THE REGIONAL DISASTER RISK MANAGEMENT FOR SUSTAINABLE TOURISM IN THE CARIBBEAN PROJECT

(ATN/OC-10085-RG)

Consultancy for the Development of Standards for Conducting Hazard Mapping, Vulnerability Assessment and Economic Valuation for Risk Assessment for the Tourism Sector

First Regional Working Draft of Standard

Note to the draft version

This first regional working draft of standard represents a draft version of the "Standard for conducting risk assessment for natural hazards in the tourism sector".

The scope of this draft is to present a preliminary version of the standard to the stakeholders for the scope of reviewing structure and contents.

This draft version of the standard is not complete and may encounter substantial modifications, according to future outcomes of the review process.

Some problems occurred during the conversion of graphics from Word to PDF.

Consultant

DRM Disaster Risk Management Switzerland SA

www.DRMonline.net

Table of Contents

1 General information ... 6
- 1.1 Scope ... 6
- 1.2 Applicability and intended audience ... 7
- 1.3 Review cycles ... 7
- 1.4 Terminology ... 7

2 Risk assessment overview ... 7
- 2.1 Risk management ... 7
- 2.2 Risk assessment ... 8

3 Risk assessment process ... 10
- 3.1 Definition of objectives ... 11
- 3.2 Analysis of hazards ... 13
- 3.3 Analysis of vulnerable elements ... 21
- 3.4 Estimation of consequences ... 23
- 3.5 Representation of results ... 25

4 Software tools for risk assessment ... 28

5 Bibliography ... 29

Appendix A – Natural hazards ... 31

Appendix B – Examples of risk assessment ... 36

Appendix C – Documentation of hazard events ... 37

Appendix D – Glossary ... 38

Index of Figures

Figure 1: Risk assessment is the central part of the risk management process. 8
Figure 2: The risk assessment process is composed of five working steps............. 10
Figure 3: Definition of objectives of risk assessment. 11
Figure 4: Analysis of natural hazards. 14
Figure 5: Representation of the degree of hazard: low, medium and high. 18
Figure 6: Inventory of elements at risk.. 21
Figure 7: Estimation of consequences.. 23
Figure 8: Representation of results... 25
Figure 9: General layout of maps. 26

Index of Tables

Table 1: Identification of objectives of risk assessment. 12
Table 2: Prioritization of hazards. 15
Table 3: Necessary data/maps for hazard analysis. 16
Table 4: Representation of qualitative hazard. 17
Table 5: Probability of hazard occurrence. 18
Table 6: Overview of hazard analysis criteria. 20
Table 7: Colours to be used in maps. 27
Table 8: Map symbols. 28

1 General information

1.1 Scope

This standard describes the methodologies to conduct risk assessment for natural hazards in the tourism sector in the states of the Caribbean Community (CARICOM).

The presented risk assessment procedure is modular and open and most of the modules can be executed individually and, if necessary, elements of the assessment procedure can be replaced, and additional elements can be added. The assessment can be performed at different map scales – site specific, local, regional – at a qualitative or quantitative level.

The standard considers atmospheric hazards (tropical cyclone), geologic hazards (landslide, land subsidence, rockfall), hydrologic hazards (coastal erosion, debris flow, drought, flood, storm surge) and tectonic hazards (earthquake, tsunami, volcanic eruption). The draft version considers tropical cyclone, rockfall, flood, and earthquake.

The document reflects the multi-step character of risk assessment, and is structured into five major parts:

- **Definition of objectives.** Initially, the objectives of risk assessment must be defined, addressing motivation, scope, level of detail, scale of assessment as well as expected results.
- **Analysis of natural hazards.** The natural hazards are identified according to their importance in the study area and analyzed to determine their degree of hazard. This can be done choosing from a qualitative or quantitative approach, based on the availability and quality of the necessary data to perform such analysis.
- **Analysis of vulnerable elements.** The elements at risk due to natural hazards must be identified and their degree of vulnerability is to be determined. Elements at risk are installations and essential infrastructures of tourism, people and communities, environmental assets, and connected economic activities.
- **Estimation of consequences.** The consequences of the exposure of vulnerable elements to natural hazards are determined in terms of direct and indirect damages and losses. According to the level of assessment the results are either expressed qualitatively or quantitatively.
- **Representation of results.** The standard determines how the results of risk assessment are to be displayed in reports and on maps defining layout, scale, colours and symbols of maps of hazards, vulnerable elements and consequences.

The documentation of events of natural hazards and their consequences is an essential prerequisite for conducting risk assessment. The standard proposes a form for the standardized documentation of natural hazard events for future analysis.

1.2 Applicability and intended audience

The standard describes the procedures for conducting risk assessment in the tourism sector. The standard is applicable to assess the risks of existing and of planned tourism infrastructure.

The standard is to be used complementary to existing local, national and regional procedures, and can be adapted to fit specific needs.

The direct users of the standard are professionals of a technical-scientific profile, such as engineers, land use planners and scientists.

1.3 Review cycles

Several aspects of the risk assessment cycle are subject to change. It is thus recommended that the standard and the respective working steps are reviewed and updated regularly.

1.4 Terminology

The terminology used in this standard is in agreement with ISDR, UN DHA/IDNDR (1992). See the glossary in Appendix D for a description of the used terms.

2 Risk assessment overview

2.1 Risk management

Risk management is the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (ISDR).

The overall goal of risk management is to control, and if possible, reduce risks. The entire process requires the involvement of the affected community in order to successfully manage risks, by the development and implementation of sustained risk management options.

The individual working steps of risk management are (Figure 1):

- **Definition of objectives.** Initially the objectives and scope of risk management must be defined, addressing intent, scale and extent of the assessment as well as expected results.
- **Risk assessment.** The risks must be identified and evaluated, thus the consequences that hazards may have on elements at risk are to be determined, either in a qualitative or quantitative way. The resulting risks are compared to commonly accepted or tolerated levels that are to be identified by community involvement.

- **Identification and selection of risk reduction option.** If the identified risks exceed the levels of tolerance and acceptance, options of risk reduction must be identified, chosen and implemented. Options are risk acceptance or avoidance, reduction of likelihood of occurrence or of consequences, and transfer of risks. Each of these options is evaluated by means of a cost-benefit analysis, where the costs of the risk reduction operations are compared to the resulting benefits in terms of reduced risks. The option with the most suitable cost-benefit ratio is identified.
- **Implementation of option.** The risk reduction option which has been identified as suitable in the previous working step is implemented.
- **Monitoring and review.** Several components in the risk management procedure may change over time, such as the hazard situation or the number and characteristics of the elements at risk. Monitoring of the major elements in the risk management process and the definition of review cycles are fundamental parts of risk management.

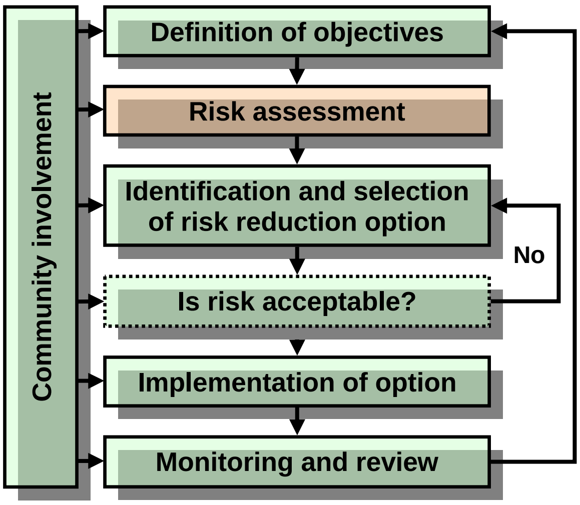

Figure 1: Risk assessment is the central part of the risk management process.

2.2 Risk assessment

The assessment of risks is an essential part of the risk management cycle (Figure 1). The main objective of risk assessment is the identification and quantification of risks, by analyzing its main components – hazards and elements at risk – and determining the respective consequences.

Risk assessment can be described as a procedure of five main working steps (Figure 2).

Step 1 – Definition of objectives

In the initial step the general framework of the assessment must be defined, preliminarily determining key characteristics, such as motivation, extent and scale of the assessment as well as types of hazards and vulnerable elements to consider. It is also important to develop a preliminary idea of the expected results.

Step 2 – Analysis of hazards

The hazards which are important for the study area must be identified, choosing from a wide range of possible threats, such as atmospheric hazards (tropical cyclone), geologic hazards (landslide, land subsidence, rockfall), hydrologic hazards (coastal erosion, debris flow, drought, flood, storm surge) and tectonic hazards (earthquake, tsunami, volcanic eruption).

The present hazards are prioritized according to their importance. Each hazard is analyzed and the degree of hazard is determined for the entire study area. Based on the availability of historical hazard data or model assumptions, the hazards are analyzed selecting from two analysis schemes: qualitative and quantitative.

Qualitative schemes are only capable of identifying the presence of a hazardous situation, such as flood in a flood-prone area or rockfall in the immediate vicinity of a rock slope. Quantitative schemes can deliver the degree of hazard in terms of frequency of occurrence and physically determinable hazard characteristics, such as the flow depth of a one-hundred-year event for floods.

Step 3 – Analysis of vulnerable elements

Hazards are a possible threat to a number of elements at risk, such as the physical assets of tourism, individual or communities of people connected to tourism, environmental aspects important to tourism, and economic activities linked to it. These elements can be directly or indirectly at risk. In a first step, the elements at risk must be identified and inventorized. In a second step the degree of vulnerability must be identified individually for each vulnerable element as a function of the expected intensity of a hazard event.

Step 4 – Estimation of consequences

The consequences that arise from the exposure of vulnerable elements to natural hazards are estimated, by superimposing the hazards on the elements at risk. The consequences are direct damages to the building stock and infrastructures of tourism, transportation facilities and infrastructure, direct losses such as cost of repairs and replacement, income loss, casualties, and indirect losses, such as supply shortages, sales decline, and other economic losses.

Step 5 – Representation of results

The risk assessment concludes with a proper documentation of the results on maps and in reports. The standard gives guidance on how to represent hazards, vulnerabilities and risks on maps, defining layout, scales, colours, and symbols.

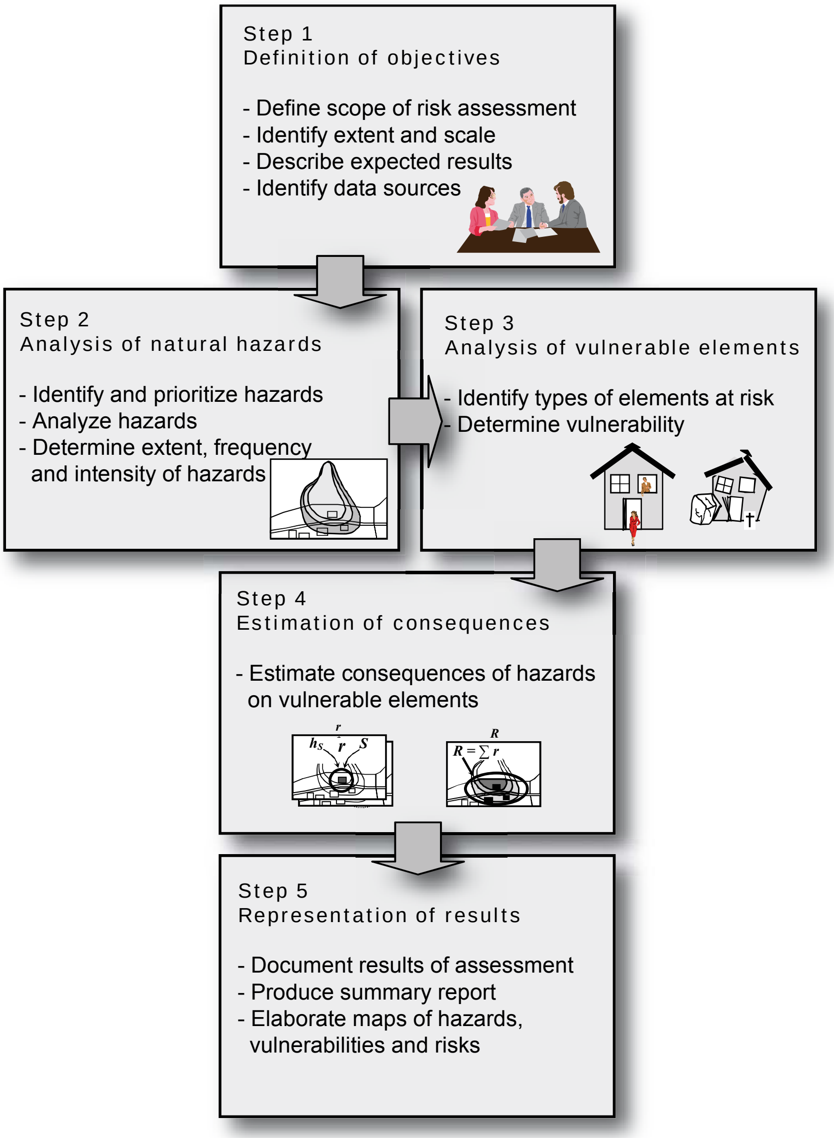

Figure 2: The risk assessment process is composed of five working steps.

3 Risk assessment process

The risk assessment process has the following individual working steps, which are discussed in the corresponding section of the standard:

- Definition of objectives (section 3.1).
- Analysis of natural hazards (section 3.1.5).
- Analysis of vulnerable elements (section 3.3).
- Estimation of consequences (section 3.4).
- Representation of the results (section 3.5).

3.1 Definition of objectives

3.1.1 Summary

Initially the objectives of risk assessment must be defined and the expected results determined (Figure 3). This is done by anticipating the entire process of risk assessment in a preliminary way, according to the step-by-step procedure presented in Figure 2. Table 1 can be used to help identifying the objectives. The individual aspects of this initial working step are discussed below.

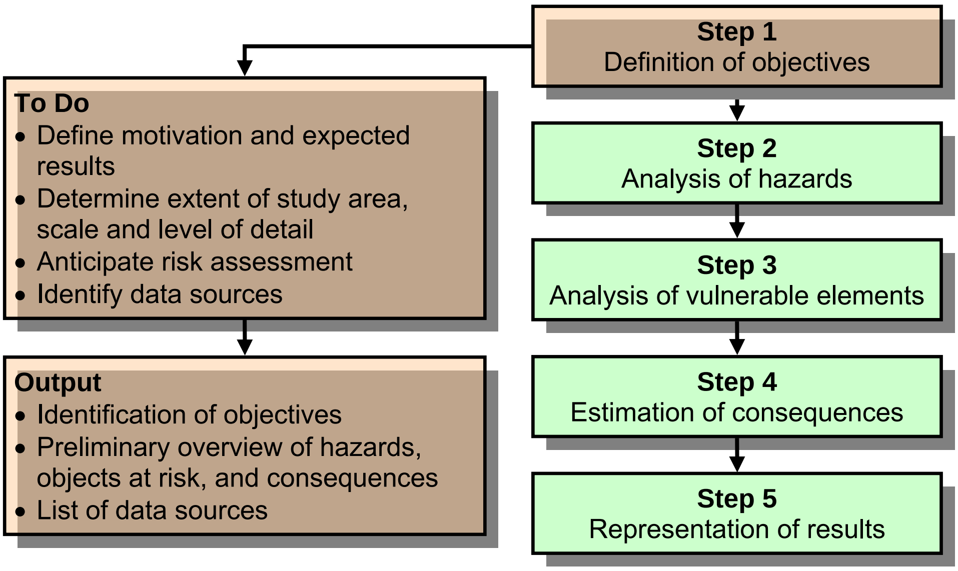

Figure 3: Definition of objectives of risk assessment.

3.1.2 Motivation and expected results

Define the objectives of risk assessment and the expected results, identifying the motivation for the conduction of risk assessment.

3.1.3 Extent and scale of assessment

Define the geographic extent and scale of the assessment. Evaluate focus, scale and level of detail of assessment: Individual or groups of tourism installations (site-specific, at typical scales of 1:1’000), local (community-based, at typical scales of 1:10’000) or regional (parts or an entire nation or international, at typical scales of 1:100’000 and greater)?

3.1.4 Hazards to consider

Define preliminarily the hazards to be considered in the assessment. Choose from atmospheric hazards (tropical cyclone), geologic hazards (landslide, land subsidence, rockfall), hydrologic hazards (coastal erosion, debris flow, drought, flood, storm surge) and tectonic hazards (earthquake, tsunami, volcanic eruption).

Table 1: Identification of objectives of risk assessment.

<table>
<tr><th colspan="4">Objectives of risk assessment</th></tr>
<tr><td>Describe objectives</td><td colspan="3">……………………………………………………………………………………
……………………………………………………………………………………</td></tr>
<tr><td>Extent</td><td>☐ Site specific</td><td>☐ Local</td><td>☐ Regional</td></tr>
<tr><td>Scale</td><td colspan="3">1 : ………………………………</td></tr>
<tr><td>Assessment</td><td>☐ Qualitative</td><td colspan="2">☐ Quantitative</td></tr>
<tr><td colspan="4">Hazards to consider</td></tr>
<tr><td>Types of hazards</td><td colspan="3">Atmospheric: ☐ Tropical cyclone
Geologic: ☐ Landslide ☐ Land subsidence ☐ Rockfall
Hydrologic: ☐ Coastal erosion ☐ Debris flow ☐ Drought
☐ Flood ☐ Storm surge
Tectonic: ☐ Earthquake ☐ Tsunami ☐ Volcanic eruption
☐ Other: ………………………………</td></tr>
<tr><td colspan="4">Elements at risk to consider</td></tr>
<tr><td>Types of elements</td><td colspan="3">Tourism: ☐ Buildings ☐ Infrastructure
Specify: ……………………………………………………………………………
☐ People/Population
Specify: ……………………………………………………………………………
☐ Transport infrastructure
Specify: ……………………………………………………………………………
☐ Economy
Specify: ……………………………………………………………………………
☐ Environment
Specify: ……………………………………………………………………………</td></tr>
<tr><td colspan="4">Assessment of consequences</td></tr>
<tr><td>Direct damages/losses</td><td colspan="3">☐ Fatalities, injured
Destroyed/damaged:
☐ Buildings ☐ Service infrastructure ☐ Traffic infrastructure
☐ Environmental aspects
Specify: ……………………………………………………………………………
Losses:
☐ Unemployment
☐ Cost of repair/replacement
Specify: ……………………………………………………………………………</td></tr>
<tr><td>Indirect losses</td><td colspan="3">☐ Losses in connected economies
Specify: ……………………………………………………………………………</td></tr>
</table>

3.1.5 Vulnerable elements to consider

Define which vulnerable elements are to be considered in the analysis, such as buildings and infrastructures of tourism, transport infrastructure, people, economies connected to tourism, and vital elements of the environment, such as beaches and reefs.

3.1.6 Estimation of consequences

Define which consequences are to be assessed, such as direct damages to the building stock and facilities of tourism, transport infrastructure, or direct losses, such as casualties, cost of repair and replacement, income losses or indirect losses as supply shortages, sales decline and economic losses.

3.1.7 Data sources

Based on the above points, sources of necessary data for conducting the risk assessment must be preliminarily identified, such as base maps, data on natural hazards and elements at risk, such as formerly conducted hazard mapping vulnerability assessment initiatives.

An overview of situations regarding hazard mapping, vulnerability assessments and digital maps in the CARICOM countries is given in CDERA (2003A) and CDMP. CDERA (2003B) presents country reports for Anguilla, Antigua, Bahamas, Barbados, Belize, British Virgin Islands, Dominica, Grenada, Guyana, Haiti, Jamaica, Martinique, Montserrat, Nevis, Puerto Rico, St. Lucia, St. Kitts, St. Vincent, Suriname, Turks and Caicos, and Trinidad and Tobago.

3.2 Analysis of hazards

3.2.1 Summary

In this working step the relevant hazards are identified and prioritized according to their importance for the study area. The hazards considered in the standard are classified into five hazard groups according to their nature and origin, as atmospheric, geologic, hydrologic and tectonic.

The complete procedure of hazard analysis must be conducted for each hazard individually.

The hazards are analysed to determine the degree of hazard. Two approaches can be applied, qualitative or quantitative, depending on the availability and quality of the necessary data:

- A qualitative approach is applied to hazard situations, where only the extent of a hazard can be determined, but no further quantification can be made.
- A quantitative approach is applied when sufficient data is available to determine frequency and intensity of the occurrence of hazards, allowing the classification of hazards in terms of return periods and respective hazard intensities.

The various steps of hazard analysis, identification, prioritization and determination of degree of hazard are described in more detail below.

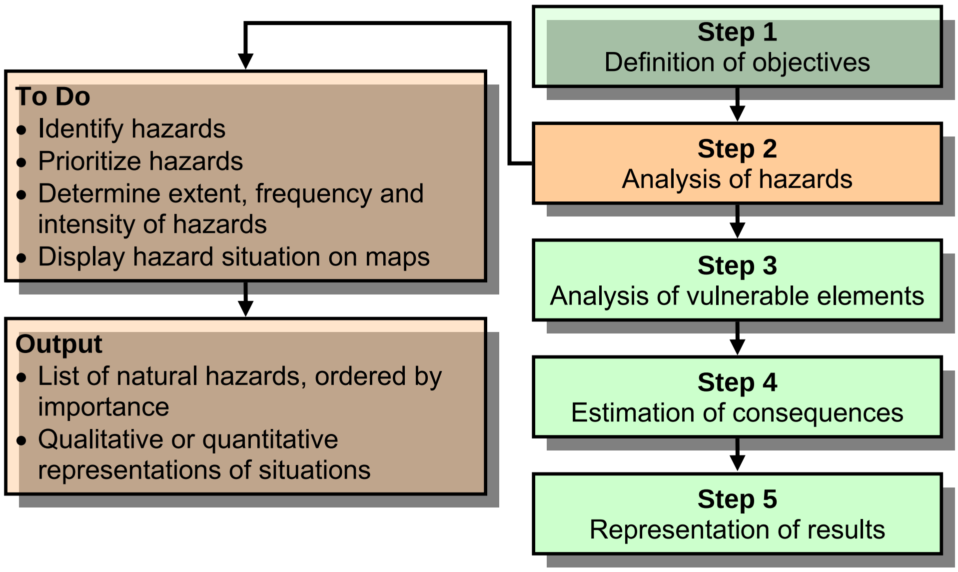

Figure 4: Analysis of natural hazards.

3.2.2 Identification of hazards

The standard considers atmospheric, geologic, hydrologic and tectonic hazards. See Appendix A and Appendix D for a more detailed description of natural hazards.

3.2.3 Prioritization of hazards

The prioritization of hazards has the scope of focusing the risk assessment procedure on important hazards, adapting the procedure to the study area.

An overview of the hazard situations at a regional and national level can be found in the international database EM-DAT or NATHAN and in the regional and country reports on natural hazards by CDERA (2003A, 2003B).

Table 2 can be used as a help identifying the priority hazards in the study area. In this qualitative procedure, for each hazard the following information is to be provided, using historical data sources.

- Type of hazard phenomenon
- Years of occurrence of such hazard in the study area
- Number of hazard events in the considered years
- Impacts due to this hazard (injured, fatalities, damages, destruction of buildings, infrastructures, economic losses)
- List of available data which was used for compilation

Based on the data entered in the table, a qualitative ranking can be established. According to this list of priority hazards the further risk assessment procedure is conducted, starting with the most important hazards.

Table 2: Prioritization of hazards.

Rank	Hazard	Years	Number of events	Consequences	Available data and maps
	Atmospheric				
	Tropical cyclone				
	Geologic				
	Landslide				
	Land subsidence				
	Rockfall				
	Hydrologic				
	Coastal erosion				
	Debris flow				
	Drought				
	Flood				
	Tectonic				
	Earthquake				
	Tsunami				
	Volcanic hazard				
	Other				

3.2.4 Analysis of degree of hazard

3.2.4.1 Necessary data for analysis

In order to perform a hazard analysis, data is necessary from which information regarding the occurrence can be obtained. See Table 3 for the type of information, which is necessary for hazard analysis.

Table 3: Necessary data/maps for hazard analysis.

Hazard	**Necessary data/maps for qualitative/Quantitative analysis**
Atmospheric	
Tropical cyclone	Q: Expected wind speed/Saphir-Simpson scale with 10% exceedance probability in 10 years
Geologic	
Landslide	q: Landslide maps showing localization of landslides Q: Data on landslide activity (frequency and velocity)
Land subsidence	q: Localization of areas prone to land subsidence
Rock fall	q: Localization of areas prone to rockfall Q: Statistics on rockfall occurrence
Hydrologic	
Coastal erosion	q: Localization of areas showing areas prone to coastal erosion Q: Historical aerial photographs
Flood	q: Localization of areas prone to flooding Q: Statistical data of flood flow depths
Debris flow	q: Localization of areas prone to debris flows Q: Maps of debris flow depths
Drought	q: Localization of areas prone to drought Q: Statistical, hydrological data on rivers, reservoirs, water production
Tectonic	
Earthquake	Q: Maps of earthquake intensities, peak ground accelerations, soil cover maps
Tsunami	Q: Localization of coastal areas prone to tsunami
Volcanic hazard	q: Localization of volcanoes by historical activity

3.2.4.2 Qualitative analysis

A qualitative analysis is conducted in cases where it is not possible to describe a hazard quantitatively in terms of frequency and intensity. This can be due to insufficient quantity or quality of data, or complexity of the hazard, or in the case of hazards which occur at very low frequencies, but in rather well defined areas. In this case the hazard analysis delivers the area which is prone to a certain hazard. Examples can be a particular area in a flood plain, which is known to be flood prone, but only insufficient data exists on occurrence and exact geographical coverage and water depths.

Using this approach it is, as a consequence, not possible to perform a quantitative assessment of risks, but it can be used to identify the type and number of elements that are at risk due to a certain natural hazard.

The area prone to a hazard is identified graphically on a topographic base map using a dashed red signature (RGB code 255/0/0), as shown Table 4.

Table 4: Representation of qualitative hazard.

Undifferentiated degree of hazard	Red (255/0/0)	Area is prone to hazard

3.2.4.3 Quantitative analysis

The degree of hazard is described by means of two parameters, probability of occurrence and intensity. Both probability and intensity are divided into three classes (low, medium, high):

- **Probability:** The probability of occurrence (derived from return period or frequency of the hazard within a certain period of time) is divided into three classes, of low, medium and high. For gravitational hazards, the classes range from 1 to 30, 30 to 100 and 100 to 300 years, the class boundaries being thus at 30, 100 and 300 years, corresponding to frequencies of 0.033, 0.01 and 0.0033 per year.
- **Intensity:** The intensity of hazards is described by parameters which are characteristic for the impacts due to a hazard. Intensity, as well, is divided into three classes of low, medium and high intensity.

In a few cases the assessment is linked directly to the intensity: In cases where the frequency (or return period) is difficult to assess, is standardized, or has only little importance.

3.2.5 Degree of hazard

The degree of hazard is expressed using a 3-step scale of low, medium and high hazard, expressed in colours by yellow, orange and red. The colours express the degree of hazard in terms of the likelihood of injury/death of people, animals and damage to buildings by the impact of natural hazards:

- High hazard (red): Area is prone to high degree of hazard. People are at risk, both inside and outside of buildings. Rapid destruction of buildings is possible.
- Medium hazard (orange): Area is prone to medium degree of hazard. People are at risk of injury outside of buildings. Considerable damage to buildings is likely.

- Low hazard (yellow): Area is prone to low degree of hazard. People are at low risk of injury, slight damage to buildings is possible.
- No hazard (no colour): Area is not prone to hazard. According to the current knowledge there is no threat due to natural hazards.

The colours red, orange and yellow are used on topographic maps to display the degree of hazard, which is present in a certain area. The corresponding RGB colour codes to be used are listed in section 0. For each natural hazard, an individual map must be elaborated.

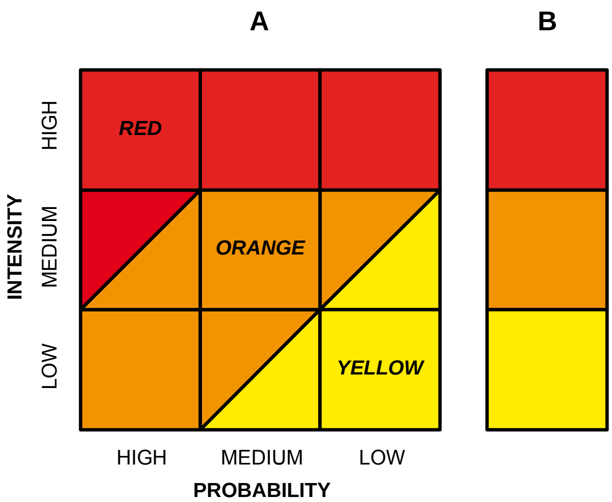

Figure 5: Representation of the degree of hazard: low, medium and high.

3.2.5.1 Frequency

Frequency (f) is measure of the temporal occurrence of natural hazards, and is the inverse of the return period T, such as f = 1/T. In the case of gravitation hazards, the frequency of occurrence is divided into 3 classes, according to the boundaries of return periods of 30, 100 and 300 years. The 100 year limit corresponds to a value applied in the design of flood protection.

Table 5: Probability of hazard occurrence.

Probability Category	Example for a 50 year return period [%]	Return period as an indication of the probability [years]
High	100 to 82	1 to 30
Medium	82 to 40	30 to 100
Low	40 to 15%	100 to 300

Whereas the concept of return periods is rather evident for some hazards, such as tropical cyclones, earthquakes and floods, it is rather difficult to evaluate for other hazards, such as many of the geological hazards, as landslides and land subsidence, or volcanism, which often are non-recurring processes. This situation can be overcome, when the triggering of events can be linked to recurring meteorological conditions.

For many natural hazards the return period has thus only limited meaning. The temporal character of a natural hazard is better established by the probability of occurrence for a given duration of land use. The probability of occurrence is linked to the return period as

$$P = 1 - \left(1 - \frac{1}{T}\right)^n$$

where P is the probability of occurrence, T is the return period (T=1/f) and n is the time period of observation, for example 50 years.

An Example: In a time period of 30 years, an event with a return period of 30 years has a probability of occurrence of 64% (or about two in three), of 26% (about one in four) for a 100 year return period, and of 10% (about one in ten) for a 300 year return period.

3.2.5.2 Intensity

The hazard intensity is a measure for the extent of damage that is caused by a natural hazard. The intensity is divided into three levels of low, medium and high. The individual levels have the following meaning:

- **High intensity:** People and animals are at risk of injury, buildings can be heavy damaged or destroyed.
- **Medium intensity:** People and animals are at risk of injury. Moderate damage to buildings can occur.
- **Low intensity:** People and animals are at low risk. Surface damage of buildings is can happen.

The assessment of **intensity** is determined according to the scales proposed in Table 6.

Table 6: Overview of hazard analysis criteria.

Hazard		Analysis criteria			
		Qualitative (Area prone to hazard)	Quantitative: Intensity		
			Low	Medium	High
Atmospheric	Tropical cyclone	-	SS 1	SS 2 to 3	SS 4 to 5
Geologic	Landslide	Area prone to hazard	v_f < 2 cm/year	2 cm/y < v_f < 10 cm/y	v_f > 10 cm/y, or strong differential movements
	Land subsidence	Area prone to hazard	-	h_s < 0.5 m and A_c < 100 m^2	h_s > 0.5 m and A_c > 100 m^2
	Rockfall	Area prone to hazard	E < 30 kJ	30 kJ < E < 300 kJ	E > 300 kJ
Hydrologic	Coastal erosion	Area prone to hazard	TBD	TBD	TBD
	Debris flow	Area prone to hazard	-	h_f < 1 m or v_f < 1 m/s	h_f > 1 m or v_f > 1 m/s
	Drought	Area prone to hazard	TBD	TBD	TBD
	Flood	Area prone to hazard	h_f < 0.5 m	0.5 m < h_f < 2 m	h_f > 2 m
	Storm surge	Area prone to hazard	h_f < ?	? < h_f < ?	h_f > ?
Tectonic	Earthquake	-	PGA < ?	? < PGA < ?	PGA > ?
	Tsunami	Area prone to hazard	h_f < ?	? < h_f < ?	h_f > ?
	Volcanic eruption	Area prone to hazard	Last eruption before 1800 a. C.	Last eruption after 1800 a. C.	Dangerous volcanoes according to IAVCEI

Symbols: PGA: peak ground acceleration, SS: Saphir-Simpson scale, E: kinetic energy (rotational and translational), h_f: flow depth, v_f: flow velocity, h_s: entity of subsidence, A_c: Area of collapse, TBD: to be defined.
*: Probability classes according to return periods:
- For gravitational hazards: High (1 to 30 years), Medium (30 to 100 years), Low (100 to 300 years).
- For earthquake: Return period of 475 years, corresponding to 10% probability of exceedance in 50 years.
- For tropical cyclone and flood: Return period of 100 years, corresponding to 10% probability of exceedance in 10 years.

3.3 Analysis of vulnerable elements

3.3.1 Summary

Natural hazards impact the natural and built environment where they occur. In this working step, the vulnerable elements which are at risk due to natural hazards are inventorized and their degree of vulnerability, in terms of susceptibility to damage, is to be assessed as a function of the expected intensity of a hazard (Figure 6).

3.3.2 Inventory of elements at risk

The process of inventorizing the elements at risk is determined by the objectives of the risk assessment and should include primarily the installations of tourism that may at risk due to the impacts of a natural hazard (such as hotels and directly connected facilities), the people working in tourism and then be extended to more external infrastructures and services that are necessary for the operation of tourism, such as traffic infrastructure, and the connected industries. To be included are also the tourist attractions of environmental, historical or cultural importance.

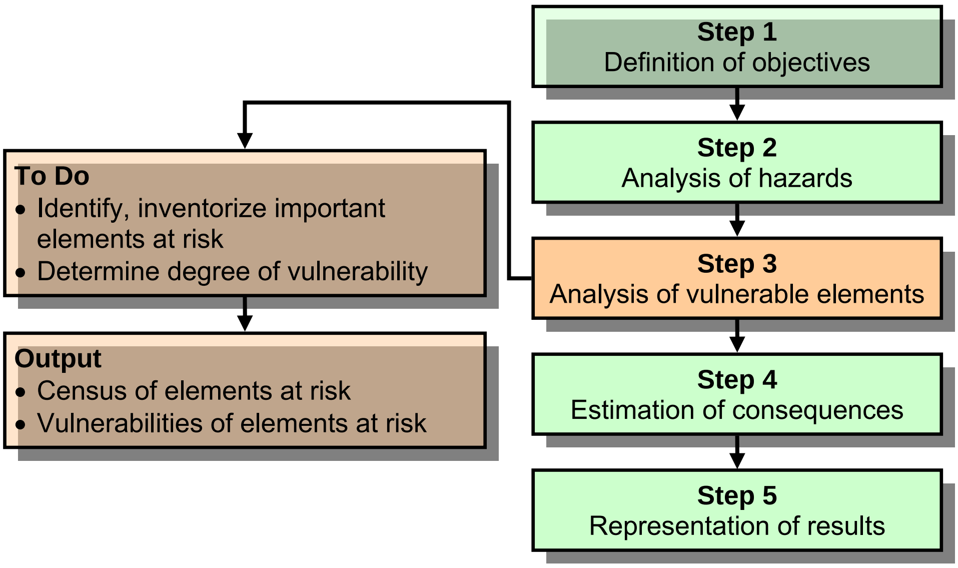

Figure 6: Inventory of elements at risk.

In order to analyze the direct and indirect consequences of natural hazards to tourism it is necessary to have an as complete as possible view on the data structure of tourism.

The necessary data is discussed below, see section 3.5 for guidelines on how these elements are to be represented on maps.

3.3.2.1 Tourism buildings and vital infrastructure

Tourism is at the center of risk assessment, so a complete census of the physical installations of tourism must be performed, focusing mainly on buildings that host tourists (hotels, guest houses, etc.) and the directly connected vital facilities for drinking water and energy supply.

Hotels and guest houses

Hotels and guest houses are identified by their precise geographic location, tourist capacity (grouped into three classes of low, medium and high capacity), number of storeys, and type of construction (wood, masonry, concrete).

Vital infrastructures

Vital infrastructures are to be identified by their type, such as water supply, sewerage, energy.

3.3.2.2 Transport infrastructure

The necessary infrastructure for tourism is identified and categorized as airports, seaports, highways, bridges, tunnels. The elements are to be grouped into classes of importance (local, regional, national).

3.3.2.3 Emergency infrastructure

The essential infrastructure for emergency management is to be identified and mapped. These include the locations of shelter infrastructure, ambulances, police, fire brigade, hospitals and civil defence.

3.3.2.4 Environmental aspects

Several aspects of the natural and historical or cultural environment are essential for tourism, such as beaches, reefs, historical sites, and cultural sites. These elements are to be represented on maps.

3.3.2.5 Demographic data

In order to determine the socio-economic effects of natural hazards events on the communities and local economies which are linked to tourism, it is necessary to have base statistics on the population, indicating data such as:

- Distribution of age, gender, race, and disabled
- Income distribution, poverty, number of owners and renters
- Workforce location data

3.3.2.6 Economic data

In order to determine and identify the economic connection between tourism and other economic sectors, it is necessary to have economic statistics of the study area, including data, such as:

- Employees in tourism and incomes produced
- Employees in connected economies and incomes produced (tourist services, transport, business, food, agriculture, etc.)

3.3.3 Estimation of degree of vulnerability

Vulnerability is connected to the intensity of an event. This characteristic of the interaction between hazard and vulnerable object is necessary for the identification of the expected damage and thus for the determination of risk.

3.3.3.1 Physical vulnerability

Physical vulnerability is the susceptibility to damage of the built environment (buildings and infrastructure), and are expressed in percent of the total damage of a building or infrastructure, and ranges from 0 to 100 %. The procedures to determine the physical vulnerability is described in the corresponding hazards in section Appendix A.

3.3.3.2 Socio-economic and environmental vulnerability

Socio-economic and environmental vulnerability is the susceptibility of societies, economies and the environment to the impact of natural hazards. The conduction of the analysis is based on the analysis of the societal and economic context of tourism and its susceptibility to the occurrence of natural hazards.

Due to the complexity of the systems to analyze and the need of detailed data of a certain quality, the determination of the socio-economic and environmental vulnerability is a complex and challenging task. The analysis can be performed according to NOAA-CVAT, NOAA-RVAT and ECLAC (2003).

3.4 Estimation of consequences

3.4.1 Summary

In the concluding step of risk assessment the consequences that arise from the presence of vulnerable elements in an area which is prone to natural hazards are estimated (Figure 7). This is done by superimposing the hazards on the vulnerable elements. The results are, according to the chosen approach, qualitative or quantitative estimates of risk.

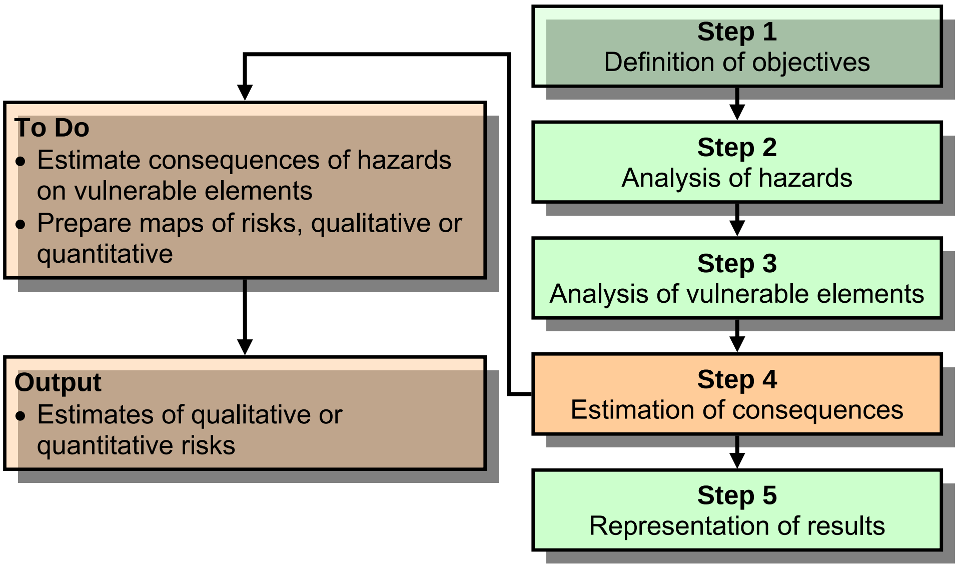

Figure 7: Estimation of consequences.

The consequences are direct damages to the building stock and infrastructures of tourism, essential transportation facilities and infrastructure, direct losses such as cost of repairs and replacement, income loss for the operators of tourism and the connected population, casualties, and indirect losses, such as supply shortages, sales decline, and other economic losses to industries which are connected to tourism.

3.4.2 Qualitative risks

Qualitative representation of risks show elements at risk. The qualitative character of representation is due to limitations in availability and quality of data to perform the previous steps of analysis of hazards and vulnerabilities.

3.4.3 Quantitative risks

The ultimate goal of risk assessment is the quantification of risks. There are basically two possibilities to represent quantitative risks.

3.4.3.1 Risks due to an event of known entity

Risks are estimated with respect to an event of known frequency and intensity, such as a hurricane of Saffir-Simpson scale 2 or a 100-year-flood. The intensities and corresponding vulnerabilities and resulting damages are summed up to represent the total risks due to such an event.

The resulting risks are expressed in US$ for monetary risks or fatalities for risks for lives.

For convenience, in map representations the quantified risks are grouped into 3 classes of low, medium and high risks, which are represented by the colours yellow, orange and red, as described in more detail in section 3.5.

3.4.3.2 Risks normalized to annual probability

The risks due to a certain hazard event are referred to the annual risk, by multiplying the total risk by the frequency of occurrence.

The resulting risks are US$ per year for monetary values and Fatalities per year for risks for lives.

This procedure can also be applied to situations where several hazards with individual intensities and frequencies are analyzed to obtain the total risk due to multiple hazards.

For convenience, in map representations the quantified risks are grouped into 3 classes of low, medium and high risks, which are represented by the colours yellow, orange and red, as described in more detail in section 3.5.

3.5 Representation of results

3.5.1 Summary

The procedures and outcomes of risk assessment are documented in a summary report and on maps (Figure 8), according to the specifications. The specifications give guidelines on the map products, and their layout, scale, colours and symbols.

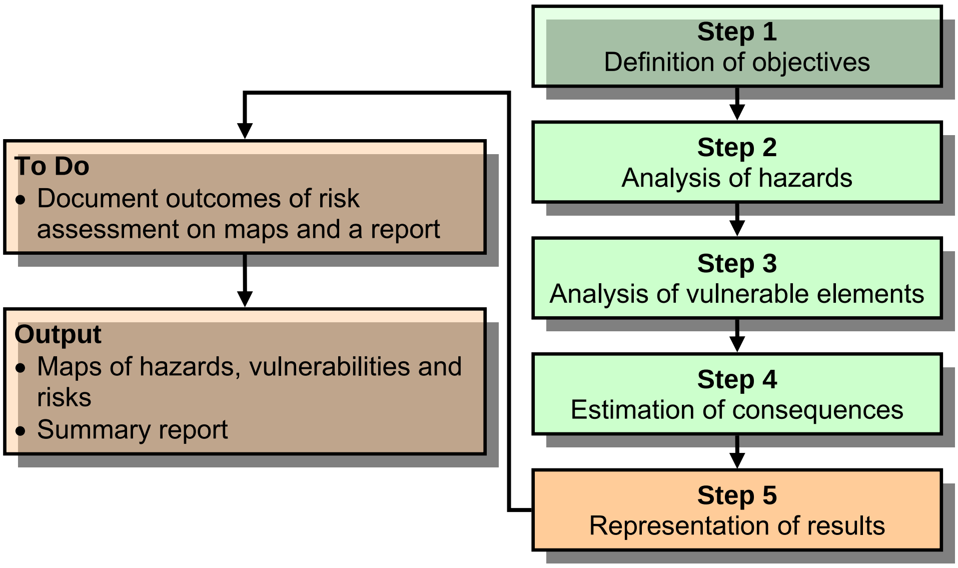

Figure 8: Representation of results.

3.5.2 Maps

The map representations of the outcome of risk assessments follow a common outline and specifications, as shown in shown below. The outcomes are displayed on hazard maps, maps of vulnerable elements and risk maps (Figure 8). See Appendix B for example outputs of risk assessment.

3.5.2.1 Hazard maps

Hazard maps show the threat which is present due to a natural hazard. Each hazard must be displayed individually. The map representation is restricted by the degree of detail which was employed to analyse a hazard (section 3.2).

- **Qualitative hazard maps**: The hazard map shows the presence of a hazard, without specifying its degree.
- **Quantitative hazard maps**: The hazard map shows the degree of hazard, using the proposed colour scale.

The type of hazard analysis (qualitative or quantitative) must be specified in the map explanation.

3.5.2.2 Maps of vulnerable elements

Maps of elements at risk show the elements that are at risk, if possible identifying their degree of vulnerability.

3.5.2.3 Risk maps

Risk maps show the resulting risks. According to the selected hazard analysis approach (qualitative or quantitative) the displayed risks are qualitative or quantitative, as:

- **Qualitative risk maps**: The risk map shows the presence of risks, in terms of the location of vulnerable objects within the area of occurrence of a hazard.
- **Quantitative risk maps**: The risk map shows quantified risks. The output shows the risks, using the proposed colour scale.

3.5.2.4 Map specifications

3.5.2.4.1 Layout

The maps follow a common layout, composed of three elements, as shown in Figure 9: The field “Map cover sheet” is of “letter” size and contains the map title and scale. The field “Map legend” lists the symbols and colours used on the map. The field “Explanations” contains additional and explanatory text and disclaimers necessary for the comprehension of the information displayed on the map. The field Map shows the map with a scale bar and a North arrow, as shown below.

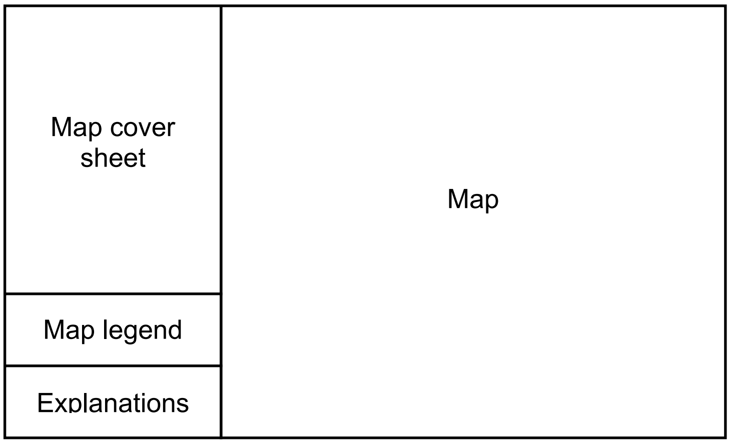

Figure 9: General layout of maps.

3.5.2.4.2 Scales

The following indicative map scales are to be used to represent the results of risk assessment:

- Site-specific assessment: 1:1’000
- Local assessment: 1:10’000
- Regional assessment: 1:100’000

Table 7: Colours to be used in maps.

Colour code	Degree of hazard, vulnerability, risk
Red (227/35/34)	High
Orange (242/148/0)	Medium
Yellow (255/236/0)	Low

3.5.2.4.3 Colours

For all aspects of risk assessment, hazard, vulnerability and risk, the same colour code is used (Table 7). The meaning of the colour coding is to be described in the map field “Descriptions” (see section 3.5.2.4).

3.5.2.4.4 Symbols

Table 8 shows the symbols to be used on the maps to display vulnerable objects and elements of emergency management.

3.5.3 Reports

The conduction of a risk assessment must be documented in a report, documenting and detailing the procedure that was followed. It should contain:

- Description of objectives, extent, scale of assessment.
- Data sources that were used to perform the risk assessment.
- Documentation of the single working steps of the assessment.
- Description of the results, including disclaimers and limitations.

The report accompanies the maps that are produced.

3.5.4 Electronic map and data formats

The standard defines the formats for facilitating the exchange of electronic data layers and electronic maps for printing and presentation purposes.

- In order to facilitate the exchange of data, any data layers produced in a GIS environment are to be saved in the quasi-standard for vector and raster data: ESRI shapefiles for vector data and ESRI grid files for raster data. Most GIS software contains converters to read and write ESRI shapefiles and grid files. A freely available stand-alone software for the conversion of geographic data formats is OPENEV.
- Finalized maps are to be saved from the GIS software in PDF (Portable Document Format) by Adobe, a document format for exchanging and printing high quality map documents. The reader application ADOBE READER is freely available at Adobe Systems Inc.

Table 8: Map symbols.

Symbol	Description	Symbol	Description
Buildings		*Transport Infrastructure*	
H-1	Hotel, high capacity	A-1	Airport, international
H-2	Hotel, medium capacity	A-2	Airport, regional
H-3	Hotel, low capacity	A-3	Airport, local
Utility infrastructure		S-1	Seaport, international
	Electricity	S-2	Seaport, national
		S-3	Seaport, local
			Highway, 1st class
			Highway, 2nd class
			Highway, 3rd class
Tourist attractions: environmental, cultural, historical			
B	Beach	R	Reef
H	Historical site	C	Cultural site
Emergency infrastructure			
P	Police	H	Hospital
F	Fire brigade	D	Civil defence
A	Ambulance	S	Shelter

4 Software tools for risk assessment

Risk assessment of natural hazard is based on the analysis of geographically referenced data. The operations of risk assessment are executed using two types of computer software:

- Geographic information systems (GIS) are used to compile the necessary input data and produce map output. Examples of common GIS software are ArcGIS, Idrisi and the freely available GRASS.

- Spreadsheet calculation programs are used to perform risk calculations. Examples of such software are the spreadsheet software contained in the office suite MICROSOFT OFFICE or the freely available office software package OPENOFFICE.ORG.

5 Bibliography

Adobe Reader: Internet resource: www.adobe.com.

ArcGIS: Geographic Information System software by Environmental Systems Research Institute (ESRI). www.esri.com.

BUWAL (1999): Risk analysis for gravitational natural hazards. Part I: Methodology. Part II: Case studies and data. In German, with English abstract. Swiss Federal Office of Environment, Forest and Landscape, Bern, Switzerland. Internet resource: www.bafu.admin.ch.

CADM: Caribbean Disaster Management Project, Internet resource: www.cdera.org/projects/cadm.

CDERA (2003a): Status of hazard maps, vulnerability assessments, and digital maps in the Caribbean. Caribbean Disaster Emergency Response Agency (CDERA). Internet resource: www.cdera.org.

CDERA (2003b): Status of hazard maps, vulnerability assessments, and digital maps. Country reports for Anguilla, Antigua, Bahamas, Barbados, Belize, British Virgin Islands, Dominica, Grenada, Guyana, Haiti, Jamaica, Martinique, Montserrat, Nevis, Puerto Rico, St. Lucia, St. Kitts, St. Vincent, Suriname, Turks and Caicos, and Trinidad and Tobago. Caribbean Disaster Emergency Response Agency (CDERA). Internet resource: www.cdera.org.

CDMP (1999): Caribbean Disaster Mitigation Project, 1999. Organisation of American States (OAS). Internet resource: www.oas.org.

CHAMP: Caribbean Hazard Mitigation Capacity Building Programme. Internet resource : www.cdera.org/projects/champ.

Conefall: A program to estimate the maximum run-out of rockfalls. Jaboyedoff M., Labiouse V. Internet resource: www.quaterra.org.

CRSP: Colorado Rockfall Simulation Program, Version 4. Jones C. L., Higgins J. D., Andrew R. D., Colorado Geological Survey. Denver Colorado, U. S. A.

ECLAC (2003): Handbook for Estimating the Socio-economic and Environmental Effects of Disasters. Economic Commission for Latin America and the Caribbean (ECLAC) and International Bank for Reconstruction and Development (World Bank). Internet resource: www.eclac.cl.

EM-DAT: Emergency Events Database. Centre for Research on the Epidemiology of Disasters (CRED). Université Catholique de Louvain. Internet resource: www.emdat.be.

Evans S.G., Hungr O. (1993): The assessment of rockfall hazard at the base of talus slopes, Canadian Geotechnical Journal, v. 30, pp. 620-636.

GRASS: Free open-source Geographic Information System software. Internet resource: grass.osgeo.org.

Iida K. (1970): The generation of tsunamis and the focal mechanism of earthquakes. In: Tsunamis in the Pacific Ocean. Editor: Adams W.M. East West Center Press. Honolulu, pp. 1-8.

Idrisi: Geographic Information System software by Clark Labs. www.clarklabs.org.

ISDR: Terminology: Basic terms of disaster risk reduction. International Strategy for Disaster Reduction. Internet resource: www.unisdr.org.

Johnson M.E. (1997): Caribbean Storm Surge Return Periods: Final Report. Organization of American States (OAS) and United States Agency for International Development (USAID). Internet resource: www.oas.org/CDMP/document/johnson/statpapr.htm.

Lander J.F., Whiteside L.S., Lockridge P.A. (2002): A brief history of tsunamis in the Caribbean Sea. International Journal of the Tsunami Society. Vol 20, No. 2. Internet resource: library.lanl.gov/tsunami.

Mason B.G., Pyle D.M.,·Oppenheimer C. (2004):The size and frequency of the largest explosive eruptions on Earth. Bull Volcanol, Vol. 66, pp. 735-748.

Microsoft Office: Office software suite by Microsoft Corp. www.microsoft.com.

NATHAN: NATural Hazards Assessment Network. Munich Re. Internet resource: mrnathan.munichre.com.

NOAA-CVAT: Community Vulnerability Assessment Tool (CVAT). NOAA Coastal Services Center. Internet resource: www.csc.noaa.gov.

NOAA-RVAT: Risk and Vulnerability Assessment Tool (RVAT). NOAA Coastal Services Center. Internet resource: www.csc.noaa.gov.

NWSI 10-604: Tropical cyclone definitions. National Weather Service Instruction 10-604. June 1, 2008. Internet resource: www.nws.noaa.gov/directives.

OpenEV: A free computer program for viewing and analysing raster and vector geospatial data in 2D and 3D. Internet resource: www.openev.sourceforge.net.

OpenOffice.org: Free open-source office software suite. Internet resource : www.openoffice.org.

Raetzo H., Lateltin O., Bollinger D., Tripet J.P. (2002): Hazard assessment in Switzerland – Codes of Practice for mass movements. Bulletin of Engineering Geology and the Environment. Vol. 61, No. 3, pp. 1435-9529.

TAOS/L: The TAOS/L Storm Hazard Model and CDMP TAOS/L Applications. Organization of American States (OAS) and United States Agency for International Development (USAID). Internet resource: www.oas.org/cdmp/hazmap/taos/taosdoc/taosfull.htm.

UN DHA/IDNDR (1992): Internationally agreed glossary of basic terms related to disaster management. United Nations Department of Humanitarian Affairs, International Decade for Natural Disaster Reduction, Geneva.

Appendix A – Natural hazards

In this appendix technical information on hazard identification, analysis and physical vulnerability are described.

The draft standards considers tropical cyclone, rockfall, flood, and earthquake.

A.1 Atmospheric hazards

Atmospheric hazards are due to tropical cyclones, which are low-pressure disturbances in the atmosphere that produce strong winds and heavy rainfall.

A.1.1 Tropical cyclone

Tropical cyclones are classified according to their increasing intensity as tropical disturbance, tropical depression, tropical storm and hurricane. For hurricanes, the Saffir-Simpson scale is used for classification according to the wind speed and height of storm surge. Their destructive potential is mainly due to elevated wind speeds and consecutive storm surges. The accompanying heavy rainfall can cause flooding.

A.1.1.1 Degree of hazard

The hazard originating from topical cyclones is principally wind. Tropical cyclones have several levels, according to the wind speed (Table A.1).

The evaluation of the degree of hazard is conducted according to a storm of expected Saffir-Simpson scale with a 10% exceedance probability of in 50 years, which corresponds to an event with a return period of 475 years.

In order to match the standard scheme of low, medium and high hazard, the expected Saphir-Simpson level is divided into three classes as low hazard (SS 1), medium hazard (SS 2 to 3), high hazard (SS 4 to 5).

Degree of hazard	Expected SS
Low	SS 1
Medium	SS 2 to 3
High	SS 4 to 5

A.1.1.2 Physical vulnerability

The physical vulnerability can be estimated according to the wind speed-damage curves presented in NATHAN.

Table A.1: Classification of tropical cyclones (NWSI 10-604).

Tropical cyclone	**Wind speed km/h (mph)**	**Storm surge Height m (ft)**	**Damages**
Tropical depression	0-62 (0-38)	0 (0)	Only minor.
Tropical storm	63-117 (39-73)	0-0.9 (0-3)	Only minor.
Saffir-Simpson 1 (SS 1)	119-153 (74-95)	1.2-1.5 (4-5)	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also some coastal flooding and minor pier damage.
Saffir-Simpson 2 (SS 2)	154-177 (96-110)	1.8-2.4 (6-8)	Some roofing material, door, and window damage of buildings. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected anchorages break moorings.
Saffir-Simpson 3 (SS 3)	178-209 (111-130)	2.7-3.7 (9-12)	Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.
Saffir-Simpson 4 (SS 4)	210-249 (131-155)	4.0-5.5 (13-18)	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.
Saffir-Simpson 5 (SS 5)	≥ 250 (≥ 156)	≥ 5.5 (≥ 18)	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required

A.2 Geologic hazards

Geological hazards include phenomena of ground-failure, such as landslides, land subsidence and rockfall.

A.2.1 Rockfall

Rockfalls are down slope movements of individual rock elements and are characterized by their speed (below 40 meters/second) and the size of their elements (rocks have diameter below 0.5 meter, blocks are larger). Rock avalanches have larger volumes of more than one million cubic meters and higher velocities.

A.2.1.1 Degree of hazard

At a qualitative scale the concept of shadow angle is applied to estimate the maximum run-out distance of rockfalls (Evans & Hungr 1993). This analysis can be carried out in a geographic information system (GIS) or by using special computer programs (Conefall).

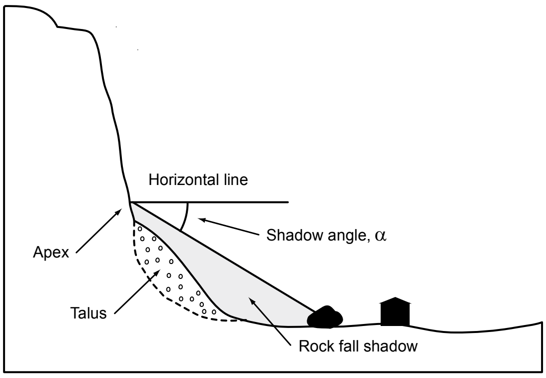

Figure A.1: Concept of shadow angle to estimate the maximum run-out of rock falls (Evans & Hungr 1993).

A quantitative analysis is conducted by determining the reach and impact energy of rock fall elements by trajectory modelling. Several two-dimensional and three-dimensional computer programs exist to perform such an analysis (CRSP). Required output is the position of rockfall elements and respective impact energy.

According to Raetzo et al. (2002) the intensity is identified by the impact energy due to translation and rotation a falling rock element develops, and is measured in kiloJoule (kJ). The intensity classes are low (smaller than 30 kJ), medium (30 to 300 kJ) and high (greater than 300 kJ).

A.2.1.2 Physical vulnerability

The destructive potential is due to the impact of rock elements with buildings, facilities, traffic infrastructures and people.

The vulnerability of building walls can be qualitatively described as follows: The 30 kJ limit corresponds to the maximum impact energy oak-wood stiff barriers (e.g. rail sleepers) can resist, the 300 kJ limit corresponds to the impact energy a properly built reinforced concrete wall can resist (Raetzo et al. 2002).

A.3 Hydrologic hazards

Hydrologic hazards are water related phenomena, such as costal erosion, debris flow, drought, flood, and storm surge.

A.3.1 Flood

Flood is an overflow of water (often including sediment) beyond the confines of a stream or other body of water over land that is normally dry. Triggering circumstances are periods of rainfall of extraordinary intensity and/or duration and are thus often accompanying tropical cyclones. The damage potential is due to the water flow depth.

A.3.1.1 Degree of hazard

A qualitative analysis includes the identification of flood plains, areas which are historically known to be prone to flooding. Historical analysis can be complemented by aerial photography analysis.

A quantitative analysis requires the knowledge of the flow depths of a 100-hundred-year flood. This can be done based on a statistical analysis of historical flood data or by modelling. Computer programs to model floods are Flo2D, HEC-RAS, Mike 11, and Telemac.

The intensity of flooding is given by the flow depth. The intensity classes are low (flow depth below 0.5 meters), medium (0.5 meter to 2.0 meters) and high (higher than 2 meters).

A.3.1.2 Physical vulnerability

To be completed.

A.4 Tectonic hazards

Tectonic hazards are due to the tectonic set-up of the area, thus to the interaction of the tectonic plates, namely the Caribbean and North- and South-American plates. Tectonic hazards are earthquake, tsunami and volcanic eruption.

A.4.1 Earthquake

An earthquake is the consequence of sudden releases of seismic energy in the upper crust, which are due to the interactions of tectonic plates. The magnitude of an earthquake is conventionally related to the Richter magnitude scale, with magnitude three or lower earthquakes being mostly imperceptible and magnitude seven causing serious damage over large areas. The effects of an earthquake, in terms of perception by people and damages to structures, are measured by the twelve-level, modified Mercalli scale. The damage potential is due to cyclic loading-unloading of structured, subsurface condition is an important co-factor (liquefaction of unconsolidated soils). The magnitude of earthquakes is conventionally by the Richter scale.

A.4.1.1 Degree of hazard

Earthquakes are classified according to their peak ground acceleration (PGA) or to their perception by people and their effects they have on buildings by the Modified Mercalli scale (MMI). Both scales are connected by empirical relationships such as RICHTER or WALD ET AL.

A.4.1.2 Physical vulnerability

The physical vulnerability to earthquakes can be generally estimated by the MM-Intensity-damge curves contained in NATHAN.

Appendix B – Examples of risk assessment

B.1 Qualitative assessment

A few examples will be inserted here for illustration.

B.2 Quantitative assessment

A few examples will be inserted here for illustration.

Appendix C – Documentation of hazard events

Natural hazard event report	
Hazard	
Type of hazard	*Identify type of natural hazard:* Atmospheric: ☐ Tropical cyclone, specifically tropical … ☐ Disturbance ☐ Depression ☐ Storm ☐ Hurricane/SS … Geologic: ☐ Landslide ☐ Rockfall ☐ Subsidence Hydrologic: ☐ Coastal erosion ☐ Debris flow ☐ Drought ☐ Flood ☐ Storm surge Seismic: ☐ Earthquake ☐ Tsunami ☐ Other: ……………………………………………………………………… *Description, comments:* …………………………………………………………………………………… ……………………………………………………………………………………
Area of occurrence	*Identify the area of occurrence:* ……………………………………………………………………………………
Date, time occurrence	*When did the natural hazard occur?* ……………………………………………………………………………………
Direct losses/damages	
Direct losses/damages	*Identify direct losses:* ☐ Fatalities ☐ Injured ☐ Destroyed/damaged buildings ☐ Destroyed/damaged infrastructure ☐ Damages to the environment *Description, comments:* ……………………………………………………………………………………
Indirect losses/damages	*Identify indirect losses:* ☐ Economic losses to connected economies *Description, comments:* …………………………………………………………………………………… ……………………………………………………………………………………

Appendix D – Glossary

Source : NWSI 10-604, UN DHA/IDNDR (1992), ISDR.

Term	Explanation
Acceptable risk	Degree of human and material loss that is perceived by the community or relevant authorities as tolerable in actions to minimize disaster risk (UN DHA/IDNDR 1992).
Consequences	The damages or losses (partial or full) to individual persons or a community, property, the environment and economic activities that can be quantified in some unit of measure.
Debris flow	A high-density mud flow with abundant coarse-grained materials such as rocks, tree trunks, etc (UN DHA/IDNDR 1992).
Drought	Period of deficiency of moisture in the soil such that there is inadequate water required for plants, animals and human beings (UN DHA/IDNDR 1992).
Drought index	Computed value which is related to some of the cumulative effects of a prolonged and abnormal moisture deficiency (UN DHA/IDNDR 1992).
Earthquake	A sudden break within the upper layers of the earth, sometimes breaking the surface, resulting in the vibration of the ground, which where strong enough will cause the collapse of buildings and destruction of life and property (UN DHA/IDNDR 1992).
Element at risk	The population, buildings and civil engineering works, economic activities, public services and infrastructure, etc. exposed to hazards (UN DHA/IDNDR 1992).
Exceedance probability	Probability that a given magnitude of an event will be equalled or exceeded (UN DHA/IDNDR 1992).
Flash flood	Flood of short duration with a relatively high peak discharge. Causes inundation, and because of its nature is difficult to forecast (UN DHA/IDNDR 1992).
Flood	Significant rise of water level in a stream, lake, reservoir or a coastal region (UN DHA/IDNDR 1992).
Floodplain	An area adjacent to a river, formed by the repeated overflow of the natural channel bed (UN DHA/IDNDR 1992).
Frequency	The inverse of → return period.
Infrastructure	Public services of a community that have a direct impact on quality of tourism, such as vital services (water supply, sewer treatment), transportation infrastructure (airports, seaports, highways, bridges, tunnels, railways, canals).
Intensity	A measure of the effects of a hazard.
Intensity (macroseismic)	A number by which the consequences of an earthquake at a particular place are scaled by its effects on persons, structures, and earth materials. Intensity scales in most common use are the

	modified Mercalli (MM) scale (UN DHA/IDNDR 1992).
Inventory	Census of the assets (population, property, and environment) considered at risk in an area.
Landslide	In general, all varieties of slope movement, under the influence of gravity. More strictly refers to down-slope movement of rock and/or earth masses along one or several slide surfaces (UN DHA/IDNDR 1992).
Liquefaction	Loss of resistance to shear stress of a water-saturated sandy soil (UN DHA/IDNDR 1992).
Magnitude	A measure of the strength of a hazard event.
Magnitude (“Richter scale”)	Devised by C.F. Richter in 1935, an index of the seismic energy released by an earthquake (as contrasted to intensity that describes its effects at a particular place), expressed in terms of the motion that would be measured by a specific type of seismograph located 100 km from the epicentre of an earthquake. Nowadays several “magnitude scales” are in use. They are based on amplitudes of different types of seismic waves, on signal duration or on the seismic moment (UN DHA/IDNDR 1992).
Microzonation (microzoning)	Subdivision of a region into areas where similar hazard-related effects can be expected. Seismic microzonation is the mapping of a local seismic hazard using a large scale (order of magnitude from 1:5’000 to 1:10’000). (UN DHA/IDNDR 1992).
Natural hazard	Natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Natural hazards can be classified by origin namely: geological, hydro-meteorological or biological. Hazardous events can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing (ISDR).
N-year event (see also return period)	Magnitude of an event, the mean return period of which is N years. (UN DHA/IDNDR 1992).
Return period	The average time between occurrences of a particular hazardous event (UN DHA/IDNDR 1992).
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (ISDR).
Risk	Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability (UN DHA/IDNDR 1992).
Risk assessment	A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (ISDR).
Risk management	The systematic process of using administrative decisions,

	organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (ISDR)
Risk, collective	Risk to which a community is exposed.
Risk, individual	Risk to which an individual is exposed.
Rockfall	Free-falling or precipitous movement of a newly detached segment of bedrock of any size from a cliff or other very steep slope (UN DHA/IDNDR 1992).
Saffir-Simpson hurricane scale	A scale ranging from one to five to describe the intensity of hurricanes, according to the sustained one-minute averaged wind speed at ten meter elevation.
Storm surge	A sudden rise of sea as a result of high winds and low atmospheric pressure; sometimes called a storm tide, storm wave, or tidal wave. Generally affects only coastal areas but may intrude some distance inland (UN DHA/IDNDR 1992).
Subsidence	Collapse of a considerable area of land surface, due to the removal of liquid or solid underlying or removal of soluble material by means of water (UN DHA/IDNDR 1992).
Tropical cyclone	Generic term for a non-frontal synoptic scale cyclone originating over tropical or sub-tropical waters with organized convection and definite cyclonic surface wind circulation (UN DHA/IDNDR 1992). Further divided with increasing intensity into tropical disturbance, tropical depression, tropical storm, and hurricane.
Tsunami	A series of large waves generated by sudden displacement of seawater (caused by earthquake, volcanic eruption or submarine landslide); capable of propagation over large distances and causing a destructive surge on reaching land. The Japanese term for this phenomenon, which is observed mainly in the Pacific, has been adopted for general usage (UN DHA/IDNDR 1992).
Volcanic eruption	The discharge (aerially explosive) of fragmentary ejecta, lava and gases from a volcanic vent (UN DHA/IDNDR 1992).
Vulnerability	(i) The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (ISDR). (ii) Degree of loss (from 0% to 100%) resulting from a potentially damaging phenomenon (UN DHA/IDNDR 1992).
Vulnerability assessment	Procedure to determine the degree of → vulnerability.