsunamis treat rivers the same as harbours; once they enter the mouth the wave travels significant distances up-river.

Sri Lanka's south east coast which is characterised by riverine estuaries, narrow mouthed bays and lagoons bordered by sand dunes, flat sandy beaches and headlands experienced significant damage for the December 26, 2004 tsunami. In four case study locations that suffered particularly severe damage near shore transformation processes interacted with the shoreline geometry. In each location tsunami waves funnelled into a narrow bay or lagoon; where the younger sand dunes at low lands between older dunes were breached. The combined interaction contributed to extensive damage including devastation of vegetation including mangroves. (See S.S.L. Hettiarachchi, S.P Samarawickrama, (2006) and S.U:.P Jinadasa, E.M.S. Wijerathne (2005).

Smooth low lying lands and young dune areas are particularly vulnerable because of the lack of frictional dissipation. Note sparse vegetation; lack of low lying undergrowth (shrubs and grasses)

Tsunami effects are also increased in the lee of circular-shaped islands, as demonstrated by the devastation to Aone on Okushiri Island in 1993 and Babi Island in Indonesia which is a small island off of Flores Island (Yeh et al 1994).

Eco-System Features (off shore and on-shore)

Ecological and geomorphic features in the off shore and near shore environments can mitigate or exacerbate potential damage. Such features have dual importance because they a) are prone to damage such as coral reefs, dunes, and vegetation including trees, shrubs and grasses and b) can reduce damage farther inland. They are the first line of protection against most coastal hazards because they create friction thereby reducing the forces of strong winds and waves.

Off shore:

- Coral reefs
  - Presence and condition of coral reefs (natural breakwaters that reduce coastal erosion.)
  - Health of coral indicative of various phenomena including sediment transport, during and deposition rate influenced by erosion, cyclone flooding;
- Sand dunes, berms, wetlands and marshes
  - Presence and condition of dunes and/or berms/wetlands (reduce impact and velocity)

    - Health of dunes and berms indicative of various phenomena including sediment transport, during and deposition rate influenced by erosion
- Indications of bank erosion from scouring
  Scouring and bank erosion impacts vegetation by undercutting the buffer from direct wave impacts. It also results in sediment transport which can negatively impact the micro eco-system.

Coastal bank erosion

- Assessment of forests and other vegetation
  Presence and characterization including recent changes of vegetation:
    - Dune grasses and creepers
    - Shrubs
    - Forests
    - Agriculture-paddies etc.
    - Other

Multiple varieties of littoral woodlands and dense vegetation can be effective in stabilizing soil and retarding erosion thereby protecting inland uses (note relatively straight coastal configuration)

Man made Features (Land Use and infrastructure)
Land use patterns are a reflection of changing demographics and settlement trends. In some instances lack of institutional oversight contributes to, or even creates, unsafe conditions through allowance of such practices as encroachment into floodplains, inadequate drainage provisions, filling of wetlands and destruction of coastal vegetation including dune grasses and mangrove forests. All the above practices, may further exacerbate impacts of natural hazards including slope instability, erosion, and siltation which, in turn, lead to increased frequency and losses from small and medium size disasters.

Current conditions and practices must be documented as a benchmark that can be compared with past land use patterns. To monitor trends the documentation will identify changes that have occurred during a specified time period e.g. over the last 25 years. Land management practices that could influence the future will also be identified, e.g. encroaching urbanism which threatens forested lands.

Inventory elements include:

- Land use
  - Built up areas including houses, hotels and related uses
  - Changes in land use (e.g. abandoned chena, or abandoned Paddies) or proposed changes (e.g. new hotels, harbor facilities)
  - Schools, hospitals, other buildings with potential high life loss or community importance
  - Paddies and agriculture
  - Cultural and Archaeological sites
- Infrastructure
  - Major roadways and railroads
  - Ports and Fishing Harbors
  - Coastal and Shore Protection (Seawalls, Dikes, etc)
  - Other
- Interactions

Interactions between the components of the coastal management area are important to identify. Such interactions include utilization patterns of the various eco system regions.

One aspect of land use is access. Without proper guidance access to beach can destroys dune vegetation

Part IV: Risk Assessment: Potential Loss Assessment

Objectives

Risk provides the basis for decision making and institutional acceptance of protective measures. Risk is calculated by correlating information derived from the Hazard Assessment and the Vulnerability Assessment i.e. Hazard + Vulnerability=Risk. The characteristics of risk are then analyzed in terms of estimated probability of occurrence, magnitude and incidence of losses which can be calculated both in quantitative and/or qualitative terms.

Synthesis: "hot spots"

Spatially correlate hazards and designate: "Hot Spots" where multiple occurrences and or types of events occur for example coastal erosion and/or coastal flooding.

Calculate Probability of Occurrence

Frequency of events is an important indicator of both past and future loss patterns. Because cumulative implications are important, the analysis must consider not only a large event such as a cyclone or tsunami, but also multiple less severe, events such as winter storms. Annualized losses over a ten or twenty year time frame from lesser events may equal or even exceed the losses from a large event.

The probability of occurrence is based on frequency as documented by historical records and scientific evidence. The time period for reoccurrence is based on criteria selected for a specific plan, for example over a 30 year period an event is anticipated with:

- High Probability
- Medium Probability
- Low Probability

Communities in close proximity to each other often have different probabilities of hazard occurrence. Comparison of two communities in the southern portion of Sri Lanka illustrates similarities and differences in probable occurrences. Community #1, Hikkaduwa, is flat; prone to coastal and riverine flooding, bank erosion, and storm surge. Riverine flooding is often accompanied by channel migration with extensive sediment transport and/or deposition. The probability of coastal storms, riverine flooding and coastal erosion is therefore high. The historical experience of cyclones directly impacting Hikkaduwa is low; geological evidence would indicate that the probability of another tsunami impacting the area is also low. Community #2, Marissa, on the other hand is characterized by variable terrain-flat areas as well as coastal bluffs and hillsides prone to erosion and seasonal landslides during the monsoon season. It has a medium, as opposed to low, probability of cyclone impact. Table 2 compares the probability of hazard occurrence for the two communities.

Table 2
Probability of Hazard Occurrence: Comparing two Communities in Sri Lanka

	High		**Medium**		**Low**	
	Community #1 Hikkaduwa	Community # 2 Marissa	Community #1 Hikkaduwa	Community # 2 Marissa	Community #1 Hikkaduwa	Community # 2 Marissa
Cyclone				X	X	
Tsunami					X	X
Landslide		X			X	
Coastal Storms	X	X				
Riverine Flooding*	X			X		
Coastal Erosion	X	X				

**List perennial and seasonal rivers and streams*

Consequence Analysis

Some high probability events may have low consequence individually but may occur multiple times per year. Over a 20 or 30 year period, the losses, such as from coastal erosion, could be significant. Conversely, the consequences (losses) from a single cyclone or a tsunami would be high. The consequences from the more severe event may—or may not exceed the more frequent lesser hazards. Weighting of the consequences is therefore an important aspect of the risk assessment and the ensuing development of the mitigation strategy plan.

Table 3
Level of Single Event Consequence: Hikkaduwa Case Example

	High Consequence	Medium Consequence	Low Consequence
Cyclone	X		
Tsunami	X		
Landslide		X	X
Coastal Storms		X	X
Riverine Flooding		X	X
Coastal Erosion		X	X

Incidence of Consequences

Comparison of characteristics and approximate magnitude of potential loss under alternative event scenarios is an important vehicle to evaluate consequences of various scenarios. The consequences should be evaluated in terms of the four variables identified during the Vulnerability Assessment:

- Ecosystems
- Influences of Geomorphology
- Manmade features (land use and infrastructure, existing protections (breakwaters, dikes, revetments etc) societal and economic variables

The risk assessment correlates conditions such as leveled dunes and removal of vegetation prior to the tsunami with damage to homes, livelihood (fishing), and ecosystems (erosion, destruction of trees).

Phase II: Mitigation Strategy Planning

Phase II establishes the means to reduce risk of losses. Such losses reduction is achieved through application of mitigation tools and implementation strategies that address characteristics of risk that are defined during the risk assessment. The Mitigation Phase consists of two parts:

Part I Identify Mitigation Tools
Part II Evaluating and Selecting Mitigation Tools

Part I: Identify Mitigation Tools

Objectives
A variety of actions intended to reduce the likelihood of losses are identified. Specific objectives and implementation priorities are tailored to community needs and characteristics of hazard exposure.

Engineered Approaches
Engineered barriers must be able to withstand overtopping wave forces at crest level. Such barriers are expected to remain stable during the progression of the storm event including during tsunami run-up and drawdown. If such a system is breached at a weak point there is a high possibility of progressive collapse leading to greater inundation.

Breakwaters and Seawalls
A breakwater is an offshore structure providing protection from wave energy or by deflecting currents. A seawall is a hard coastal defense constructed on shore to prevent the passage of waves and to dissipate energy. Modern seawalls tend to be curved to deflect wave energy back, thereby reducing forces. In the event of overtopping designs typically incorporate drainage systems.

Seawalls can be effective defenses in the short term. In the long term however the backwash tends to be reflected to the beach material beneath and in front of the seawall; which is erosive. Specific design solutions and on-going maintenance are import considerations to reduce such negative effects.

Dikes and Levees
A dike (also known as a levee) is an artificial earthen wall built along the edge of a body of water such as a river or the sea to prevent flooding. Dikes are often found where low banks or dunes are not strong enough to protect against flooding.

Revetments
Revetments on banks or bluffs are placed in such a way as to absorb the energy of incoming waves. They may be either watertight, covering the slope completely, or porous, to allow water to filter through after the wave energy has been dissipated.

Waves break on revetments as they would on an unprotected bank or bluff, and water runs up the slope. The extent of runup can be reduced by using stone or other irregular or rough-surfaced construction materials.

Breakwaters and revetments are often used to protect critical infrastructure such as boat harbors and coastal roadways

Ecosystem Management
Ecosystem management including the use of vegetation has been recognized worldwide as a means to reduce exposure to multiple hazards. Non-structural tools through ecosystem management create friction to slow velocity; they constitute porous barriers against wind and waves. The underlying purpose is to prevent or reduce erosion of coastlines, estuaries, and riverbanks through three main processes:

- Functioning as a porous buffer by creating friction thereby reducing wave action and current energy
- Binding and stabilization of substrate by plant roots and deposited vegetative matter to reduce erosion
- Trapping of sediments

Enhance Coral Reefs
Coral Reefs are the first line of defense to slow wave energy

Preserve and Enhance Dune Formation and Sand bars
Dune formation and restoration is achieved by stabilizing soil. The first colonizers on bare sand are a species of plants known as creepers. Wind borne sand collects in and around them as they grow forming small hummocks, which are then colonized by fresh seedlings. Gradually sandy hillocks are formed and additional species colonize and stabilize the sand preventing wind induced erosion. Gradually the soil quality improves to establish suitable conditions for growth of more substantial shrubs, which in turn create favorable conditions for the growth of trees.

Planned Forests (Porous Barriers)
Dense plantings of trees (planned forests) have multiple functions. The natural porous structure of littoral woodlands with deep roots, generate a stable barrier against wind and wave forces. They can be an efficient natural energy absorber of steady flows and long waves. They are also an effective means to stabilize banks from erosion and scouring. Such stabilization will also reduce downstream siltation.

Many communities impacted by the Indian Ocean tsunami, have cited the presence of mangroves as positive contributions to reduction of wave velocity and amplitude. It is essential to recognize that some species of mangroves are more appropriate than others because each species has differing characteristics, e.g. some are brittle and some are supple. It is also vital to consider that the geometry of the site will influence the behavior of the vegetation.
In the 1998 Papua New Guinea tsunami a large number of people were killed and/or maimed as they became impaled on splintered mangrove trees. Others took refuge in palm trees that, when uprooted, became flying missiles. Reports indicate that people who took refuge in Casuarinas trees survived (Dengler and Preuss 1999). A number of uncertainties remain to be investigated including whether the palm trees were shallow rooted or whether the instability resulted from geological conditions such as a shallow clay layer. It should be noted that research has been conducted on specific species for tsunami mitigation (Hirashi and Harada (2003).

Mangroves splintered by 1998 Papua New Guinea tsunami injured or killed many victims. Damaged trees in frontal tiers of the forest apparently protected those further back

Wetlands

Wetlands of various types serve similar coastal protection functions to vegetation functions because both features create friction which slows the speed of the waves. They also create opportunities for water detention and retention.

Hybrid Strategies

Relative effectiveness of mitigation tools is evaluated in relation to specified community benchmarks or goals and priorities which are defined by local stakeholders based on the risk assessment. Priorities are established to minimize risk based on probability of occurrence(s) and/or anticipated consequences. Table 4 illustrates correlation of goals with alternative mitigation strategies.

Table 4
Correlate Goals with Alternative Mitigation Tools (using Tsunami as Example Hazard)

Sample Goals	**Strategies**	
	Barrier	**Management**
Reduce the impacts of tsunami waves prior to reaching the shoreline	Breakwater	Coral reef protection and enhancement
Reduce the inland movement and velocity of tsunami waves	Dike Revetments	Dune protection vegetation planting littoral forests, land use policies including set backs
Facilitate access to/from the water including evacuation		Construct, maintain, and sign pedestrian access routes

Part II: Selecting and Evaluating Integrative Mitigation Strategies

Objectives

Mitigation strategies are typically hybrid approaches that combine a number of measures to maximize benefits while addressing the unique characteristics and requirements of a site and a community. It is incumbent on each community to identify alternative actions potentially appropriate to its requirements and to evaluate those strategies in relation to its unique priorities.

Integrative Mitigation Strategies

No mitigation tool is responsive to all hazards or appropriate for all locations. Hybrid approaches integrate diverse tools, for example forest plantings with land use and infrastructure planning and vegetation management programs.

Mitigation entails difficult choices between competing claims on fragile areas. Choices will involve trade-offs and the need to reconcile opportunities for ecosystem enhancement or restoration such as forests, preserving wetlands, reestablishing dunes or mangroves; with securing infrastructure; and reestablishing the tourist industry agriculture or fishing indusries.

Evaluation criteria must address such as variables as frequency of hazard occurrence as well as consequences which are quantifiable (e.g. number of hectares destroyed ecosystems, potential lives lost, cost to construct and maintain etc) and in other are qualitative (e.g. social dislocation and opportunity costs in terms of lost opportunities).

A word of caution at this point is important. Land use decisions pertaining to the coastal zone are invariably complex and often highly politicized. The thumbnail summaries below are only intended to exemplify complex considerations addressed by the decision making process. They therefore do not capture the subtleties of political processes that erupt over allocation of scarce land uses.

Case Example #1: Hilo, Hawaii Tsunami Reconstruction: Central Urban Core)

Background

In 1946 Hilo Hawaii was struck by a tsunami generated by an earthquake in the Aleutian Islands; it was stuck again in 1960 by a tsunami generated by the great Chilean earthquake. Both events inflicted significant damage on Hilo’s downtown urban core, located at the head of Hilo Bay. Because of its crescent shape wave forces are focused at the narrow end of the bay. In both events the tsunami overtopped the Hilo breakwater.

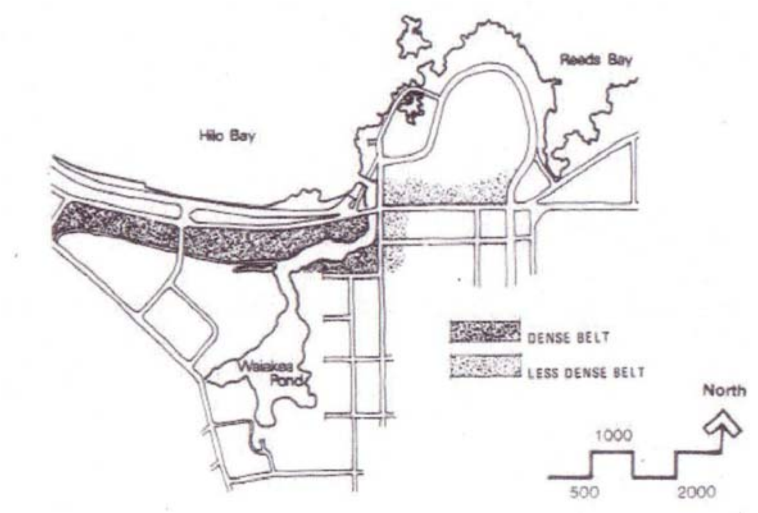
The two Hilo case studies illustrate differing approaches to hazard mitigation that have been adopted for Hilo’s coast. The differences, in part, reflect different timing for plan preparation; Project A was prepared in the immediate recovery period after the 1960 tsunami; Project B (located outside of the urban renewal area but within the tsunami experience area) was prepared approximately 18 years after the tsunami.

Mitigation Concept

After the second tsunami in 1960 a multi part plan was proposed to rebuild Hilo’s downtown core consisting of the following components:

- Increase the height and length of the existing breakwater and create a large dike along the waterfront to protect development
- Construct a redevelopment project outside of the inundation area
- Dedicate damage area as open space for park use

- Plant a dense tsunami "forest"



Hilo Redevelopment Proposal included Plans for a Tsunami Forest

Project Status and Evaluation Considerations

Breakwater

Prior to the tsunami Hilo was protected by a breakwater that had been designed and constructed against winter storms. It had been constructed between 1908 and 1929 upon a submerged reef in Hilo Bay. Immediately after the tsunami the U.S. Army Corps of Engineers (COE) approved funding to extend the breakwater by 4,000 feet and raise its height to 20 feet above the mean sea level.

Over the decades of the 1960's and 1970's the community debated the advisability of increasing the breakwater height because modification of the breakwater would become a strong visual statement. Public opinion viewed the breakwater as a "towering" wall that would block views to sea. Business interests also questioned the aesthetics of the breakwater which they feared could negatively impact tourism. While the controversy brewed, the COE continued to evaluate the economics of the breakwater; including the inability to assure complete protection from another seismic wave. In the late 1970's the tsunami breakwater was deauthorized.

Outcome: Not Implemented

Mall and Civic Center

A high percentage of Hilo's commercial and office space was destroyed by the tsunami, thus top priority of decision makers responsible for recovery was economic recovery. To stimulate the "rebirth" of the city Kaiko'o Mall and a new County office complex were developed upland of the old town center, on land that was elevated with fill.

Outcome: Implemented

Community Park

The Bayfront Park was developed on land that was mandated to remain as open space under the redevelopment plan. The Park became an important site for a wide range of community

activities. The open space was also considered to be the visual connection between the town and the bay.
Outcome: Implemented

<u>Tsunami Forest</u>
The tsunami forest consisted of a dense band of tall trees to create friction and provide buffer from waves. The tall trees were to be supplemented by low shrubs to provide soil stabilization. Feasibility of the fully functional forest as planned was hampered by the importance of the coastal highway, and connector roadway with major streets leading almost to the Bay's edge. The forest as proposed would have provided no protection for the coastal highway. Realigning the roadway to create the necessary depth for the forest would have reduced the size of the park. Realignment would also have necessitated extensive additional land acquisition. Finally, implementation of the tsunami forest would have created a visual buffer to the sea. The complexity of implementation, plus lack of public support reduced commitment to implementation. A thin band of coco palms was planted –rather than the dense forest.

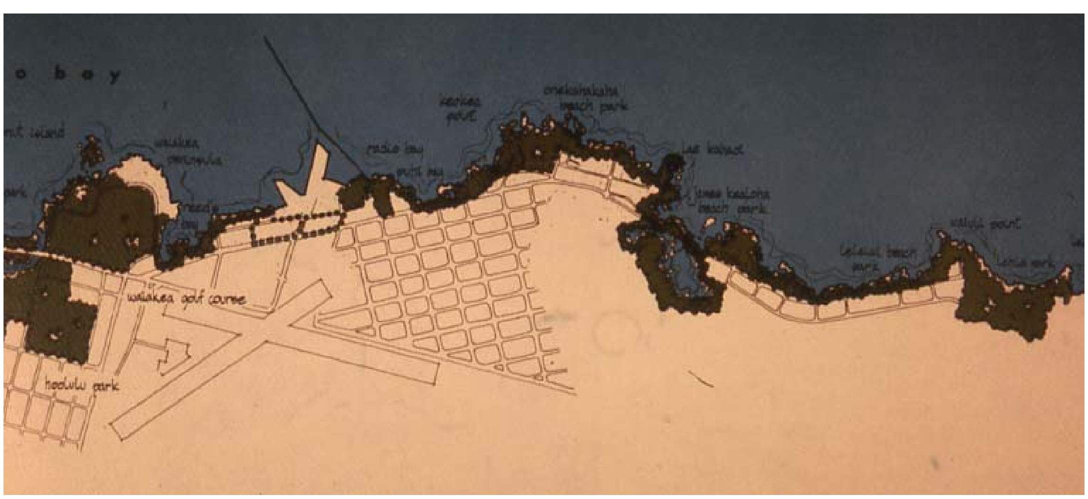
Outcome: Not Implemented

Case Example 2: Hilo Keaukaha Shoreline Plan

Mitigation Concept:
In 1979 the City of Hilo adopted the Keaukaha Shoreline Plan for the portion of the Hilo Shoreline that adjoined the commercial core. The Keaukaha coast experienced damage in the 1946 and 1960 tsunami; the community hospital was destroyed in 1961 by a winter storm (presumably it had been damaged but survived the tsunami). The coast is regularly impacted by winter storms, and coastal flooding. The County's major tourist area was located at one edge of the coast; the remainder accommodates the port as well as residential uses and beach parks.

Project Status and Evaluation Considerations

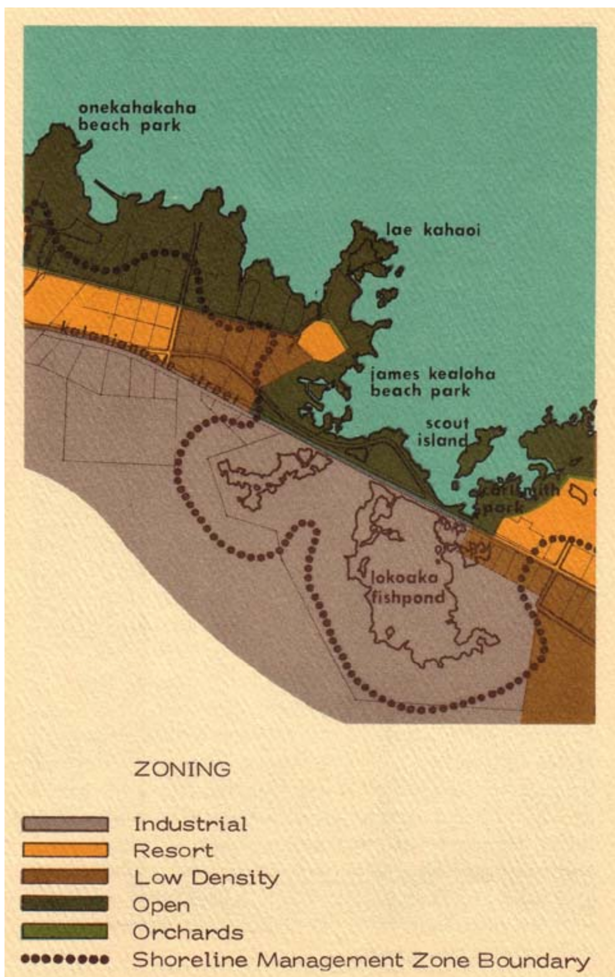
<u>Area wide Concept</u>
The County of Hawaii adopted a policy to create a forested greenbelt along the Keaukaha coast. The dense vegetated buffer had multiple purposes; on the one hand a string of parks and trails would be developed; on the other hand the forested parks would provide protection against recurrent storms, and future tsunamis.



Keaukaha Shoreline Planning Area indicating a forested belt along the Keaukaha Coast

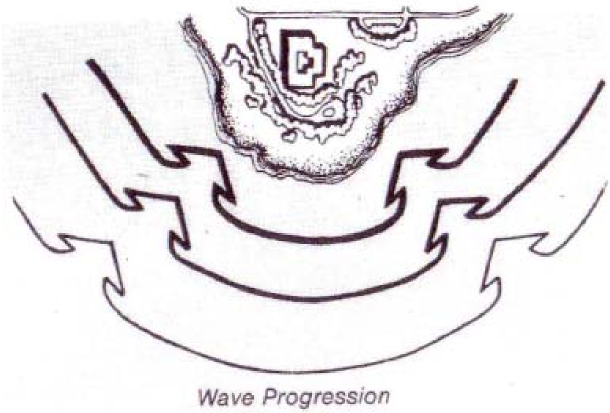
<u>Sub-Area Concept</u>
Activities and land uses on Keaukaha coast were grouped into eight overlapping but identifiable character areas that were used as the basis for the n integrated park and trail system, interspersed with residential uses--interrupted by the port. Division of the coast into sub-areas was one planning tool used to identify and address specific needs and/or conflicts between uses.

In order to implement the coastal greenbelt concept it was important to retain the unique eco systems that characterized the coast. Most important were a large lagoon and major stands of trees. The lagoon was heavily used by local fishermen and was therefore considered by the community to be an important resource. During the Keaukaha plan preparation phase the County was simultaneously developing plans to expand the coastal road within the existing right of way which would have destroyed the lagoon and trees. Transportation planners were persuaded to realign the route inland outside of the tsunami experience zone. This decision retained the lagoons while maintaining detention, and reducing vulnerability to recurring disruption from winter storms—which reduced maintenance costs. The coast route was partially funded with Federal funds because a compoenent of the interstate highway system.

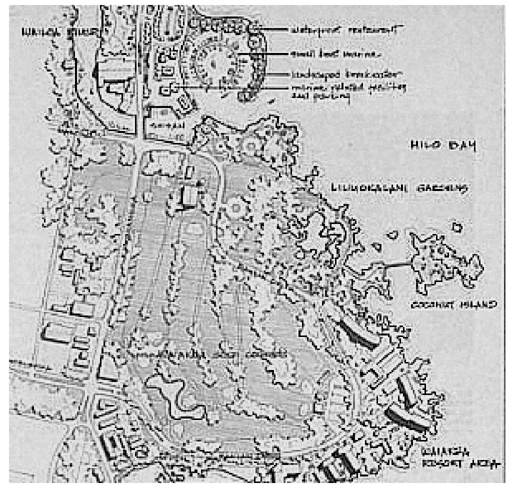


Keukaha Sub area concept with lagoon saved by roadway realignment to provide additional depth for planting and safety from disruption caused by storms or tsunami

<u>Project Site</u>
Public and private development is required to comply with setback and landscape requirements—irrespective of the owner. Plantings on the hotel/resort site (right drawing below) are in required setbacks and are the responsibility of private land owners. These dense plantings are intended to provide protection from storms and from tsunami. Buildings in both graphics below existed prior to adoption of the plan.



Coastal land form



Project area site plan: setbacks with protective buffers

<u>Plan Outcomes</u>
All components of the Keaukaha plan implemented. County acquired the park lands which are maintained as part of overall county park budget.

Case Example 3: Sri Lanka: Reducing River Bank Erosion

Mitigation Concept

Bank erosion caused by riverine flooding has been a recurring problem. Multiple seasonal flooding, events can result in incremental bank erosion, loss of neighbouring property, degradation of water quality. Sediment transport to the sea leads to channel migration which can result in siltation of corals and other marine organisms. Cumulatively these effects can be extremely damaging. The following two photos compare mitigation in two setting compare to approaches to bank stabilization when priorities differ.

Project Descriptions and Evaluation Considerations

Project A: Mangrove Forest, Hikkaduwa, Sri Lanka

A mangrove forest has been planted reduce low bank erosion, while also protecting adjoining wetland areas that accommodate water detention and drainage. Costs are in the planting because the maintenance is minimal. Some continued erosion occurs during maturation of the buffer forest.

Mangrove forest used for bank stabilization: Hikkaduwa Sri Lanka

Project B: Marissa Roadway Stabilization
Continuous bank erosion is threatening to undermine the roadway. In order to reduce the threat of access disruption a retaining wall was constructed to protect the road from erosion caused by the migrating channel. Because of the location of the erosion other solutions such as vegetation plantings were not feasible. Sedimentation is not reduced by the "hard" solution—as it is for Project A.

Retaining wall to stabilize roadway: Marissa, Sri Lanka

Case Example 4: Coastal Erosion Mitigation
Mitigation Concept
Provide protection against coastal erosion thereby reducing threat to critical roadway. The project consists of a raised embankment and revetment with plantings on the shore side of the embankment.

Project Descriptions and Evaluation Considerations

Project A Coastal Hardening- Sri Lanka

Critical segments of Sri Lanka's coastal roadway are at or below sea level. Restoration and maintenance of safe access was the prime consideration; "hard solution" was selected as an economic imperative. Some trees have been planted between the embankment and the road, however there is insufficient area for a deep tsunami forest. Seasonal fluctuation in beach sand has been reported; during periods of low sand there is reduced access to the water by fishermen and others and it becomes impossible for fishermen to pull their boats onto land.

Bank Revetment; Sri Lanka ***Tree planting on inland side of revetment***

Project B Hybrid Protection, Hawaii

Required setbacks from the high water together with required retaining walls and low dune plantings permit buffering from winter storms while encouraging continued beach nourishment. Project continues use of private property with government enforcement of standards and regulations.

Vegetation protection low retaining walls and required setbacks of residential development

Case Example #5 Multi uses with forest buffers
Mitigation Concept
Forest buffers are combined with other uses to a) provide protection against tsunamis and coastal storms and b) accommodate private property based uses.

Project A: Forest buffer and wetland agriculture (rice paddies) Sanriku Coast, Japan
Combination of tsunami forests with wetland/land use that facilitates water detention to absorb storm water run off and/or tsunami inundation. This use also creates a deterrent to people from moving into the hazard zone.

Combination of protective planting with agriculture to provide detention for storm water and coastal flooding water.

Projects B & C Residential Projects behind and tsunami forest
Dense tsunami forests have been planted to protect homes from tsunamis and from the more frequent storm waves. In the case of Hawaii the forests have been planted along the shoreline in the area mandated by State Law as setback buffer from the coast.

Sanriku Coast, Japan

Island of Kauai, Hawaii

In both cases homes are located behind tsunami forests planted along the shore. Dense plantings are between the houses.

Case Example 6: Dune Preservation and Restoration Program
Mitigation Concept:
A first step to improving the environment for forests is to stabilize soil conditions through dune enhancement. Such dune management programs are multi-faceted because they include: restrictions on leveling, restrictions on access; planting programs and maintenance.

Evaluation Considerations
Costs include the need for enforcement because such programs will initially be unpopular by many sectors: hotel developers often maintain that dunes block views and/or pathways to the beach; housing constructed through the informal sector often occurs in dune areas—which must be prohibited and alternative locations found. In addition access routes including paths and standards must be developed and clearly marked.

Benefits will be to stabilize soils, reduce coastal erosion including sediment deposition and siltation. These benefits, in turn, reduce degradation of corals, and related environmental assets.

Pedestrian trail with sign: Please keep off the dunes—soil stabilization project (Oregon, USA)

Structure pathway for particularly sensitive dune (Oregon, USA)

Phase III: Institutional Issues to Encourage Planting of Forests and Trees as part of Coastal Management

Objectives
Forest and tree planting and management programs must become integrated with overall institutional processes associated with coastal management.

Part I Institutional Issues Relating to Forests and Trees in Comparison to Other Structures

Institutional Overview of Case Examples
Application of forests and trees to hazard reduction is inherently a multi-disciplinary multi sectoral field that requires commitment and cooperation among multiple agencies and donors. The first step to integrating forests and other planting programs into coastal management is to

assess the current institutional practices as they positively or negatively influence vegetation management.

Case Example 1 Hilo Bayfront reconstruction plan after 1960 tsunami
Implementing Responsibility
No oversight body responsible for coordinating all components of the project on a long term basis. Multiple components of the project not developed by local planners Planning process did not consider the feasibility of the recommendations

Breakwater	U.S. Army Corps of Engineers—unpopular with locals
Redevelopment project	County with federal funds and oversight
Park	County
Tsunami Forest	County

Case Example 2: Hilo- Keaukaha Shoreline Plan
Implementing Responsibility
A single oversight body was responsible for all components of the project on a long term basis. It was also responsible for coordinating with multiple departments and stakeholders including private parties (hotels, residents, shop owners and others).
Implementing Responsibility:

Acquire open space for planting	County
Realign roadway	County with Federal funds
Building setbacks	County
Tree planting within setbacks	County requirements implemented by private owners

Case Example 3: Riverine Bank Erosion
Both projects have single purpose objectives—not part of comprehensive plan

Project A: Sri Lanka Mangrove Forest
Implementing Responsibility:
National-Department of Forestry

Project B: Riverine Bank Erosion Sri Lanka Retaining Wall
Implementing Responsibility
Multiple National entities including; Road Development Authority

Case Example 4: Coastal Bank Erosion
Project A: Sri Lanka embankment
Implementing Responsibility
Multiple National entities including- Coast Conservation Department; Ports and Harbors; Road Development Authority

Project B: Honolulu Vegetation Buffer
Implementing Responsibility

Setback Standards:	administered and enforced by local government
Planting	local government

Case Example 5: Multi uses with forest buffers
Implementing Responsibility for all projects (in Japan and USA)
Forest planting: local and national government
Residential development: private owners in accordance with local laws

Case Example 6: Dune Restoration and Access State of Oregon
Dune preservation and restoration goales part of State Land Use Law; individual dune restoration projects administered locally
Implementing Responsibility

Dune preservation goals:	State of Oregon
Dune preservation program:	Local community with funds from State

Themes of Successful implementation
The case studies indicate that inclusion of forests and trees as part of an integrated strategy most often occurred under the following conditions:

a) Multiple Proponents
Part of an overall plan with commitment form multiple stakeholders. Successful efforts have reflected inter-sectoral "buy in"; and have been multi-disciplinary in their objectives. For example the Keaukaha Shoreline plan and forest/rice paddies in Japan demonstrate multiple proponents in preserving and enhancing vegetation.
b) Land availability
Land must be available for a forest project to be feasible. Where land acquisition is problematic and/or where immediate shore protection is necessary "hard" solutions tend to be preferred. In communities where coastal set backs are enforced, such lands have been used e.g. Hawaii and Japan.
c) Management Program
A coordinating body must exist to oversee multi sectoral projects from their inception through implementation and long term management. Environmental management must be grounded on coordinated policy implementation and institutional consistency

Part II: Create Management Program for Enforcement and Oversight

Coastal areas are traditionally among the most intensively used portions of a community with many competing objectives and stakeholders for limited resources. Coastal Management therefore requires a consistent framework for decision making. Pre-requisites to coordinated implementation of vegetation management programs include the following actions:

Create and Empower Oversight Body to Oversee Management Program
Implementation of objectives that promote planting of trees and forests highlights the need to integrate eco-system management with other development/economic objectives. Such integration requires a mechanism to coordinate planning and decision making. An oversight body is essential to orderly coastal management. This body would integrate and coordinate forest management with coastal management and disaster management. This body with also have the mandate and authority to coordinate polices between different jurisdictional authorities (including local/national/and or different ministries with differing priorities e.g. forestry and transportation).

Institute Regulatory Consistency
Enforcement of standards on both public and private property development—including prohibition on building in designated areas is essential to long term implementation of vegetation management programs.

Predictable regulatory oversight is based on three factors:

1. Designated Coastal Management Zone
Administrative zones are defined within which to apply mitigation strategies that are sufficiently large to encompass both the direct hazard and the area influenced by the potential hazard.

Tier 1 Coastal Zone
Define the land area directly impacted by each hazard such as coastal flooding riverine flooding, landslides, cyclone, and/or tsunami during the hazard analysis. Where applicable sub zones should also be defined e.g. the floodway and the floodplain--the floodway is an ideal location for planting.

Tier 2 Coastal Influence Zone
Define the area which includes both features that are vulnerable to damage and which potentially can reduce wave and wind impacts thereby reducing susceptibility to collateral damage. The area includes the off shore and near shore environments in which ecological influences such as trees and forests are or could be located.

2. Define Standards and rules for allowable and preferred uses in the coastal management zone
Articulated goals must guide future development to desired locations, and building construction must comply with standards. Note: many of the "successful" case study examples in this paper have used mandated setback areas to plant forest buffers.

3. Adopt and Enforce Regulations
Enforcement of laws such as set back regulations and construction laws as well as prohibition of practices such as coral or sand mining will significantly contribute to reduced exposure to hazards. It is essential that commitment to regulations be enforced by funding staff positions e.g. no construction of any kind (including by the informal sector) on building in designated areas.

Facilitate integrated Planning Processes through Data Sharing
A fundamental aspect of coordinated coastal management is the ability to correlate baseline data collected by many stakeholders including national ministries, local agencies and NGO's. Review of planning processes in many countries throughout Asia indicates that data sets are not readily available to departments and agencies that have not collected it. This lack of data sharing is a serious impediment to integrative management.

Public education on the importance of coastal management
Sustained coastal management including implementation of forests requires local commitment. It is crucial that all sectors (public and private) accept that implementation of planting programs is long term. Before forests reach maturity extensive land management may be required to prevent use of young trees for fire wood, or other purposes.

Conclusions

Coastal regions will always be focal points for society's uses, including for commerce tourism, recreation, housing, fishing, and many other uses. Without sensitive integrative management ecological disturbances, such as replacing littoral forests with transportation corridors, will result in irreversible disturbances. Integrative multi-sectoral planning has the merit of institutionalizing societal needs with the needs of healthy eco-systems. Unfortunately the needs of society are multi-faceted, with differing values held by differing constituencies. Fortunately the value of forests and other vegetation buffers have been clearly demonstrated by recent disasters.

Integrated coastal zone management balances ecosystem preservation and restoration against the short and long term needs of society. Such balancing of disparate and seemingly conflicting requirements necessitates establishing priorities to which participating stakeholder can ascribe. Multi-sectoral integrative planning establishes a framework within which to structure such a systematic program. Clear identification of risk factors is only the first step in establishing locations for forests, and vegetation buffers. The next step is to develop the management plan with an institutionalized administrative structure.

REFERENCES

Ted Bryant HomePage "Questions and Answers about Tsunami" UOW Earth & Environmental Sciences Tsunami Research Q & A

Dengler, Lori and Jane Preuss, (January 1999) Reconnaissance Report on the Papua New Guinea Tsunami of July 17, 1998 EERI Special Earthquake Report

County of Hawaii, (1974) *Hilo Downtown Development Plan*, December 31, 1974 Prepared by Belt Collins and Associates for County of Hawaii Planning Department.

County of Hawaii, *Keaukaha Shoreline Plan* (1978) Prepared by Walters, Kimura and Associates, Inc. for County of Hawaii Department of Parks and Recreation

FEMA Coastal Construction Manual FEMA 55CD Third Edition May, 2000

Hawaii State Foundation on Culture and the Arts Office of George S. Walters (April 1969) "Environmental and Urban Design Proposals: East Hawaii Project/City of Hilo" Funded by the U.S. National Endowment of the Arts, with County of Hawaii and the State of Hawaii Department of Land and Natural Resources.

Hirashi, T and K. Harada "*Greenbelt Tsunami Prevention in South Pacific Region* report of the Port and Airport Research Institute, Japan, (PARI) Vol. 42, No. 2 2003

National Tsunami Hazard Mitigation Program (NOAA, USGS, FEMA, NSF, ALASKA, California, Hawaii, Oregon and Washington) March 2001, Designing for Tsunamis Seven Principles for Planning and Designing for Tsunami Hazards.

Preuss, Jane, P. Raad, R Bidoae, 2001 "Mitigation Strategies Based on Local Tsunami Effects" in *Tsunami Research at the End of a Critical Decade* Gerald T. Hebenstreit Editor; Kluwer Academic Publishers

The Sri Lankan Parliament Select Committee to Recommend Steps to Minimize the Damages from Natural Disasters

S.S.L. Hettiarachchi and S.P. Samarawickrama "Experience of the Indian Ocean Tsunami on the Sri Lankan Coast *International Conference on Coastlines, Structures and Breakwaters, Institution of Civil Engineers, UK, 20-22 April 2005.*

S.S.L. Hettiarachchi, Professor, University of Moratuwa, Sri Lanka S.P Samarawickrama, Senior Lecturer, University of Moratuwa, Sri Lanka "The Tsunami Hazard in Sri Lanka Strategic Approach for the protection of lives, ecosystems and infrastructure" *Indian Ocean Tsunami, Special Issue : Coastal Engineering Journal, Society of Civil Engineers, Japan, 2006*

S.U.P. Jinadasa, E.M.S. Wijerathne, "Assessment of Geo-morphological Influences to Protect the Tsunami Hazardous southeastern Coastal Belt of Sri Lanka" *Asian and Pacific Coasts 2005 September 4-8 2005 Jeju, Korea*

UKLanka .net (June 6, 05)

United Nations Food and Agriculture Organization (FAO) “Rehabilitation of Tsunami-Affected Forest Ecosystems: Strategies and New Directions” *Background Information Regional Coordination Workshop* 7-8 March 2005 Bangkok, Thailand.

Urban Development Authority, Environment and Landscape Division; *A Basic Guide to Design, Planting and Establishment of Coastal Greenbelts in Sri Lanka*, In Press

Urban Regional Research (1988); Planning for Risk: Comprehensive Planning for Tsunami Hazard Areas for National Science Foundation (Principal Investigator: Jane Preuss)

Urban Regional Research (1982) Land Management in Tsunami Hazard Area s for National Science Foundation (Principal Investigator: Jane Preuss)

USAID Sri Lanka Tsunami Reconstruction Project, working papers

Wetland Conservation Project, Sri Lanka *Wetlands are no Wastelands: A Manual and Strategy for Conservation and Development of Wetlands*; Central Environmental Authority (Sri Lanka)/Euroconsult (Netherlands) October 1994

Yeh, Harry, Philip Liu, Michael Briggs and Costas Synolakis 1994 Propagation and amplification of tsunamis at Coastal Boundaries *Nature* November 1994