# LANDSLIDE HAZARD ZONATION MAPPING AND MITIGATION IN SRI LANKA
# SRI LANKA URBAN MULTI-HAZARD DISASTER MITIGATION PROJECT (SLUMDMP)

## 1. Background

The heavy loss of life as well as the unprecedented damage to property and infrastructure resulting from landslides during the monsoon periods in the years of 1968 and 1986 prompted the Government of Sri Lanka to take serious notes of the losses and initiate appropriate measures for the reduction of the impact of landslides. In 1990, the National Building Research Organization (NBRO) proposal on implementing a comprehensive program to identify the vulnerable areas to reduce the vulnerability to landslide was accepted by UNDP and UNCHS who agreed to provide the technical and financial assistance, this initiated a hazard zonation program to identify landslide areas under the "Lanslide Hazard Zonation Mapping Project (LHMP)". This project was implemented in seven areas: Badulla, Nuwara Eliya, Ratnapura, Kegalle, Kandy, Matale, Kalutara. In order to integrate these efforts with the regional and urban planning process, Sri Lanka Urban Multi hazard Disaster Mitigation Project was implemented on 1st October 1997. Ratnapura Town was selected as the site for the demonstration project and it was further replicated in other towns as of part of Sri Lanka Urban Multi-hazard Disaster Mitigation Project (SLUMDMP), implemented by Centre for Housing Planning and Building (CHPB) in partnership with NBRO and Urban Development Authority (UDA), under the Asian Urban Disaster Mitigation Program (AUDMP) of ADPC.

This case study reports on the risk assessment methodology undertaken under the SLUMDMP with the application of rapid assessment in Ratnapura Municipality. The rapid assessment, unlike the conventional scientific method, which makes use of GIS technology, was identified as the most suitable means under the circumstances with the limited time and resources. The obtained results were later use in development of an "Action Plan for Natural Disaster Management for Ratnapura Municipal Council Area". This case presents the basic elements of a conventional GIS based mapping tool.

## 2. Overview of the Tools/ Techniques used in Assessment

The application of a scientific methodology for the selection of priority areas by identifying the actually vulnerable areas required long field surveys within a limited time frame and that approach was found to be inappropriate for the project. Rapid assessment method, therefore, was adopted with sufficient quality control over the required information commensurate with the scale.

An appropriate scoring system was also used to derive maps to represent the areas listed in the above category. Base maps of 1:100,000 scale was used to collect the data from the field and the final product of the hazard zonation map was completed at the scale of 1:50,000.

## 3. Methodology and Outputs

### 3.1. The Landslide Hazard Mapping Process

To produce a Landslide Hazard Zonation map under a conventional method, Factor maps were compiled initially with the use of following categories of "state-of-nature" maps.

- Bedrock geology and structure
- Past landslide and colluvium
- Hydrology and drainage
- Slope range and slope category
- Landform and erosion
- Land use management.

The basic data are gathered from field surveys as well as from desk studies. A set of "derived maps" are then deduced from these maps using an appropriate scoring (point) system which are later analyzed by the use of a computer program.

Landslide Hazard Zonation map is the final product of integrating effects of all categories of maps mentioned above with the case of GIS software such as PC ARC/INFO. The methodology for mapping process is summarized in figure below.

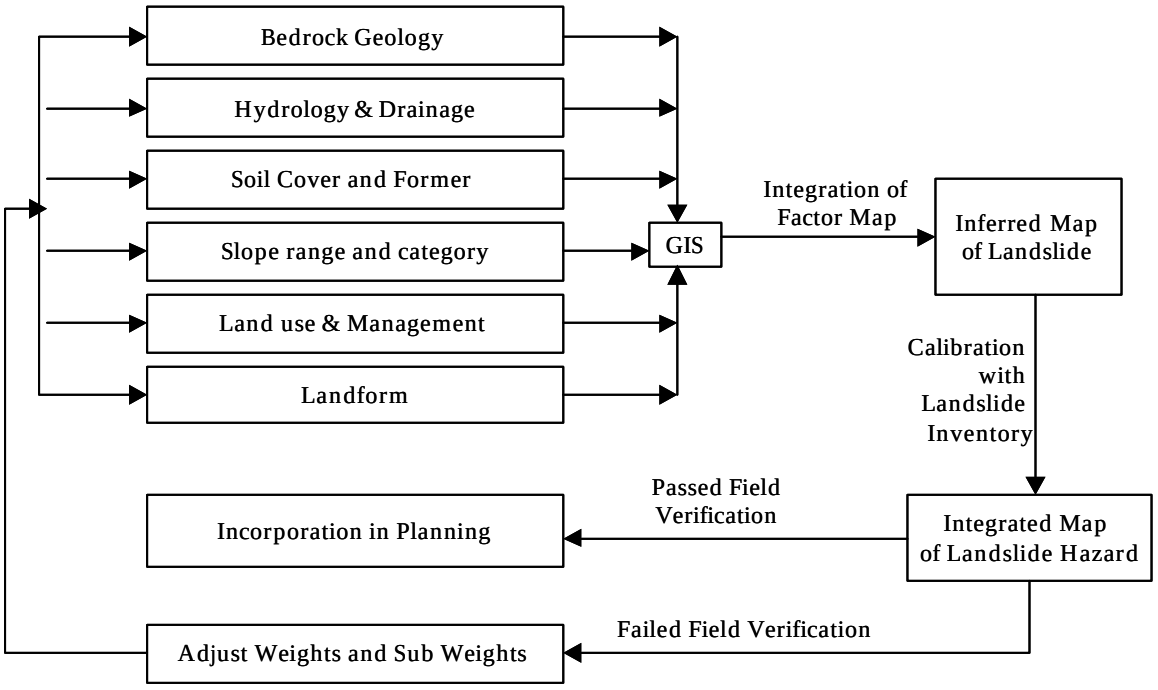


Fig 1: Landslide Hazard Mapping Methodology

The table on the following page indicates the relative weightings used in mapping process. It illustrates the allocated weights for attributes and factor maps according to the statistical analysis and expert knowledge.

Table1: Relative weightings for major factors and sub-factors in terms of their landslide potential

| **Major factors, Maximum Weighting & Qualitative rating** | | | **Sub-factors, Maximum Weighting & Qualitative rating** | | | **Sub-factor elements Linguistic rating (x), Qualitative Rating (y) & Score (z)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | **x** | **y** | **z** |
| Bedrock Geology & Geological Structure | 20 | B | Lithology | 8 | A | Marble | Very low | E | 0 |
| | | | | | | Weathered rock | Low | D | 1 |
| | | | | | | Granite, garnet biotite gneiss and all others | Medium | C | 3 |
| | | | | | | Charnockite, granulite or bedrock not exposed | High | B | 5 |
| | | | | | | Quartzite | Very high | A | 8 |
| | | | Amount & Direction of dip (degrees) | 4 | C | Dip and scrap 70-90 | Very low | E | 0 |
| | | | | | | Dip and scrap 55-70 | Low | D | 1 |
| | | | | | | Dip 10-30, scrap 45-55 and interim slopes | Medium | C | 2 |
| | | | | | | Dip 0-10, scrap 30-45 | High | B | 3 |
| | | | | | | Dip 30-55, scrap 0-30 | Very high | A | 4 |
| | | | Deviation Angle (degrees) | 6 | B | Angle 25-120 | Very low | E | 0 |
| | | | | | | Angle 10-25 or 120-155 | Low | D | 2 |
| | | | | | | Angle 155-180 | High | B | 4 |
| | | | | | | Angle 0-10 | Very high | A | 6 |
| | | | Discontinuities, lineaments, faults & master joints | 2 | E | To be decided on case to case basis | Very low | E | 0 |
| | | | | | | | Very high | A | 2 |
| Surface deposits (colluvium & residual soil) | 10 | A | Soil cover (m) | 10 | A | Bare bedrock | Very low | E | 0 |
| | | | | | | Colluvium<1, Overburden<2 | Low | D | 2 |
| | | | | | | Colluvium 1-3, Overburden 2-8 | Medium | C | 8 |
| | | | | | | Colluvium 3-8, Overburden >8 | High | B | 9 |
| | | | | | | Colluvium >8, Overburden >8 | Very high | A | 10 |
| Slope Range & Slope Category | 25 | A | Slope range & category (degrees) | 25 | A | Slope category I (>40) | Very high | A | 25 |
| | | | | | | Slope category II (31-40) | High | B | 16 |
| | | | | | | Slope category III (17-31) | Medium | C | 13 |
| | | | | | | Slope category IV (11-17) | Low | D | 7 |
| | | | | | | Slope category V (0-11) | Very low | E | 5 |
| Hydrology & Drainage | 20 | B | Relief Amplitude (m) | 5 | A | Relief>350 | Very low | E | 1 |
| | | | | | | Relief 0-170 | Medium | C | 2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| & Drainage | | | (m) | | | Relief 170-350 | Very high | A | 5 |
| | | | Hydrological map unit Area (sq.km) | 4 | B | Area 0-0.07 or > 0.5 | Very low | E | 1 |
| | | | | | | Area 0.07-0.2 | Medium | C | 2 |
| | | | | | | Area 0.2-0.5 | Very high | A | 1 |
| | | | Hydrological map unit shape (form factor) | 4 | B | 0.6-1.0 | Very low | E | 1 |
| | | | | | | 0.3-0.6 | Medium | C | 2 |
| | | | | | | <0.3 | Very high | A | 4 |
| | | | Drainage density (km/sq.km) with or without soil cover | 5 | A | With >5 or without >10 | Very low | E | 1 |
| | | | | | | With 3-5 or without 6-10 | Medium | C | 2 |
| | | | | | | With 0-3 or without <6 | Very high | A | 5 |
| | | | Proximity to water bodies | 2 | D | To be decided on case to case basis | Very low | E | 0 |
| | | | | | | | Medium | C | 1 |
| | | | | | | | Very high | A | 2 |
| Land use & Management | 15 | C | Land use & Management | 15 | A | JT1, JC, JQ, JWb, W1, S1 | Very low | E | 3 |
| | | | | | | JT2, JR, JWp, HP, HK, HW, W2, W3, W4, S2, S4 | Medium | C | 8 |
| | | | | | | HA, G1, G2, S3, N1, N2, N3, N4 | Very high | A | 15 |
| Landform | 10 | D | Landform | 10 | A | F11, F12, F31-35, F43, F91-92, F94, A10-13, X1, X2 | Very low | E | 1 |
| | | | | | | F41, F42, F44-48, F53 | Medium | C | 3 |
| | | | | | | F51, F52, F54-58, X13, X14 | High | B | 5 |
| | | | | | | F61, F62, F71-74, F81-83, F92, X11, X15 | Very high | A | 10 |

Note: With the technical and financial assistance from UNDP/UNCHS Landslide Hazard Mapping in Badulla and Nuwaraeliya districts had been carried out by the NBRO. Preparation of hazard maps for Ratnapura and Kegalle districts was completed by NBRO and the Kandy District Mapping is in progress under the Government Grant.

The main objective of this mapping exercise was to identify areas vulnerable to landslide hazard and establish good engineering practices in planning and construction through consultancy services, creation of public awareness, introduction of guidelines to ensure proper construction procedures with the ultimate aim of landslide hazard mitigation.

The landslide hazard zonation maps are available at 1:50,000 scale covering the districts of Matale, Kandy, Kegalle, Nuwara Eliya, and Ratnapura. 1: 10,000 scale maps are also available for selected areas in Badulla and other districts listed above at NBRO website www.nbro.gov.lk. *Source: http://www.nbro.gov.lk/*

### 3.2. Hazard Mapping using Rapid Assessment

During the process of rapid assessment of landslide prone areas, the method used under SLUMDMP, only three types of "state-of-nature" maps were used. They are:

- Bedrock geology and structure: It qualifies the geological factors that effect the stability of slopes. The main factors considered are: (i) Steepness of the dip of the bedrock foliation; (ii) The orientation of the topographic slope with respect to the attitude of the bedrock foliation and (iii) The presence of faults or lineaments.
- Slope range and slope category: Different slope categories and the intensity of contour lines are considered in preparing this map.
- Land use management: The impact of improper land use practices such as cutting, de-rooting, quarrying and mining, etc. , are incorporated in mapping methodology giving due consideration to how well the land is managed or maintained.

An appropriate scoring (point system) was also used to produce the above derived maps. To ensure the quality of the derived maps, Geological maps produced by Geological Survey and Mines Bureau (GSMB), lad use and slope maps of Landuse Policy Planning Department and topographic maps of Survey Department are used as base data.

Finally, the derived maps are analyzed using the same computer program used under the conventional method in order to produce the final landslide zonation maps.

### 3.3. The Parameters

#### 3.3.1. Landslide Susceptibility Evaluation

The weighting table in the previous page is applied for the maps of Bedrock Geology and Structure, Slope Range and Slope Category and Land Use Management.

#### 3.3.2. The Outputs

The scale of the complete map was 1:50,000 and the different zones on the map were labeled in color based to the following categories.

a) Safe slopes
b) Landslides are expected
c) Modest level of landslide hazard exists
d) Landslides are not likely to occur
e) Landslides have occurred in the past
f) Landslide potential cannot be evaluated.

### 3.3.3. The Advantages and Disadvantages of the two mapping systems in relation to the scales of the maps:

- The printed 1:50,000 scale maps were useful in identification of the priority areas, macro level planning of development projects.
- The printed 1:10,000 scale maps were useful at regional level for detailed field mapping processes
- The manpower required in 1:10,000 maps was much higher then the 1:50,000 scale maps and these maps were also more time consuming to prepare.

**Samples of landslide hazard maps for Ratnapura municipality :**

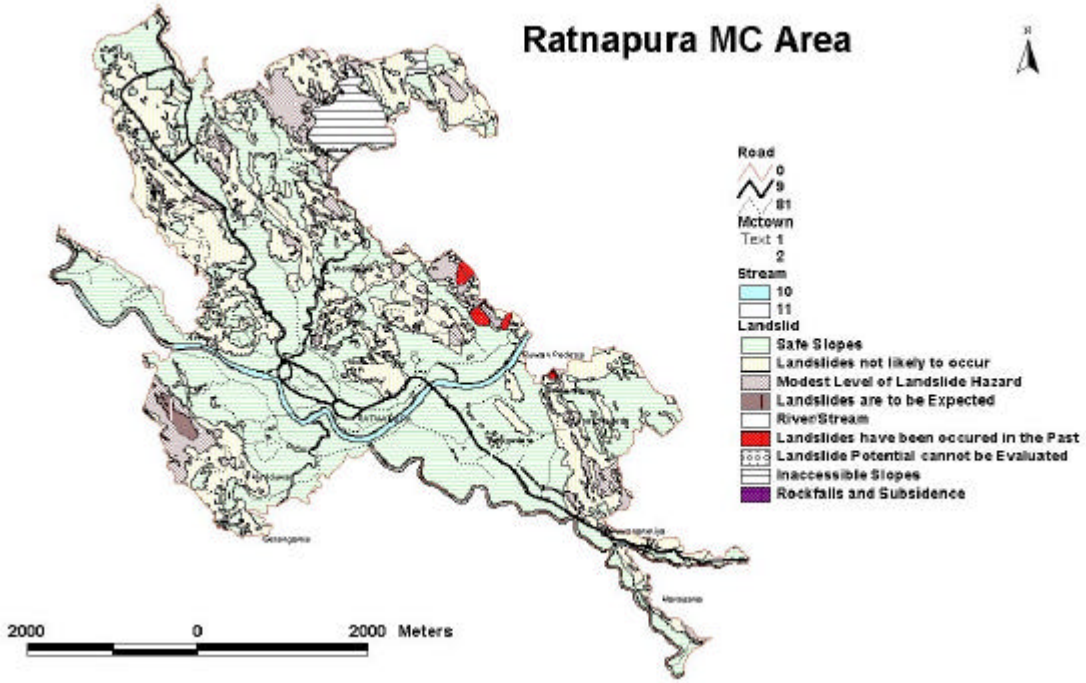


Fig 2: Landslide map of Ratnapura Municipality area

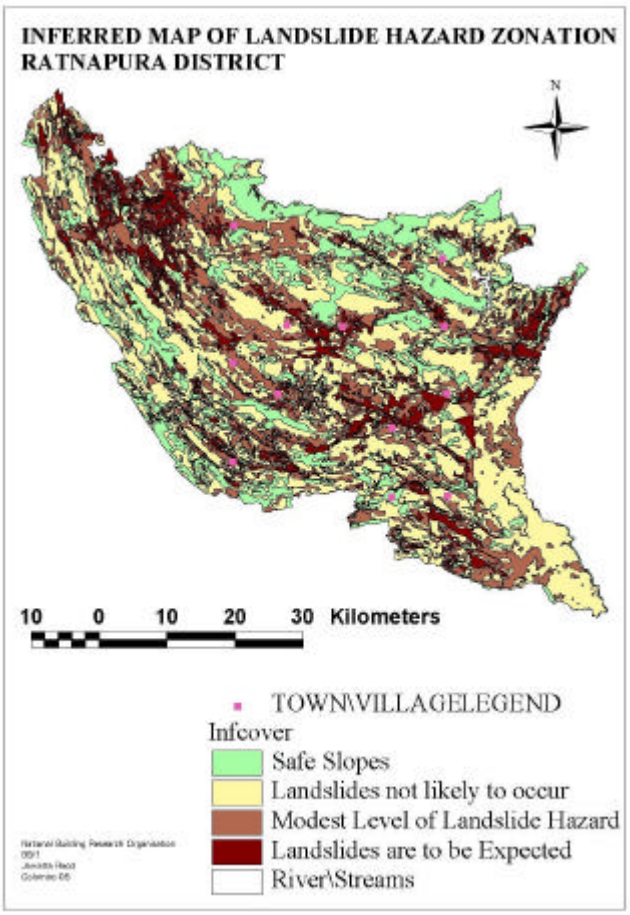


Fig 3: Inferred map of Landslide Hazard Zonation – Ratnapura District

## 4. Integration of Hazard Zonation Maps in Development Planning in Ratnapura Municipal Council Area

The landslide hazard zonations maps prepared by NBRO under the SLUMDMP and other map data collected by Urban Development Authority (UDA) of Sri Lanka were used to determine the vulnerability and subsequently prepare the risk matrix according to the electoral wards of Ratnapura Municipality.

The following types and applications of maps are recognized to provide information for risk control planning guide to assess the risks and to subjectively rank the importance of identified community hazard impacts:

- At Regional level: Regional map of past landslides, Evaluation of soils data and geological maps, Reconnaissance slope maps;
- Town / district level: Slope and stability maps;
- Site specific level: Site maps based on field investigations.

An Action Plan for Natural Disaster Management for Ratnapura Municipal Council Area was developed in April 1999, identifying multi-hazard risk control techniques and options.

## 5. Extensions to other areas

As of December 2004, activities are still being replicated under the SLUMDMP in other cities in Sri Lanka. CHPB, NBRO and UDA are working with ADPC's AUDMP for replicating the project to other cities. ADPC is providing technical inputs for the construction of disaster resistant houses for the communities, which were relocated. A number of workshops and training seminars are being conducted on GIS Application in Hazard Mapping for the local authorities so as to strengthen the sustainability of the project initiated for disaster mitigation activities.

## 6. References


i. SLUMDMP, (April 1999). ***Action Plan for Natural Disaster Management for Ratnapura Municipal Council Area.***

ii. AUDMP, (August 2000). ***Project Completion Report of the Sri Lanka Urban Multi-Hazard Disaster Mitigation Project.***

iii. R.M.S.Bandara (September 2002) *Hazard Mapping and delineating multiple risks of natural disasters under the SriLanka Multi Hazard Disaster Mitigation Project* **Proceedings on Regional Workshop on Best Practices in Disaster Mitigation: Lessons Learned from the Asian Urban Disaster Mitigation Program and other initiatives(AUDMP) and other initiatives** ADPC,; Bali Indonesia. Available online: http://www.adpc.net/audmp/rllw/default.html

iv. AUDMP, ADPC (2003). *'Community based disaster risk reduction in Central Sri Lanka- Mitigating landslide and rock fall damage in urban Nawalapitiya'* **Safer Cities 5: Case studies on mitigating disasters in Asia and the Pacific**
Available online: http://www.adpc.net/AUDMP/library/safer_cities/5.pdf

v. AUDMP, ADPC (2003). *'Promotion of Disaster Mitigation in Sri Lanka- Piloting disaster risk communitcaiton through empirical approach'* **Safer Cities 6: Case studies on mitigating disasters in Asia and the Pacific**
Available online: http://www.adpc.net/AUDMP/library/safer_cities/6.pdf


## 7. Additional Web Resources

**ADPC:** www.adpc.net
**AUDMP:** http://www.adpc.net/udrm/udrm.html
http://www.adpc.net/AUDMP/sri.html
**National Building Research Organisation:** http://www.nbro.gov.lk/
**Centre for Housing Planning and Building:** http://www.chpb.gov.lk/

8. **For more information contact**

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