Post Tsunami Survey for Hazard Map preparation in Sri Lanka

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Abstract

This paper describes preparation of high resolution spatial data sets from a rapid Tsunami survey in Sri Lanka. Three international teams and more than 15 national organizations carried out surveys in three affected cities. The objective of the survey was to produce a tsunami hazard map for three selected cities in Sri Lanka and use the information gathered for a number of studies. The survey included topographic measurements with real time kinematic GPS, building damage survey, wave run up, wave heights and tsunami strength measurements.

1 Introduction

Sri Lanka experienced its worst natural disaster on the 26th of December 2004. The massive earthquake registering 9.0 on the Richter scale that struck off the coast of Sumatra, Indonesia at 00 59 GMT set off a series of tsunami waves that reached coastal areas of Bangladesh, India, Indonesia, Kenya, Malaysia, the Maldives, Mauritius, Myanmar, Reunion, Seychelles, Somalia, Sri Lanka, Tanzania, and Thailand from about 15 min in Indonesia, 2 hours in Sri Lanka and 14 hours in Cape Town, South Africa.

Sri Lanka was one of the hardest hit countries in terms of loss of life, infrastructure and assets. Between two to three hours after the first earthquake, waves reached more than two thirds of the coastal area of Sri Lanka. Current estimates stand at more than 31000 lives lost, over 4000 missing and 1 million affected. Almost half of the affected lost their livelihoods. According to the CRED database, Sri Lanka with 1809 persons killed per 1 million inhabitants had the highest number of per capita casualties from all natural disasters in the world in 2004. Indonesia, the worst affected from the Tsunami had 759 people killed per million. The estimated economic losses vary from around 6.0% of the national GDP (by ADB/JBIC/World Bank) to 8% (by TAFREN). These are staggering numbers for any country, but especially for Sri Lanka when they are compared in relative terms and the capacity to recover.

Early warning and evacuation are the most effective response strategies for such very low frequency high impact disasters. At the same time, the reconstruction now taking place should be based on an assesment of risks and appropriate measurs to minimize losses from a future similar disaster. Although the frequency of Tsunami in Sri Lanka is very small, we should avert rebuilding the same disaster. To assess risks, accurate representation of topography is a pre-requisite when inundation impacts on people are considered. Similarly, the surface roughness of land effectively determines flow velocity and hence flow accumulation. Inundation velocities are much higher in smooth surfaces such as water bodies and therefore the roughness differences should be adequately incorporated in the simulation exercises.

In this survey, Elevation data, Land cover data and Population data, were compiled, suplementing missing data to facilitate hazard and risk assessment in three coastal cities in Sri Lanka that represent different physical as well as socio-economic characteristics of the country.

2 Survey locations

Depending on the socio-economic and physical characteristics, the towns of Galle, Hambanotata and Trincomalee have been selected for the survey. The figure 1 show the location of the three cities selected for the survey. In terms of casualties Galle and Hambantota districts are the hardest hit areas following Ampara District. Galle is the most important city among the heavily affected cities, being the largest city in the southern coastal belt. The total devastation of Hambantota city, especially the thin land strip between the sea and the lagoon has merited especial attention in to risk assessment of the city.

Trincomalee was selected as the city is home to all ethnic groups in Sri Lanka and a unique collaboration is possible in the city among all ethnic groups in the reconstruction process.

3 DEM preparation

The DEM is required for the preparation of a risk map as well as for the simulation of evacuation processes. The spatial resolution for these modeling is considered as 5 - 10 m and vertical accuracy is expected to be around 10 cm order. The following strategy was adopted in the preparation of data after considering resource availability, data needs and time constraints. Firstly, all available elevation data are collected and digitized. Depending on the location, two additional forms of data are measured and incorporated in to the survey. The first is the total station survey along the coastal line that would help to correct any recent developments not present in the existing data. The second and most important source for the current survey is the Real time Kinematic (RTK) GPS survey, that provides absolute x,y,z spot values for any desired locations. The RTK GPS survey is carried out to complement the existing elevation data sets as well as to record other features such as water ways, embankment, wave-run-up, etc. The base source of data is taken as the 1:5000 digital data set produced by the Sri Lanka Survey Department. This data set covers the southern area from Colombo to Hambantota as well as parts of Trincomalee. The data set has elevation and land cover features. These features were organized as so that can be directly used in GIS applications. Different existing data sets have been prepared with various coordinate systems. In order to compile the data it was decided to use GPS84 coordinate system to process most of the data including the GPS measurements and finally to translate all the data to Sri Lanka 'Kandawala' datum.

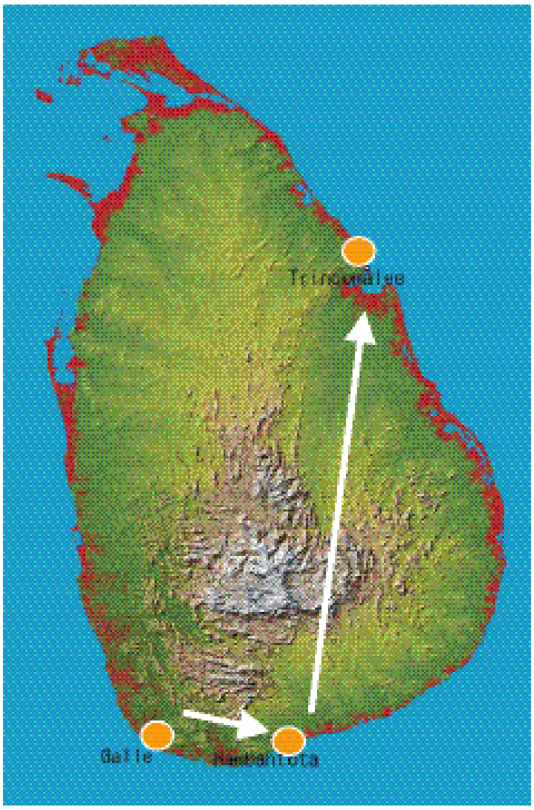


Figure 1: The locations of the three cities where field surveys were carried out

3.1 Galle

3.1.1 Existing Digital Data

The surveying department of Sri Lanka has a 1:5000 digital data set for the Galle District. The data set contain roads, building boundaries and coastline information. In addition to these features, contours at 5m intervals are also available in this data set. This base data set can be obtained from the Survey Department of Sri Lanka.

3.1.2 Existing Contour Data

During a visit to the Galle Regional office of the Survey Department of Sri Lanka, it was found that a 2 feet interval contour map that had been made in 1976 covering the Galle District to be available in hard copy. The maps have been prepared in local coordinate systems and thus it was necessary to find the original control points of the map and to register their coordinates in the WGS84 coordinate system so that they can be integrated with the RTK GPS measurements. The digitization of the contour data had been carried out at the Asian Institute of Technology.

3.1.3 Total Station Survey

A topographic survey covering 200 m from the coastal line for the whole length of Galle City was carried out (figure 2(a)) by the survey group from the Central Engineering Consultancy Bureau of Sri Lanka. These data are used to supplement the two sources of data described earlier.

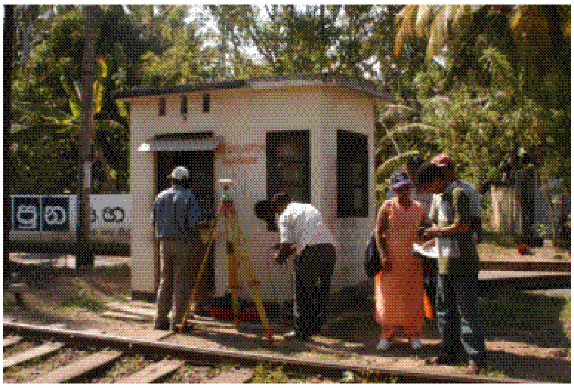
(a) Total Station survey along coast line carried out by CECB

(b) The Kinematic GPS team of the Survey Department who carried out the topographic survey

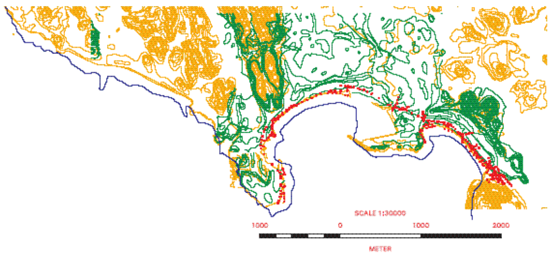
Figure 2: Field Survey Teams

3.1.4 Kinematic GPS Survey

The GPS survey team of the Survey department 2(b) provided the control points for building damage and coastal zone elevation surveys using Real time Kinematic GPS survey sets. In addition, they have measured the tsunami inundation extent with the team from the coastal conservation department and surveyed the water ways in the Galle city. Figure 3(a) shows an inundation measurement activity.



(a) Inundation measurement by the Survey Department and Coastal Conservation Department Teams



(b) Different data sources used in the creation of DEM for GALLE (high elevations - existing 1:5000 data, low eleations 2ft - contour local data, coastal area - Total Station measurements

Figure 3: Merging field data with other existing sources

3.1.5 Galle DEM from the merged datasets

In order to prepare the elevation data set for the Galle area, the following data sets were merged.

1:5000 Digital Data 5m interval contour data were taken from the Survey Department 1:5000 digital maps.

2 feet contour map The contours are digitized and only those contours that are not in conflict with the 1:5000 map are added to the new data set

Total Station Survey The points measured by the total station survey are used as point data to the new data set.

Coastal Line The coastal line is added as a break line to the new data set.

These different data sets described above are shown in figure 3(b). Using all these data a 5m resolution elevation data set was created to be used as the reference elevation data set for the Galle City.

3.2 Hambantota

Similar to the Galle DEM preparation, the base map for Hambantota was taken as the existing 1:5000 digital data from the Survey Department of Sri Lanka. The existing contour intervals of 5m are too sparse to cover the most vulnerable coastal areas. In order to improve the coverage a detailed Real time Kinematic GPS survey was carried out for the city. In additon to topographic survey, building damage survey too was carried out in the city. The figure 4 shows the city view with the most vulnerable low lying area that was once densely populated.

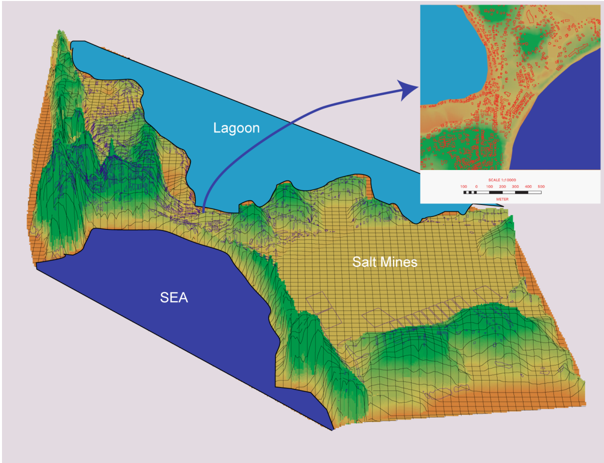


Figure 4: The narrow strip between the sea and the lagoon was totally devastated by the Tsunami

3.3 Trincomalee

As in the case of Hambantota the existing resolution of 1:5000 data set for Trincomalee is too coarse to accurately describe the topography of coastal area. Further, Kiniya, the most affected area in the region is not covered in the existing data. A Real time Kinematic GPS topographic survey therefore was carried out for Kiniya as well as for additional topographic points in the main Trincomalee area.

4 Wave Loads

The strength of Tsunami was analyzed by the Japanese team (University of Tokyo and Tsukuba University) estimating the strength of structures/structural members of damaged and undamaged buildings. As far as possible, simple structures or stuctural components were selected for the analysis so that the effect of building frame on the load analysis is minimal.The load that would be required for the desctruction of each of these members were calculated and the corelation with the Tsunami wave height has been investigated. The figure 5 shows that walls that cannot withstand a force equivalent to a hydrostatic pressure from a wave height about 2.5 times the actual wave height have collapsed (Source: Prof. Nakano, IIS, University of Tokyo). From the analysis, it is possible to develop a wave impact potential map by a simple corelation of wave height even without a knowledge of the actual velocities.

5 Inundation

The wave height at run-up in many places in Southern and Western regions varied from about 5m to 2m depending on the coastline characteristics and the elevation of land and sea. The figure 6(a) shows a compilation of various wave heights measured by different organizations. Based on these run-up and inundation information described in figure 3(a), the the the maximum wave heights were estimated and are shown in the figure 6(b).

6 Hazard map

Now it is possible to develop the Tsunami Hazard map by combining the inundation and run-up information with the tsunami height - wave impact relation taken from figure 5. Such a figure for Galle city is shown in figure 7 which shows the potential load based on the maximum wave height and the relation given in figure 5

7 Reconstruction Needs

The Tsunami disaster in Sri Lanka is one of the biggest disaster to affect a country. In addition to loss of lives and economic damage, about 1 million of the population has been affected and an estimated 450,000 have lost their livelihoods. A household income distribution survey by the WFP - ILO teams found that about 80% of the affected population spends less than Rs. 100,000.00 (USD 100) a month, which is less than a dollar per day per person for a family of 5 members *even before the tsunami*. The official poverty line is about Rs. 1500 per person / month, which is required to ensure basic nutritional intake. That translate to a Rs. 7500 /month for a family of four. 30% of the population spent only 5000 Rs. / month which put the family members below poverty line. The cost of food is relatively high in Sri Lanka, and people spent a large fraction of their income on food. Due to the general poverty of the region and relatively high cost of food, there is very little resilience or surplus to rebound and government support as well as leadership is essential for the recovery of the affected communities.

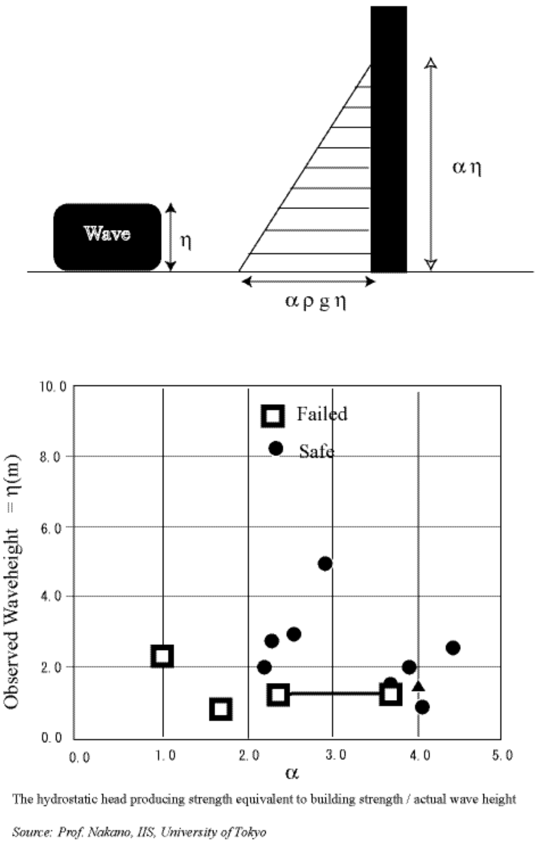
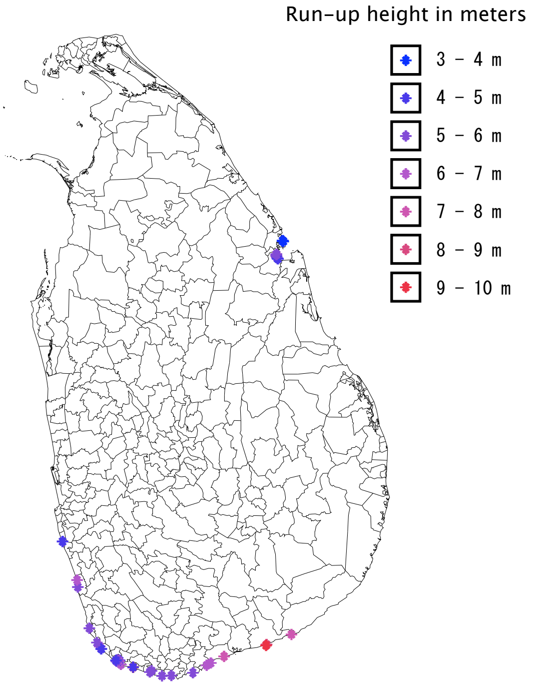


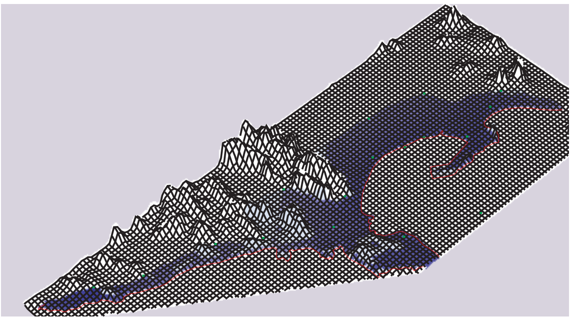
Figure 5: Analysis of wave impact on wall structural stability

There are several issues the government has to respond immediately and effectively. Providing houses has the priority among them. There are two basic problems in building new houses for those who lost their houses. On the average 4000-5000 new housing units are built annually in Sri Lanka. The need to build 100,000 new houses within a span of 1-2 years puts heavy pressure on construction materials and technicians required for the job. Acquisition of land has become a major problem. After the Tsunami the government has declared a 100m no construction zone in the West and Southern regions and a 200 m free zone in the East. However there had been a severe opposition to this zoning by many fishermen as well as the main opposition party. Securing land to implement the zoning from inland areas to move the current residents has proved to be a slow process where available land and people's requirements have to be matched.

The major challenge for the government in the reconstruction process is not only to make a disaster free community, but also to make it *'poverty free*. In this context it is essential to incorporate disaster resilience in to development planning and make every effort to make rebuilding a process that would bring security from poverty together with security from disasters. In this respect it should be borne in mind that Tsunmai is a very low frequency disaster in Sri Lanka, and a holistic approach to disaster reduction considering multi-hazards at different frequency ranges should be taken starting from this event.



(a) Runup measurements from the current survey as well as from other groups



(b) The maximum inundation map for the Galle area estimated from observations

Figure 6: Runup measurements and Galle Inundation

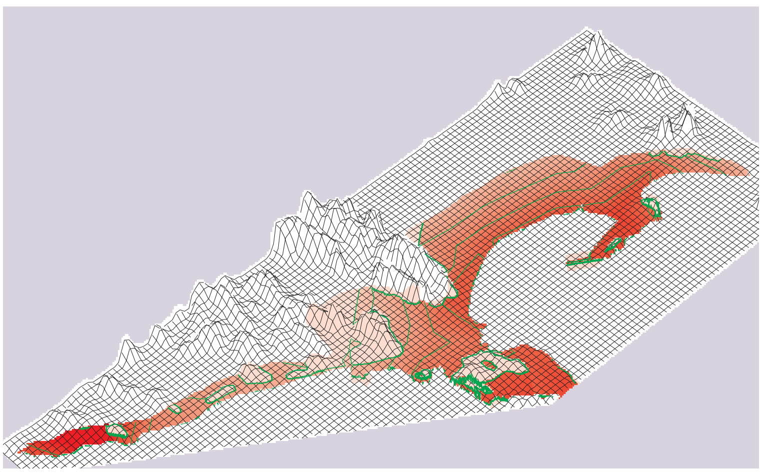


Figure 7: The maximum load on structures that would be taller than the wave height