LANDSLIDE RISK ASSESMENT

SOME DEFINITIONS

Landslide Inventory (I): *This is an essential part of any landslide zoning. It involves the location, classification, volume, travel distance, state of activity and date of occurrence of landsliding in an area.*

Landslide Susceptibility (S): *Areas prone to slope failure or that where a landslide may travel onto or retrogress into it.*

Landslide Hazard (H): *The probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon.*

Elements at Risk (E_r): *Means the population, properties, economic and social activity, etc., at risk in a given area.*

Vulnerability (V): *Means the degree of loss of a given element or set of elements at risk of a given magnitude. It is expressed on a scale from 0 (no damage) to 1 (total loss).*

Specific Risk (R_s): *Means the expected degree of loss due to a particular natural phenomenon. It may be expressed by the product of Hazard times Vulnerability*

Total Risk (R): *Means the expected number of lives lost, person injured, damage to property, or destruction of economy activity due to a particular natural phenomenon, and is therefore the product of specific risk and element at risk*

Type of zoning

TECHNICAL ISSUE

POLITIC, ECONOMIC, SOCIAL AND TECHNICAL ISSUES

LANDSLIDES INVENTORY

SUSCEPTIBILITY MAP

HAZARD MAP

RISK MAP

SCALE

PLAN DEVELOPMENT

AVAILABLE INFORMATION

TECHNIQUES OF ANALYSIS

COST

UNCERTAINTY

INVOLVED SUBJECTS

The SCALE

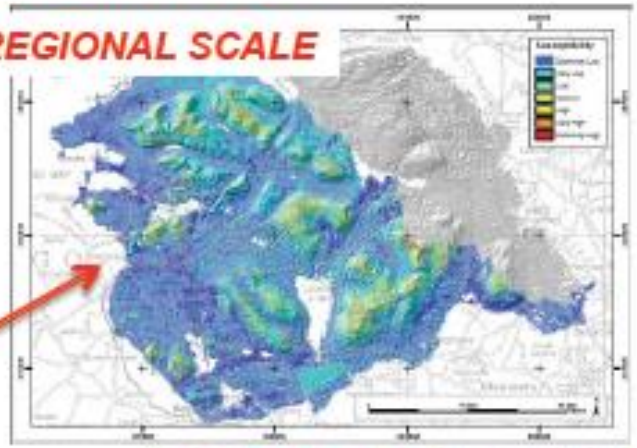
Susceptibility and Hazard Zoning

SMALL SCALE	*< 1:100,000*
MEDIUM SCALE	*1:100,000 – 1:25,000*

Hazard and Risk Zoning

LARGE SCALE	*1:25,000 – 1:5,000*
DETAILED SCALE	*> 1:5,000*

REGIONAL SCALE



BASIN SCALE

LOCAL SCALE

The PURPOSE

The SCALE	Indicative Range	Typical Area of zoning	The PURPOSES Example of Zoning Application
SMALL SCALE	< 1:100,000	> 10,000 km²	LANDSLIDE INVENTORY AND SUSCEPTIBILITY TO INFORM POLICY MAKERS AND THE GENERAL PUBLIC
MEDIUM SCALE	1:100,000 – 1:25,000	1,000 – 10,000 km²	LANDSLIDE INVENTORY AND SUSCEPTIBILITY ZONING FOR REGIONAL DEVELOPMENT, OR VERY LARGE SCALE ENGINEERING PROJECTS. PRELIMINARY LEVEL HAZARD MAPPING FOR LOCAL AREAS
LARGE SCALE	1:25,000 – 1:5,000	100 – 1,000 km²	LANDSLIDE INVENTORY, SUSCEPTIBILITY AND HAZARD ZONING FOR LOCAL AREAS. INTERMEDIATE TO ADVANCED LEVEL HAZARD ZONING FOR REGIONAL DEVELOPMENT. PRELIMINARY TO INTERMEDIATE LEVEL RISK ZONING FOR LOCAL AREAS AND THE ADVANCED STAGES OF PLANNING FOR LARGE ENGINEERING PROJECTS
DETAILED SCALE	> 1:5,000	Several Hectares to 1,000 km²	INTERMEDIATE AND ADVANCED LEVEL HAZARD AND RISK ZONING FOR LOCAL AND SITE SPECIFIC AREAS AND FOR DESIGN PHASE OF LARGE ENGINEERING STRUCTURES, ROADS AND RAILWAYS

INTERNATIONAL GUIDELINES (FELL ET AL., 2008)

Recapping:

Inventory mapping

1) Susceptibility MAP — WHERE

Frequency Assessment (of landslide or triggering factor)

2) Hazard MAP — WHERE, WHEN

- Elements at risk
- Temporal-spatial probability
- Vulnerability

3) Risk MAP — WHERE, WHEN, WHAT, HOW MUCH

BASIC, INTERMEDIATE, ADVANCED
Level Zonings
for Inventory mapping

BASIC: -Prepare Inventory of landslides in the area from aerial photographs and/or satellite imagery, and by mapping and from historic records. The inventory includes the location, classification, volume (or area).
-Identify the relationship to topography, geology and geomorphology
-Show this information on inventory maps along with topographic information including contours, property boundaries, mapping grid, roads, streams, etc.

INTERMEDIATE: **The same activities as basic plus:**
-Distinguish different parts of landslides
-Map landslide features and boundaries
-Collect and assess historical information on the activity of landslides

ADVANCED: **The same activities as Intermediate plus:**
-Prepare an inventory of geotechnical data
-Implemented investigation to better define geotechnical conditions
-Geotechnical analysis to understand slope instability processes
-Advanced temporal cataloguing of periodic reactivations
-Temporal windowing of specific triggering events to provide inventory dataset which can be used in advanced validation approaches

BASIC, INTERMEDIATE, ADVANCED Level Zonings for Susceptibility MAP

BASIC:
-Prepare a Geomorphologic Map
-Prepare a landslide Inventory
-Prepare calculations of the % of the total landslide count for each susceptibility class, the % of the area affected by landslides for each class and the % of each class in comparison to the total study area

INTERMEDIATE:
The same activities as basic plus:
-Obtain basic soil classification and depths in the study area
-Classify more complex terrain units
-Quantitative rating of the landslide susceptibility areas based on overlapping techniques

ADVANCED:
The same activities as Intermediate plus:
-Detailed mapping and geotechnical investigations to develop an understanding of the mechanics of landsliding, hydrogeology and stability analyses.
-Perform data treatment analysis (discriminate; neural networks; fuzzy logic; logistic regression; etc) and develop quantitative ratings to obtain susceptibility classes
-Perform deterministic and/or probabilistic stability analyses

BASIC, INTERMEDIATE, ADVANCED Level Zonings for Frequency Assessment

BASIC: -Assess the historic frequency of landsliding from the incident database including activity indicators such as cracked buildings, displaced fences, bent and tilted trees

-Assess frequency from geomorphology evidence such as the freshness of slide scarps and other surface features associated with landslide movement using subjective assessment.

INTERMEDIATE: The same activities as basic plus:

-The use of proxy data such as carbon 14 dating, or in raised alluvial terraces in valleys which may have been blocked by landsliding.

-Relate history of landsliding to rainfall intensity and antecedent rainfall, or to snow melt

-As an alternative to estimating from historic data, assess frequency by subjective assessment, e.g. by assessing the probability of landsliding given a rainfall or seismic load

ADVANCED: The same activities as Intermediate plus:

-Relate the history of landsliding or factor of safety to rainfall, slope geometry, piezometric level, geotechnical properties.

BASIC, INTERMEDIATE, ADVANCED Level Zonings for Assessing the element at Risk

BASIC: Make an assessment of:
-The Population who live, work and travel through the area
-Property such as houses, buildings, roads, railways etc.

INTERMEDIATE: As above in greater degree of detail. Economic consequences may be included

ADVANCED: As above in detail. Economic consequences will be estimated such as the implications of loss of a road providing access to a town until repairs are carried out

BASIC, INTERMEDIATE, ADVANCED

Level Zonings for Assessing the temporal-spatial probability of the element at Risk

BASIC:

Life loss Risk

-For person at risk in residential areas assume that their temporal-spatial probability is 1.0

-For other type of development make an approximate assessment based on an estimation of use of the buildings

-For roads and railways make an approximate assessment of temporal-spatial probability from the traffic volumes

Property loss Risk

-For buildings the temporal-spatial probability is 1.0

-For vehicles make an approximate assessment of temporal-spatial probability from the traffic volumes

INTERMEDIATE:

Life loss Risk

-For all situations estimate temporal-spatial probability taking into account of the nature of development, living and work pattern, existence of protected places, traffic and the intensity of landsliding

Property loss Risk

-As for basic assessment although in more detail

ADVANCED:

As above, with greater detail in the assessment, particularly the temporal/spatial distribution of the element at risk

Type of Zoning : Susceptibility map

Landslides Inventory

- LOCATION
- CLASSIFICATION
- AREAL EXTENT AND VOLUME
- CREEPING ZONES
- STATE OF ACTIVITY

+

- RUN-OUT DISTANCE

+

- THE AREA INTO WHICH THE SLIDE MAY
  - travel
  - retrogress
  - enlarge

Type of Zoning : Hazard map

Hazard definition:

PROBABILITY THAT A PARTICULAR DANGER (THREAT) OCCURS WITHIN A GIVEN PERIOD OF TIME IN A GIVEN LOCATION

KEY-WORDS:

PARTICULAR DANGER	GIVEN PERIOD OF TIME	GIVEN LOCATION
Type of Landslide	Frequency	Triggering
Magnitude/Intensity		Propagation

HAZARD MAP

RECOMMENDED TYPES AND LEVELS OF ZONING AND ZONING MAP SCALES RELATED TO LANDSLIDE ZONING PURPOSE

	Scale description	Indicative range of scales	Zoning methods			Zoning levels			Type of zoning		Purpose
			Basic	Intermediate	Sophisticated	Preliminary	Intermediate	Advanced	Susceptibility	Hazard	
Susceptibility and Hazard zoning	Small	< 1:100,000	*			*			*		Regional zoning - Information
	Medium	1:100,000 to 1:25,000	*	(*)		*	(*)		*	(*)	Regional zoning - Information - Advisory
Risk zoning	Large	1:25,000 to 1:5,000	*	*	*	*	*	*	*	*	Local zoning - Information - Advisory - Statutory
	Detailed	> 1:5,000	[*]	(*)	*	[*]	(*)	*	(*)	*	Site specific zoning - Information - Advisory - Statutory - Design

Notes: *Applicable; (*) May be applicable; [*] Not recommended or not commonly used.

INTERNATIONAL GUIDELINES (FELL ET AL., 2008)