D2.1 Background Knowledge and Research Assessment

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EXECUTIVE SUMMARY

This deliverable summarizes the national risk assessment (NRA) for Cyprus. It includes general information on Cyprus and the context of the completed NRA study. The risk assessment methodology used in the study is described along with its application on four predefined hazards, namely: Earthquake and Tsunami, Floods, and Fires in forests and rural areas. The risk assessment was carried-out on each hazard and the data obtained for each hazard are used to develop an integrated risk matrix, illustrating the risk level exerted from these hazards. The methodology for the development of the risk matrix is based on impact analysis, which is used for the formation of singular risk matrices for the impact categories involved in the study.

Keyword List: Risk Assessment Methodology, Earthquake, Tsunami, Flood, Fire, Structural and Social Vulnerability

INTRODUCTION

The Final Report on the National Risk Assessment (NRA) of Cyprus includes general information on Cyprus and the context of the completed NRA study. The risk assessment methodology used in the study is described along with its application on seven predefined hazards, namely: Earthquake and Tsunami, Floods, Water scarcity, Large-scale technological accidents, Fires in forests and rural areas, Sea level rise and Coastal Erosion and Marine Pollution. The risk assessment was carried-out on each hazard and the data obtained for each hazard are used to develop an integrated risk matrix, illustrating the risk level exerted from these hazards. The methodology for the development of the risk matrix is based on impact analysis, which is used for the formation of singular risk matrices for the impact categories involved in the study. It should be noted that the selection of the hazard scenarios for the formulation of the risk matrix was conducted by the corresponding experts to represent moderate likelihood. Further scenarios can be implemented using the adopted methodology to provide results for rarer events. Furthermore, two independent studies prepared for the Ministry of Agriculture, Rural Development and Environment of Cyprus that referred to the effect of climate change on health and land desertification.

In the SENDAI framework of the United Nations, with a timeframe of 2015-2030, is the successor instrument to the ***Hyogo Framework for Action (HFA) 2005-2015***: *Building the Resilience of Nations and Communities to Disasters*. The European Union has developed a strategy for achieving the objectives of the Framework. In particular, with the decision of the Council of the European Union and the European Parliament, 1313 / 2013EU on a *Union Civil Protection Mechanism* (**UCPM**), Member States were required to submit a summary of national risk assessments to the Commission. Based on Article 6 of the UCPM decision, Participating States submitted summaries of NRAs by 22 December 2015, and will do so every three years thereafter. Cyprus fulfilled its institutional obligation before December 22, 2015, as provided for in the decision, with a preliminary report. In December 2016, Cyprus completed its national risk assessment and informed the Commission of this by sending its final report. The next date for the submission of the 3rd national risk assessments is 22 December 2018.

The preparation of the 3rd national risk assessment for the Republic of Cyprus, which contains the probability of occurrence, potential consequences, Cyprus's exposure analysis and vulnerability analysis for the following predefined hazards:

• Earthquake and tsunami.

• Floods.

• Water scarcity.

• Large-scale technological accidents.

• Fires in forests and rural areas.

• Sea level rise and coastal erosion.

• Marine pollution.

• Hazards synergy.

Furthermore, as part of the UCPM legislation mentioned above, Member States provided the European Commission with summaries of the main elements of their National Risk Assessments (NRAs). According to the produced report[1], "*contributions received were of varying levels of details, and reflected varying levels of progress and completeness in the production of NRAs. Certain summaries demonstrated a high level of advancement in undertaking a national assessment of disaster risks and using this exercise to contribute directly to emergency planning. In a relatively high number of cases, however,* ***information on the range of disaster risks and their assessment at a national level remains limited or is not yet finalised***".

Cyprus is one of these cases that provided limited information especially on the main risk analysis factors, i.e. the impact/consequences and the probability/likelihood of occurrence.

[1] COMMISSION STAFF WORKING DOCUMENT: Overview of Natural and Man-made Disaster Risks the European Union may face

1 GENERAL INFORMATION ABOUT CYPRUS: SOCIO-ECONOMICAL SCENARIO POPULATION PROJECTION

General description (PIO, 2018)

Location: Cyprus is the third largest island in the Mediterranean, after Sicily and Sardinia, with an area of 9,251 sq. km (3,572 sq. miles), extending 240 km (149 miles) from east to west and 100 km (62 miles) from north to south. It is strategically situated at the north-eastern corner of the Mediterranean, at the crossroads of Europe, Africa and Asia: at a distance of 300 km north of Egypt, 105 km west of Syria, and 75 km south of Turkey; Greece lies 380 km to the north-west (Rhodes – Karpathos).

Topography: Cyprus has two mountain ranges: the Pentadaktylos range, which runs along almost the entire northern coast, and the Troodos massif in the central and south-western parts of the island which culminates in the peak of Mount Olympus, 1.953 m above sea level. Cyprus' coastal line is indented and rocky in the north with long sandy beaches in the south. Between the two ranges lies the fertile plain of Messaoria. Forests cover approximately 19% of the total area of the island. Furthermore, in Cyprus there are two salt lakes. Cyprus's topography is depicted in Figure 1.

Figure 1 – Cyprus topography (DLS, 2018)

Climate: Cyprus has a Mediterranean climate: hot dry summers from June to September and mild, wet winters from November to March, which are separated by short Autumn and Spring seasons of rapid change in weather patterns in October, April and May. Sunshine is abundant during the whole year, particularly from April to September when the daily average exceeds eleven hours.

Population: according to official statistics, the population of Cyprus is 947.000 (December 2016) with the following distribution: - 74,6% (706.800) Greek Cypriots - 9,8% (92.200) Turkish Cypriots [estimate] - 15,6% (148.000) foreign residents and workers.

Greek and Turkish are the official **languages**. English is widely spoken.

Religion: Greek Cypriots are predominantly Christian and adhere to the Autocephalous Greek Orthodox Church of Cyprus. Turkish Cypriots are predominantly Sunni Muslims, while Maronites belong to the Maronite Catholic Church, Armenians predominantly to the Armenian Apostolic Orthodox Church and Latins to the Latin Catholic Church.

Political Status: Cyprus gained its independence from British colonial rule in 1960. In 1974 Turkey invaded Cyprus and occupied 36,2% of its sovereign territory. A ceasefire line still runs across the island and cuts through the heart of the capital, Lefkosia (Nicosia), dividing the city and the country. Although its northern part is under foreign occupation, the Republic of Cyprus is internationally recognised as the sole legitimate state on the island with sovereignty over its entire territory, including the areas occupied by Turkey (PIO, 2018).

Government: Cyprus is an independent sovereign Republic with a presidential system of government. The constitution provides for separate executive, legislative and judicial branches of government with independent powers. The President is both Head of State and Government. The executive power is exercised by the President through an appointed Council of Ministers. The Council of Ministers exercises executive power in all matters. Each Minister is the head of his or her Ministry and exercises executive power on all matters within that Ministry's domain. Legislative authority is exercised by a unicameral House of Representatives. The House consists of 56 members, which are elected for a five-year term.

Cyprus and EU: On 1 May 2004 the Republic of Cyprus became a full member of the EU. Accession to the EU was a natural choice for Cyprus, dictated by its culture, civilisation, history, its European outlook and adherence to the ideals of democracy, freedom and justice.

Socio-economical scenario

One of the main targets in the EU is to reduce poverty by lifting at least 20 million people out of the risk of poverty or social exclusion by 2020. this situation means that people at risk of poverty or social exclusion were in at least one of the following situations (eurostat, 2018):

1. at risk of poverty after social transfers (income poverty).
2. severely materially deprived.
3. living in households with very low work intensity.

Furthermore, according to eurostat (2018) in 2016 the following facts characterise this issue:

- 118.0 million people in the EU lived in households at risk of poverty or social exclusion; 23.5 % of the population.
- 17.3 % of the population in the EU were at risk of poverty.
- 10.5 % of the population aged 0-59 years in the EU lived in households with very low work intensity.
- 7.5 % of the population in the EU were severely materially deprived.

The statistical comparison on this issue between the EU and Cyprus is shown in Table 1. the table provides information on different age groups. For 2017, the situation is relatively the same among the age groups in Cyprus but is higher than the overall EU risk. Among these age groups, the elderly in Cyprus have comparatively higher risk of poverty or social exclusion than their EU counterpart.

Table 1. People at risk poverty or social exclusion, by age group (% of specified population)

Year	Total		Aged 0-17 years		Aged 18-64 years		65 years and over	
	EU	Cyprus	**EU**	Cyprus	**EU**	Cyprus	**EU**	Cyprus
2006	25,3	25,4	27,5	21,3	24,8	21,4	24,7	55,6
2009	23,3	23,5	26,5	20,2	22,8	19,9	21,7	48,6
2012	24,7	27,1	28	27,5	25,3	25,8	19,3	33,4
2013	24,6	27,8	27,9	27,7	25,5	28,2	18,2	26,1

2014	24,4	27,4	27,8	24,7	25,4	28,3	17,8	27,2
2015	23,8	28,9	27,1	28,9	24,7	30,5	17,4	20,8
2016	23,5	27,7	26,4	29,6	24,2	28,1	18,2	22,9
2017	22,5	25,2	24,5	25,5	23,2	25,3	18,1	24,6

Population projection

The projection of Cyprus population showing the changes between 2015 to 2080 is shown in Figure 2 using data obtained from eurostat (2018). The graph contains information on the following scenarios:

- Higher, lower , and no migration.
- Lower fertility.
- Lower mortality.

The biggest variation is caused by the higher migration scenario, followed by the lower mortality and the greatest decline is caused considering no migration.

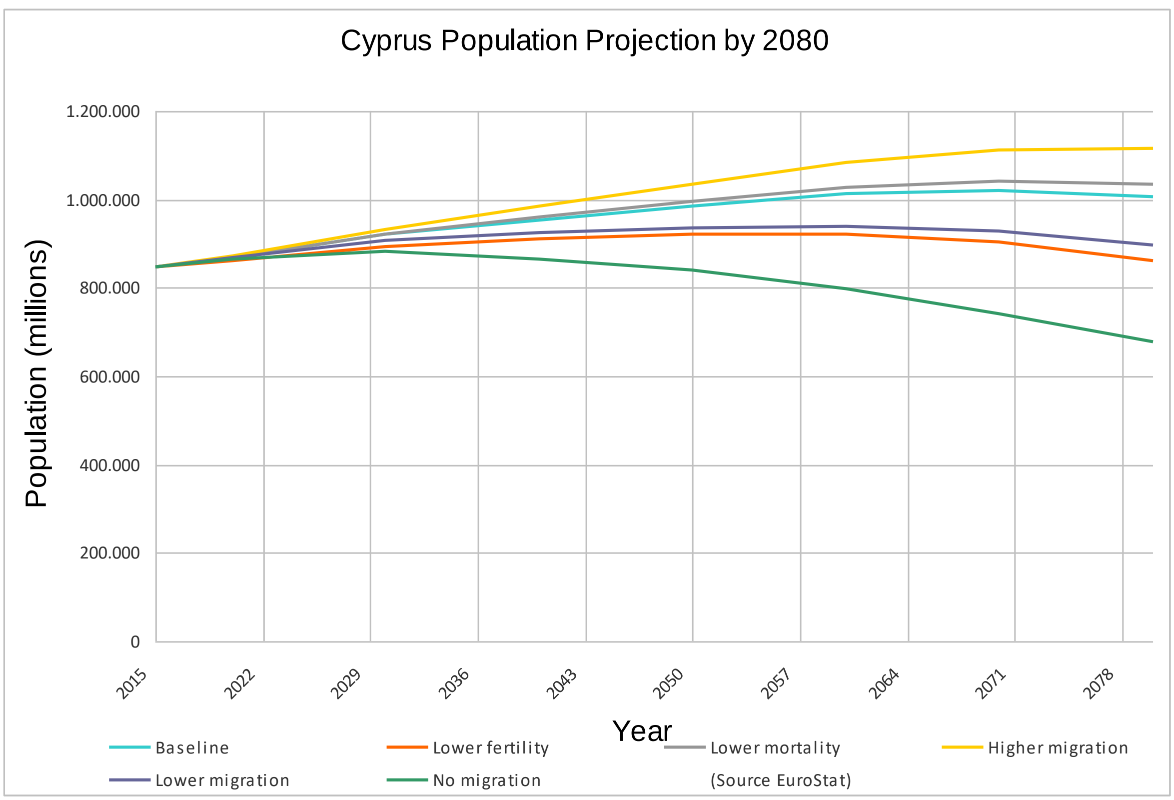


Figure 2 – Cyprus population projection by 2080 (eurostat, 2018)

The following tables list information according to demographic reports and data released by the statistical service of the Republic of Cyprus. In listed period, 2000-2017, the proportion of population under 15 decreased and the over 65 has increased. Also the life expectancy has increased and the birth rate has decreased.

Table 2. General demographic indicators of Cyprus

Population (thousands)	2000	2010	2014	2015	2016	2017
Total	697,5	839,8	847,0	848,3	854,8	864,2
Males	342,7	408,8	411,8	412,7	416,7	421,5
Females	354,8	431,0	435,2	435,6	438,1	442,7
Population distribution by age (%)	2000	2010	2014	2015	2016	2017
0-14 years	22,3	16,8	16,4	16,4	16,3	16,2
15-64 years	66,4	70,5	68,9	68,5	68,1	67,9
65+	11,3	12,7	14,6	15,1	15,6	15,9
Life expectancy at birth (years)	2000	2010	2014	2015	2016	2017
Men	----	79	80,2	79,8	80,3	80,0
Women	----	83,7	84,2	83,5	84,7	84,1
Population change	2000	2010	2014	2015	2016	2017
Annual growth rate at mid-year (%)	1,0	2,6	-1,0	-1,2	0,8	1,2
Natural increase rate (per 1000 residents)	4,5	5,6	4,5	4,0	4,7	3,7
Net migration (number)	+3.960	+15.913	-14.826	-2.000	+2.499	+6.201
Fertility	2000	2010	2014	2015	2016	2017
Live births (number)	8.447	9.801	9.258	9.170	9.455	9.229
Crude birth rate (per 1000 residents)	12,2	11,8	10,9	10,9	11,1	10,7
Total fertility rate	1,64	1,44	1,31	1,32	1,37	1,32
Mortality	2000	2010	2014	2015	2016	2017
Deaths (number)	5.355	5.103	5.424	5.859	5.471	5.996
Crude death rate (per 1000 residents)	7,7	6,2	6,4	6,9	6,4	7,0
Infant mortality rate (per 1000 live births)	5,6	3,2	2,1	2,7	2,6	1,3

Table 3 lists the population distribution in districts (urban and rural areas). The data show that the majority of the population lives in urban areas with a higher tendency that rural areas.

Table 3. Population per district (in thousands)

District-Total	2000	2010	2014	2015	2016	2017
Total	697,5	839,8	847,0	848,3	854,8	864,2
Nicosia	277,9	328,0	329,5	330,0	332,2	335,9
Famagusta	37,8	46,3	46,8	46,9	47,0	47,5
Larnaca	116,2	142,3	144,0	144,2	144,9	146,5
Limassol	199,5	235,5	236,6	237,0	239,4	242,0
Paphos	66,1	87,7	90,1	90,2	91,3	92,3
District-Urban areas	2000	2010	2014	2015	2016	2017
Total	480,1	567,2	569,3	570,2	576,9	577.574
Nicosia	204,1	240,2	241,0	241,4	244,2	244.500
Famagusta	----	----	----	----	----	----
Larnaca	71,1	84,3	84,8	84,9	85,7	85.874
Limassol	159,2	181,1	180,0	180,3	182,6	183.658
Paphos	45,7	61,6	63,5	63,6	64,4	63.542
District-Rural areas	2000	2010	2014	2015	2016	2017
Total	217,4	272,6	277,7	278,1	277,9	279.386
Nicosia	73,8	87,8	88,5	88,6	88,0	89.620
Famagusta	37,8	46,3	46,8	46,9	47,0	47.338
Larnaca	45,1	58,0	59,2	59,3	59,2	59.491
Limassol	40,3	54,4	56,6	56,7	56,8	56.184
Paphos	20,4	26,1	26,6	26,6	26,9	26.753

References

P.I.O. (2018), Press and Information Office, Republic of Cyprus, N.83/2018

DLS (2018), Department of land and Surveys Portal

Eurostat (2018), Statistics explained, https://ec.europa.eu/eurostat/statistics-explained/index.php/Main_Page

2 RISK ASSESSMENT METHODOLOGY

The methodology to implement the objectives on the Cyprus NRA is based on the:

- Sendai Framework and NDRA Guidelines
- EU risk assessment guidelines[2] and,
- Requirements of the International Standards ISO 31000[3] and ISO 31010[4].

In addition, some elements/guidelines, e.g. for the formation of scenarios, the development of the risk matrix, presentation and visualisation of data, have been adapted from NRA of other EU countries, namely:

- UK-*National Risk Register of civil emergencies* (public version of the classified NRA).
- Netherlands- *National Risk Assessment No.6* and *Working with scenarios, risk assessment and capabilities.*

Germany- *Method of Risk Analysis for Civil Protection.*

General process for risk assessment

As depicted in figure 3, **risk assessment** is the overall process of risk identification, risk analysis and risk evaluation.

[2] COMMISSION STAFF WORKING PAPER: Risk Assessment and Mapping Guidelines for Disaster Management

[3] IEC/ISO 31000:2009, Risk management – Guidelines

[4] IEC/ISO 31010:2009: Risk management — Risk assessment techniques

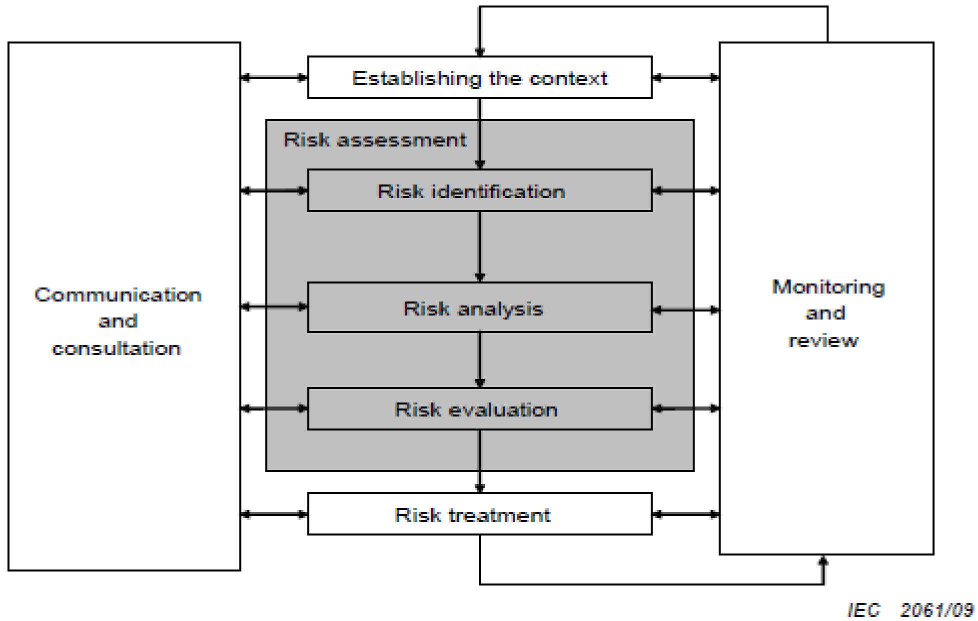


Figure 3 – Contribution of risk assessment to the risk manasgement process (ISO31010)

The **risk identification** process includes identifying the causes and source of the risk i.e. hazard, events, situations or circumstances, which could have a major influence upon objectives and the nature of that impact. For this project, whereas the hazards have already been identified by the contracting authority (CA), the pending task regards the development of hazard scenarios. This will be followed by the risk analysis and evaluation.

Risk analysis consists of determining the consequences and their probabilities for identified risk events, taking into account the presence (or not) and the effectiveness of any existing controls. The consequences and their probabilities are then combined to determine a level of risk. All three items, namely consequences, probabilities and existing control measures will be considered in this study. Furthermore, consequences analysis will be considered in terms of human, economic & environmental and political/social impacts, which each impact will be analysed in terms of vulnerability and exposure. The risk will be estimated considering the probability of hazard's occurrence, vulnerability and exposure.

For the proposed study, both single-risk analysis and multi-risk assessments will be performed as per EU guidelines[1] on the subject. To determine the singular risk from a pre-defined hazard in isolation (independent) from the other hazards a single-risk assessment is necessary and it will be followed. On the other hand, multi-risk assessment determines the total risk considering the interaction and interdependency between several hazards in terms of possibility and vulnerability, e.g. follow-on hazardous events such as earthquake and tsunami. Therefore this approach will be used to determine the risk due to the hazards synergy through identified multi-risk scenarios considering the interdependent hazards and also for the development of the risk matrix and mapping for all the hazards analysed.

Risk evaluation involves comparing estimated levels of risk with risk criteria defined when the context was established, in order to determine the significance of the level and type of risk. Risk evaluation uses the understanding of risk obtained during risk analysis to make decisions about future actions on issues like whether a risk needs treatment, priorities for treatment, whether an activity should be undertaken and which of a number of paths should be followed. In the context of this study, risk based criteria will be established to enable for risk evaluation. These base criteria will be defined regarding their magnitude of acceptability and tolerance, which will be the benchmark of assessing and calibrating the severity of each type of risk.

Methodology for NRA-CY

The designed methodology to implement the NRA-CY has adapted the sequence described above, i.e. risk identification→risk analysis → risk evaluation. To satisfy the objectives set in this project, there is a need to summarise and compare the risks estimated from the predefined hazards. Therefore, by examining the provisions and techniques/tools described in ISO 31010, the ***technique of scenario analysis*** is chosen for the risk assessment and it will be applied to identify the hazard scenarios and execute the impact analysis using **risk indices** and a **scoring approach**. Additionally, for the risk analysis of specific applications (e.g. WP6-Large scale technological accidents) other techniques such as the ***fault tree analysis*** and ***event tree analysis*** will be also employed. Such approach is supported by ISO31010, which states that "*more than one technique may be required for complex applications*".

The comparison of the hazard's risk level will be carried out using the ***risk matrix (consequence/probability matrix) method***, which will utilise the results of the impact analysis. The designed methodology, ***risk matrix based on the impact analysis in the scenario based***

approach, described herein is depicted in figure 4: the produced hazard scenarios will be assessed through an impact analysis, which will provide data to be used in the risk matrix.

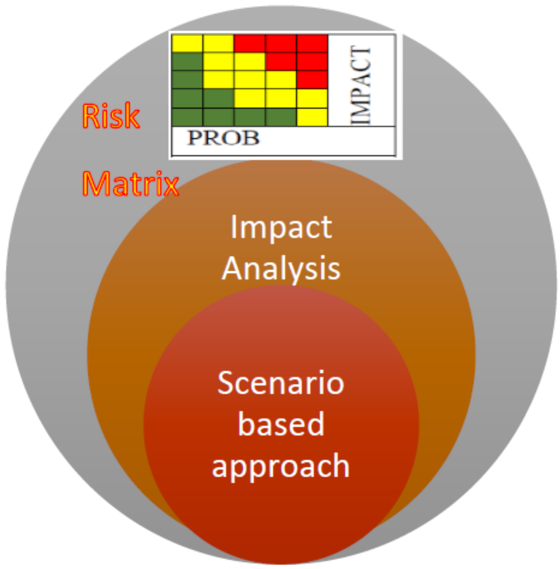


Figure 4 – The NRA implementation methodology

Implementation steps

The NRA implementation methodology will be executed in four distinctive, interconnected, sequential steps, herein tasks 1-4. The chapters 3 to 11 that describe the risk assessment of the predefined hazards will have similar format and will consist of the following four distinctive steps/tasks:

Task 1: Hazard scenario identification

To develop each scenario, inputs are obtained from historic data and reports from governmental departments, scientific reports published for case studies in Cyprus, research reports prepared by local (public and private) universities. Further to data based in past experience, scenarios have been developed considering events and impacts which have so far not occurred but are plausible in the future. Assumptions have been used where necessary for relationships that there is lack of data. For every developed scenario the information leading to its definition are described in the relevant chapter.

The issue in this step was, which scenarios to choose or develop, as many situations in most cases can be transformed to scenarios. Therefore, general criteria used for the scenario building for each hazard include:

- Level of impact.
- Hazard scenario probability.
- Level of consequences.
- Other guidelines specified in EU guidelines for specific hazards.

The time period covering the development of scenarios will be adjusted and justified will be determined according to the hazard type. No time horizon has been set that is being applied for all hazards.

For every hazard, three (3) scenarios are identified and selected (from the range of possible scenarios) having different limits /types for the comparison to be meaningful (some scenario can co-exist, i.e. the expected scenario can represent either worst or better scenario, or even both):

- ❖ Worst scenario-Plausible with upper risk limit/level.
- ❖ Expected scenario-the scenario to be considered (to be prepared for). This scenario for every hazard is presented in the risk matrices of chapter 12.
- ❖ Best case/mild scenario-Plausible with lower risk limit

Task 2: Exposure and vulnerability of socioeconomical parameters

In risk analysis the **impact on human, economics & environment and political/society**, is analysed in terms of <u>vulnerability and exposure</u>. Therefore in this stage using a semi-quantitative approach when possible, for every hazard the exposure and vulnerability in these three categories is determined using numerical indicators (rating scales).

Task 3: Probabilistic scenarios analysis/ consequences and impact assessment

At this step, the probability of occurrence of each hazard scenario will be determined along with the associated consequences. Therefore, (taking into account all three categories of impacts) the risk is estimated as a function of the probability of hazard's occurrence (p), vulnerability (V) and exposure (E) as shown below,

Risk=R=*f* (p*E*V)

Task 4: Quantification of existing treatment measures and suggestions for adaptation and mitigation measures

In this final step, existing treatment measures are examined in order to determine whether the risk and/ or its magnitude is acceptable or tolerable and whether a risk will be accepted or treated as part of the national level risk assessment. Accordingly, suggestion for mitigation measures are specified where necessary.

Chapters design

Considering the aforementioned approach, a chapter (Ch3-11) is dedicated for each hazard.

Chapter 3-Earthquake and Tsunami: This chapter will examine seismic scenarios based on both historic data and possible future events including those triggering the formation of tsunami.

Chapter 5-Floods: This chapter will examine the flood hazards in Cyprus including flash floods and urban floods and will identify the most vulnerable flood areas from developed flood model scenarios.

Chapter 11-Fires in forests and rural areas: The work in this chapter includes forest and rural vegetation classification, which will allow the identification and mapping of fire hazard potential across the country and thus will lead to the preparation of hazard scenarios.

3 EARTHQUAKE AND TSUNAMI

Cyprus is located at the boundary between the Eurasian, Arabian and African plates within a complex tectonic setting. Studies (e.g. Papazachos and Papaioiannou, 1999) have demonstrated that the Anatolian subplate, to which Cyprus belongs, is forced to move westward by the collision of the African plate, which moves north north-eastward relative to the Eurasian one, and the Arabian plate, which moves northwards in a faster rate. The North Anatolian Fault and the East Anatolian fault (Figure 5), the two major strike-slip faults, enable this western movement of the Anatolian Subplate.

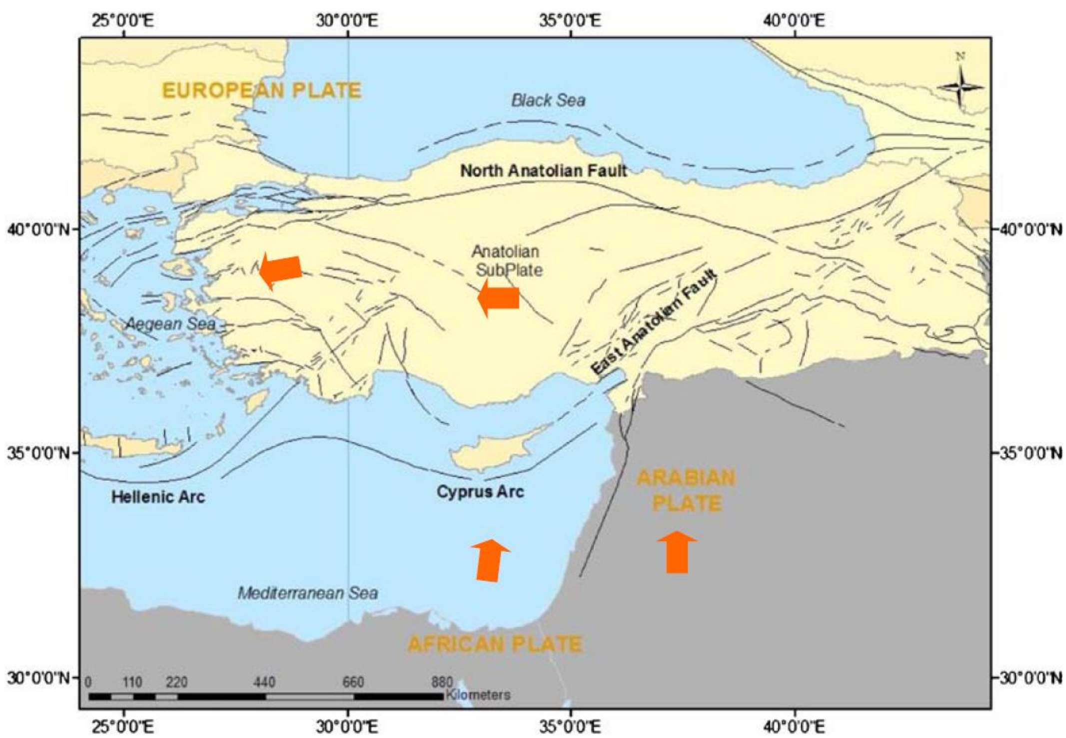


Figure 5 – Principal tectonic elements to the Northeastern Mediterranean Region where Cyprus belongs (Barka et al., 1997)

The Cyprus Arc, being the boundary accommodating the movement between the African and Anatolian subplate, is relatively less active than the neighboring Hellenic Arc, Dead Sea and East

Anatolian faults, being though the origin of several shallow earthquakes. According to historical records (Ambraseys, 1965; Galanopoulos and Delibasis, 1965; Kalogeras et al., 1999), Cyprus has suffered from at least 16 destructive earthquakes the past 2000 years and numerous smaller earthquakes (Figure 6). It is worth-noticed that modern instrumentation began in the island only after 1997 and thus, the seismic catalogue until then is composed by empirical relationships and various international sources. The largest earthquakes mostly occurred at the southern part of the island, causing damage in Paphos, Limassol, and Famagusta (e.g. the earthquakes of 342 with estimated magnitude of Mw=7.4, 1222 with Mw=6.8, 1577 with Mw=6.7, 1785 with Mw=7.1, 1940 with Mw=6.7 (Cagnan and Tanircan, 2010).

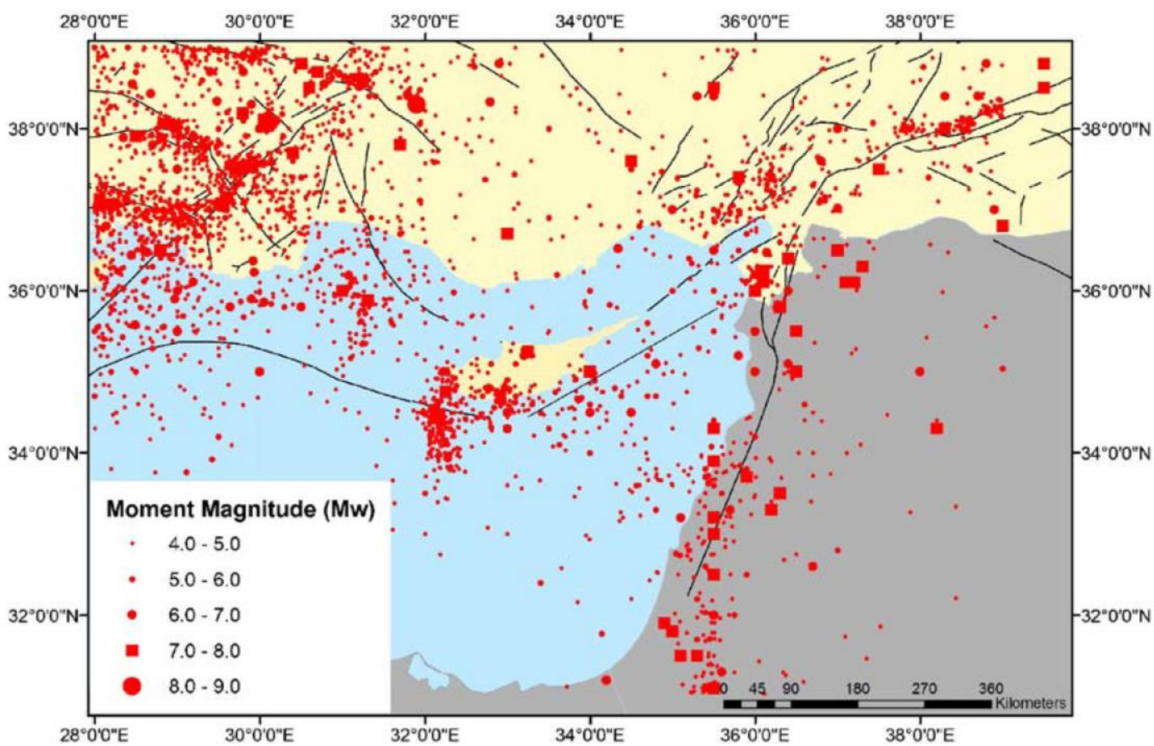


Figure 6 – Distribution of shallow earthquake epicenters in the northeastern mediterranean region from 2150 B.C. to 2006 A.D. The soild lines are mapped and inferred faults. Map and Data from Cagnan and Tanircan (2009), Geological Survey department of Cyprus (1995), Barka et al. (1997) and USGS (1999)

Hence, the first large event in the region for which seismic data from digital network was available, was in 1996, of Mw=6.8 and shallow depth. Its epicentre was in the offshore to the southwest but a violent shock was felt almost throughout the island. Although building damage was limited, 20 people were slightly injured and 2 were the reported fatalities from indirect causes. Similarly, in 1999 an earthquake of Mw=5.6 with epicentre close to Limassol tremored the island with as many as 40 injuries mainly due to panic (Cyprus-mail, 2015). In 2015, a Mw=5.8 earthquake violently shocked the districts of Paphos up to Limassol mainly with contents damage. Finally, the latest deadliest earthquake that hit the island was in 1953 (Mw=6.1) and caused 40 fatalities, 100 injuries and extensive damage to 158 villages and the city of Paphos (Ambraseys, 1992).

All of the abovementioned make evident the need for thorough and continuously up-to-date study of the seismic hazard and risk of the island of Cyprus. Currently, the seismic zonation map of Figure 7 is used as part of the National Annex of Eurocode 8 (EN 1998-1:2004) after revision of the first zonation map as composed by the Geological Survey Department for the national seismic code (Cyprus Civil Engineers and Architects Association, 1992) based on historical macroseismic data. Several other studies have been performed following probabilistic more refined approaches (Erdik et al., 1997; GSHAP Program, Giardini et al., 1999; SESAME Project, Jimenez et al, 2001; EMME Project, Erdik et al, 2012; SHARE Project, Giardini et al, 2013).

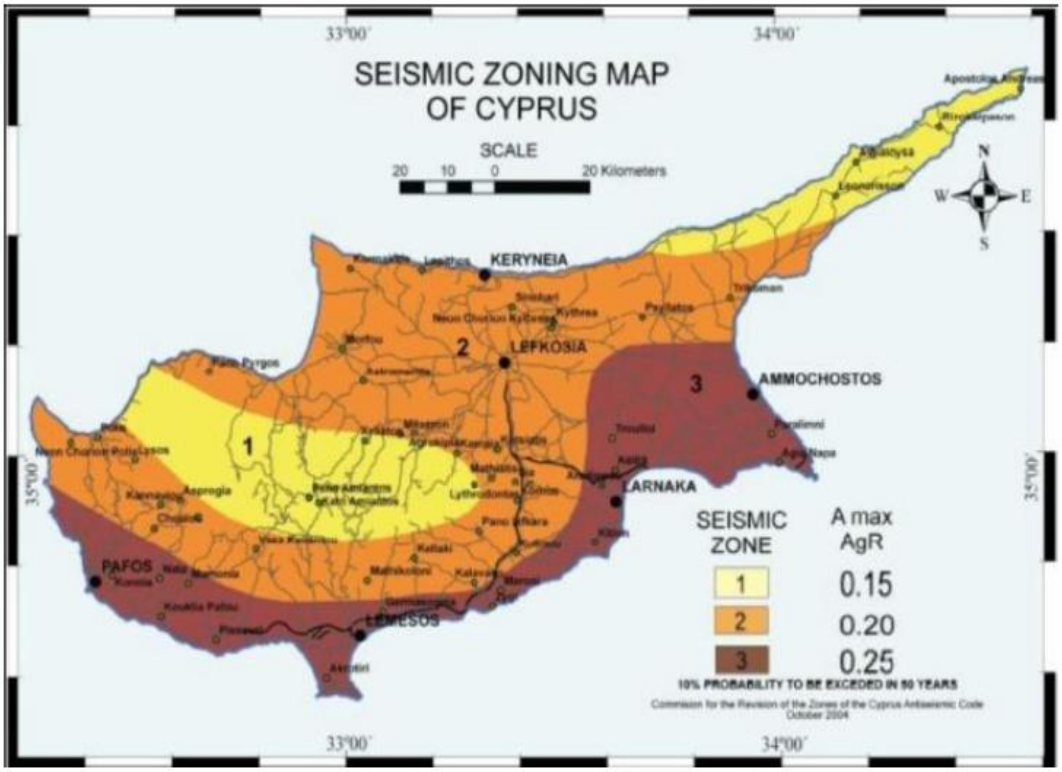


Figure 7 – Seismic zonation map of Cyprus (EN 1998-1:2004)

Limited work has been done, however, to the risk assessment at urban or national level for Cyprus (Gountromichou et al., 2017a within PACES Project; Chrysostomou et al., 2014 within EMME Project, Erdik et al., 2012), although the outcome of the seismic risk assessment is more comprehensive and exploitable by the stakeholders and community. Hence, the seismic risk will be assessed in the current study based on existing hazard models (SHARE project, Giardini et al., 2014), exposure and vulnerability models that have been composed by previous works (Chrysostomou et al., 2014; Kyriakides et al., 2015) and the outcome will be given in monetary, building damage and affected population terms. Both probabilistic and deterministic analyses have been performed to provide results (aggregated and spatially distributed figures), at annual and probability-related basis, and for selected seismic scenarios.

For the performance of seismic hazard and risk analysis, the OpenQuake platform (Silva et al., 2013), developed within the Global Earthquake Model Foundation (GEM, 2018), has been applied. The engine is open-source, open-code and has the possibility to perform both probabilistic hazard and risk assessment and scenario damage and risk computation. Tailor-made hazard, exposure and vulnerability models have been uploaded together with customized logic trees to account for epistemic uncertainties. The open-source QGIS software has been used for the mapping of the results.

For the seismic risk assessment at national level, probabilistic seismic hazard and risk analysis has been initially performed. The risk outcome is in terms of monetary loss and is provided at aggregated level for the island and the four major cities and spatially distributed with gridded maps. Moreover, the risk analysis of two seismic scenarios with 10% and 2% probability of occurrence was performed. Monetary and human loss (casualties, injuries, displaced population) was estimated as well as damage distribution among the main structural typologies. Reference is made to the importance of a future social vulnerability and integrated risk analysis.

Seismic hazard assessment

In order to assess the risk that a structure faces to sustain a certain level of damage from given earthquake shaking, it is necessary first to calculate the probability of exceedance of the level of ground shaking for a range of intensity levels. Hence, Probabilistic seismic Hazard Analysis will be first performed, able to provide the requested intensity measures (Peak Ground Acceleration, spectral amplitude, seismic intensity, etc) in function to recurrence rate. Following to this analysis, risk analysis (combining the exposure and vulnerability model) for all the generated ground motion fields (potential ground shaking scenarios) will lead to the probability-related loss estimation.

Probabilistic seismic hazard analysis

Input hazard models

For the implementation of Probabilistic Seismic Hazard analysis, the classical integration procedure as proposed by Cornell (1968) and formulated by Field et al. (2003) has been incorporated into OpenQuake software and performed in the study herein for investigation time of 50 years. The input files are the *Seismic source model*, that is a collection of seismic sources describing the seismic activity (geometry and activity rate of each source) in a region of interest, and the *Ground motion model*, that associates Ground Motion Prediction Equations (GMPEs) and distribution weights to each tectonic region, given the occurrence of an earthquake rupture.

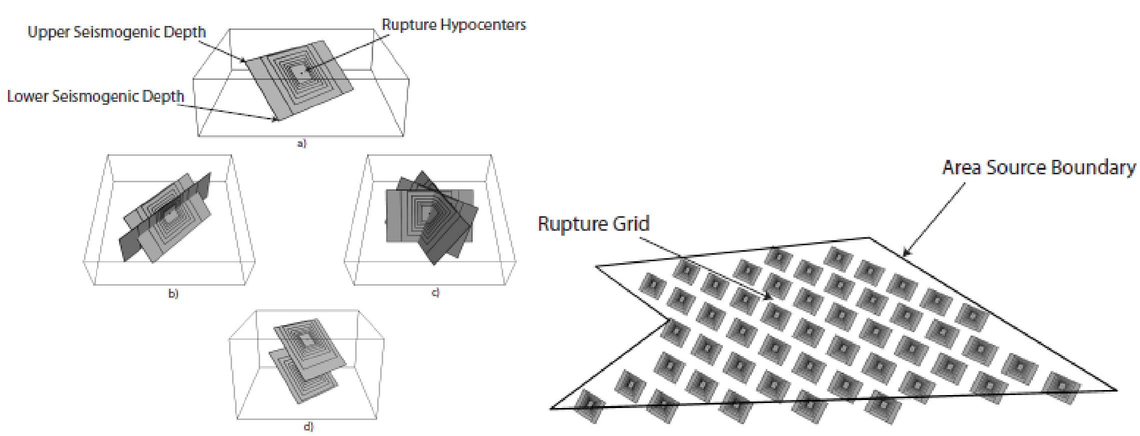
For the analysis, herein, the following three *seismic source models* (ESHM13) developed for SHARE project (Giardini et al., 2013) in the OpenQuake format (Pagani et al., 2014) have been used. Each of the models uses different assumptions to estimate earthquake activity rates in the European region.

1. Classic Area Source model: Contains the area source model (Figure 8a,b). Parametrization includes: magnitude-frequency distribution, temporal occurrence model, magnitude-area scaling relationship, definition of nodal planes, centroids and constrains of rupture planes.

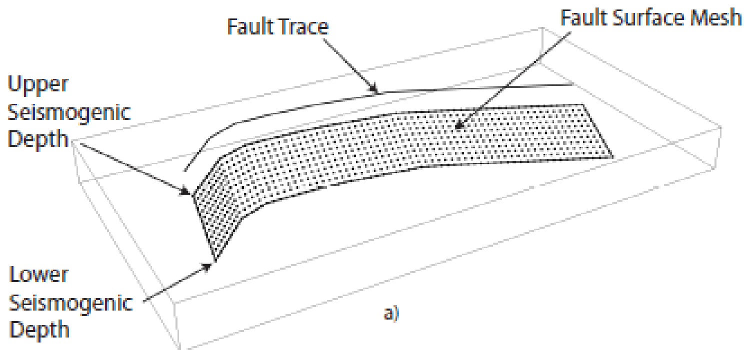
2. Fault-Source and Background model (FSBG): a model that combines activity rates based on fully parameterised faults imbedded in large background seismicity zones (Figure 8c). Contains fault source and the background seismicity model. Parametrization includes: magnitude-frequency distribution, temporal occurrence model, magnitude-area scaling relationship, definition of fault surface and faulting style.

3. SEIFA model: a kernel-smoothed model that generates earthquake rate forecasts based on fault slip and smoothed seismicity. The following information is contained: Location, Geometry, Incremental annual rate in 0.1 magnitude bins stating from Mw=4.5, cumulative annual rate, log1(cumulative annual rate).

It is noted that due to computational resource limitations, the crust (active and stable shallow) tectonic zone has been removed from the model.



(a) (b)



(c)

Figure 8 – Graphical representation of earthquake ruptures (a) as generated by point sources for different input parameters ; (b) as generated by an area source, mainly originated by point sources uniformly distributed along an area ; (c) as a portion of a fault surface mesh, simulated in OpenQuake engine (Pagani et al., 2014)

In Figure 9 the fault top traces and planes of composite seismogenic sources (in grey) and the subduction traces (in color) of the Cyprus and Hellenic Arc, as compiled for the European Database of Seismogenic Faults (EDSF) within SHARE project, are illustrated for Cyprus. EDSF includes only faults that are capable of generating earthquakes of magnitude equal to or larger than Mw5.5 and aims at ensuring a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area (Basili et al., 2013). These have been incorporated into the abovementioned source models. Moreover, data from the two SHARE European Earthquake (SHEEC) sub-catalogues 1000-1899, 1900-2006 (Grünthal et al., 2013, Grünthal and Wahlström, 2012 and Stucchi et al., 2012) has been used for the generation of abovementioned the source models, as a basis for computation.

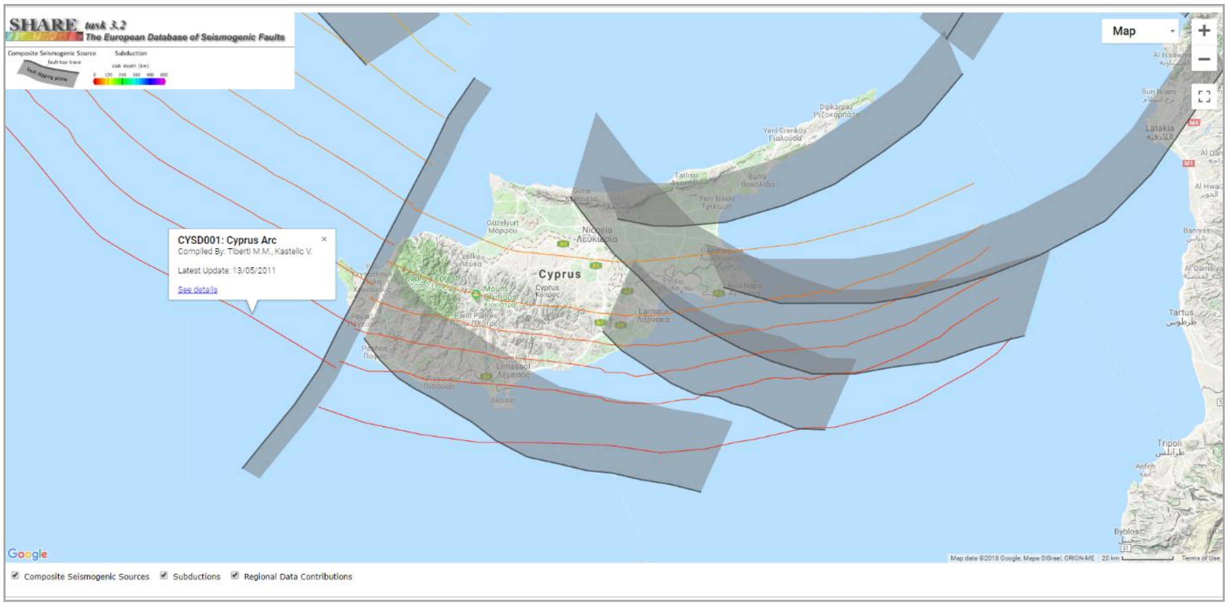


Figure 9 – Extract of the European Database of Seismogenic Faults from Basili et al. (2013)

The *Seismic Source model logic tree* is essential integral component of PSH Analysis and describes the epistemic uncertainties associated with the construction of seismic source models used for different tectonic regions. The tailored logic tree proposed by SHARE project, used herein, is relatively simple with higher weight attributed to the Area Source model.

On the other hand, a more complex *Ground Motion model logic tree* defines the Ground Motion model which comprises different Ground Motion Prediction Equations, per tectonic setting, with their respective defined uncertainty. The Ground Motion Prediction Equations are empirically derived equations that correlate the source (and its parameters) with the propagation path and the site of interest (e.g. magnitude, distance and Vs30) leading to the computation of a ground motion parameter. The GMPE logic tree of SHARE Project (Figure 10) has been incorporated and the equations for Peak Ground Acceleration (PGA) and Spectral acceleration (Sa) have been applied, according to the hazard calculator.

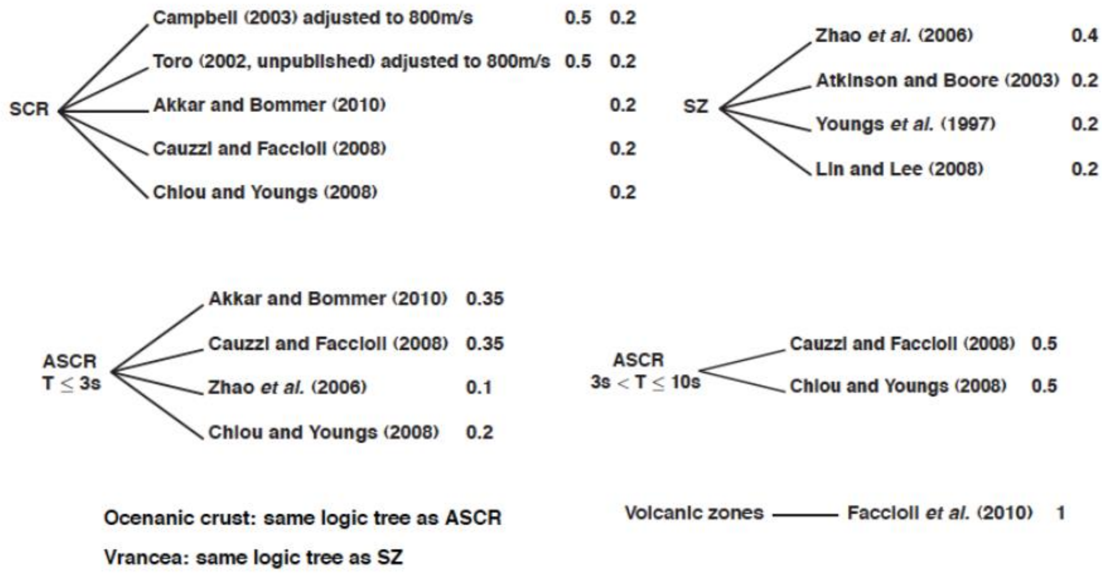


Figure 10 – Ground motion prediction equation logic tree for SHARE (Woessner et al., 2013)

For the definition of the *site conditions*, a simplified model based on the Shear wave velocity (Vs30) map of USGS (Figure 11) has been used.

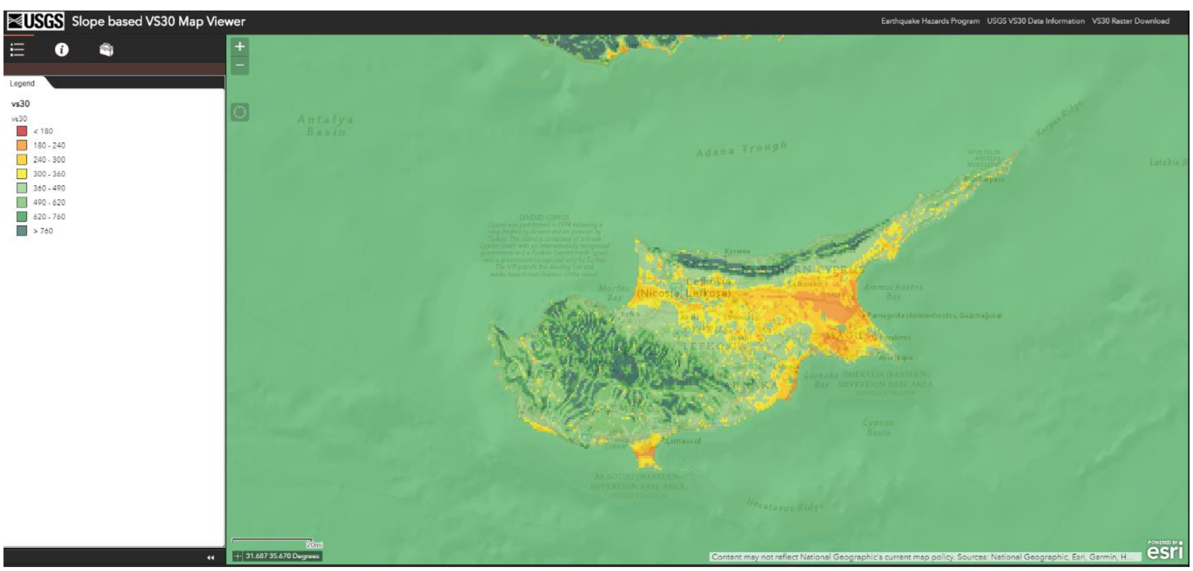


Figure 11 – Shear wave velocity map of Cyprus (USGS, 2018)

3.1.1.1 Output – Seismic hazard curves

The information extracted from the probabilistic seismic hazard analysis is summarized in the *seismic hazard curve* which combines the rate (or probability) of exceedance of a range of intensity levels for different ground motion parameters at a given site. This curve is composed by consideration of exceedance of ground motion parameter levels by all possible earthquake ruptures included in the seismic source model within a given investigation time.

The curves below depict the Peak Ground Acceleration (PGA) (Figure 12) and the Spectral acceleration at T=0.3 s (Figure 13) with the corresponding probability of exceedance in 50 years. They have been plotted for the main cities of Cyprus for which PGA varies between 0.3 and 0.5g and Sa varies between 0.7 and 1.0g. It may be seen that the seismic hazard in Paphos and Limassol is the most elevated in the island, being in the vicinity of the shallow seismic subduction zones of the Cyprus and the Hellenic Arc (Figure 9). The elevated seismic hazard in the southwestern part of the island is also evident by the maps of Figure 14 to Figure 17).

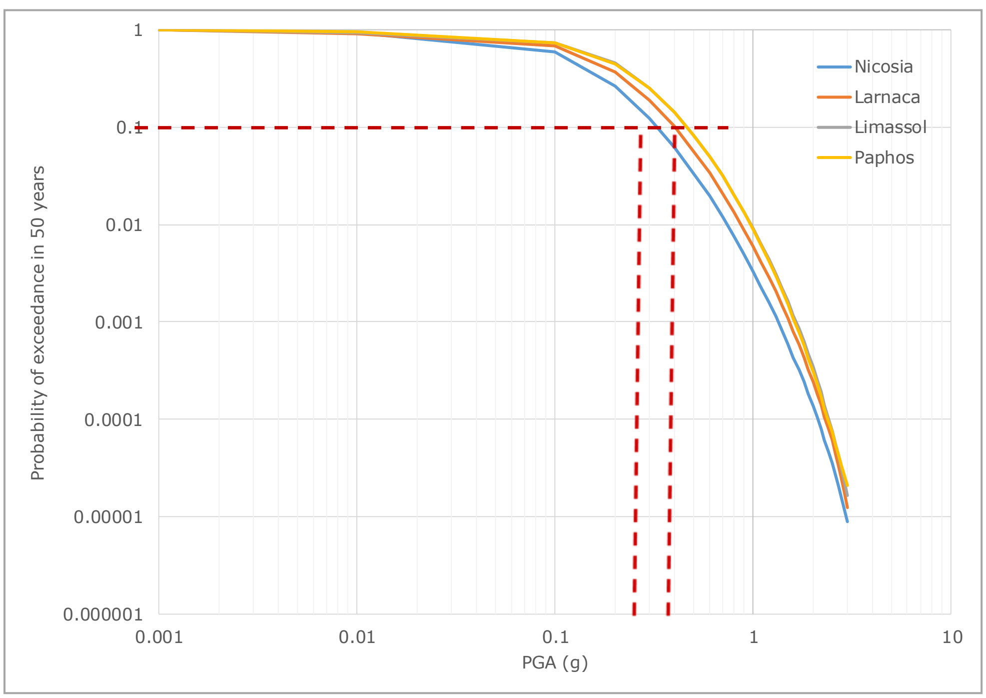


Figure 12 – Hazard curves for the main cities of Cyprus in PGA extracted from PSHA

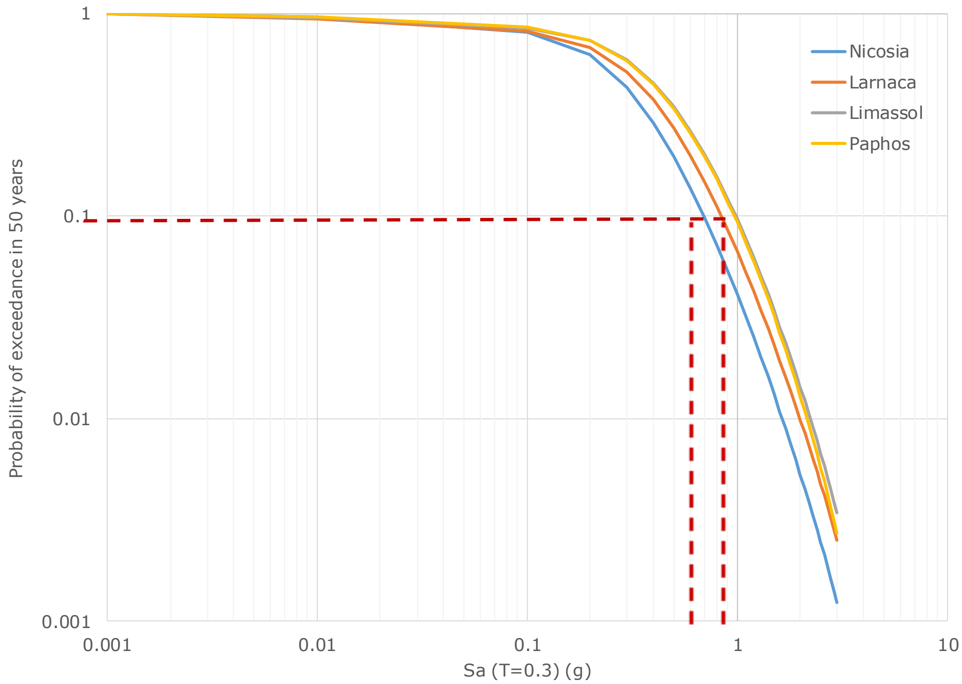


Figure 13 – Hazard curves for the main cities of Cyprus in Spectral acceleration at T=0.3 s from PSHA

3.1.1.2 Output – Seismic hazard maps

The seismic hazard maps below express the distribution of the ground motion parameters under study for the given recurrence period (T). Figure 14 and Figure 15 illustrate the distribution of the Peak Ground Acceleration (PGA) for T=475 and T=2500 years, respectively. It is evident that the highest seismic hazard is concentrated in the southwestern part of Cyprus. More precisely, along the southwestern shore of the island, where Lemessos and Paphos are located, PGA exceeds 0.45g (for T=475years) and 0.8g (for T=2500 years. Interesting is the comparison with the current seismic design map (**Error! Reference source not found.**) which anticipates max design PGA, in the same regions, equal to 0.25g (for T=475 years).

Figure 16 and Figure 17 illustrated the distribution throughout the island of spectral acceleration at fundamental period of 0.3 s with T=475 and T=2500 years, respectively. Values vary between 0.4 and 1.10g for T=475 years while for T=2500 design spectral acceleration n at 0.3 s varies between 0.9g (at the northern part of the island) to 2.0g. in the south-western.

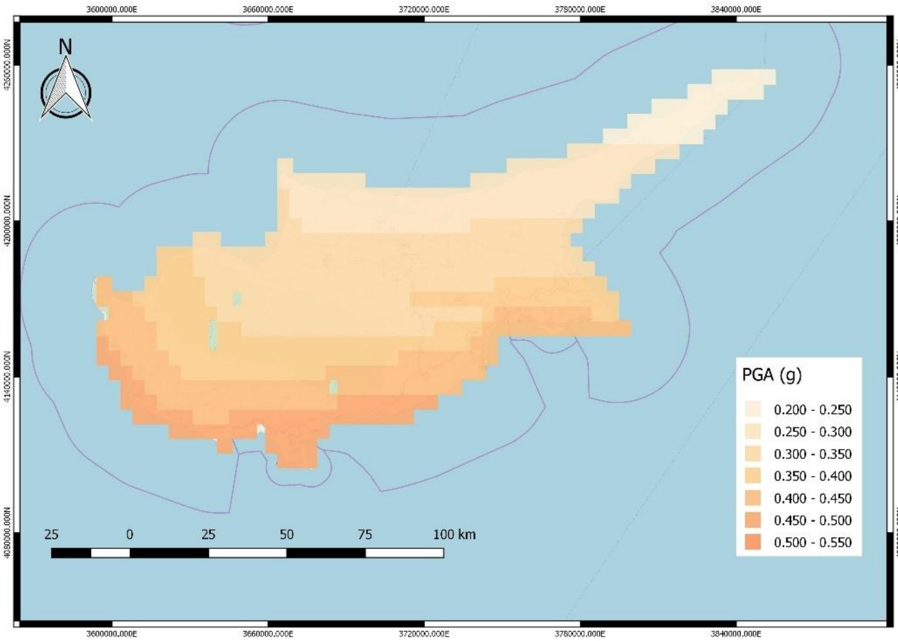


Figure 14 – Mean seismic Hazard map in PGA for probability of esceedance 10% in 50 years (T=475 years)

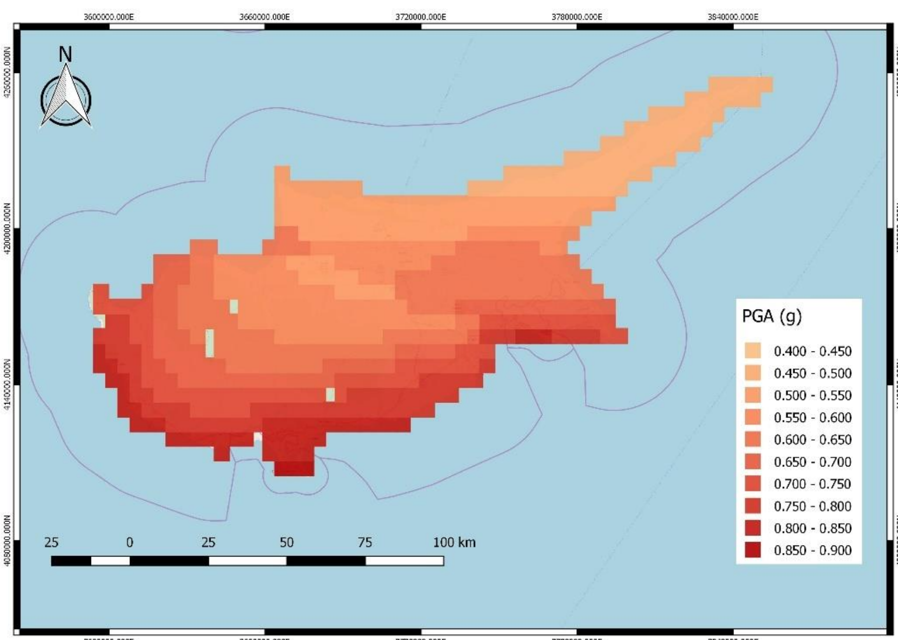


Figure 15 – Mean seismic Hazard map in PGA for probability of esceedance 2% in 50 years (T=2500 years)

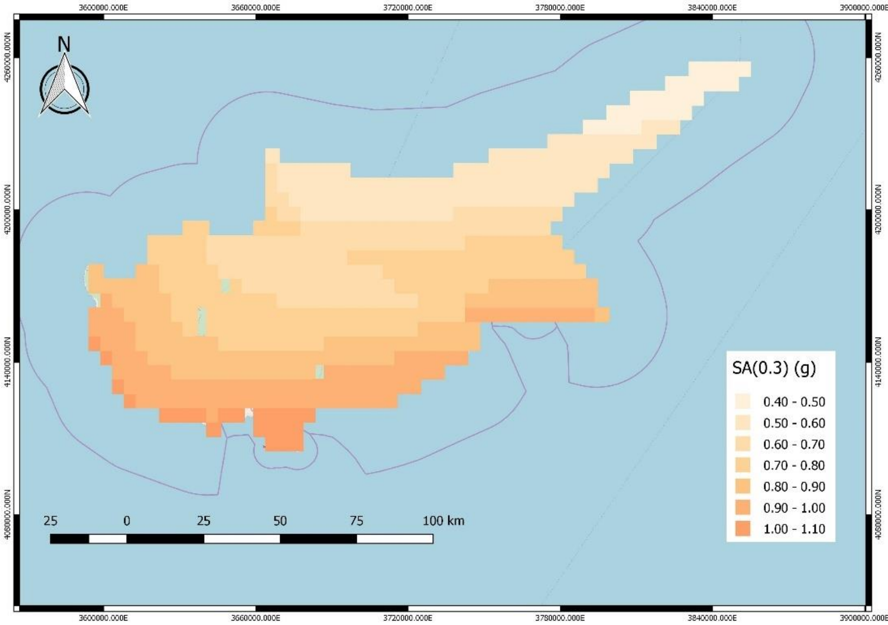


Figure 16 – Mean seismic Hazard map in Spectral acceleration at T=0.3 s for probability of esceedance 10% in 50 years (T=475 years)

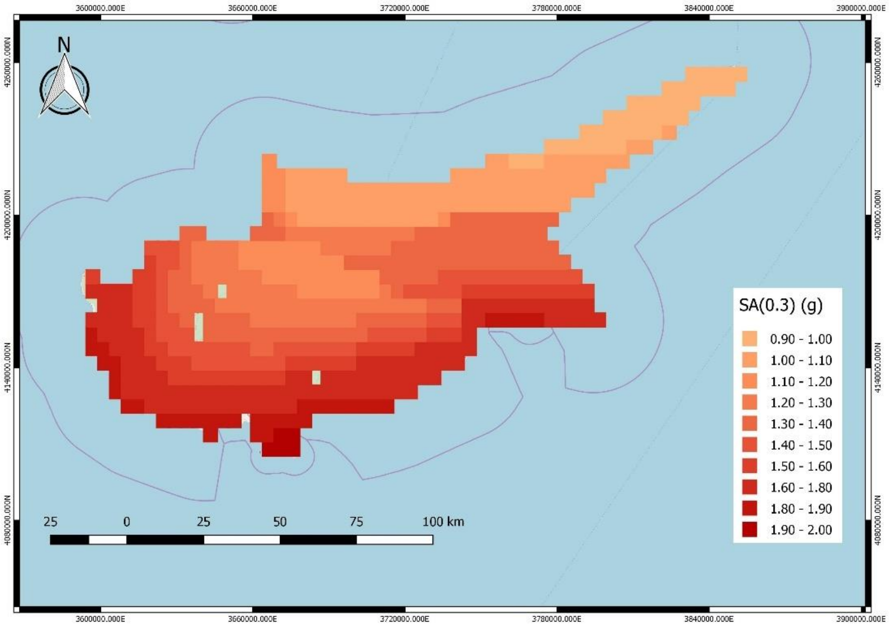


Figure 17 – Mean seismic Hazard map in Spectral acceleration at T=0.3 s for probability of esceedance 2% in 50 years (T=2500 years)

4 EXPOSURE MODEL AND STRUCTURAL VULNERABILITY

Exposure model

The exposure model for Cyprus refers to the building stock and the permanent population. Main source of both databases is the 2011 Population Census of Cyprus and the GIS based building database of the Department of Lands and Surveys. All data was collected by to the local representatives of EMME project (Giardini et al., 2016), as reported in Chrysostomou et al. (2014) and was kindly provided by the authors of the latter work for the purposes of the current study. Within EMME project, a 1x1km^2 grid was generated for the entire island and a number of buildings, per building typology, and population is given per grid.

The classification of buildings per typology has taken place following the European Building Taxonomy Classification, as defined during the RiskUE project (2003). The criteria of the classification are the material, the construction period, as far as the seismic design codes are concerned and the building height. Hence the following typologies are available, according to Chrysostomou et al. (2014): bearing masonry, reinforced concrete (RC) frames for low- to mid-rise and high-rise buildings and further distinction of RC structures for low ductility (or with no Earthquake Design Code-ERD) and moderate ductility (with ERD). It is noted that, given that no detailed information is given with respect to the typology of masonry, no distinction was made between adobe and simple stone material. It has been also observed that all masonry buildings are built before 1975. The low- to mid-rise buildings have been grouped together, based on the availability of fragility curves (Par. **Error! Reference source not found.**). As explained by Kyriakides et al. (2015), fragility curves for low-rise buildings (for average height of 2 stories) have been generated due to their multitude, as well as fragility curves for high-rise buildings (for average height of 7 stories) due to their observed vulnerability. Mid-rise building of 3-5 stories height have not thoroughly examined due to low damage recording from previous earthquakes and limited resources. Design with seismic codes was enforced in 1992.

Figure 18 demonstrates the typological distribution of buildings throughout the island with ratios and absolute numbers. The total number of buildings, as registered in the Censuses is 326820. It is evident that low to mid-rise RC buildings with no seismic design codes (ERD) is the predominant typology (57% of the building stock) with its counterpart with ERD being the following one in multitude (27%). 17% of the registered building stock is made of bearing masonry, being mainly encountered in the Northern part of the island (**Error! Reference source not found.**), if not accounting for the major cities. High-rise buildings correspond to around the 3% of the island's building stock. It should be noted that a number of high-rise buildings have been erected in the main cities in the period from 2011 but, considering that these are individual structures following the most modern seismic design provisions, their exclusion from the exposure model is not considered to significantly affect the overall risk outcome.

Figure 19 to Figure 23 illustrate the spatial distribution of buildings throughout the island. As expected, there is a high concentration (>3000 buildings per grid) in the big cities (Nicosia, Paphos, Limassol, Larnaca). Comparing Figure 22 and Figure 23, it is interesting to comment upon the fact that buildings designed with ERD codes, hence erected after 1992, are allocated also out of the big cities. Finally, in Figure 24 the population distribution per grid has been illustrated, indicating the expected correlation between population and number of buildings distribution.

The replacement value considered per structural typology is part of the exposure module of a risk study. Based on empirical data and for simplification reasons, the **average area per floor** has been decided for all typologies between **80 and 100m²**. The **replacement cost** only for structural works ranges between **600 and 800 euro/m²**. The **total structural replacement value** of the exposed assets is estimated around **32 billion euro**. No differentiation of the buildings per occupancy has been assumed.

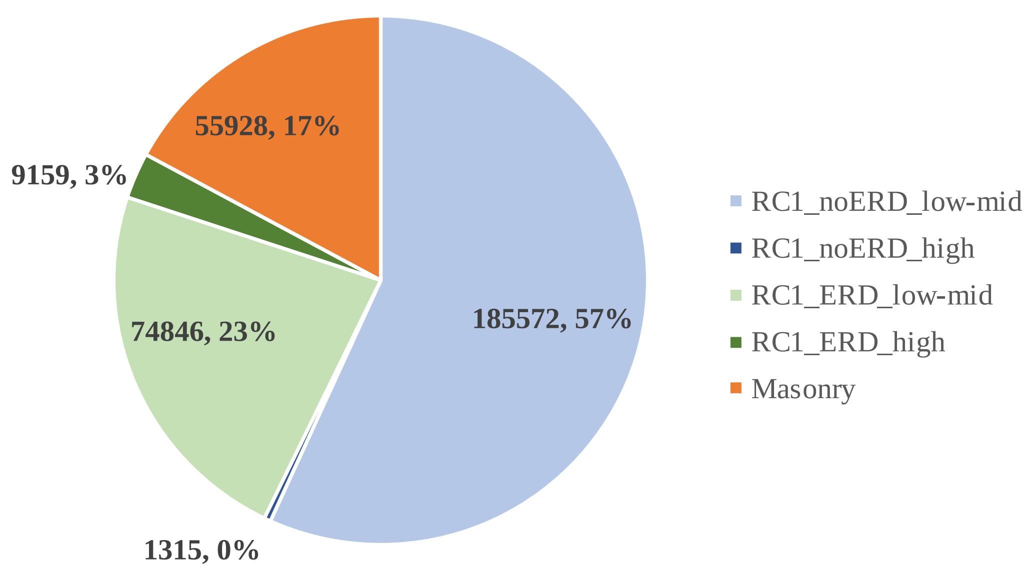


Figure 18 – Distribution of building typologies for the island of Cyprus

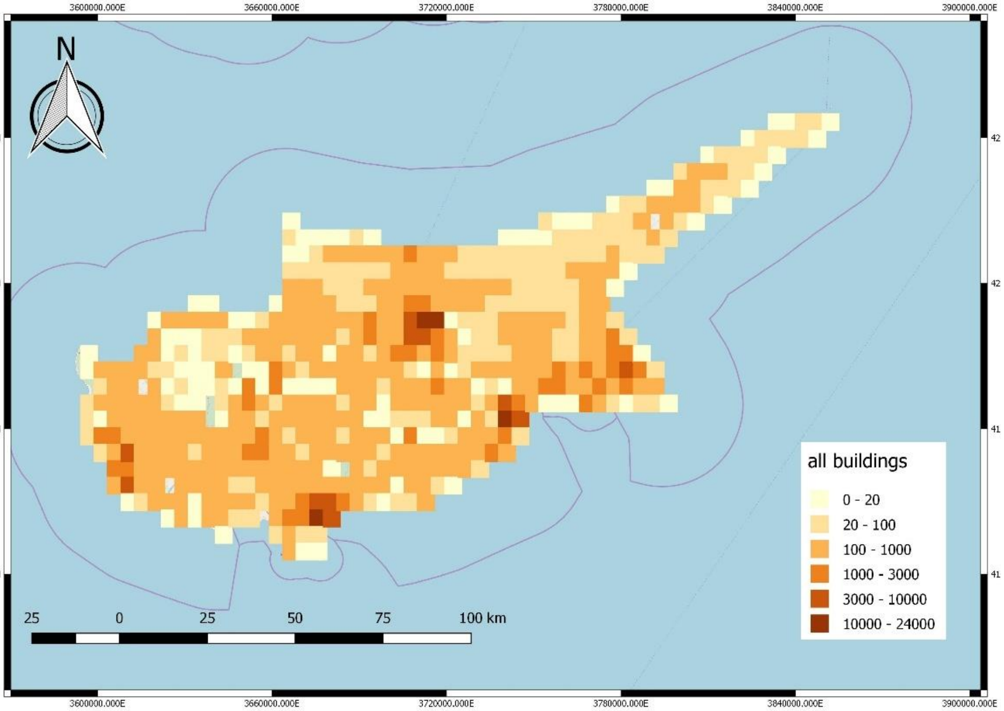


Figure 19 – Distribution of number of buildings

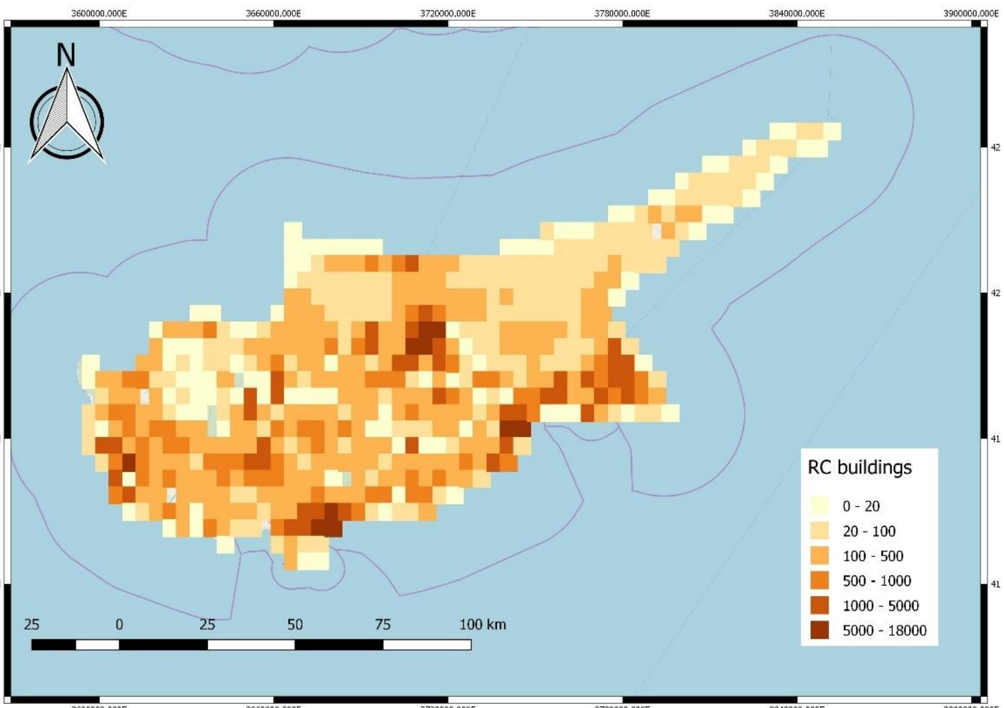


Figure 20 – Distribution of number of RC buildings

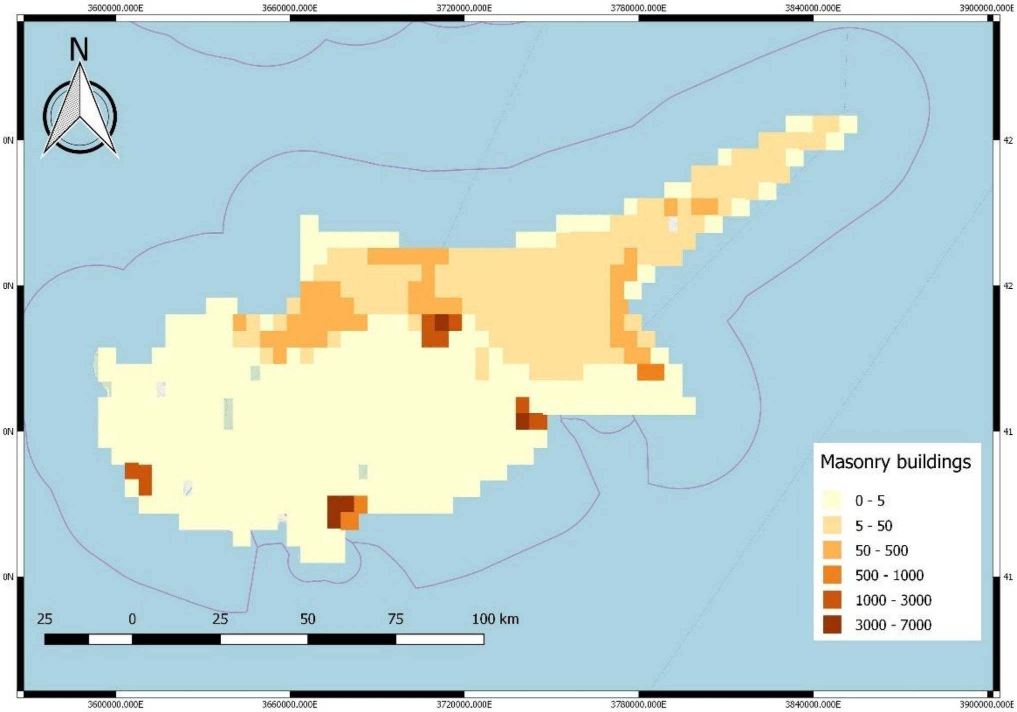


Figure 21 – Distribution of number of masonry buildings

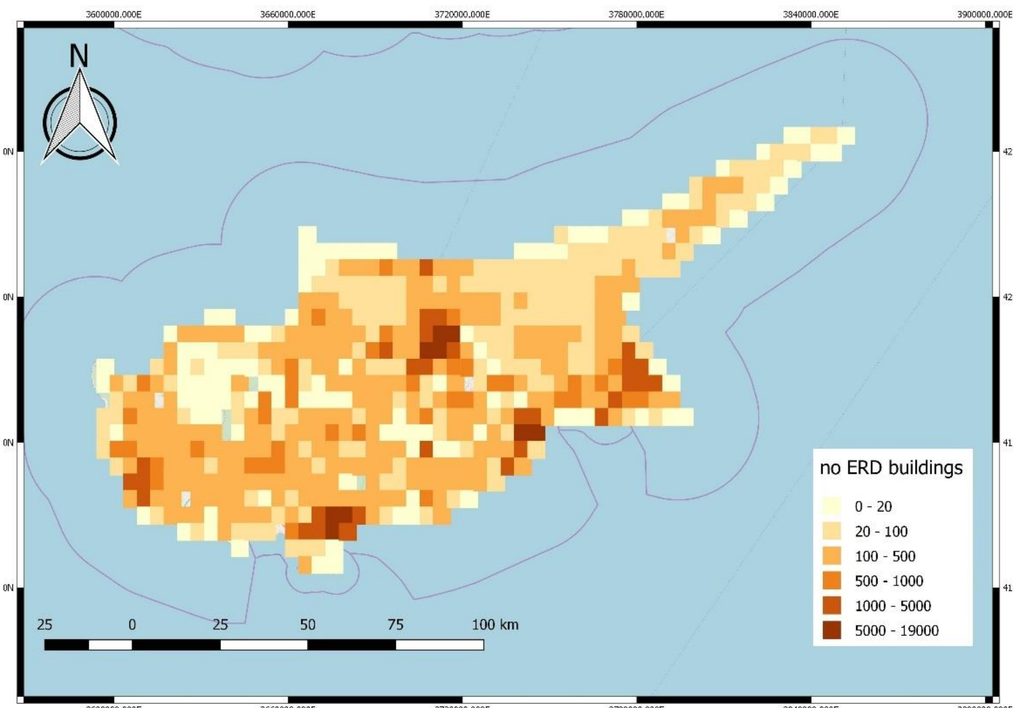


Figure 22 – Distribution of buildings without ERD codes

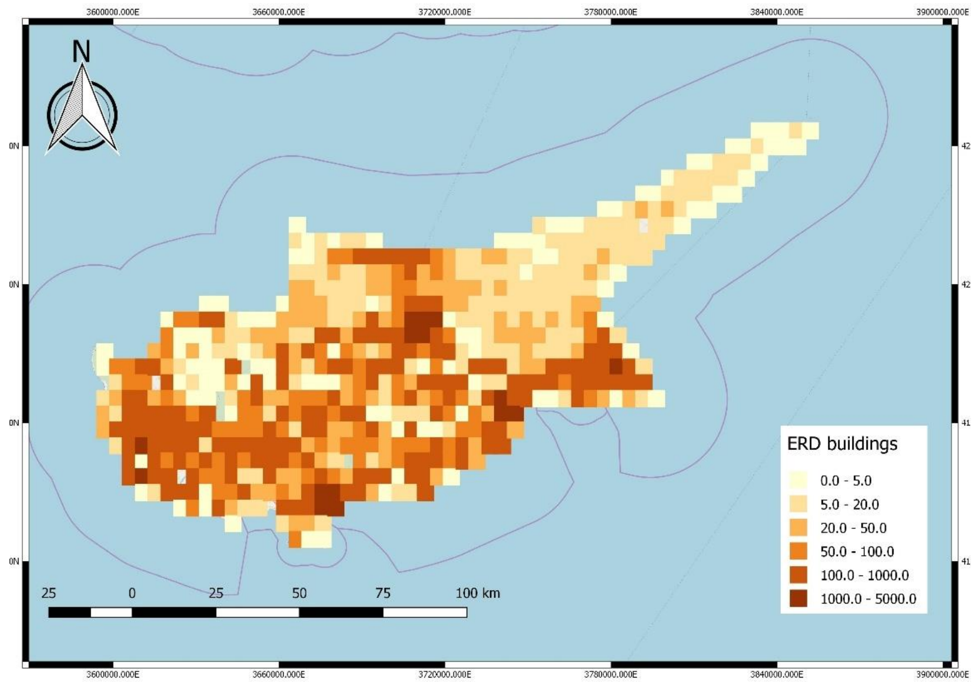


Figure 23 – Distribution of buildings with ERD codes

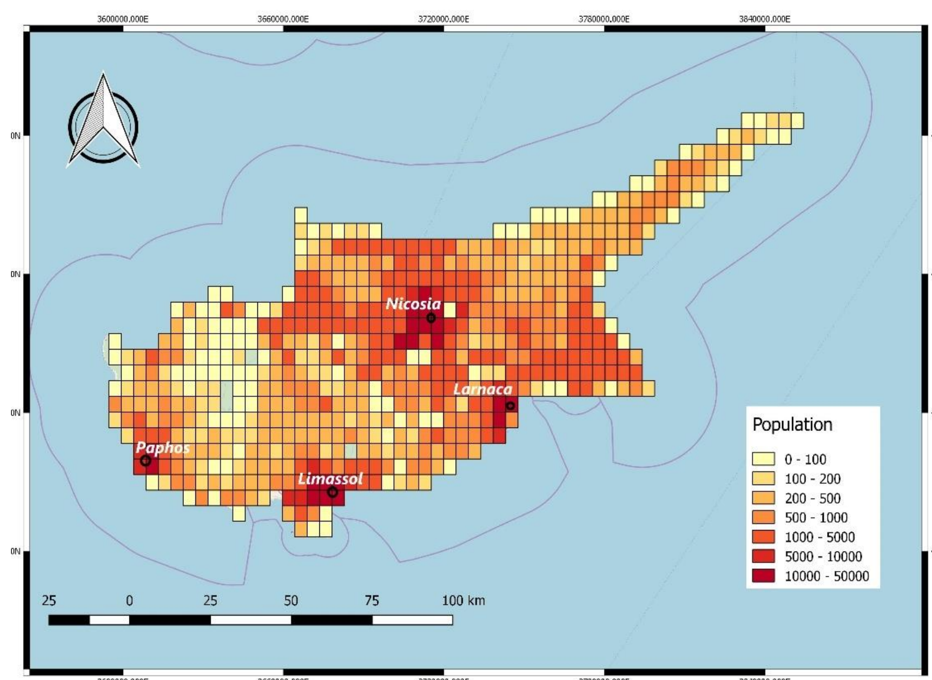


Figure 24 – Distribution of permanent population

Physical (structural) vulnerability model

The structural vulnerability, being defined as the expected resistance of a structure or a structural typology when exposed to the seismic hazard. It is intrinsic parameter of the structure and depends on its structural, mechanical and geometric characteristics. For the performance of a reliable seismic risk study with probabilistic distribution of loss estimates, it is fundamental to apply a representative vulnerability model. This is expressed by fragility curves or functions (i.e. *continuous relationships expressing the conditional probability that different damage states will be exceeded at specified ground motion levels*), developed in analytical way, as explained below. For the convergence of a set of fragility curves, per structural typology, to a vulnerability curve, consequence functions are employed. The latter, as described below, are composed by damage ratios per damage state, which describe the ratio of cost of repair to cost of replacement, based on empirical data.

Structural fragility functions

For the reinforced concrete buildings, which represent the 83% of the Cypriot building stock, fragility curves analytically derived after the study of Kyriakides et al. (2015) for Limassol buildings, have been employed. These have been developed for low-rise (average height of 2 stories) and high-rise (average height of 7 stories) buildings, with ERD (Eurocodes) and no seismic design. For accounting for building variability within each structural typology, structural characteristics (material strength and detailing) were treated probabilistically using the Latin Hypercube Technique. In total, 60 building models have been simulated and 420 time-history analyses were performed for 7 sets of real acceleration records matched to the acceleration spectra of the 2 seismic zones of Limassol, after the Microzonation study of CGCD (2000).

Initially, fragility curves were first developed in terms of spectral displacement (Sd), by recording the top storey displacement at each damage level, and have been converted to PGA by means of the Limassol spectra (CGCD), considering that their combination with hazard studies in terms of PGA is more common. Hence, and for reasons of their validation with other studies of the same region's literature (Kappos et al., 2003) the latter have been implemented, as listed in Table 4. The fragility curves were derived by fitting the mean and standard deviation values of PGA to the lognormal distribution. The Damage States adopted are the following with the described damage thresholds (per Eurocodes) reached during the non-linear analyses. For reasons of compatibility with OpenQuake the wording used herein for the 4 levels of damage has been also marked below.

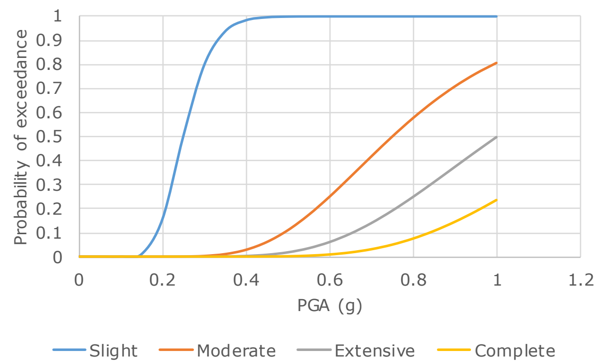
- **Damage Limitation (DL)** with columns yield rotational capacity (θy) – **Slight (S)**
- **Significant Damage (SD)** with ¾ of column's ultimate rotational capacity (θu) – **Moderate (M)**
- **Near Collapse (NC)** with column's ultimate rotational capacity and shear capacity – **Extensive (E)**
- **Building Collapse (FAIL)** with all columns of a floor reach NC limit or a max inter-storey drift of 4% is reached – **Collapse (C)**

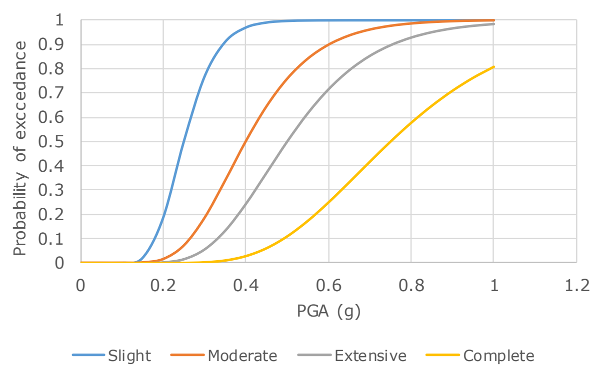
As far as bearing masonry buildings are concerned, in the absence of local studies, it has been decided to make use of curves referenced in literature of the same region, for which engineering expertise demonstrates the existence of similar typology as in Cyprus. Hence, from the GEM/OpenQuake Physical risk Dataset, the analytical fragility curves developed by Ahmad et al. (2010) for the Euro-mediterranean masonry low to mid-rise masonry buildings have been selected. The curves are derived after non-linear static analyses (pushover) of prototype 2D buildings and seismic hazard obtained from 10 natural US accelerograms and IBS-2006 rock acceleration spectra. Uncertainties in lateral stiffness, strength and damage limit states are taken into account through Monte Carlo simulations. They have been derived for 5 damage states, in terms of spectral displacement (Sd) and PGA and for the purposes of their implementation in OpenQuake with the 4-Damage State approach, some transformations have been adopted.

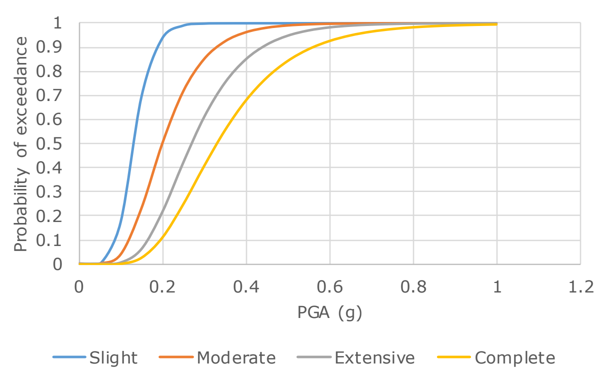
The selected fragility functions have been uploaded to OpenQuake platform after having been included into the GEM/OpenQuake Physical Risk Datasets for Cyprus.

Table 4. Mean and standard deviation of fragility curves of all structural typologies implemented in the current study

<table>
<tr><th>Typology</th><th colspan="3"></th><th></th></tr>
<tr><td rowspan="5">RC with ERD

Low-mid-rise (Kyriakides et al., 2015)</td><td></td><td>μ</td><td>σ</td><td rowspan="5">
</td></tr>
<tr><td>S</td><td>0.25</td><td>0.22</td></tr>
<tr><td>M</td><td>0.75</td><td>0.33</td></tr>
<tr><td>E</td><td>1.0</td><td>0.33</td></tr>
<tr><td>C</td><td>1.25</td><td>0.31</td></tr>
<tr><td rowspan="5">RC with ERD

High-rise (Kyriakides et al., 2015)</td><td></td><td>μ</td><td>σ</td><td rowspan="5">
</td></tr>
<tr><td>S</td><td>0.25</td><td>0.25</td></tr>
<tr><td>M</td><td>0.40</td><td>0.32</td></tr>
<tr><td>E</td><td>0.50</td><td>0.32</td></tr>
<tr><td>C</td><td>0.75</td><td>0.33</td></tr>
<tr><td rowspan="5">RC without ERD

Low-mid-rise (Kyriakides et al., 2015)</td><td></td><td>μ</td><td>σ</td><td rowspan="5">
</td></tr>
<tr><td>S</td><td>0.13</td><td>0.28</td></tr>
<tr><td>M</td><td>0.20</td><td>0.39</td></tr>
<tr><td>E</td><td>0.27</td><td>0.38</td></tr>
<tr><td>C</td><td>0.33</td><td>0.41</td></tr>
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<table>
<tr>
<td>RC without ERD

High-rise (Kyriakides et al., 2015)</td>
<td>
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<tr><td></td><td>μ</td><td>σ</td></tr>
<tr><td>S</td><td>0.17</td><td>0.24</td></tr>
<tr><td>M</td><td>0.21</td><td>0.37</td></tr>
<tr><td>E</td><td>0.30</td><td>0.50</td></tr>
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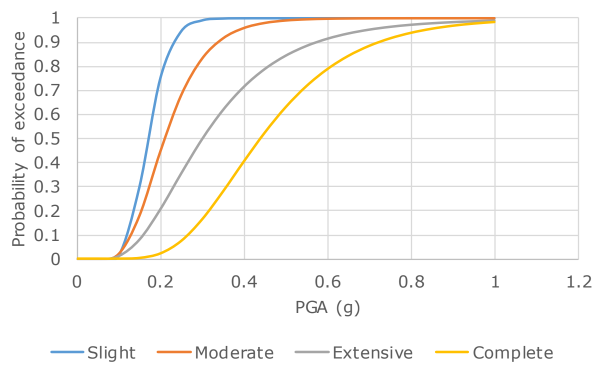
<td>
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<td>Masonry without ERD

low rise (Ahmad et al., 2010)</td>
<td>
<table>
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<tr><td>S</td><td>0.25</td><td>0.22</td></tr>
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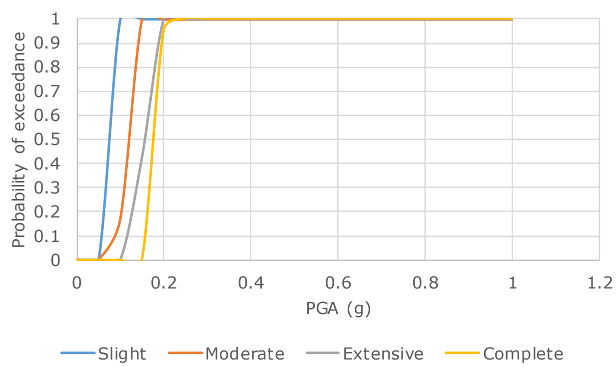
<td>
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Structural vulnerability functions

For the final derivation of vulnerability curves, functions that describe a total loss ratio for each level of intensity measure (here PGA is used), the adoption of a consequence (or damage ratio) model is necessary. The latter expresses the ratio of cost of repair with respect to the cost of replacement for each damage state. This is usually constructed based on damage information claimed by householders in financial terms following a damaging earthquake when requesting financial aid. This data was not easily available at this phase for Cyprus and thus published models by Kappos et al. (2006), based on the Greek reality, have been adopted considering no major discrepancies due to their similarities with the structural typologies (Table 5). The multiplication of the set of fragility curves per structural typology with the damage ratios at each intensity (PGA) level leads to a unique continuous function of loss ratio per intensity measure level per structural typology (Figure 25). No coefficient of variation has been assumed.

It is interesting to observe that the no ERD structures present similar response for both low to mid-rise and high-rise buildings while the ERD buildings, with significantly more favourable seismic performance, present discrepancies according to their height. In particular, the high-rise buildings are observed to be more vulnerable due to higher displacement demands. On the other hand, for interpretation of the no ERD structures response, it may be noted that high-rise buildings have construction detailing and dimensions which, as opposed to low-to-mid-rise buildings, enhance their ductile performance and allow for redistribution of the seismic loading.

Table 5. RC and masonry damage ratios from Kappos et al. (2006)

	Slight	Moderate	Extensive	Complete
RC	0.05	0.2	0.45	0.8
Masonry	0.12	0.3	0.55	0.85

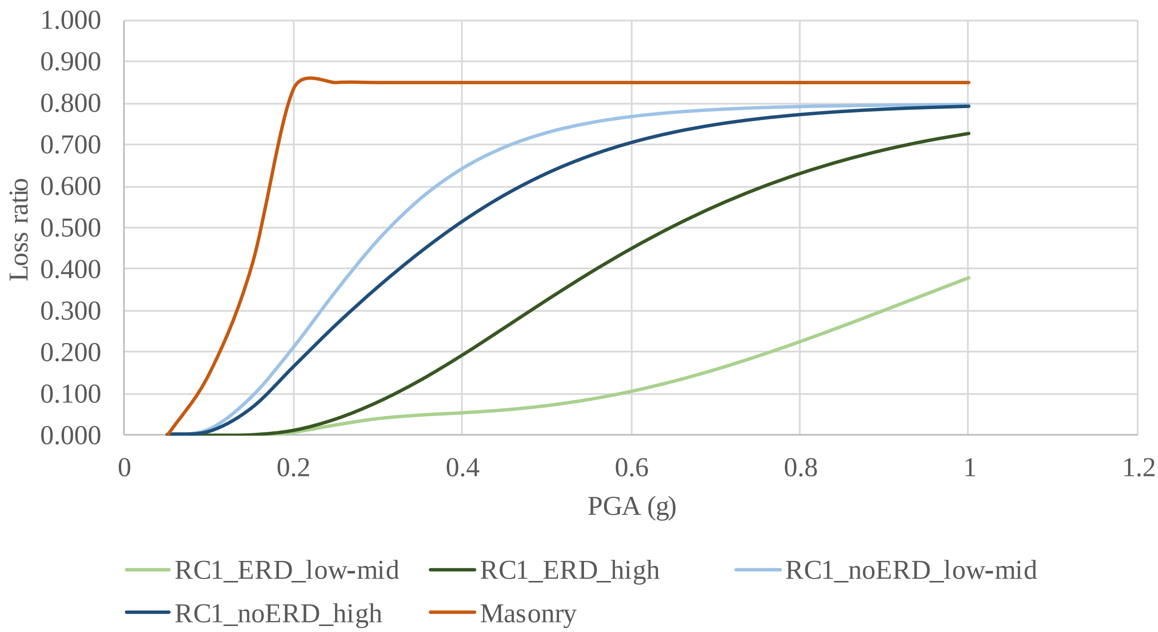

Figure 25 – Loss functions for all structural typologies

5 SEISMIC RISK ASSESSMENT

Following the probabilistic hazard analysis that allow us to obtain the seismic hazard outputs, OpenQuake platform gives us the opportunity to perform a variation of probabilistic analysis, the so-called Stochastic event-based analysis. During this, the seismicity of a region is simulated according to the source models by generating *stochastic event sets* (or synthetic catalogue) for a given time span. Simulations are generated with the Monte Carlo (i.e. random) sampling procedure and a stochastic event set comprises a sample of the full population of ruptures. The number of the latter (ruptures generated by a source) depends on the probability distribution sampled by the Monte Carlo simulation or, in other words, the number of occurrences of each one in a time span.

From the stochastic event sets and the associated ground motion fields ("objects describing geographic distribution around a rupture of a ground motion intensity measure"), probabilistic seismic risk analysis takes place and leads to the calculation of loss distribution for individual assets, as well as aggregated loss distribution for all the assets of the exposure model, within a specified time period. For each ground motion field, the intensity measure level at a given site is combined with the predefined vulnerability functions per structural typology, randomly sampling loss ratios for the exposure model. Hence, monetary loss for the structural damage is estimated at asset level (which contains a number of buildings of specific structural typology) and for the entire portfolio for realizations with given probabilities of exceedance. The final loss estimate is deduced after multiplication of the loss ratio with the asset's replacement value.

From the above-mentioned loss output, it is possible to identify the realization and the corresponding earthquake rupture that has the requested probability of exceedance in order to determine seismic scenarios for further study.

Probabilistic loss estimates

Loss exceedance curves (aggregated losses)

Loss exceedance curves represent a list of losses and respective probabilities of exceedance, or the equivalent return periods. The loss exceedance curve is a comprehensive outcome of a probabilistic risk assessment and widely used, as it may provide a loss estimate for any probability of interest (Figure 26). In order to obtain a realistic approach for loss estimates within 10000 years, it was deemed necessary to perform stochastic event -based risk analysis for 50,000 years or investigation time of 50 years for 1000 stochastic event sets per logic tree path.

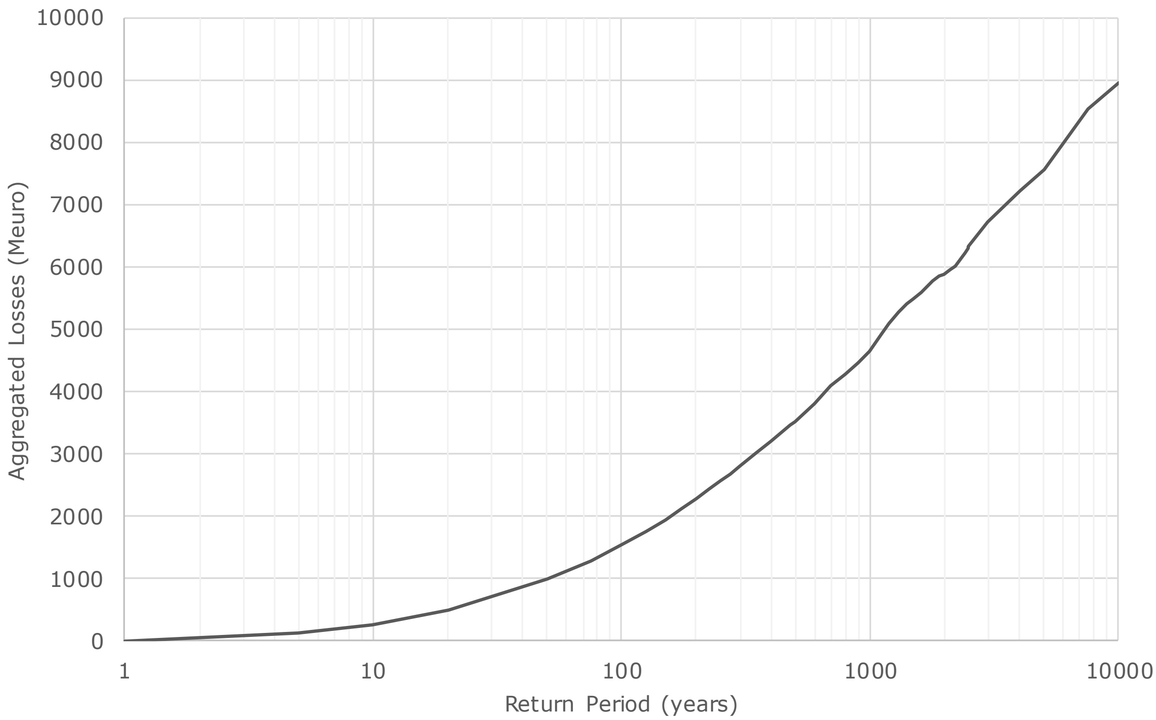

Figure 26 – Loss exceedance curves

The *loss table* of Table 6 below has a list of the expected mean aggregated loss with annual frequency distribution and probability of exceedance within a 50 years time-span. Moreover, for a more comprehensive provision of the results, the return periods are calculated as a result of the Poisson probability model over 50 years. The results for the most interesting probabilities have been highlighted.

It is, therefore, noted that for the design earthquake with **T=475 years** (or 10% probability of exceedance), the expected aggregated mean loss is **3.46 billion euro,** what corresponds to the **14.5% of Cyprus island GDP** (Gross Domestic Product). For **T=2500 years** (or 2% probability of exceedance) the expected aggregated mean loss is **6.3 billion euro**, what corresponds to **26.6% of Cyprus island GDP**.

The mean loss ratio is calculated with normalization of the aggregated loss over the total replacement value of the entire building portfolio (~32 billion euro).

Table 6. Aggregated loss table for various return periods

Annual frequency of exceedance	Return period (years)	Probability of exceedance in 50 years	Mean loss (in million euro)	Mean loss ratio
1.00000	1	1.000	0	0.000
0.20000	5	1.000	114	0.004
0.10000	10	0.993	262	0.008
0.05000	20	0.918	497	0.016
0.02000	50	0.632	992	0.031
0.01000	100	0.393	1540	0.048
0.00500	200	0.221	2290	0.072
0.00333	300	0.154	2810	0.088
0.00211	475	0.100	3460	0.108
0.00100	1000	0.049	4660	0.146
0.00050	2000	0.025	5890	0.184
0.00040	2500	0.020	6330	0.198
0.00020	5000	0.010	7570	0.237
0.00013	7500	0.007	8550	0.268

0.00010	10000	0.005	8960	0.281

Average annual loss

By integration of the loss exceedance curves over the risk investigation time (t=50 years), estimation of the average annual loss takes place. This is equal to **116 million** euro, what corresponds to the **0.50% of the island's GDP**.

Moreover, the *average annual loss ratio (AALR)* is computed as the quotient between the abovementioned total loss and total replacement value for the entire portfolio and is estimated equal to **0.36%**. **Table 7** lists the aggregated average annual loss for the entire island and for the major cities (the assumption of two grid cells for all cities was adopted for compatibility). Limassol presents the highest expected annual loss due to both its increased seismic hazard and exposed buildings value. Moreover, the population exposed to the corresponding seismic risk (here structural loss) is also listed. It is interesting that Nicosia's exposed population is almost as high as Nicosia's for significantly lower average annual loss, what is explained by the high population density of Cyprus capital.

Table 7. Average annual loss (in euro) and corresponding exposed population

	Total	**Nicosia**	**Larnaca**	**Limassol**	**Paphos**
AAL	116,176,893	6,677,008	8,709,120	12,328,240	8,672,600
Population	1,022,406	50,072	37,232	54,248	33,643

Figure 27 illustrates the disaggregation of the total average annual loss per structural typology and Figure 28 the disaggregation of average annual loss ratio per structural typology. The latter has been computed over the total replacement value assumed per typology. From both Figures, it is evident that masonry and no ERD low to mid-rise buildings contribute the most to the total average annual loss being the most vulnerable typologies. This is even more evident from Figure 28. The latter typology corresponds also to the largest building population what places it on top of the overall loss contribution ranking (Figure 27). No observation of spatial correlation of specific typologies with increased seismic hazard can be made.

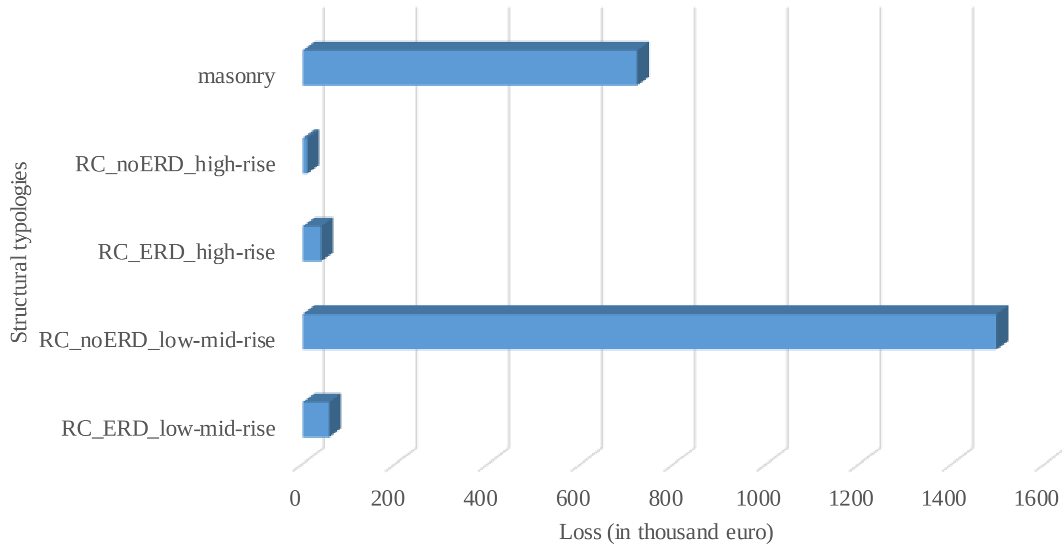

Figure 27 – Disaggregation of average annual loss per structural typology

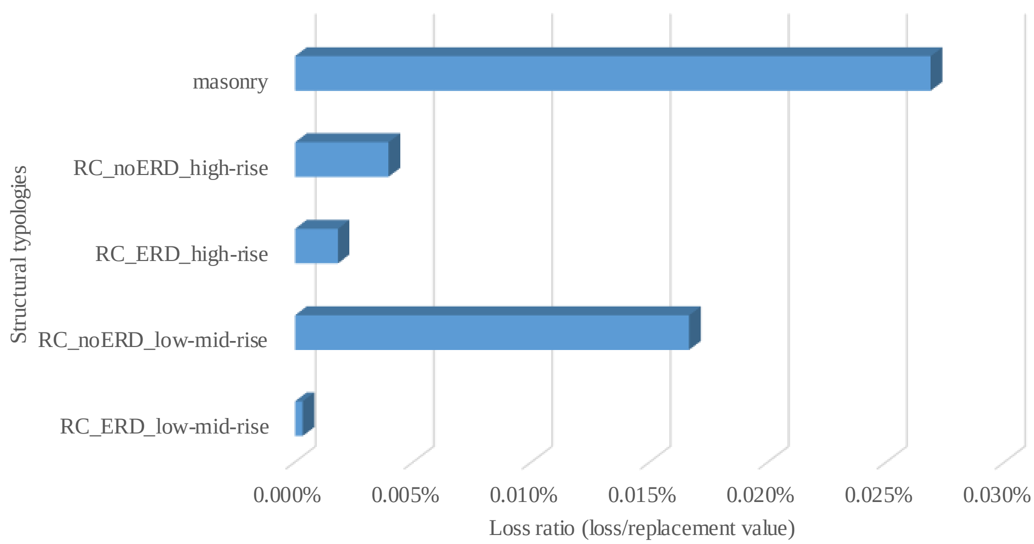

Figure 28 – Disaggregation of average annual loss ratio per structural typology

Loss maps (Distributes losses)

The probabilistic loss maps below (Figure 29, Figure 30) contain the aggregated average losses per grid that have a specific probability of exceedance within a 50 years time-span throughout the region of interest. As expected, the spatial loss distribution does not change for the two return periods and highest loss is concentrated at the big cities, although the hazard is not equally distributed. It is noted that Limassol presents the highest expected loss while the affected area of Nicosia is more expanded as opposed to Paphos and Larnaca.

The graphs of Figure 31 and Figure 32 demonstrate the disaggregation of total average loss and loss ratio per structural typology for the two return periods. Results are compatible to what discussed about the average annual loss and the highest contribution of loss is attributed to the no ERD low to mid-rise buildings (for total loss) and masonry (for loss ratio). It is characteristic that for both return periods the loss ratio for masonry buildings exceeds 50%, what, in a simplified way, means that for the potential seismic event with 10% probability of occurrence in 50 years, the expected damage to the masonry building stock could lead to the loss of more than 50% of its total structural value.

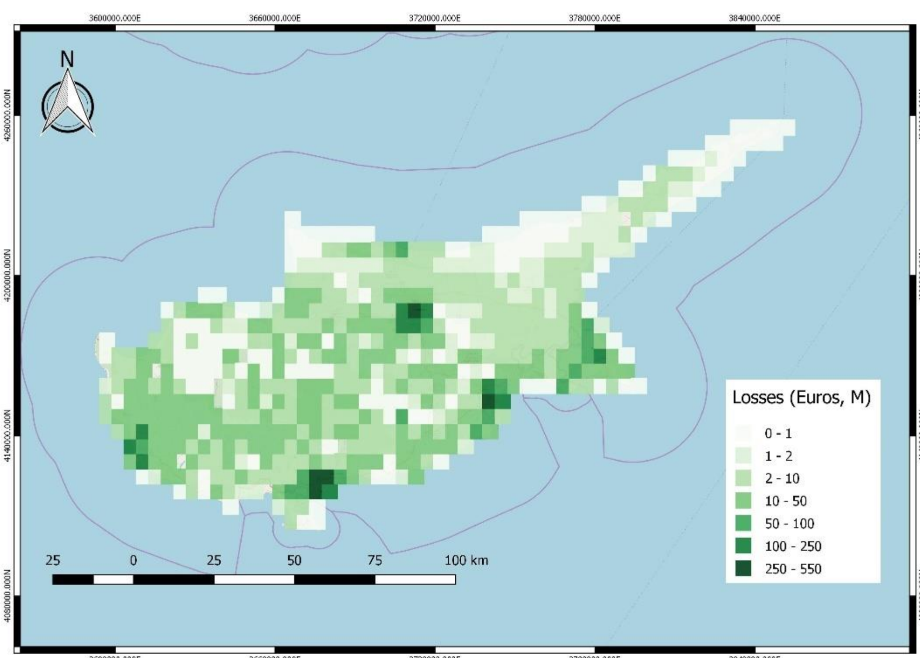

Figure 29 – Loss map (in million euro) for 10% probability of exceedance in 50 years (T=475 years)

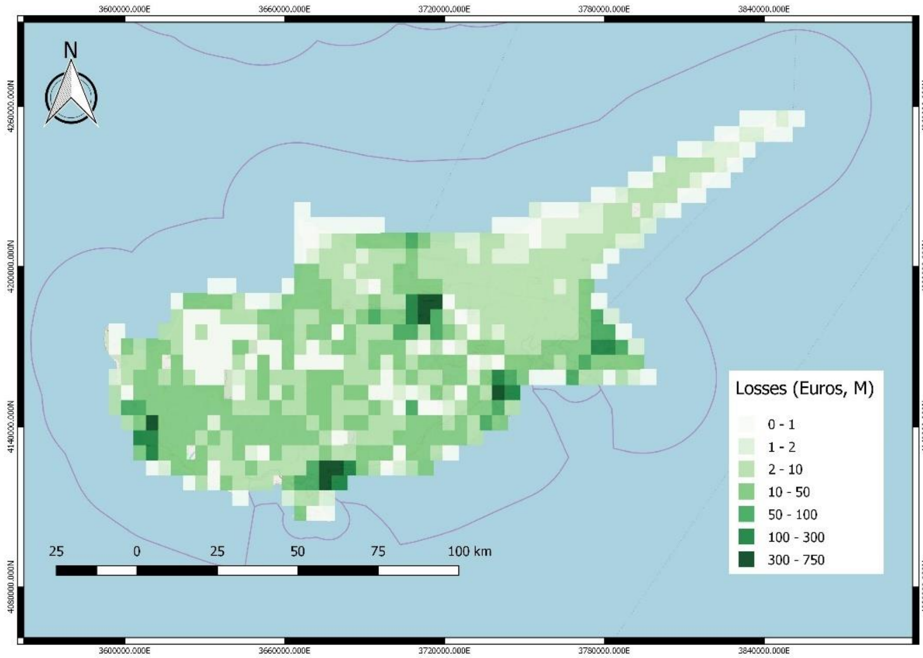

Figure 30 – Loss map (in million euro) for 2% probability of exceedance in 50 years (T=475 years)

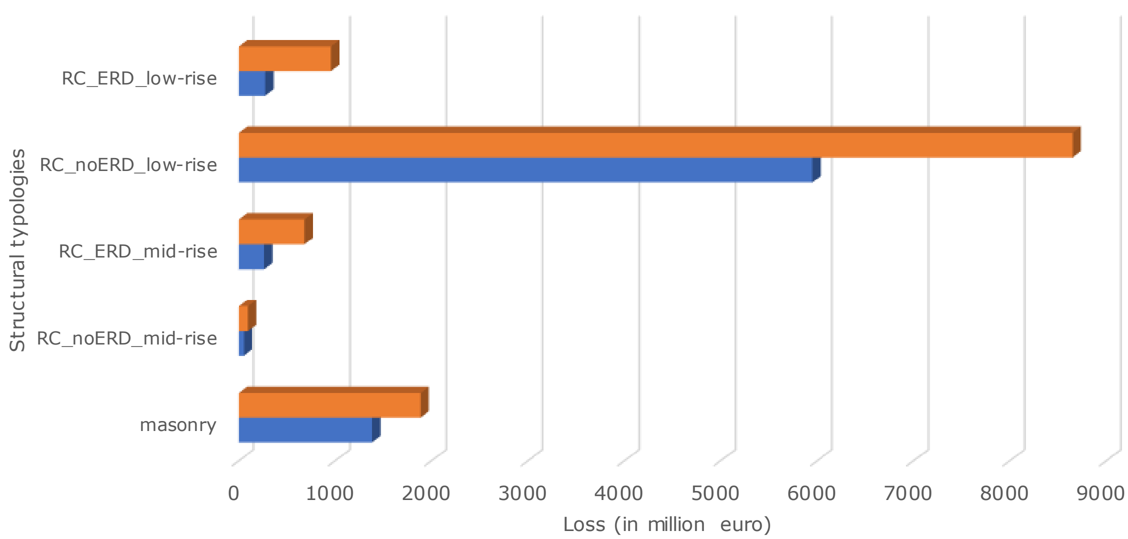

Figure 31 – Loss per structural typology with 10% and 2% probability of exceedance in 50 years (T=475 and 2500 years)

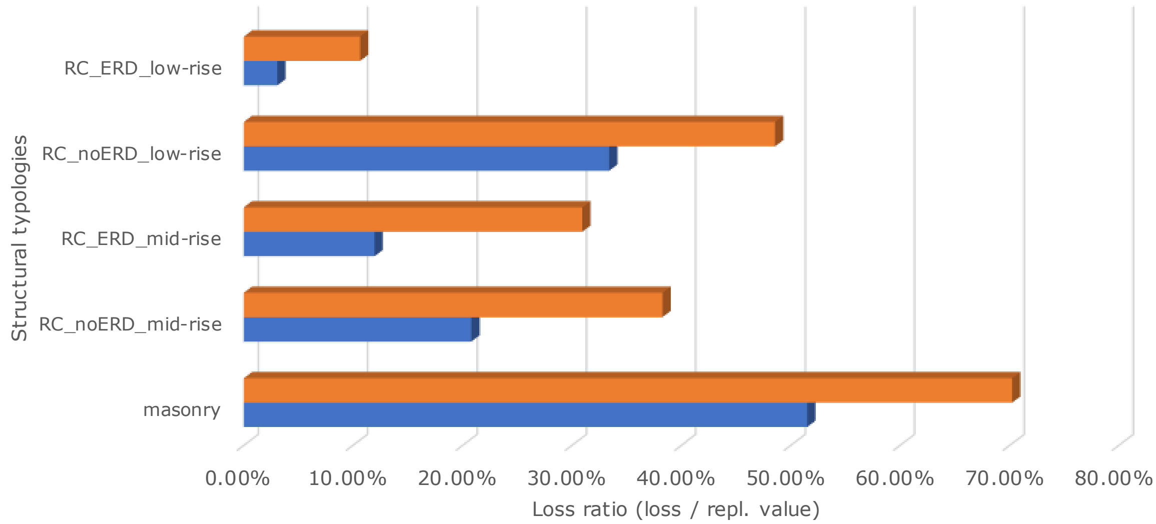

Figure 32 – Loss ratio per structural typology with 10% and 2% probability of exceedance in 50 years (T=475 and 2500 years)

6 SCENARIO-BASED RISK ANALYSIS

Two seismic scenarios have been analysed. The first has probability of occurrence 10% in 50 years (or return period of 475 years), leading to aggregated loss with 10% probability of exceedance. The second one has 2% probability of occurrence (or return period of 2500 years) with loss with respective probability of exceedance. The selection of the earthquake ruptures has been randomly made among all the different realizations (15) of the stochastic catalogue. The GMPE that was decided to be implemented was that of Akkar and Bommer (2010) following the recommendation of Cagnan and Tanircan (2010). Each scenario was performed for a number of 1000 ground motion fields (for different ruptures within the fault).

InFigure 33, the geometry of the simulated faults and the hypocenter of the rupture, with the given probability of occurrence, are projected on the earth's surface on the island of Cyprus. The fault geometry and characteristics and the rupture magnitude of the selected events are summarized inTable 8.

Figure 33 – Projected geometry of faults of seismic scenarios on the island of Cyprus (green line depicts top edge of the fault plane, red line bottom edge)

Table 8. Characteristics of earthquake ruptures for seismic scenarios

Return period	**Fault geometry**	**Fault characteristics**	**Rupture magnitude**
T = 475 years	<topLeft lon="33.3458862" lat="34.6093445" depth="6.5558157"/> <topRight lon="33.0992165" lat="34.7026100" depth="6.5558157"/>	Strike: 294.757 deg Dip: 32.353 deg Rake: 0 deg	Mw = 6.9

	<bottomLeft lon="33.4420662" lat="34.7806168" depth="19.8441849"/> <bottomRight lon="33.1949921" lat="34.8740730" depth="19.8441849"/> Length: 50km Hypocenter Lat: 34.741734 Lon: 33.270561 Depth: 13.2km		
T = 2500 years	<topLeft lon="32.6790581" lat="34.6694412" depth="0"/> <topRight lon="32.2133713" lat="35.1708832" depth="0"/> <bottomLeft lon="32.9856491" lat="34.8597031" depth="30"/> <bottomRight lon="32.5207596" lat="35.3623161" depth="30"/> Length: 140 km Hypocenter Lat: 35.004456	Strike: 322.444 deg Dip: 40.522 deg Rake: 0 deg	Mw = 7.7

	Lon: 32.581825 Depth: 13.2km		

Monetary loss outcome

The total average aggregated loss for the T=475 years scenario is **7.71 billion euro** and for the T=2500 years scenario is **9.37 billion euro**.

Figure 34 depicts distribution of the aggregated loss per grid for the T=475 years scenario. Considering the vicinity of the fault to Limassol (**Error! Reference source not found.**) and the high exposure value, Limassol and its surroundings is the most heavily affected area.

Figure 35 illustrates the spatial distribution of the number of buildings that has reached the damage state Collapse for the selected seismic event with 10% probability of occurrence in 50 yeras. It is interesting that although the monetary loss is mainly concentrated in the big cities, heavily damaged building ("Collapsed") are encountered throughout the southwestern Cypriot territory as well as in the surroundings of Nicosia. As previously discussed, old masonry and RC buildings are present throughout the island, they are vulnerable, yet with low individual contribution to the total loss due to their small area and height and low replacement value compared to the newer structures.

As far as the "bigger" scenario is concerned with 2% probability of occurrence in 50 years, Figure 36 and Figure 37 illustrate the corresponding spatial distribution of loss and collapsed buildings. It may be noticed that the affected areas are shifted to the western part of the island, compatible to the faults trace location. Although the maximum absolute number of collapsed buildings is lower, they are encountered in much wider zones than in the previous scenario. Moreover, although the number of collapsed buildings may not change significantly, more important levels of damage are observed to a larger amount of structures. Hence, high losses cover a wider part of the grid, especially towards the West, where Paphos is located.

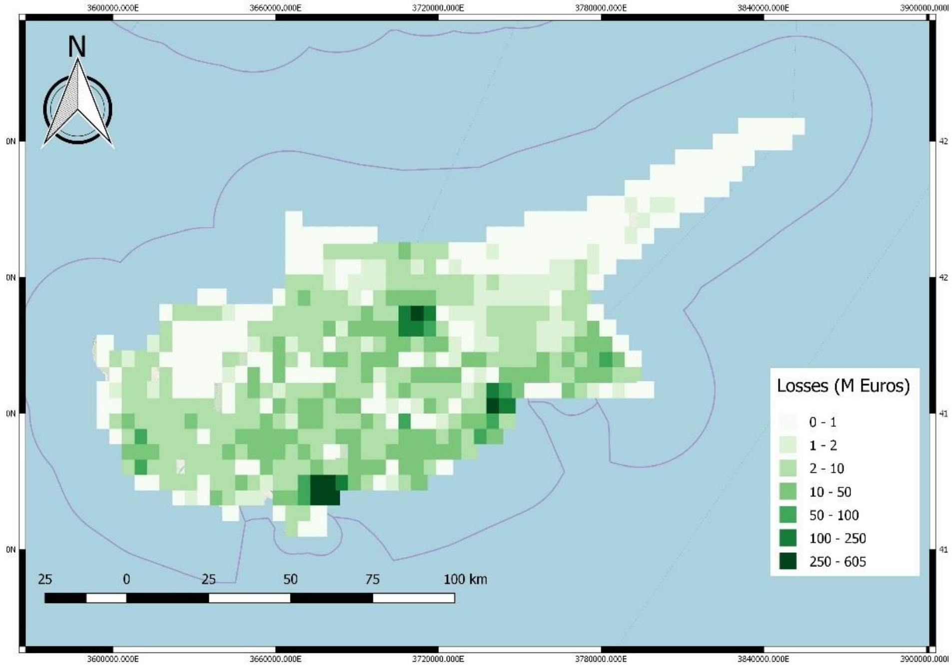

Figure 34 – Loss map (in million euro) for seismic scenario with 10% probability of occurrence in 50 years (T=475 years)

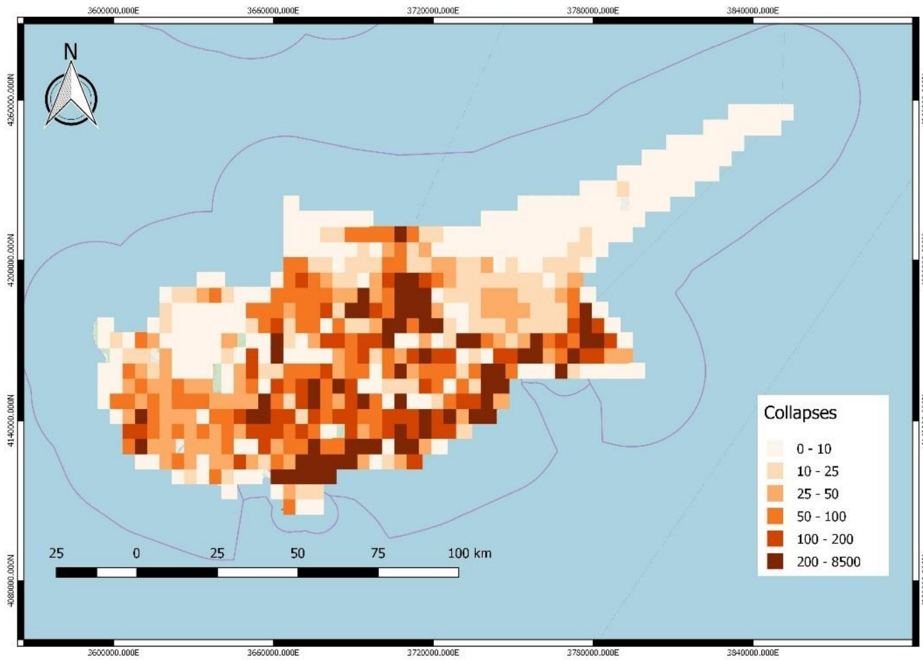

Figure 35 – Collapse map (in number of buildings) as a result of damage assessment for a seismic scenario with 10% probability of occurrence in 50 years (T=475 years)

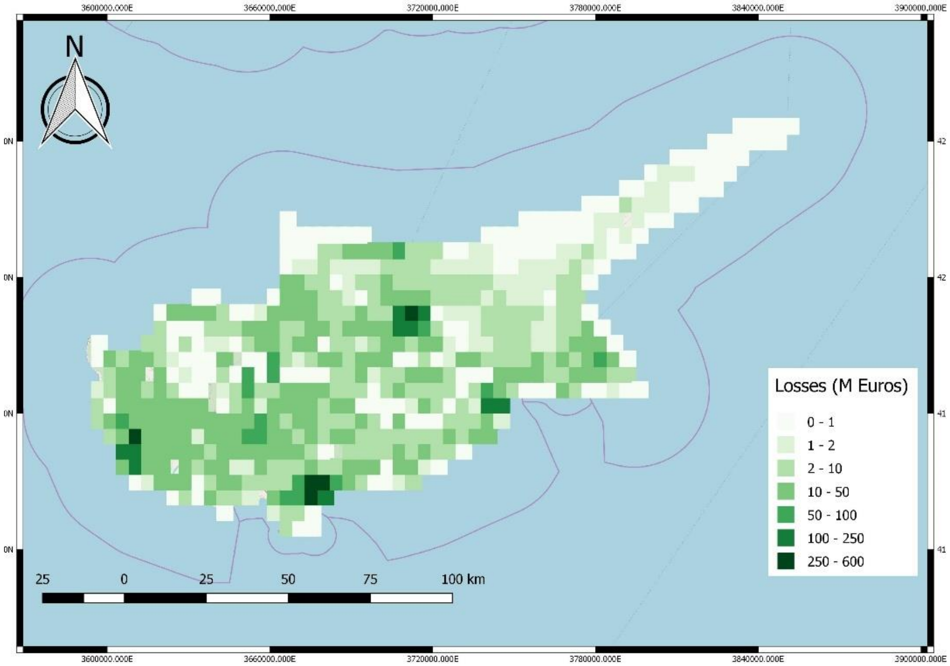

Figure 36 – Loss map (in million euro) for seismic scenario with 2% probability of occurrence in 50 years (T=2500 years)

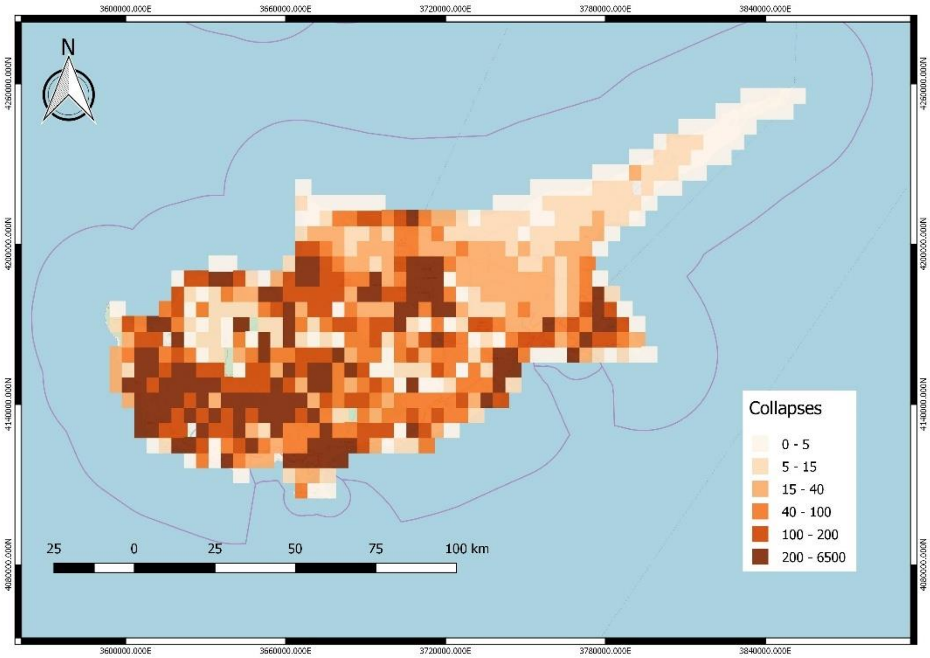

Figure 37 – Collapse map (in number of buildings) as a result of damage assessment for a seismic scenario with 2% probability of occurrence in 50 years (T=2500 years)

Figure 38 and Table 9 demonstrate the number of buildings that suffer from different damage states for the two analysed seismic scenarios. In addition, **Error! Reference source not found.** marks also the ratio of buildings over the total building stock. It is interesting to notice that the 25.64% and the 32.37% of the total building stock for the T=475 and the T=2500 years scenario, is expected to reach the “Collapse” damage state, respectively. Moreover, the 40.07% and 32.19% is expected to present no damage.

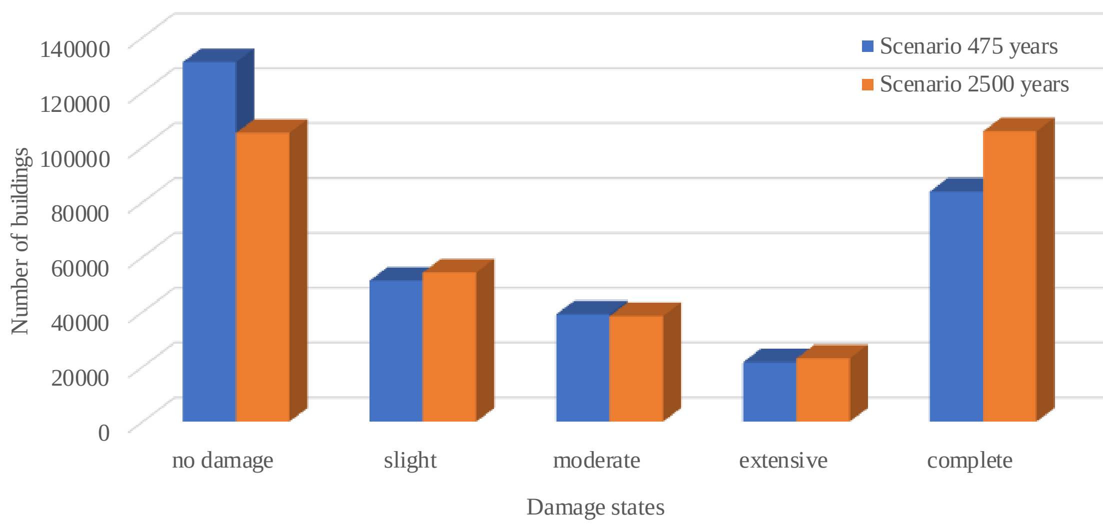

Figure 38 – Distribution of number of buildings per damage state for the two studied scenarios

Table 9. Number and ratio of buildings per damage state for the two studied scenarios

	T = 475 years		T = 2500 years	
	Number of buildings	**Ratio**	**Number of buildings**	**Ratio**
no damage	130,954	40.07%	105,193	32.19%
slight	513,45	15.71%	54,317	16.62%
moderate	39,099	11.96%	38,450	11.76%
extensive	21,621	6.62%	23,069	7.06%

complete	83,812	25.64%	105,801	32.37%

The disaggregation of the damage outcome per structural typology (Figure 39,Figure 40) provides observations for further analysis and indications for potential targeted interventions. Hence, for both scenarios, the majority of "collapsed" buildings are encountered in the masonry and no ERD low-to-mid-rise typology, and especially to the latter one which has the highest building population. This is even clearer with the graph of Figure 41 which depicts the ratio of collapsed buildings per structural typology. It is evident, therefore, that for both scenarios for the masonry and the no ERD low-to-mid-rise typologies, more than 30% of their stock is expected to present damage at the level of collapse.

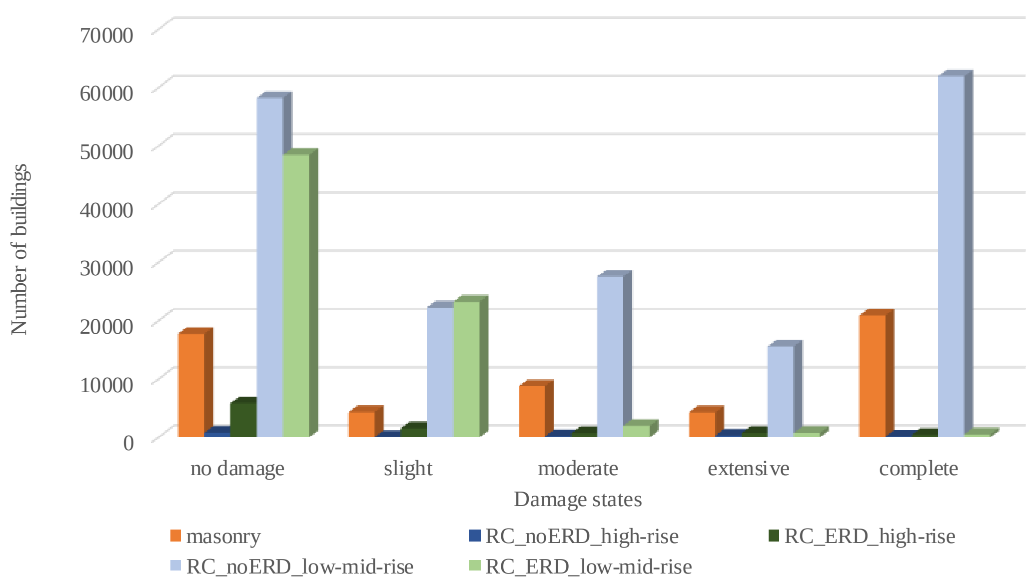

Figure 39 – Disaggregation of damaged buildings per damage state and structural typology for seismic scenario with T=475 years

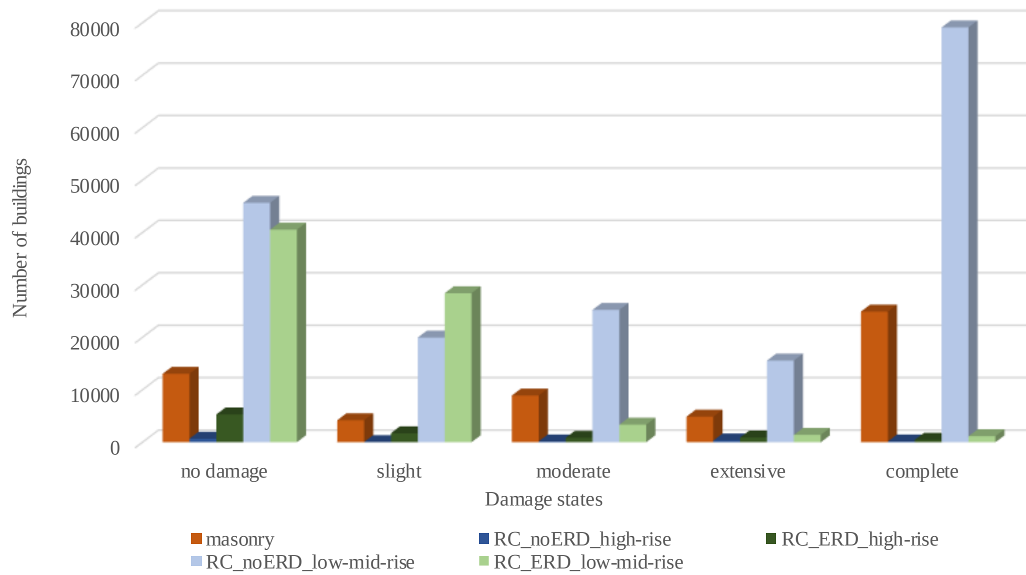

Figure 40 – Disaggregation of damaged buildings per damage state and structural typology for seismic scenario with T=2500 years

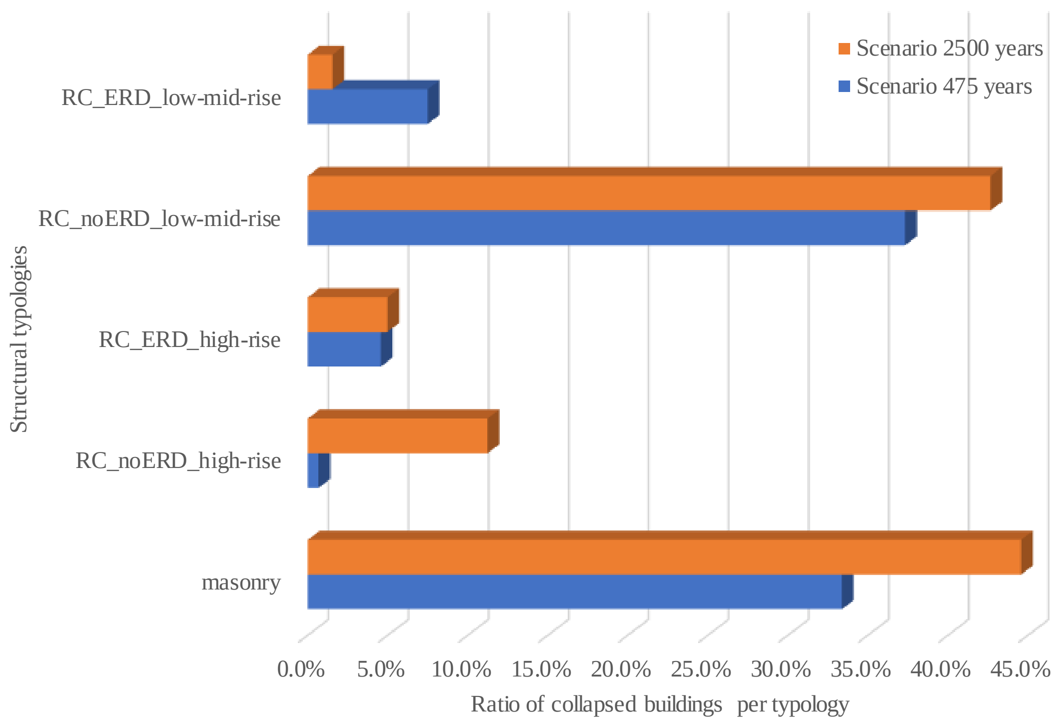

Figure 41 – Ratio of collapsed buildings over total number of buildings per typology for the two studied scenarios

The presentation of results with the ratio of damaged buildings per the total stock per structural typology provides more representative results of the typological performance for each scenario. For the T=475 years and T=2500 years scenarios of Figure 41 andFigure 42, it is evident that more than 30% and 40%, respectively, of masonry and no ERD low-to-mid-rise buildings are expected to reach the "Collapse" state, while a significant ratio of more than 20% of no ERD high-rise buildings presents extensive damage at the 2500 years scenario. It is interesting, moreover, that around 20% of ERD low-to-mid-rise buildings and 10% of ERD high-rise buildings are estimated to suffer from moderate and extensive damage according to the 475 and 2500 years scenario, respectively. This variation may be attributed to the spatial distribution of the building typologies since the main impact zone of the two seismic events varies.

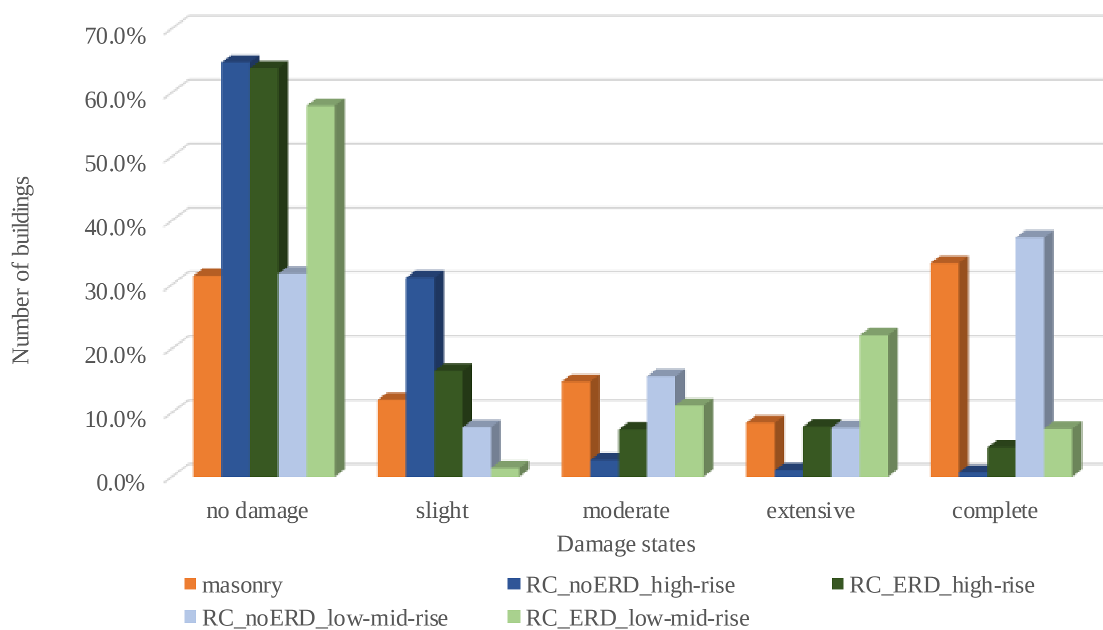

Figure 42 – Disaggregation of ratio of damaged buildings per damaged state and structural typology for seismic scenario with T=475 years

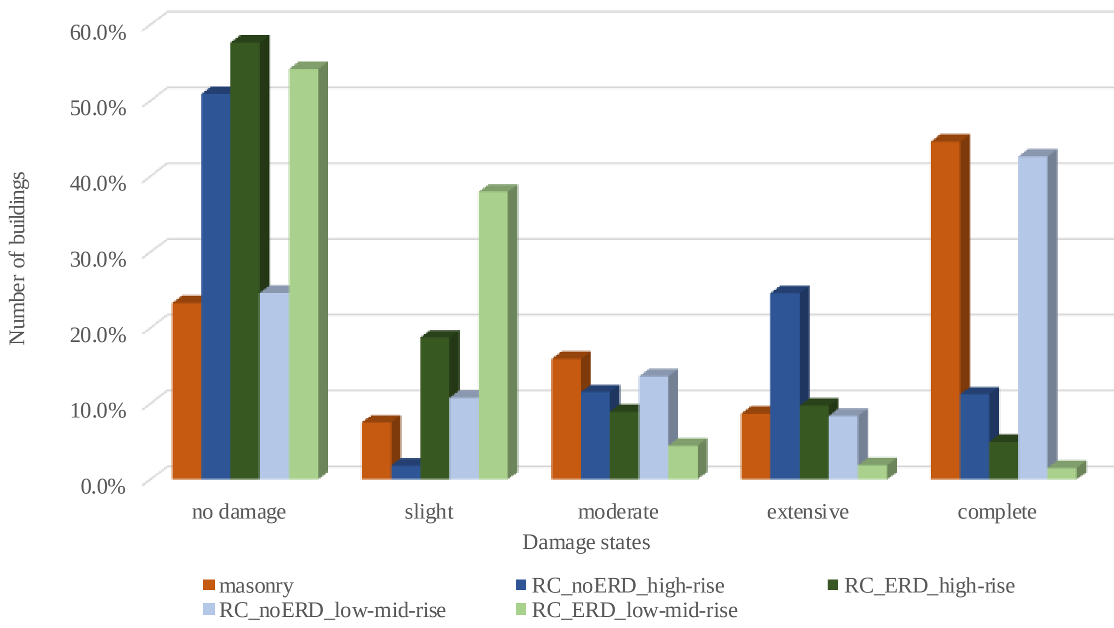

Figure 43 – Disaggregation of ratio of damaged buildings per damaged state and structural typology for seismic scenario with T=2500 years

Human loss outcome

For the seismic scenarios, risk in terms of human loss has been also estimated in order to obtain a number of affected population to be elaborated as order of magnitude for disaster management purposes. This estimate is valuable for preparedness of the Civil Defence and municipalities for healthcare capacities, short and long-term accommodation, emergency response and relevant budget allocation.

Casualities (fatalities)

For the human casualty modelling (fatalities) the model of Coburn and Spence (2002) has been adopted with the values for the parameters as proposed by Spence for Thessaloniki case study (Greece) within LESSLOS project (Spence, 2007). This model enables the straight correlation of casualties with the vulnerability of the buildings, other than their use. Given the predominant presence of RC building, the coefficients corresponding to this typology have been adopted for all building blocks. The casualties (fatalities) have been separately estimated for day and night time, considering 80% of residential buildings and 20% of non-residential. An equivalent casualty model has been computed from which, in combination with "Complete" fragility curves, new fatality-related vulnerability curves were derived for each typology and uploaded to OpenQuake software. The base model is:

$$K_S = [M_1 \cdot M_2 \cdot M_3 \cdot (M_4 + M_5 \cdot (1 - M_4))]$$

Where:

M_1: the occupancy rate per building block (number of people / m^2 of building area). Here it is adopted equal to 0.025, mean proposed value for Thessaloniki (thus 40 m^2 per inhabitant, for simplification equal for all typologies.

M_2: a coefficient that depends on the use of the building at the time the earthquake strikes.

It is taken equal to 0.49 for day time and 0.70 at night time, assuming 80% residential buildings and 20% non-residential. Occupancy rates of 40% for residential building in day time and 75% for non-residential is assumed. Similarly, 75% for residential and 40% for non-residential buildings is assumed for night-time. Further investigation could be made based on actual statistical data, what has been though out of the scope of the present study.

M_3: ratio of inhabitants trapped in the building due to collapse, given “Collapse” state. This parameter is based on empirical data and an average value of 0.18 is adopted for the 475 years scenario and 0.26 for the 2500 years scenario.

M_4: the coefficient that correlates collapse with fatalities (dead or unsavable), taken for RC buildings equal to 0.4 and for masonry equal to 0.1, based on empirical casualty data and building collapse mechanisms

M_5: stands for the mortality due to collapses, taken as 0.7 for RC buildings and 0.45 for masonry buildings, again based on empirical statistical data.

Casualities (injuries)

The scope of this module is to provide an estimation of non-fatal casualties, or injuries in need of a greater degree of medical care and in need of transition to healthcare facilities. The availability of health-care structures in case of a strong seismic event can be, thus, studied so as to be guaranteed. The model adopted herein is the one proposed by HAZUS (1999) for indoor casualties and it has been applied only for Injury Severity 2. Hence, the casualty event tree described by HAZUS (1999) has been trimmed for estimation of Severity 2 injuries, to which all the branching probabilities (all four fragility curves) contribute:

$P_{Sev.2} = [P(ds_{\_S})*P_{Sev,2\_S} + P(ds_{\_M})*P_{Sev,2\_M} + P(ds_{\_E})* P_{Sev,2\_E} + P(ds_{\_C})*P_{Sev,2\_C}] * M_2$

The casualty rates ($P_{Sev,2\_i}$) for each damage state (i) is given in Table 10 and P(ds_i) refers to the fragility function per damage state. The M2 coefficient, to account for occupancy rates at residential and non-residential buildings, differentiating day and night-time, has been equally adopted after engineering judgment which allowed the variation of the initial model.

Table 10. Casualty rates per severity level and damage state (DG)

	Slight (%)	Moderate (%)	Extensive (%)	Collapse (%)
Reinforced Concrete	0.0	0.03	0.10	1.0
Masonry	0.0	0.10	0.20	2.0

The expected number of occupants injured per Severity 2 or in fatal state ($EN_{occupants}$) is a product of the number of occupants per asset at the time of earthquake (day-time, night-time) ($N_{occupants}$) and their probability of being injured ($P_{Sev,2}$) computed as vulnerability curves in loss human ratio terms. The population included in the input file refers to the total registered population per asset, as given by the 2011 Census and elaborated by Chrysostomou et al. (2014).

$EN_{occupants\_Sev,i} = N_{occupants} * P_{Sev,2}$

Displaced population

Earthquakes can cause loss of function or habitability of buildings, as described by the damage grades classification. The estimation of the affected number of population that would need to be displaced provides useful figures (order of magnitude) to stakeholders for anticipation of post-disaster provisions and/or evacuation planning. The households in need of housing are distinguished in those seeking for short-term public shelter at the immediate post-disaster phase and the long-term displaced ones, due to loss of habitability of their homes (red and yellow-tagged buildings). In the current study, the shelter model of HAZUS (1999) has been applied with proper engineering judgment and omission of American-based coefficients only for the long-term displaced population. This refers to the estimated number of inhabitants that would seek for accommodation for a period of several months since their residents are in need of major repairing or rebuilt, due to extensive damage.

The estimated amount of people expected to remain displaced “long-term”, due to severe damage or collapse of their residences, is computed from the probabilities of reaching damage states Extensive and Collapse (fragility curves). The population of the exposure model refers to the permanent population per the 2011 Census, irrespectively of the occupancy, occupancy rate and time of the day.

HAZUS (1999) suggests reduction coefficients to be applied upon the above-estimated numbers, with weight factors based mainly on US reality (ethnic, income, ownership, age considerations). In the current study, these weight coefficients have been omitted but, reference is made to the contribution of social vulnerability to the final estimate.

Based on past experience registered in Gountromichou et al. (2017b) as part of PACES Project, the estimated ratio of the affected population that would seek for long-term public accommodation strongly depends on the economic, age and cultural background of the homeowners. For example, in Emilia Romagna (Regione Emilia Romagna, 2012) only 40% of the evacuated population were housed in tent camps as a large amount of the displaced people has arranged their alternative housing by themselves. Moreover, alternative accommodating structures are often offered (hotels, ships or trains). Finally, the final number will reduce throughout the time, in function to the seasonal weather, age and culture of affected population, geographical location and economic background. It is characteristic that 2 months after Emilia’s earthquake, only 30% of the initial hosts remained in tent camps and only 19% were still in need of housing after 5 months.

Considering the above-mentioned, the Cypriot mentality and family bonds, the possibility of ships to be used as floating residents and the large amount of touristic lodges, the 50% of the estimated displaced population is expected to be in need of public sheltering in tents or other portable structures.

InTable 11, the numbers of fatalities, injuries (severity 2) and long-term displaced population have been listed for the major cities, as emergency and post-disaster management primarily takes place at municipality level. Again, it is underlined that the figures should be taken into account for disaster management purposes as per order of magnitude. For the interpretation of the results, the loss maps of Figure 34 and Figure 36, being the most comprehensive outcome of structural risk assessment, should be combined with the population distribution map of Figure 24 and map of Figure 33 which depicts the trace location of the causative faults for the two scenarios.

As far as the 475 years scenario is concerned, triggered by the activation of a WNW-ESE fault, dipping NNE, in the vicinity of Limassol, leads to about 40 fatalities, for day or night scenario, few hundreds of injuries and around 12,000 potentially long-term displaced residents, in Limassol city and its surroundings. The 2500 years scenario, with a 140m long NW-SE fault dipping NE, located towards the western part of the island, affects less Limassol, yet high numbers are also encountered in this area due to the population and buildings density. Paphos, is the most affected city for this scenario, being in the vicinity of the causative fault, with 30 to 45 fatalities, several dozens of injuries and around 9,000 of displaced people. Nicosia, also, presents a significant number of displaced population for both scenarios, ranging between 3,000 and 4,000, due to its population density, while the injuries, ranging between 30 and 60 people, are considerable numbers. Finally, Larnaca seems to be more affected by the 475 years scenario with 7-10 fatalities, 25-60 injuries and around 3,400 potentially displaced population.

It is noted, that due to the dimensions of the grid cells (1x1km^2) and the intention to keep a compatible approach for all cities, two grid cells per city have been considered, including the city center and some surroundings. Hence, any differences from reported cities population are justified.

Table 12 presents also the ratios of the affected population with respect to the exposed population in the same cell grids. Although the absolute numbers are more useful for disaster management and preparedness purposes, these relative figures provide a more representative picture of the extent each city is affected by each seismic event.

In Table 11, the total affected population of the island is also marked. It may be, thus, commented that, given the high numbers for all scenarios, exceeding by far the summation of the major cities, it is evident that casualties and displaced population is well dispersed throughout the island. These aggregated numbers are useful for centralized administration of the prevention and response of the national seismic risk strategy.

Table 11. Affected population for the two seismic scenarios

Cities	Fatalities				Injuries				Displaced	
	475 years		2500 years		475 years		2500 years		475 years	2500 years
	Day	Night	Day	Night	Day	Night	Day	Night		
Nicosia	6	8	12	17	22	51	30	68	3,003	3,996
Larnaca	7	10	4	5	26	60	10	25	3,412	1,404
Limassol	34	48	29	41	110	219	69	146	12,973	8,456
Paphos	1	1	31	45	3	10	78	176	498	8,973
Total	217	313	381	545	736	1493	878	1778	93,276	110,415

Table 12. Ratio of Affected population for the two seismic scenario

Cities	**Fatalities ratio (%)**				**Injuries ratio (%)**				**Displaced ratio (%)**	
	475 years		**2500 years**		**475 years**		**2500 years**		**475 years**	**2500 years**
	Day	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**		

Nicosia	0.01	0.02	0.02	0.03	0.04	0.10	0.06	0.14	6.00	7.98
Larnaca	0.02	0.03	0.01	0.01	0.07	0.16	0.03	0.07	9.16	3.77
Limassol	0.06	0.09	0.05	0.08	0.20	0.40	0.13	0.27	23.91	15.59
Paphos	0.00	0.00	0.09	0.13	0.01	0.03	0.23	0.52	1.48	26.67
Total	0.02	0.03	0.04	0.05	0.07	0.15	0.09	0.17	9.12	10.80

7 SOCIAL VULNERABILITY AND INTEGRATED RISK ANALYSIS

An integrated strategic planning of prevention and management of natural hazards in countries of any living standard should take seriously into account both physical and social vulnerability. This innovative approach applies to the needs for less technocratic and more anthropocentric adaptation of the concept of vulnerability as the safety of human life doesn't depend only on the severity of the natural hazards and the quality of the built environment but also is related with the socioeconomic and political structures of the community and society.

Social vulnerability is a complex and multidimensional concept, a dynamic and ever-changing situation which, though, for measurement proposes is considered as static. The social vulnerability is a concept that assists to identify those characteristics and experiences of population that enable them to respond and recover from natural hazards (Cutter et al., 2003). Practically, it obtains a (comparative) measure through the variations of variables such as age, gender, education, occupation, economic status and quality of building stock. Socio-economic data that may alternate impacts of seismic hazard on population are generally extracted from National Population and Household Censuses.

The integration and implementation of Social Indices in the vulnerability analysis can contribute to the decrease of seismic risk as it implies that less casualties, injuries and economic losses involved in public health are anticipated. Therefore, in addition to the study on the seismic hazard and its impact on the built environment, it is possible to construct the social exposure model of the area of study, including spatial distribution of the socioeconomic characteristics of the population, such as age, gender, access to resources and education, distribution of income, institutional capacities, religion and other parameters (Cutter et al., 2003). Combination of variations of the above-mentioned socio-economic variables yields to the estimation of the Social Vulnerability Index (SoVI), which consists of a comparative measure of social vulnerability. Combination of SoVIs leads then into a composite indicator, summarizing the distribution of vulnerable population in respect to the damage within the affected area, setting social priorities as respond, preparedness and recovery link to population characteristics. The composite indicator summarizes the complex reality of social vulnerability and is implemented in the vulnerability analysis as modification factor of the final physical risk impacts, as part of the so-called Integrated Risk analysis (Burton et al., 2014)

An integrated risk model combining physical and social risk modules is elaborated by utilizing part of OpenQuake tools. The integration and implementation of Social Indices (SoVIs) into OpenQuake contributes to the decrease or aggravation of physical risk impacts (in loss or human terms), that are calculated either by stochastic event-based or scenario-based risk analyses. This is achieved by the Integrated Risk Modelling Toolkit (IRMT) of Global Earthquake Model Foundation, an open-source GIS-implemented tool that allows the risk analyst to draw conclusions on exposure, casualties prediction, and property loss, due to physical seismic vulnerability of the assets and seismic hazard, and to combine these with socio-economic vulnerability models (Burton et al., 2014). To derive the integrated risk model, a total risk index is constructed by the convolution of the SoVI with the estimates of the average annual loss. The latter is extracted in both aggregated results and in a mapped visualisation of the final risk outcome.

8 CONCLUSIONS

The seismic risk at national level has been calculated by implementation of probabilistic hazard and risk analysis in the OpenQuake risk platform of Global Earthquake Model (GEM) Foundation. The input seismic hazard model is the available European one, developed within SHARE (Giardini et al., 2013) project. From probabilistic hazard analysis, maps with Peak Ground Acceleration (PGA) distributions with 10% and 2% probability of exceedance and respective Spectral Acceleration distributions, have been generated. Moreover, hazard curves, combining the probability of exceedance of a range of intensity levels in terms of PGA, have been incised for the four major cities.

The exposure and vulnerability models have been provided by local studies (Chrysostomou et al., 2014; Kyriakides et al., 2015). The stochastic event-based risk analysis yielded aggregated loss estimates for several return periods, from which the loss exceedance curve for the island has been constructed. The aggregated mean loss and mean loss ratio has been also listed for numerous return periods, up to 10,000 years. The average annual loss and loss ratio were also estimated for the island, equal to 116M euro and 0.36% respectively, and for the four major cities, together with the respective exposed population. Limassol presents the highest impact in monetary terms due to its increased hazard and building stock. Disaggregation of the average annual loss and the average total loss, with 10% and 2% probability of exceedance, per structural typology, allowed for extracting observations with respect to the seismic vulnerability of the different typologies. The distribution of loss for 10% and 2% probability of exceedance has been also mapped on the input exposure grid.

Two seismic scenarios have been selected, based on the outcome of the probabilistic risk analysis. Hence, the first scenario is one among those of the stochastic catalogue that have probability of occurrence 10% in 50 years and the second one with probability of occurrence 2% in 50 years. Loss maps and maps with distribution of the collapsed buildings are produced for both scenarios. The extent of impact is compatible to the location of the fault of each scenario. The number and ratio of buildings that reach each damage state have been also registered, as well in function to the structural typologies, for better understanding of their performance and impact to the overall exposure. For the two scenarios, casualty modelling was also implemented, according to which the number of expected casualties and injuries were given for the day and night scenario for the four major cities and the entire island. Finally, based on literature models and expert's judgment, an approach of the potential population in need of long-term displacement was given. Again, Limassol seems to be the most heavily affected for both seismic scenarios, considering its vicinity to the faults and the high exposed building and human population.

Concluding, it is widely recognised that seismic risk management needs to be supported by scientific estimates of the impact of seismic risk. All the results provide realistic indications of what future seismic scenarios may result and are indispensable for the prevention and preparedness phases of the disaster management cycle. Hence, budget allocation, insurance premiums and institutional resources can be anticipated, as well as designation of evacuation routes or locations of shelters and coordination centers. An insight of social vulnerability and integrated risk assessment is also given in order to promote the further integration of the human aspect into an updated future version of the present risk assessment study.

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9 TSUNAMI

Tsunami hazard in the Mediterranean Sea is low compared to the Pacific Ocean, but it is significant.

Within the Mediterranean Sea (experiencing 10% of global tsunami activity), the tsunami hazard of Greece and Italy is the highest. The Cyprus-Levantine region is classified at the lowest level (Fokaefs & Papadopoulos, 2007). Within this area, the Levantine coast is at much higher risk than Cyprus.

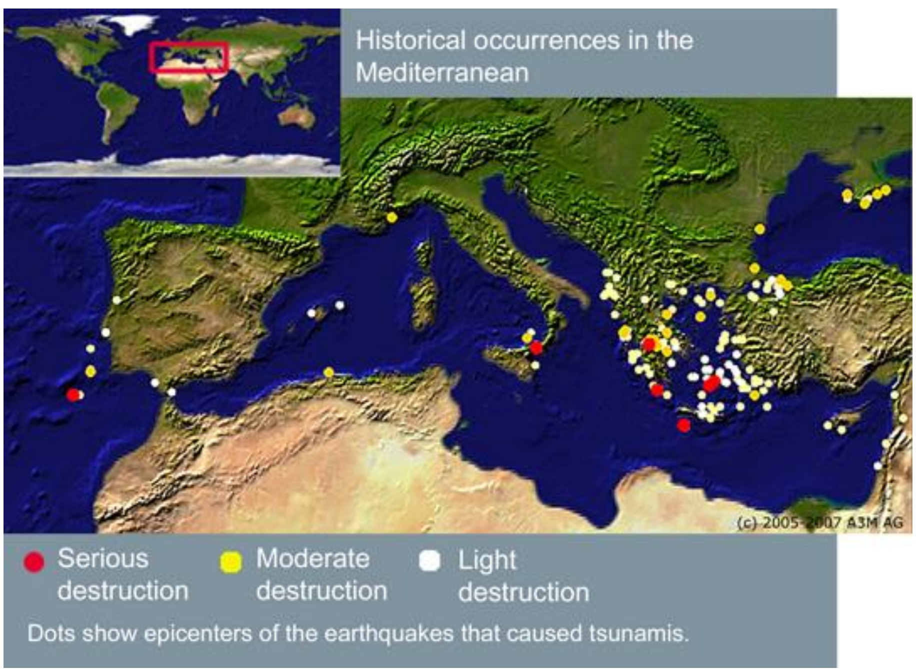


Figure 44

However, for Cyprus an association between tsunami events and earthquakes has been documented through history by

(a) Direct Observations,
(b) Archaeological Evidence &
(c) Geomorphological Evidence.

The destructiveness of some historical events at local scale and the threat caused by regional events signify the need to evaluate tsunami risk by all available means.

The most catastrophic and well documented tsunamis in the Mediterranean are:

May 2003: After a quake near the coast of Algeria a tsunami was generated which destroyed over 100 boats on Mallorca and flooded Palmas Paseo Maritimo.

August 1999: A large destructive earthquake struck north-west Turkey and generated a local tsunami within the enclosed Sea of Marmara. It occurred along the Northern Anatolian Fault zone. Its epicentre was in the Gulf of Izmit. Official estimates indicated that about 17 000 people lost their lives and thousands more were injured.

October 1963: Tsunamis can develop not only in oceans: In Italy, near the town of Longarone, the entire northern slope of Mount Toc slid into the Vaiont dam. The water spilled over the dam and destroyed a number of villages with a wave of 140 metres. 4 000 people lost their lives.

July 1956: The best documented and most recent tsunamigenic earthquake in the Aegean Sea between Greece and Turkey is the one that occurred near the south-west coast of the island of Amorgos, killing 53 people, injuring 100 and destroying hundreds of houses. The waves were particularly high on the south coast of Amorgos and on the north coast of the island of Astypalaea. At these two places, the reported heights of the tsunami were 25 and 20 m, respectively.

December 1908: Due to an earthquake and the ensuing tsunami, the city of Messina in Italy was almost completely destroyed. More than 75,000 people were killed.

November 1755: The Portuguese capital of Lisbon and its inhabitants were particularly badly hit by an earthquake that occurred in the eastern Atlantic Ocean. Two thirds of the city was destroyed from resulting fires. The people seeking refuge from the flames on the banks of the Tejo River were surprised by huge flood waves produced by the earthquake. Some 60,000 people lost their lives. The waves were even observed in Ireland and on the other side of the Atlantic on the Lesser Antilles. On the coastline of the Madeira Islands the waves still had a height of 15 metres.

1672: The Cyclade islands, especially Santorini, were shaken by an earthquake The island Kos, in the east, was completely swallowed by the ensuing tsunami.

1650: A destructive earthquake was accompanied by a submarine explosion from the Colombo Volcano, which crater lies in the sea to the northeast of the island of Santorini. There was a devastating tsunami observed on the island of Ios, north of Santorini, and waves of up to 16 m were reported.

1303 AD: The quake with an estimated strength of 8 destroyed the island Rhodos and the eastern part of Crete. It caused a tsunami which reached the Egyptian coast.

365 AD: The quake of 8 to 8.5 in the year 365 caused heavy destruction on the whole of Crete. The tsunami that developed because of the quake destroyed complete coastal regions as far as Egypt and eastern Sicily. Records indicate that 50,000 people lost their lives in Alexandria.

1628 BC: The coasts of the entire eastern Mediterranean were submerged by flood waves of up to 60m high. The wave, caused by a volcanic eruption on Santorini, a Greek island in the Aegean Sea, and is believed to be responsible for the destruction of the Minoan culture.

Due to the small extent of the Mediterranean Sea, tsunami travel times are small, from seconds up to about one hour in the eastern Mediterranean (see map below).

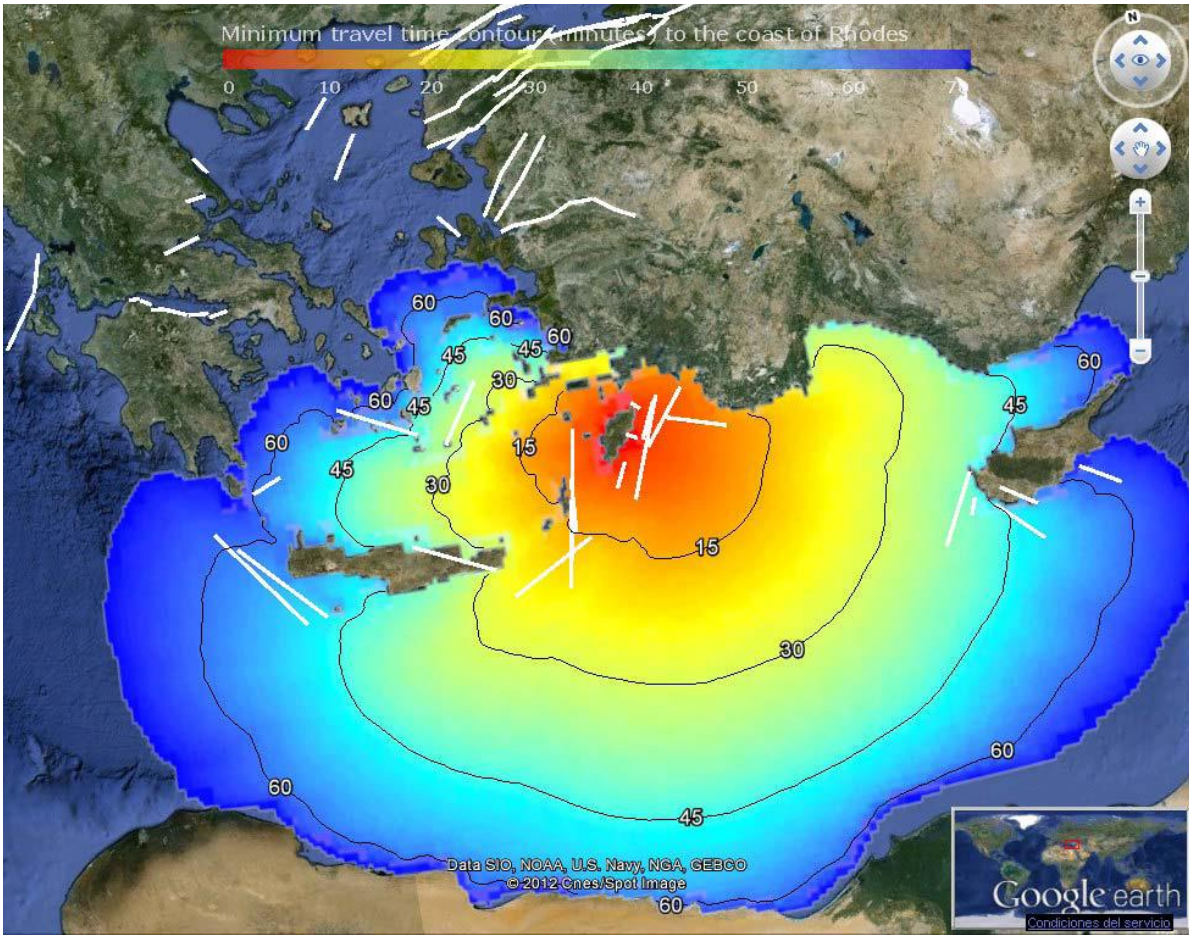
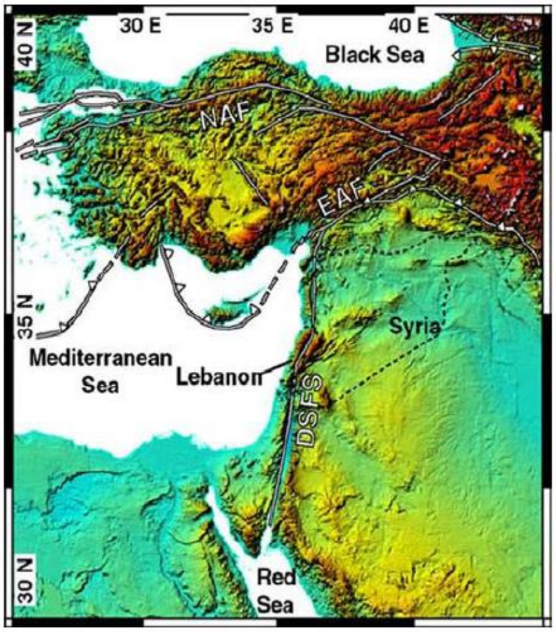


Figure 45

Tsunamigenic areas that may affect Cyprus

The eastern part of the Mediterranean Sea is seismo-tectonically dominated by possible subduction along the Cyprus Arc and the strike-slip Dead Sea Fault System.



There are two main mechanisms of tsunami generation, both of which are relevant to the east Mediterranean. These are:

(1) Shallow, high-magnitude, submarine earthquakes with cause significant vertical displacement of the ocean bottom.

(2) Earthquake-induced submarine landsliding.

Figure 46 – Tectonic setting of the Eastern Mediterranean (after Fokaefs & Papadopoulos, 2007)

The tsunamigenic areas that are expected to affect Cyprus are the Cyprus Arc, the eastern part of the Hellenic Arc and the Dead Sea Fault System. Tsunamis from these areas can originate by:

(a) Local, shallow and strong earthquakes originating along the Cyprus Arc, especially in the west and south-west of Pafos where the seismic activity is considerably higher than the other parts of the arc (e.g. the 1222 and 1953 earthquakes).

(b) Submarine landsliding near the coast of the Levantine Sea which is currently believed to be induced by earthquakes along the Dead Sea Fault System (e.g. the 1202 earthquake).

(c) Regional, shallow and strong earthquakes originating in the eastern segment of the Hellenic Arc, especially between Crete and Rhodes (e.g. the 1303 earthquake).

Reported Tsunamic on the coast of Cyprus

Whereas the Levantine coast has been struck at least 20 times (Salamos *et al.*, 2007) by tsunamis induced by earthquakes of the Dead Sea Fault System, the Cyprus and Hellenic Arcs, there is reliable evidence for **2 occasions that Cyprus was struck by a destructive tsunami (1202, 1222)** and 2 occasions that a non-destructive tsunami was seen in the area (Ambraseys & Melville, 1988, Fokaefs & Papadopoulos, 2007, Yolsal *et al.*, 2007). These are:

Table 13. Reported Tsunamic on the coast of Cyprus and Greece

Date	Source of tsunami	Area affected by the tsunami	Description
1202	Possibly landslide near the Levantine coast due to a strong earthquake in the area of Israel, Syria and Cyprus.	Levantine coast and Cyprus.	The sea between Cyprus and the Levantine coast parted and mountainous waves piled up throwing ships up onto the land. Eastern parts of the island were flooded.
1222	Strong submarine earthquake south of Pafos.	Cyprus.	One of the most destructive events reported in historical catalogues. Earthquake destruction and destructive tsunami flooding in Pafos and Lemesos. The castle of Pafos collapsed and the harbour was left without water.
1303	Strong earthquake in Hellenic Arc between Crete and Rhodes.	From Crete to Levantine coasts.	One of the largest and best documented seismic events in the history of the Mediterranean area. Destructive tsunami in Crete. Damaging sea-wave in Rhodes. Tsunami reported to be seen at SW Turkey, Egypt, Cyprus and Palestine.
1953	Strong double earthquake south-west of Cyprus.	Cyprus.	Small tsunami along the coast of Pafos which caused no damage.

It should be noted that Yolsal *et al.*, 2007, have performed simulations of the 1222 and 1303 events calculating wave heights and their distribution functions in the east Mediterranean.

There is additionally geomorphological evidence for strong tsunami action on the coasts of Cyprus (Kelletat D. & Schellmann, 2001, Whelan F. & Kelletat D., 2002, Noller *et al.,* 2005, 2011), summarized in Figures 47 and 48.

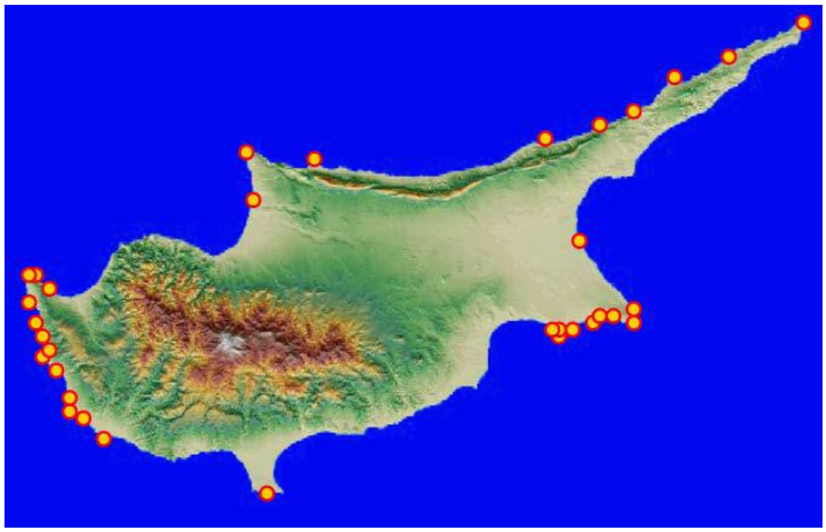


Figure 47 – Distribution of geomorphological features indicating or suggesting origin by tsunami process (after Noller et al., 2005, 2011)

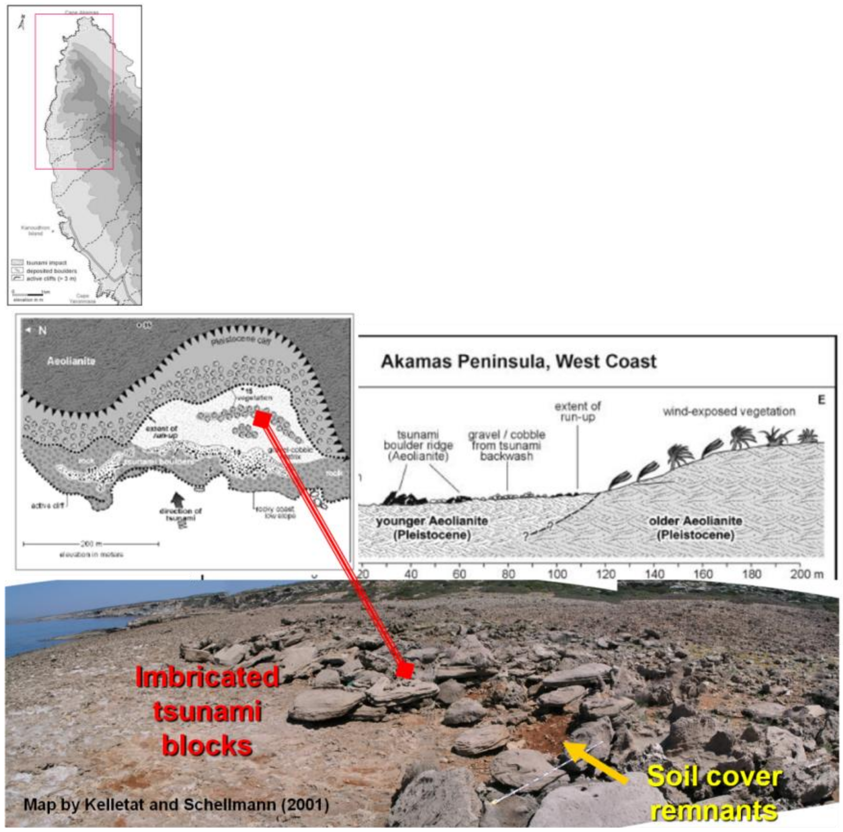


Figure 1: *Tsunami deposits in western Akamas area (after Kelletat & Shellmann).*

Figure 48 – Tsunami deposits in western Akamas area (after Kelletat & Shellmann)

Statistical evaluation of Tsunami Hazard in the Cyprus Levantine area

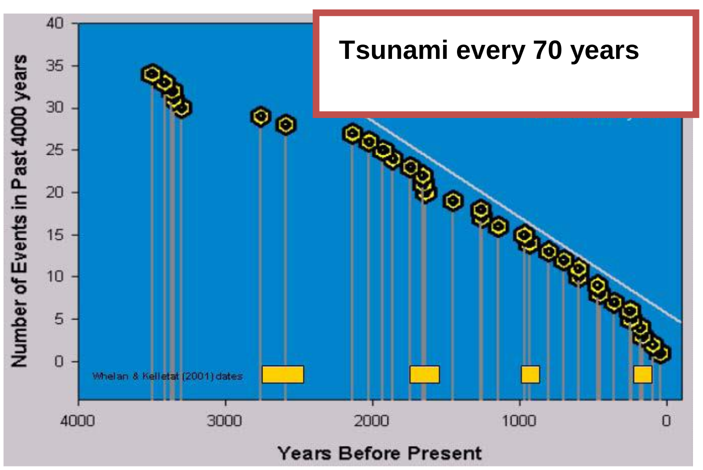
The following table summarize the results of Fokaefs & Papadopoulos, 2007 for the tsunami hazard of the Eastern Mediterranean area of Cyprus-Levantine:

Table 14. Tsunami hazard of the Eastern Mediterranean area of Cyprus-Levantine

Ts un a	Wave height (m)
I – V	<1.0
VI	2.0
VII – VIII	4.0
IX – X	8.0
XI	16.0
XII	32.0

Time Duration	Probab. Intensity >III	Probab. Intensity >V	Probab. Intensity >VIII
1	0.28	0.01	0.0001
50	0.81	0.34	0.13
100	0.96	0.56	0.24

The average tsunami recurrence in the Cyprus-Levantine Sea region is roughly estimated to be around **30 years, 120 years and 375 years for moderate (Intensity > III), strong (Intensity > V) and very strong (Intensity > VIII) events**, respectively. The rate of tsunami occurrence equals 0.033, 8.3 · 10–3 and 2.7 · 10–3 events/year for Intensity > III, V and VIII respectively. For a Poisson (random) process the probabilities of observing at least one moderate, strong or very strong tsunami are 0.28, 0.01 and 3 · 10–3 within 1 year, 0.81, 0.34 and 0.13 within 50 years and 0.96, 0.56 and 0.24 within 100 years, respectively.



However, preliminary results (Noller et al., 2005, 2011) combining geomorphic tsunami evidence and relative and absolute dating for Cyprus show that a tsunami affects the Cyprus coasts every 70 years.

Figure 49

Conclusion

Although the tsunami potential in the Cyprus region is relatively low compared to other tsunamigenic areas of the Mediterranean Sea, destructive local events, such as that of 1222, or threatening remote events of the Hellenic Arc, such as those of 1303, 1481 and numerous others, as well as the strong geomorphological evidence for tsunami activity on the Cyprus coasts, signify the need to evaluate tsunami risk by all available means.

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10 FLOODS – FAST AND URBAN FLOODS

Identification of the most vulnerable, to flooding, areas in Cyprus

The purpose of this task is to give information about the significant historic floods that took place up to year 2011 and identify the most vulnerable, to flooding, areas in Cyprus. The methodology used to identify these areas is described below. Also detailed description is given for each area that is vulnerable to flooding. All the information given in this task were taken from the Water Development Department (WDD). According to the aforementioned report, "Significant floods" are floods that have occurred in the past and have had significant effects and consequences on human health, the environment, cultural heritage and economic activities, and for which the possibility of such future events continues to exist, and major floods that have occurred in the past, which could potentially have a significant negative impact on similar phenomena in the future.

Significant historic floods

The information and description of significant floods that have occurred in the past is an essential part of Article 5 of the Act as a basis for identifying areas where there is potential of serious flood risks. These floods are events given by the Water Development Department (WDD) in a report that identifies areas for which have or may significantly have the potential of flood risks for the period of 1859 to 2011.

In Table 16, major floods are described using basic information (flood date, area code and comments), the geographical location of the affected areas and the name of the river. This table refers to 468 flood events covering the period from 1859 to 2011, as recorded by local newspapers, by the Department of Meteorology, the Water Development Department and other texts (theses / investigations).

Methodology

The methodology for identifying areas with significant potential flood risks was developed by the Water Development Department (WDD) and implemented by a consultant company. Evaluation of the methodology and suggestions for improvement were taken place prior the implementation of the methodology.

The size of a river basin seemed be a useful indicator of the volume and speed of flood flow. These elements also determine the consequences of a flood. Due to the lack of other data, it has been suggested, by the WDD, to use this indicator as a criterion for the preliminary selection of watercourses that can cause significant flood problems. From an analysis performed, concerning the historical floods of watercourses that caused deaths in Cyprus, the smallest of them had a catchment area of 8 km^2 while the average catchment area was 91 km^2. For these reasons, it was decided to use the 10 km^2 basin size as the minimum catchment area. This was taken a basis in the selection of the most vulnerable areas in terms of the flood risk. The main steps of the methodology used are:

1. Identification of the river sections with a catchment area greater than 10 km^2. During this step, GIS tools were used to identify these sections.
2. a. Classification of the following categories:
    i. Development Zones, prevailing the use of housing and the accumulation of new Public areas, with the main objective to be the protection of human health.
    ii. Industrial, Commercial, Craft and Tourist Zones, with the main objectives to be the protection of the economy, human health and the environment.

   b. Identification of historical and cultural heritage sites (based on available data).

   c. Identification of structured areas.
3. Identification of rivers that affect the areas of Step 2.
4. a. Relate all the above steps with historical floods, with reference to the victims and life losses but also to serious flood events without human casualties.

   b. Selection of some river sections used in Step 3 that were related to historical floods with victims and loss of life and / or other major floods.
5. a. Improvements/adjustments in the procedure followed in Step 4 (area selection) for areas with artificial flood protection infrastructures that minimize the likelihood of a recurring of historical flood or its impact.

b. Possible discarding of areas where the river is surrounded by a Protection Zone that covers a large part of the flood plain and mitigates the flood risk.

c. Possible increase of severity / flood risk because of climate change scenarios.

6. a. Possible addition of new areas where the evaluation of historic or non-recorded floods in connection with the current developments indicates a potential flood risk.

   b. Possible addition of new areas after increasing severity / risk because of climate change scenarios.

7. Locating areas with significant historical floods with a river basin size of less than 10 km^2 or another type of flood. Additional areas of significant flood risk, beyond the selection above based on historical data, were included. With the evaluation of the historical flood data, some other areas were added in the group of areas that have potentially significant flood risks. These were not recognized in the previous steps since for example they did not satisfy some prerequisites i.e. areas with a catchment area less than 10 km^2. This step was performed on the basis of historical data and current circumstances where the risk is considered to be significant and should be evaluated.
8. Evaluation of the flood risk recurrence and the significance of future impacts in the areas identified in step 7.

The Figure 50 below is showing schematically the 8 steps of the described methodology.

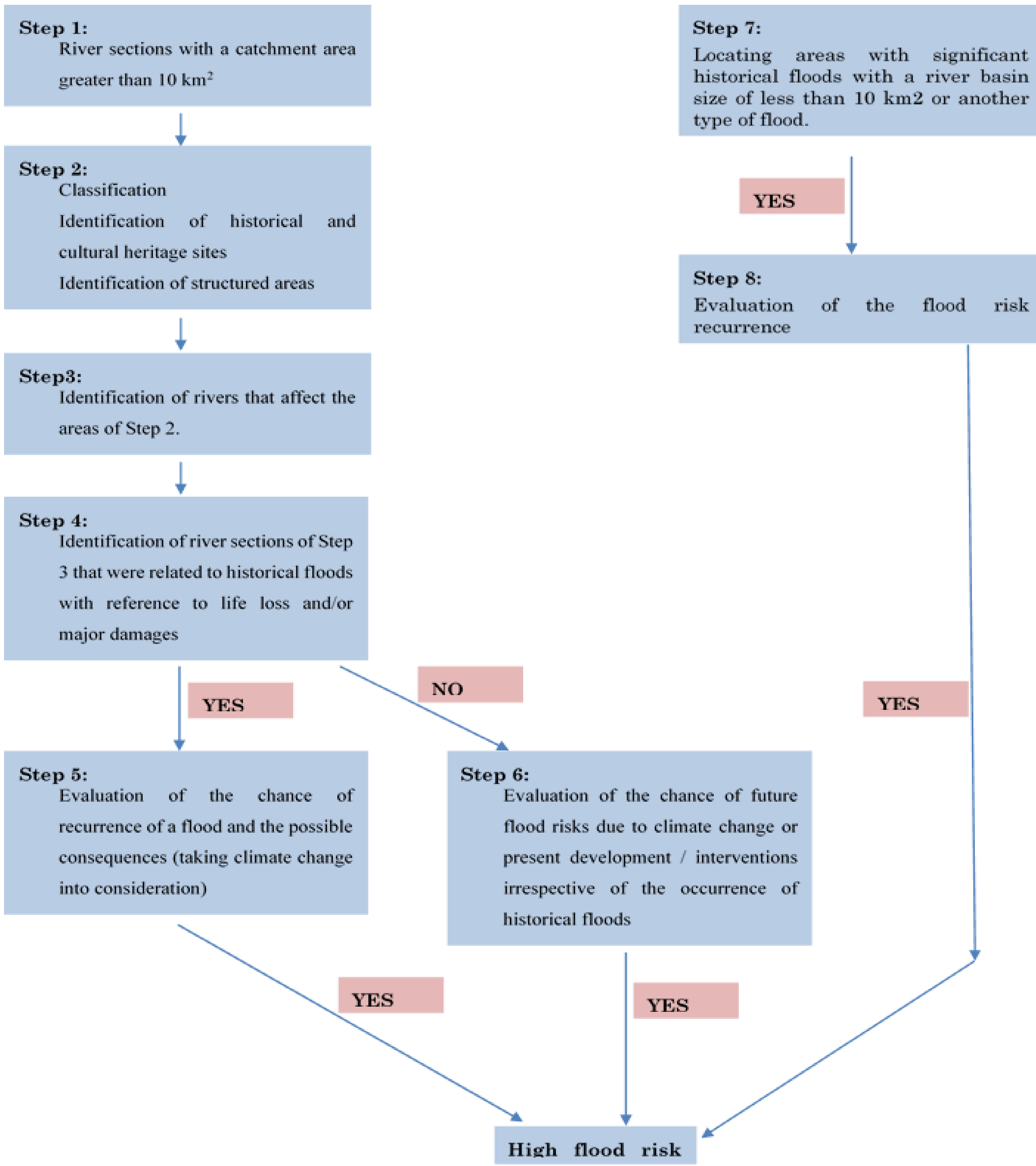

Figure 50 – Methodology for identifying areas with significant potential flood risks

Areas vulnerable to flooding in Cyprus

The areas in Cyprus, that come up, by applying the above methodology, that are having a significant flood risk are listed in this chapter. The following Table 15 shows the 19 identified areas of potential flooding in Cyprus (Table 15). Cyprus has many rivers, shown in Figure 51 while their sections that have a catchment area of more than 10 km^2 are shown in Figure 52. The end result of the above described methodology is given in Figure 53 where all 19 areas of potential flooding in Cyprus are mapped.

Table 15. Areas of potential flooding in Cyprus

A/A	Area Code	Name of River / Stream	Length of river (m)
1	CY-APSFR01	Pediaios	25 310
2	CY-APSFR02	Klimos	5 740
3	CY-APSFR03	Merikas (tributary)	3 250
4	CY-APSFR04	Kalogeros	5 630
5	CY-APSFR05	Merikas	5 690
6	CY-APSFR06	Almiyros-Alikos	7 750
7	CY-APSFR07	Paralimni	3 290
8	CY-APSFR08	Gialias	5 810
9	CY-APSFR09	Ormidia	4 960
10	CY-APSFR10	Archangelos	11 300
11	CY-APSFR11	Kamares	6 640
12	CY-APSFR12	Kosinas	8 770
13	CY-APSFR13	Limnarka	3 380
14	CY-APSFR14	Germasogeia	6 070
15	CY-APSFR15	Vathias	7 700
16	CY-APSFR16	Garyllis	13 730
17	CY-APSFR17	Marketou	3 760
18	CY-APSFR18	Komitis	3 600

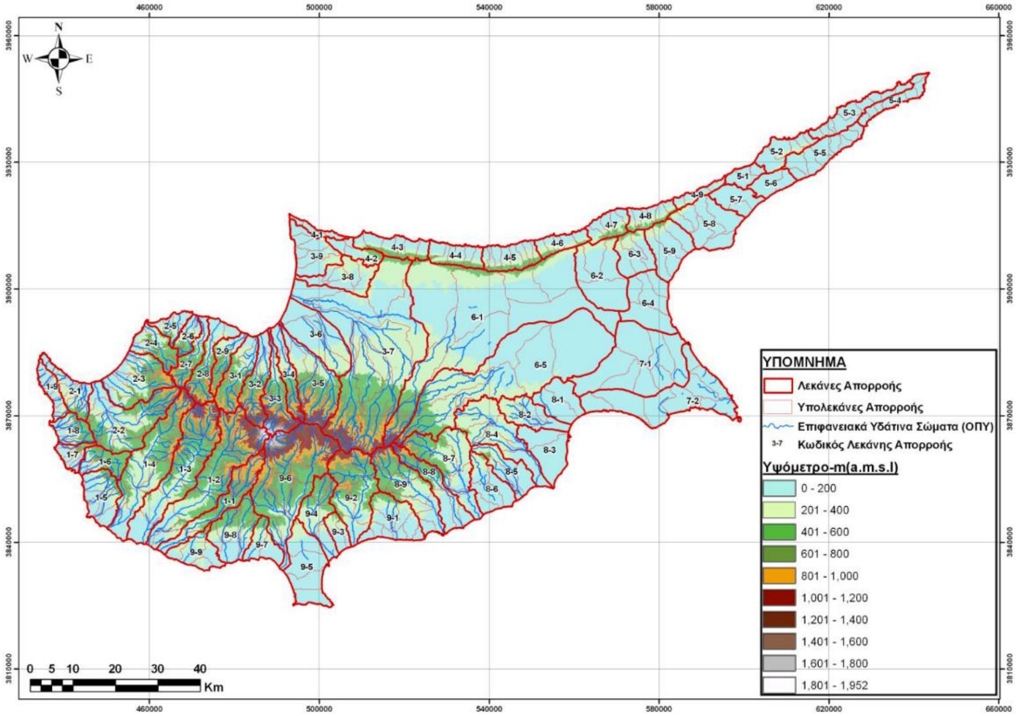

Figure 51 – Rivers in Cyprus with their basins, terrains and surface waterbodies (Source: WDD)

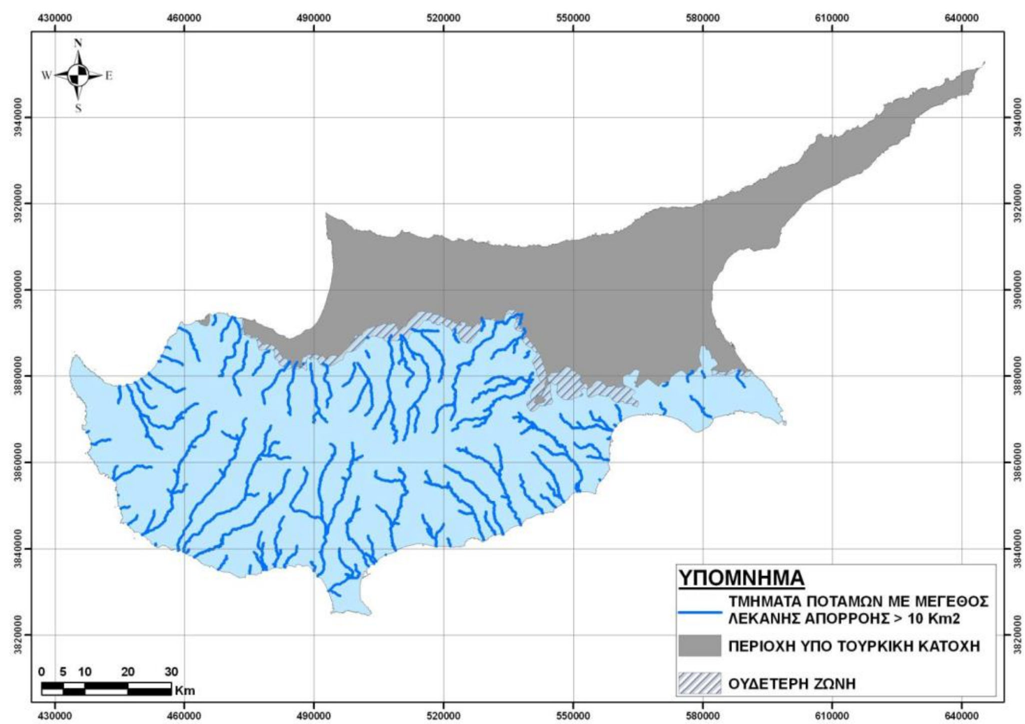

Figure 52 – River sections with a catchment are greater than 10km² (Source: WDD)

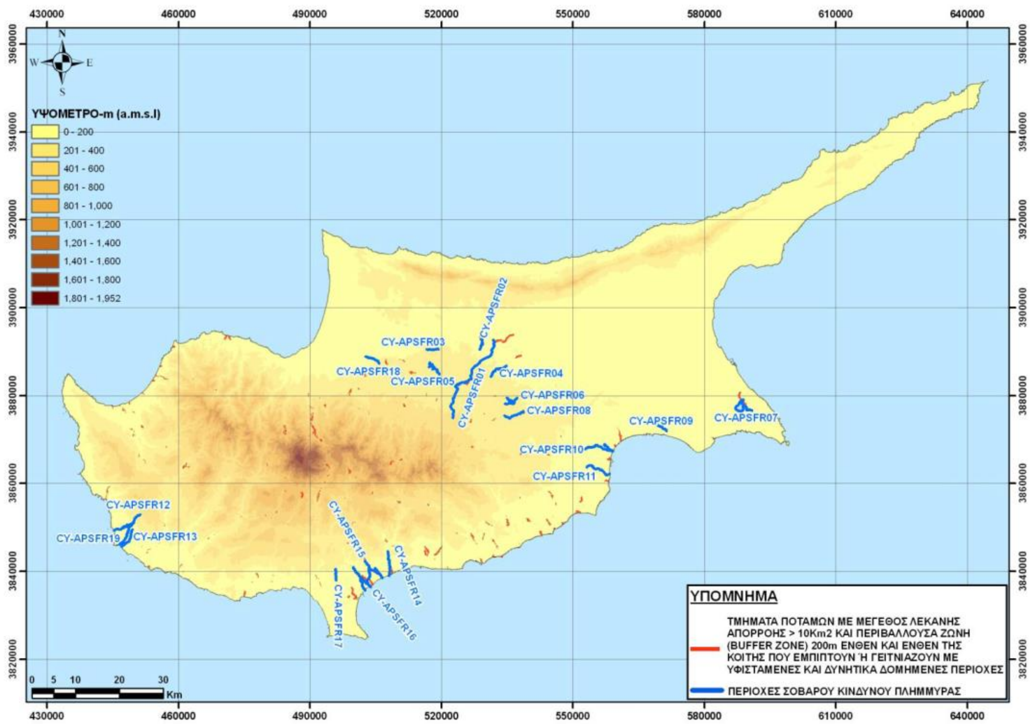

Figure 53 – Areas of potential flooding in Cyprus

Pediaios River

The section of the river affected by floods is from Politiko village to the Municipality of Nicosia and covers a distance of 25.3 km. This river is vulnerable to flash-flooding.

Part of Pediaios River passes through the Residential Communities / Municipalities of Politikou, Pera, Episkopeio, Ergates, Psimolofou, Aidayia, Devtera, Lakatameia, Engomi, Strovolos and Nicosia. The banks of the river are under increasing urbanization and population growth, while areas of the flood plain are used as sports grounds, stadiums, parks, etc. A large number of bridges benefit the transportation but not all of them were constructed with a complete Hydrologic / Hydraulic study. Also, many of these bridges are in the form of Irish Bridges that pose risks.

Over the past 150 years many floods were recorded of low to very high severity. 26 floods were of very low severity (T ~ 6 years), 10 floods were of low severity (T ~ 15 years), 4 floods were of moderate severity (T ~ 38 years) and 4 floods were of very high severity (T ~ 38 years). Some of them also caused deaths. Throughout the river, the riverbed is in the Z3 or Δα1 Protection Zone, varying in width from 20 to 200 m, (mainly this width is 100 to 120 m). The existence of this Zone reduces the risks of serious flood events and their impact. It is also noted that an enrichment dam has recently been built in the Tamasos area which, through correct operation, may allow a form of large flow management.

Klimos River

The section of the river affected by floods is in the areas of Egkomi and Agios Dometios and covers a distance of 3.3 km. This river is vulnerable to flash-flooding in combination with urban-flooding.

Part of the River Klimos passes through a fully urbanized area with Commercial, Industrial and Residential Areas, the Cyprus State Fair and sports grounds (Makarios and closed grounds). In many cases the riverbed is shape formed. There is no Protection Zone on most of the river. Historically there is a frequent presence of floods of very low (T ~ 10-20 years), low (T ~ 17-25 years) and moderate (T ~ 35-50 years) severity. From the entire length of the river section, the 1.9 km is covered (Residential Area of Makedonitissa up to Grigori Afxentiou street), while downstream Afxentiou street, the area is less inhabited, and the 1 km is uncovered.

Tributary of Merika River

The section of the river affected by floods is in the area of Kokkinotrimithia and covers 2.9 km. This river is vulnerable to flash-flooding.

Part of the tributary of the Merika River crosses the Residential Area (H2 and H3 Urban Areas) of Kokkinotrimithia. It is noted that the riverbed is not located in any Protection Zone, thus there is an increased risk of serious flood events. Although there is no evidence of a historic flood, the area is included in areas of severe danger due to its intensive urbanization over the last few years.

Kalogeros River

The section of the river affected by floods is from Strovolos to the Latsia Industrial Area and covers 5.5 km. This river is vulnerable to flash-flooding.

Part of the Kalogeros River passes through the boundaries of the Municipality of Strovolos and ends up in the Industrial Area of Latsia. Important elements are the proximity to the river of the GSP Sports Centre, the Nicosia-Limassol motorway and the Commercial and Industrial Zone that the river passes before it enters the Athalassa Park and ends up in the Athalassa dam. Throughout its length the riverbed is in a Δα1 Protection Zone of varying widths of 7 to 80 m with a prevailed size of 8-10 m. This zone is adjacent locally with Κα8 and Κα6 Residential Zones, with Commercial Industrial Zones Βδ2, Βα3, Εβ4 and Βδκ as well as the Αα1 Public Use Zone. Historically, at least one flood of very low severity and 2 low severity were recorded.

Merika River with Koutis and Katouris tributaries

The section of the river affected by floods is in the area of Paliometocho and Agioi Trimithias and covers 6.1 km. This river is vulnerable to flash-flooding.

Part of the Merika River passes through the Residential Areas of the communities of Agioi Trimithias and Paliometocho. In the Paliometocho area, the river has inflow from the Kouti and Katouris tributaries, which historically exhibited flash-floods of at least one very low, one low and one moderate severity flood (T~100 years). Throughout the length of the river, its riverbed is in a Z3 Protection Zone with a mean width of 50 m which is adjacent to Residential Zones H1, H2 and H3. Shape formation projects of the river or its tributaries that pass through Paliometocho may increase the flood severity. The sections of the 2 tributaries passing through the flow point within the Residential Area should be examined together with the Merika River section.

Almyros – Alikos River

The section of the river affected by floods is in the Industrial Area of Dali and covers 6.6 km. This river is vulnerable to flash-flooding.

The segments and the junction of the Almyros and Alikos rivers are within the important Industrial Area of Dali. These segments were extended up to 500 m upstream of the Nicosia-Limassol motorway. The entire length of the riverbed is in a Z3 Protection Zone with a mean width of 20m. Dali Industrial Area is fully developed with significant industries and large number of employees. Over the past 10 years, 2 very low and 1 moderate severity floods have been recorded. The flood that occurred on 2/12/2003 caused the death of a driver who was drifted with his car. Older floods were not recorded probably because there was no human activity in the area.

Paralimni Laki and its Inlet River

The section of the river affected by floods is in the area of Paralimni covers 2.8 km. This river is vulnerable to flash-flooding.

The part of the river that flows into Paralimni's Lake and crosses Residential Urban Areas is considered as a flood risk area. The part of the river is not in a Protection Zone and houses are very close to its riverbed. In the same area, the Tasos Markos Stadium is a place of frequent use by many people. The severity of the impacts increases due to the low slope of the river itself (~ 0.2%) and the riparian area that is not more than 1-2%. The area has historically encountered at least 2 floods of low and 1 moderate severity.

The presence of the lake downstream is expected to act as a retention and flow control area in the downstream section of the river. Taking into account the intense pressures of plot and housing separation in the areas around the Lake, as well as the environmental status of the Lake as a Natura 2000 area, it is estimated that flood risk maps should also cover the Lake itself.

Yialias River

The section of the river affected by floods is in the Areas of Nisou, Pera Chorio and Dali and covers 5.5 km. This river is vulnerable to flash-flooding.

The area has an increased rate of urbanization, while public areas (stadiums, etc.), near the riverbed, are increasing. The Nicosia-Limassol motorway passes through the upstream part of the river and for this reason the study section of the river was extended by 500 m. Another important element in the area, that increases the severity of floods, is the presence and creation of sinks due to the presence of gypsum rocks that makes the location of some houses unsafe. This phenomenon is enhanced in the presence of floods. The presence of a Z3 Protection Zone, with an average width of 100 – 150 m across the entire length of the river section, reduces to some extent the potential impact of major floods. Also, the construction of an enrichment dam, upstream the river, is under study, while its integration into flood management will be helpful. Historically, 6 - 7 floods of very low (T ~ 15-20 years), 1 of low, 1 of moderate and 1 of high severity (T ~ 100+ years) have been recorded.

Ormidia River

The section of the river affected by floods is in the area of Ormidia and covers 3.6 km. This river is vulnerable to flash-flooding.

The riverbed of the Northeaster tributary of the Ormidia river, which passes through the residential area, has been shape formed for 1 km with an open structure made of concrete with a width of about 6 - 7 m and a height of 1 m. The Northwest tributary that passes the "Vattenas" area has not been subjected to any intervention. According to the community's president an area of 0.3 km^2, located in the western and lower area of "Vattenas", is often affected by floods. The historical floods reported in 1983 and 2010 flooded the area at a height of 0.5 - 1 m. The historic flood file of the Contracting Authority does not report floods in this area. However, the recent costly concrete structure of shape forming the riverbed, as mentioned above, is indicative of a problem in the area. This construction achieved a significant reduction in flood risks, however, it is expected that the risks from the Northwester part of the river should be studied. Also, the existing concrete structure of the riverbed has to be examined and evaluated as to be consistent with the hydrology of the area. It should be noted that Ormidia is within the British Authority areas and is not covered by the Urban Planning Policy Statement. Also, there does not seem to be a Protection Zone for the riverbed.

Archangelos, Kamitsis River and their tributary

The section of the river affected by floods is in the Aradippou-Livadia area and covers 9.95 km. This river is vulnerable to flash-flooding.

A section of the Kamitsi River after the Archangelos River in the Rizoelia region flows for 2300m following the Northernmost boundary of the Residential Area and the Urban Planning Zones of the Municipality of Aradippou. The Agricultural Zone is located North of the riverbed. The riverbed is in a Δα2 Protection Zone with an average width of 40 - 50 m. The river then flows for 2500 m in the Agricultural Zone until it enters the Livadia Residential Area, from where, after 2700 m, it reaches the sea. There is no riverbed Protection Zone in the Livadia area. A tributary, from the Northeast, also crosses the Livadia Residential Area and joins the Kammitsi River at a distance of 500 m from the sea. In the Livadia area, the river passes through the K6 and K8 Residential Zones, the Eβ6 Commercial Zone, and the Bε1 Economic Activities Zone. The areas of Aradippou and Livadia, that face serious flood risks, are treated in the same way because the same rivers pass through both areas. According to the record of historical floods, Aradippou and Livadia areas have suffered at least 5 floods of very low (T ~ 20 years), 1 flood of low and 1 flood of moderate severity (T ~ 100+ years). An important fact in Livadia area is the very low slope of the terrain that prevents the rapid flood discharge to the sea, while in Aradippou the proximity of the residential area to the riverbed creates serious dangers. The Protection Zone in Aradippou area offers some reduction in flood risks. It should be noted that in Livadia area there have already been some projects for the shape formation of the existing riverbed, while some flood prodection strucures (dams) are under study for both Archangelos and Kamitsis rivers, upstream of the Aradippou community.

Kamares River

The section of the river affected by floods is in the Kamares area and covers 6.7 km. This river is vulnerable to flash-flooding and urban-flooding.

A section of the Kamares river passes through the “Kamares” Residential Area and then passes near the waste treatment plant of the area (possibly inactive), the main road of Larnaca-Limassol and the Kamares Monument and ends up flowing towards the sea through a riverbed parallel to the border of the Aliki in Larnaca area. The whole area, mainly the area of the main road near the Kamares monument, has a low terrain. From a point, 460 m upstream to downstream, the riverbed has been shape formed, underground, for the flow of the water. The Hydrological / Hydraulic sufficiency of this structure should be examined. The historical record of floods shows that over the last 30 years the area has suffered floods of very low (T ~ 8 years), low (T ~ 10 years) and moderate severity (T ~ 30 years). The existing riverbed that passes the inhabited area is not in a Protection Zone.

Kosinas River

The section of the river affected by floods is in the areas of Mesogi, Paphos city and Chlorakas and covers 9.4 km. This river is vulnerable to flash-flooding and urban-flooding.

Kosinas River flows from Mesogi (high altitudes) and reaches the sea (7 km downstream) with a relatively steep slope (5-6%). It runs through Residential Areas, which are rapidly being developed, while the Coastal Zone has been developed with hotels and tourist accommodation. The riverbed is locally covered by a Protection Zone of an average width of 30 - 40 m. The severity of the floods in the area is constantly increasing in line with residential development within the flood plain of the river and the rush of the stream flow, due to its natural inclination. Concluding, this river should be studied to obtain the necessary provisions for a smooth flood management. In the very recent past there have been floods of very low severity (T ~ 5 years).

Limnarka River

The section of the river affected by floods is in the area of Paphos city and covers 5.4 km. This river is vulnerable to flash-flooding and urban-flooding.

The river of Limnarka stems from Mesa Chorio and Armu areas, and mainly passes through the eastern boundaries of the city of Paphos, through areas that have recently developed intense urbanization. The section of the river of interest, starts at 450 m upstream of the important traffic junction on the Limassol-Paphos motorway and flows into a Protection Zone with an average width of 60 – 70 m but in some cases up to 20m, at a distance up to 1700m downstream, where the Paphiakos Athletic stadium is. From this point and for 3 km up to the sea, it passes through Residential and Tourist Zones without the existence of a Protection Zone. Between the traffic junction and the stadium there are several commercial and industrial developments within the potential floodplain of the river. During the last 10 years in the area, through which the river flows, there are flood problems at the motorway junction, the junction the Paphiakos stadium and the coastal Poseidonos Avenue. Very Low severity floods with a 3-year return period and moderate severity floods with a 5-year return period have been recorded. Also, a high severity flood has been recorded. Flows are expected to increase with continued urbanization and possible integration of the river as a recipient of urban rainwater.

Germasogeia River

The section of the river affected by floods is in the area of Germasogeia and covers 6.1 km. This river is vulnerable to flash-flooding.

The section of the Germasogeia River downstream the Germasogeia dam (with capacity of 13.6 million m^3) has inflows from small tributaries and local rainfall. During its course to the sea (6 km), it is in a Δα2 Protection Zone with an average width of 375 m, up to 800 m from the beach where the Tourist, Residential and Commercial Zones are. The aquifer in the flooded area of the river is artificially enriched with discharges from the dam and the South Pipeline, and water is used for water supplies for the area of Germasogeia - Amathountas and Limassol. In recent years, there was an increase of urbanization of the river area and pressure has been put on to use public land within the Protection Zone (eg stadiums, parking areas, etc.). The dam acts as a flood inhibitor, but there is a serious risk of flooding when the dam is full or almost full.

Vathias River and its tributary

The section of the river affected by floods is in the areas of Mesa Geitonia, Agios Athnasios and East most region of Limassol and covers 11.8 km. This river is vulnerable to flash-flooding and urban-flooding.

Vathias River flows from the hills of Fasoula and Spitali (Limassol) to about 8 - 10 km from the city centre of Limassol. At a point, 450 m above the Limassol-Pafos motorway, the river is divided into 2 sections that enter the Limassol district and end up in the sea. The western part of the Vathias river does not seem to have a riverbed. Most of it has been covered with buildings and residences. The area is at low topographical level and accumulates a large stream of rainwater. From the point 500 m downstream of the former Athenaidion High School, the river connects with the old riverbed of the Garyllis River and ends up in the sea by the old harbor. The eastern part of the river is in a less developed Residential Area, following a route up to the Macedonia Avenue. At 650 m downstream of this point, it joins a tributary that originates from the area of Agios Athanasios and together follow a course parallel to the Griva Digeni street, expelling near the hotel “Crowne Plaza”. The entire length of the riverbed is not covered by a Protection Zone. It passes through Residential, Commercial and Tourist Areas. Despite the existence of hydraulic facilities in the area, flash-floods of high flows with a return period of more than 20 years cause problems and pose risks. The flow of this river has increased and is expected to increase even more with the ongoing urbanization and the building up of new areas. Typical urban rain drainage projects do not cover the existing size of the flash-floods presented by this river. It is very likely and reasonable that the drainage plan of the areas through which this river passes to integrate it as a natural recipient.

Garyllis River

The section of the river affected by floods is in the areas of Polemidia, Agios Antonios and Karnagio (Limassol) and covers 10 km. This river is vulnerable to flash-flooding and urban-flooding.

The section of the Garyllis River, 1300m downstream of the Polemidia Dam, passes through a residential area, without the riverbed being into a Protection Zone. From the point of Macedonia Avenue, the river has been diverted to a new riverbed leading to Limassol's "Karnagio". The old riverbed passes through the area of 4 "Fanaria" and the church of Agios Antonios reaching the sea. The old riverbed is also flowing from the western part of the Vathias River at a point 500 m downstream of the former Athenaidion High School. Historical reports of floods refer to huge damages and casualties (1880 AC and older), which led to the deflection of Garyllis River. With the construction of the Polemidia Dam (with capacity of 3,4 million m^3) and the deflection of Garyllis River, the significant risks have been reduced except in the case of overflowing the dam. The current riverbeds remain as recipients of rainwater and are expected to be included, wherever possible, in local rainwater drainage plans. Due to the route of the sections through residential and commercial industries and the absence of protection zones, and the creation (under construction) of new public areas (Linear Park, playgrounds etc.), ensuring proper flood management of low and moderate severity is considered necessary. In the past, floods of very low severity (T ~ 20 years) and low severity (T ~ 50 years) have been recorded.

"Argaki of Marketou" River

The section of the river affected by floods is in the area of Ipsonas and covers 2.7 km. This river is vulnerable to flash-flooding.

Part of "Argaki of Marketou" river flows next to the Industrial Area of Ipsonas and passes through the western part of its Residential Area. The riverbed up to a distance of 1200 m from the Industrial Area is covered by a Protection Zone with an average width of 30 – 40 m. The historical record of floods refers to flood events but does not accurately determine the affected areas, although the damage may seem to be in the areas downstream of Ipsonas village. The flow of the river ends up to the west of the Port where, along with flows from other watercourses, the floods occur in the area of Zakaki.

Comitis River

The section of the river affected by floods is in the area of Astromeritis and covers 3.8 km. This river is vulnerable to flash-flooding.

Part of the river Comitis passes through the Residential Area of Astromeritis (H1, H2 and H3 Residential Zones). In this section, the riverbed is not in a Protection Zone. The artificial formation of the riverbed is likely to increase the severity of the impact of floods. In the recent past, at least one moderate severity flood has been recorded (18/1/2010).

Vasilikos Stream

The section of the river affected by floods is in the Paphos city and covers 7.4 km. This river is vulnerable to flash-flooding and urban-flooding.

Vasilikos stream in Paphos springs from the area of Mesogi and passes through the Residential Area of Paphos before reaching the sea (6500 m). Beyond the width of the natural riverbed, there is no further Protection Zone, resulting in having houses and Public infrastructures very close to or within the riverbed (e.g. Paphos Swimming Pool Centre). Although the stream has a catchment area of less than 10 km^2, it is considered essential to be considered as an area with severe floods due to its slope and its route coming from a Residential Area and Tourist and Commercial Zones. It should be noted that the area nearby the Paphos Swimming Pool Centre, is a place of frequent use with too many users. It has been hit by floods at least 2 times in the last 20 years with serious damages. Due to the ongoing intense urbanization, it is expected that flood events will be more frequent with serious economic consequences and potential impacts on human health. The stream has a riverbed up to 1.8 km from the sea. Specifically, there is a riverbed up to the "Andreas Omirou" and "Sotiraki Makrides" intersection. From this point it enters an area of reeds (0.4 km) while the existence of a riverbed or drainage is uncertain. Downstream this point towards the tourist area of Kato Paphos, the stream does not seem in having a riverbed.

Some other possible areas vulnerable to flooding

Tremithos River

The section of the river affected by floods is in the Kiti-Pervolia region and covers 4.2 km. This river is vulnerable to flash-flooding.

The part of the Tremithos river, passing downstream the Kiti dam (with capacity of 1.6 million m3), passes through the Kiti Residential Area for 1500 m, then enters the Z1 Protection Zone for 2000 m and ends up at the coastal Tourist Zone for 700 m. The riverbed located in the Z3 Protection Zone with an average width of 30 – 40 m in the Residential and Tourist area, and 80 – 100 m in the Z1 area. There is a relatively rapid urbanization in the Kiti area and in the Tourist Zone. In the land consolidation area there is also an increased tendency for the building up of individual houses / villas. Along the river there are several mounds and soil dams for the artificial enrichment of the aquifer, often using high water quantities from the dam to flow downstream for enrichment purposes at the request of the Local Irrigation Authorities. The residential development and the enriching nature of the river with its water works should be studied to a better level to manage the serious floods in the area. Note that both the enrichment dam and the presence of a Protection Zone across the river reduce serious flood risks. Flooding events of very low, low and moderate severity of sparse frequency have been recorded.

Ammos River

The section of the river affected by floods is in the area of Alambra and covers 3.2 km. This river is vulnerable to flash-flooding.

The Alambra community faces a serious problem on the drainage of the rainwater flowing from the torrent of Ammos due to the topography and especially due to the Nicosia-Limassol motorway, which essentially bridges the area. Flash-floods cannot be drained down the motorway, resulting in serious problems for the community and the motorway. The sections of the torrents passing through the Residential Area are not covered by a Protection Zone and in many cases the riverbed is unclear due to human interventions. Over the last decade (i.e. after the construction of the motorway) there was 1 flood of very low (2000) and 1 flood of moderate (2009) severity.

Urban-flooding in Larnaca

The area of the Larnaca City, surrounded by Spyros Kyprianou Avenue, Petrakis Kyprianou-Patron-Anagenisis, G. Kranidiotis, G. Digeni, Artemidos and Kotza Tepe of a total area of approximately 3 - 3.5 km^2 encounters, very often, the problem of urban flooding which has economic impacts and also potential impacts on human health. Particularly, the mainly affected areas are: Agios Lazaros, Mitropolis and Chrysopolitissa. The proper drain of rainwater in the area is difficult due to the terrain and the absence of any natural recipient. There are plans for the construction of pumping stations, specifically on Patron Street, which will pump the rainwater into the drainage system of Spyros Kyprianou Avenue and from there they will end up in the sea. Historical floods (23 events) of very low (T ~ 7 years), low (T ~ 17 years) and moderate (T ~ 30 years) severity have been recorded.

District of Larnaca

The district administration of Larnaca gave some information in 2018 about the vulnerable to flooding areas in Larnaca district. These areas are: Kamares, the city of Larnaca, Aradippou, Livadia, Pila and Ormidia. Hydrological studies took place of the areas of: Livadia, Xilotimpou, Kamares, Pila, Verki, Aradippou and Ormidia. The district administration of Larnaca, as far as the flood hazard concerns, need to have more hydrological studies for the areas of: Xilofagou, Agglisides, Kiti and Oroklini. The budget for flood protection/control works foe year 2018 was € 350 000 for the district of Larnaca (Disstrict Administration of Larnaca, 2018).

Municipality of Larnaca

Flood problems within the Larnaca Municipal Limits are presented by the water drainage (a) from rainwater basins from northwestern areas outside municipal boundaries and (b) at local level, from the non-existence or non-completion of rainfall collection systems in the city.

Management of rainfall coming from the catchment area northwest of the city:

1. Kalo Chorio river basins (Kamares).
   The Kamares area, suffered from extreme weather conditions in December 2014. There is a lot of information gathered at the District officer’s Office through the study prepared by a consortium of private companies, for the design of Flood Protection Projects for the protection of Residential Zones of the Larnaca and Aradippou Municipalities located within the catchment area of the Kalo Chorio River.
2. Aradippou rainfall catchment areas (El Greco - Timaya Canal).
   The rainwaters coming through the areas of Aradippou end up in the channel of Stratigos Timayas Avenue. According to a study, made by the Department of Public Works, a closed drainage system was constructed, which starts from the Aradippou Municipality (Australia Avenue) and passes via Larnaca area (El Greco, Stymfalidon, Ptolemaidos, Edessis, Al.

Ragavi, Penelope Delta) ending up in the big channel of Stratigou Timaya Avenue. Despite the completion of the project, floods often occur at the end of Al. Ragavis street near the Stadium of Nea Salamina and at the George Papandreou street. The Municipality of Larnaca, recently, took some flood preventing measures by strengthening the collection shafts and elevating the sidewalks in front of the G. Papandreou utility road, to prevent overflowing of the concentrated waters. These measures do not effectively solve the problems, and the existing system in the region needs further study.

3. Rainwater catchment areas of Aradippou - Livadia - Larnaca (Ximpouli Channel).
   These areas collect rainwater through existing culverts, embankment and closed channels leading to the open lined channel Ximpouli.
   For this area there was an earlier hydrological study by the Department of Public Works and at a meeting held with all the departments and services involved they finalized the proposed design of the core network which is gradually implemented through the licensing of plot separation. Since the end up of the entire system is not connected to the constructed channel of Ximpouli, the area bordered by the Municipal Limits of Livadia is often flooded.

Local flood problems in the city:

Within the city limits, rainwater collection systems are operated by three public bodies. The Municipality of Larnaca maintains the oldest network of the city, the Larnaca Sewerage Council constructs and maintains new networks in the sewerage sites and the Department of Public Works maintains rainwater collection systems built with central road projects.

At various points in the city, due to a poor system of rainwater collection or non-completion of sewerage projects, flood problems are encountered, which are addressed by temporary solutions. The planned construction of two large pumping stations by the Larnaca Sewerage Council in Katharis area, of € 10 million budget, will resolve serious flood problems in the Mitropolis - Katharis area. Small maintenance works, such as the strengthening of wells catchment or the expansion of existing networks are some of the flood protection measures taken by the Municipality of Larnaca. The municipality budget includes an annual amount of about € 40.000 for this purpose. (Municipality of Larnaca, 2018)

Municipality of Athienou

Reference to the topography and characteristics of the area:

The southern and eastern areas of the Municipality are characterized as hilly, while the west and north as lowlands with slight slopes of about 1-2%. The residential area is situated on the edge of the hilly area with slight slopes towards the north. Due to the topography of the area, the rainwater flows from the south to the north with a superficial flow to the existing slopes and / or floods.

Historic flood events:

The lack of satisfactory infrastructure works combined with the residential development of the area have limited the reception of rainwater reception areas (surface or underground) resulting in floods in vulnerable areas. Due to the topography of the area, the rainwater flows from the south to the north with a surface flow to the existing slopes and / or floods protection works. The lack of adequate infrastructure works combined with the residential development of the area have limited the reception of rainwater by the reception areas (surface or underground) resulting in floods in vulnerable areas.

Both in the wider area of the municipality and in the residential area there are no historical data / facts about serious floods. There have always been floods occurring periodically every year, flooding the streets and sometimes damaging premises. The most recent case that could be described as a flood had occurred on 10.12.2010. During that evening, after heavy rainfall on the borders of the residential area, a large amount of water passed from the residential area, resulting in several roads becoming impassable, flooded houses and estates and caused material damage fortunately without risking human lives. In the years following 2010, heavy rainfall occurred, resulting in floods but without significant material damage.

Vulnerable areas (in relation to floods):

Two vulnerable areas, within the residential area can be identified in the Athienou Municipality (Figure 54). The rainwaters from the southern agricultural area end up in these areas, due to the altitude of the roads and the topography of the area. Vulnerable areas, after a heavy rainfall, collect large amounts of rainwater, resulting in high water levels in the streets, with the risk of flooding houses and homes. Due to the lack of adequate infrastructure of flood protection works, the problem is increased.

Existing hydrological studies and areas to be studied:

Until the flood of December 2010, there was no hydrological study in the municipality. Subsequently, on the occasion of the preparation of the study for the perimeter roads and other smaller works, hydrological studies were prepared that covered specific parts of the residential area. Recently, through a bidding process, a designer was selected to prepare a hydrological study for the residential area of the Municipality. The preparation of the hydrological study is in the early stages and is estimated to be completed in about 10 months.

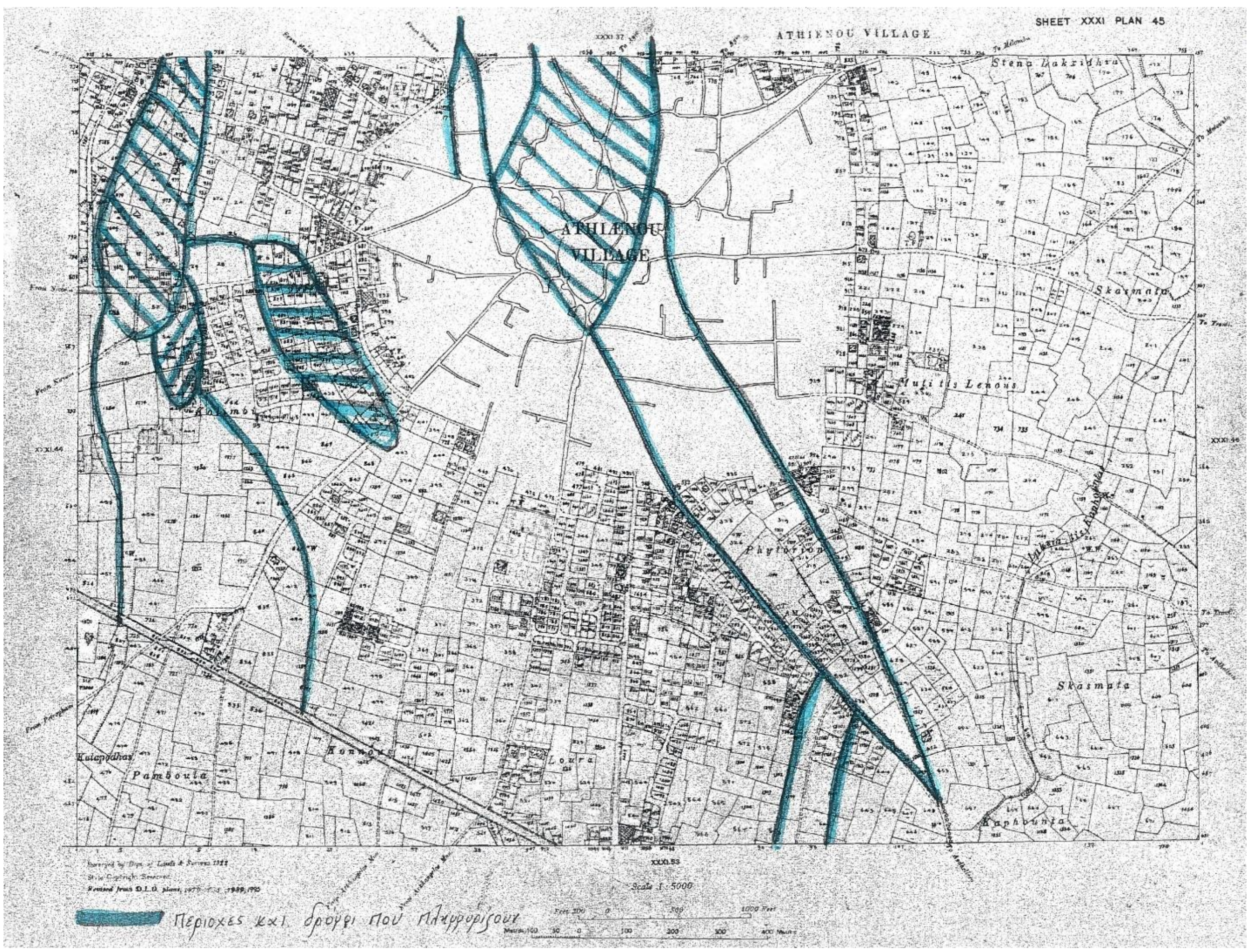

Figure 54 – Vulnerable to flooding areas (blue highlight)

Flood protection measures:

In the municipality, on some problematic streets, there is a rainwater drainage system which, in order to be effective and work properly, should be kept clean. Every year, usually in the autumn, workers of the Municipality take care of the cleaning of rainwater drains both internally and externally at the inflow points.

Available budget for flood protection projects:

In recent years, the budget of the Municipality covered the estimated costs of maintenance and cleaning of the manholes. For the current year and for the next two years, there is provision in the budget of the Municipality with a sum of €50.000 for the execution of flood prodection development projects.

Construction / infrastructures / human lives affected by floods:

Vulnerable areas are flooded, and problems have been observed that affect construction / infrastructure but not human lives.

Due to climate change, observed in recent years, there has been an increase in rainfall intensity, resulting in more frequent floods.

(Municipality of Athienou, 2018)

Municipality of Aradippou

The construction of the rainwater drainage network in the Municipality of Aradippou is based on a study / plans conducted, for the Municipality of Aradippou, by the Department of Public Works. These plans constitute the General Drainage Drainage Plan of the Municipality of Aradippou.

As far as the rainwater runoff affecting the Aradippou municipal boundaries is concerned, the following catchment areas are mentioned:

a. Areas ending in the Kamares and Aliki channel, including runoffs:

- From the area of Kalo Chorio.
- From Rizoelia Forest Area, Industrial Zone / Area, Ellados Avenue, Klimis and Laxias of Rios.

  In the aforementioned areas, as in the area of Kamaron, where the waters end up, floods have occurred in the past, in cases of extreme rainfall.

b. Area of which the rainfall ends at the channel of Stratigos Timayas Avenue, in Larnaca, which includes runoffs:

- From Laxia area, to which the highway runs and rivers from the Rizoelias area north of the Forest, a residential area between Eleftherias Avenue and Kyriakou Matsis and the area north of GSZ stadium.

Individual cases of floods have been observed in this area, mainly due to the non-completion of the sewer network. It is noted that the development in Laxias was limited to the present stage, due to the fact that it is an area with underground faults.

This changed after the most recent studies and the area already is being developed, with the need for sewer network. There are practical difficulties (altitudes existing roads and culverts, etc.) for its construction.

The Laxia area, like all the rest of said area, needs hydrological survey and constructions, as determined by individual studies done to develop additional culverts in the already built area. At the moment the general rainwater drainage plan is applied here.

c. Area where its rainwater ends in Livadia and then in Larnaca in the channel of the Ximpoulis area, which includes drains:

- From Aradippou area, the Monarka area then the Konnos area ending through the area of the Municipality of Livadia to Larnaca on the channel of the Ximpoulis area.

In the Centre of Aradippou, floods have occurred several times in the past and there is still a great risk of future floods. To solve the flood problem, a hydrological Study has been developed. The flood prevention project provided the above study has not been promoted for economic reasons.

The Municipality of Aradippou contacted a Hydrological Study for the region of Monarka. It applies to developments within the thresholds for purposes of construction of the sewerage network, taking into account the contacted hydrological studies and the overall rainwater drainage plan of the municipality prepared by Public Works.

However, it is noted that the rainwater drainage pipelines proposed by the Aradippou sewerage plans are much larger than those that exist within the Municipal Limits of the Livadia and Larnaca Municipalities.

A relevant study for the areas of Aradippou, Livadia to the Ximpoulis Channel has been prepared by the Municipality of Larnaca and is available by the Technical Service of the Municipality of Larnaka. This study demonstrates the inadequacy of existing culverts in Livadia region and before the Ximpoulis channel.

d. The Archangelos river area, whose rainwaters end up in the flood protection channel of Livadia.

The Archangelos River has overflowed several times in the past and the risk is high for future events. To solve this issue, the Municipality of Aradippou has developed a Hydrological Study of the Archangelos River Bridges.

Until now, the flood protection projects provided for in this study have not been promoted. The WDD is designing for flood protection purposes, a dam on the Archangelos River.

(Municipality of Aradippou, 2018)

District of Paphos

In general, it should be noted that the District of Paphos does not face flood problems. The only flood that has occurred in recent years was in the Latsi area of the Municipality of Polis Chrysochous on 07/01/2012. The reason for this incident was the overflow of a stream due to the clogging of a bridge from various materials and mostly debris. In that event, there was no risk of loss of life, but there was damage on vehicles, electromechanical equipment and shops/apartments furniture. According to the relative estimation made by the Technical Services of the Paphos District Administration and the Department of Electromechanical Services, the cost of repairing the losses amounted to approximately € 55.000. In this case, the bridge was rebuilt in a way that prevents the repetition of a similar incident in the future.

In 2012 there were extensive damages to the road network of the District of Paphos, due to intense / severe rainfall combined with the local problematic / unsTable 5.geological conditions. The cost of repairing the damages following, according to the Technical Services of the Paphos District Administration amounted to € 250.000. Due to the geological instability and landslide problems generally presented in the District of Paphos, the Geological Survey Department, after field investigations, proposed concrete measures to support and stabilize all cases.

In the same year, small floods occurred on agriculture land along the riverbed of the Chrysochous River, due to the overflow of the Evretou Dam. The resulted damages to various plantations in the area, was found to be due to the human factor and the illegal interventions in the riverbed.

The most serious incident happened in Paphos District in the recent past occurred on 30/10/2006 and resulted in the loss of two people's lives. Specifically, after a heavy rainfall, water overflew a bridge in the main road between the communities of Lembas - Kissonerga, which is the responsibility of the Department of Public Works. The two persons were dragged by the rushing waters of the strem in their attempt to cross the bridge by car. After this incident, the Ministry of the Interior instructed the Technical Committee of the Cyprus Technical Chamber of Cyprus to identify the technical problems that arose from this 2006 weather event in Paphos, to investigate the possible causes and submit suggestions for prevention or dealing with similar situations in the future. Generally, the reports stated that the main causes of the incident were the human intervention in the natural environment, the urban development is processed before the construction of the needed infrastructure and, finally, the volume of rainwater as a result of building development, without requiring or having hydrological studies providing measures to address these phenomena.

The Pafos District Administration, acting in accordance with the "Prevention Principle", in cooperation with the Local Authorities, proceeds with the construction of appropriate rainwater projects in the communities of the District of Paphos and in combination with the reduction of human carelessness, an effort is made to reduce the occurrence of such phenomena as the above-mentioned incidents.

Every year, various flood protection projects such as bridge construction, road maintenance, construction of concrete trenches, construction of culverts, etc. are being carried out through the Communities Development Budgets. Specifically, for 2018 it is expected that the cost of flood protection works in various communities in the District of Paphos will amount to € 1.212.000, while it should be noted that a hydrological study is contacted when required.

Furthermore, in the context of preventive measures for flood protection, Paphos District Administration is in continuous contact with the Local Authorities during the winter season, while there is cooperation with the other services involved, such as the Fire Brigade, the Police, the Civil Defense and the Department of Public Works, for the coordination of the required actions. During extreme weather, administrative and technical staff are on alert for the early tackle of any problems arise.

(Disstrict Administration of Paphos, 2018).

Table 16. Significant Historic floods (1859-2011) (Source: Water Development Department)

/A	Date	Region Name	River Name	Type of flood	Severity of flooding
1	29/10/1859	Πόλη της Λευκωσίας	Πεδιαίος	Π	Very High
2	30/10/1887	Πόλη της Λεμεσού		Π	Very Low
3	11/12/1887	Καλαβασός		Π	Medium
4	11/12/1887	Πραστειό Μόρφου		Τ	Medium
5	11/12/1887	Νικήτας		Τ	Low
6	11/12/1887	Κάτω Ζώδια		Τ	High
7	28/12/1887	Επαρχία Μόρφου		Τ	Low
8	03/06/1888	Λακατάμεια	Πεδιαίος	Π	Low
9	03/06/1888	Στρόβολος	Πεδιαίος	Π	Low
10	03/06/1888	Αθηαίνου		Τ	Low
11	11/06/1888	Στύλλοι		Π	Very Low
12	20/10/1897	Κώμη Αγίου Ηλία	Γεροπόταμος	Τ	Medium
13	06/02/1901	Δάλι		Τ	Low
14	06/02/1901	Πόλη Λευκωσίας		Τ	Low
15	05/11/1901	Πόλη της Λευκωσίας	Πεδιαίος	Τ	Low
16	05/11/1901	Έγκωμη		Τ	Low
17	05/11/1901	Καιμακλί		Τ	Low
18	05/11/1901	Π. Λεύκαρα		Τ	Very Low
19	11/01/1903	Κυθραία	Πεδιαίος,	Τ	Very Low
20	11/01/1903	Λάρνακα	Γιαλιάς	Τ	Very Low
21	15/02/1903	Έγκωμη,	Πεδιαίος	Τ	Very Low
22	15/02/1903	Μόρφου		Τ	Very Low
23	15/02/1903	Επηχώ		Τ	Medium
24	12/08/1906	Παγκύπρια,		Π	Medium
25	12/08/1906	Καλοψίδα		Π	Medium
26	12/08/1906	Γέναγρα		Π	Medium
27	12/08/1906	Πραστειό Πάφου		Π	Medium

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
53	08/06/1921	Πέτρα	Κλαύδιος, Πετρασίτης, Ελιώτης, Ξεροπόταμος	Π	Medium
54	08/06/1921	Πεντάγεια		Π	Medium
55	04/07/1926	Λευκόνοικο		Τ	Medium
56	04/07/1926	Κνώδαρα		Τ	Very Low
57	13/01/1934	Μια Μηλιά		Τ	Low
58	1936	Αχέλεια	Ποταμός της "Αχέλειας"	Π	Medium
59	1936	Καλαβασός,	Ποταμός της Καλαβασού	Π	Medium
60	1936	Περιστερώνα Λευκωσίας	Ποταμός της Περιστερώνας	Π	Low
61	1936	Επαρχία Λεμεσού		Τ	Medium
62	1936	Κάτω Αμίαντος		Τ	Medium
63	1936	Πάνω Αμίαντος		Τ	Medium
64	1936	Πέρα Πεδί		Τ	Medium
65	1936	Λιμνάτης		Τ	Medium
66	1937	Πόλη της Λευκωσίας	Πεδιαίος	Τ	Very Low
67	1937	Ακάκι	Σερράχης	Π	Very Low
68	1945	Συλίκου		Τ	Very Low
69	21/12/1952	Πόλη Λευκωσίας		Α	Very Low
70	05/11/1955	Πόλη Αμμοχώστου		Α	Very Low
71	1957	Συλίκου		Τ	Very Low
72	26/11/1960	Αμμόχωστος		ΑΚ	Low
73	15/05/1964	Πόλη Λευκωσίας	Πεδιαίος	Τ	Very Low
74	16/05/1964	Παλλουριώτισσα		Α	Low
75	16/05/1964	Άγιο Δομέτιος		Α	Low

28	11/10/1906	Αγίοι Βαβατσινιάς		T	Low
29	11/10/1906	Οδού		T	Low
30	11/10/1906	Μελίνη		T	Low
31	11/10/1906	Επταγώνια		T	Low
32	11/10/1906	Βίκλα		T	Low
33	11/10/1906	Ακαπνού		T	Low
34	11/10/1906	Ορά		T	Low
35	11/10/1906	Κελλάκι		T	Low
36	11/10/1906	Κλωνάρι		T	Low
37	18/09/1909	Γούρρη		T	Low
38	18/09/1909	Φικάρδου		T	Low
39	18/09/1909	Λαζανιά		T	Low
40	18/09/1909	Καλό Χωριό		T	Low
41	16/05/1914	Παγκύπρια		T	Very Low
42	11/12/1918	Παγκύπρια		T	Medium
43	21/12/1918	Πόλη της Λευκωσίας	Πεδιαίος	Π	High
44	21/12/1918	Π. Δευτερά		Π	Very High
45	21/12/1918	Λακατάμια		Π	High
46	21/12/1918	Στρόβολος		Π	High
47	21/12/1918	Μόρφου	Οβκός, Σερράχης	Π	Medium
48	21/12/1918	Συριανοχώρι		Π	Medium
49	21/12/1918	Πυργά Μεσαορίας		T	Low
50	21/12/1918	Δάλι,	Γιαλιάς, Τρέμιθος, Βασιλοπόταμος.	Π	Low
51	21/12/1918	Νήσου		Π	Low
52	21/12/1918	Μια Μηλιά		Π	Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
100	01/11/1967	Αβδελλερό,		K	Very Low
101	01/11/1967	Αθηαίνου		K	Very Low

76	16/05/1964	Άγιο Παύλος		A	Low
77	16/05/1964	Έγκωμη		A	Low
78	16/05/1964	Άγιοι Ομολογητές		A	Low
79	15/12/1964	Σαλαμίνα	Πεδιαίος, Γιαλιάς	T	Very Low
80	05/10/1965	Πόλη Λεμεσού		A	Very
81	05/10/1965	Παγκύπρια		A	Very Low
82	05/10/1965	Πόλη Λευκωσίας		A	Low
83	05/10/1965	Άγιος Δομέτιος		A	Low
84	05/10/1965	Άγιος Παύλος,		A	Low
85	05/10/1965	Παλλουριώτισσα,		A	Low
86	05/10/1965	Και'μακλί		A	Low
87	13/10/1965	Μόρφου		K	Very Low
88	23/10/1965	Παλλουριώτισσα		A	Very Low
89	18/10/1967	Φυλλιά	Οβγός	T	Very Low
90	18/10/1967	Μόρφου		T	Very Low
91	18/10/1967	Πόλη Λάρνακας		A	Very Low
92	18/10/1967	Πόλη Λευκωσία	Πεδιαίος	T	Low
93	18/10/1967	Στρόβολος		T	Low
94	18/10/1967	Γερόλακκος		T	Low
95	18/10/1967	Μύρτου		T	Low
96	18/10/1967	Άγιος Δομέτιος		K	Medium
97	18/10/1967	Άγιος Παύλος		K	Medium
98	18/10/1967	Έγκωμη		K	Medium
99	01/11/1967	Αραδίππου		K	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
150	04/10/1979	Άγιος Δομέτιος		A	Low
151	04/10/1979	Στρόβολος,		A	Low
152	04/10/1979	Ανθούπολη,		A	Low

102	01/11/1967	Κόσιη		Κ	Very Low
103	25/12/1968	Κούκλια	Χα-Ποτάμί	Π	High
104	25/12/1968	Ακάκι	Σερράχης, Κλάριος, Κούρρης	Π	High
105	25/12/1968	Κατωκοπιά		Π	High
106	25/12/1968	Επισκοπειό		Π	High
107	25/12/1968	Περιστερώνα		Π	High
108	25/12/1968	Κάτω Μονή		Π	High
109	25/12/1968	Φαρμακάς		Π	High
110	25/12/1968	Άσσια		Π	High
111	25/12/1968	Μόρφου		Π	High
112	25/12/1968	Καλλιάνα		Π	High
113	25/12/1968	Παλαιχώρι		Π	High
114	25/12/1968	Συριανοχώρι		Π	High
115	13/01/1969	Πόλη Λεμεσού,	Γαρύλλης,	Π	Very Low
116	13/01/1969	Γερμασόγεια,	Ποταμός Γερμασόγειας	Π	Very Low
117	13/01/1969	Καζιβερά	Σερράχης	Τ	Very Low
118	08/01/1969	Πόλη Λευκωσίας		Α	Low
119	08/01/1969	Καιμακλί		Α	Low
120	08/01/1969	Άγιος Κασσιανός		Α	Low
121	18/01/1969	Πόλη Λεμεσού		Κ	Very Low
122	21/01/1969	Κοντέα		Κ	Very Low
123	21/01/1969	Καντού		Κ	Very Low
124	21/01/1969	Τρίκωμο		Κ	Very Low
125	21/01/1969	Ερημη	Κούρης	Π	Very Low
126	19/03/1969	Μόρφου	Σερράρης	Π	Low
127	19/03/1969	Μάσσαρι		Π	Low
128	05/08/1971	Πόλη Λευκωσίας		Α	Medium
129	05/08/1971	Παλλουριώτισσα		Α	Low
130	05/08/1971	Καιμακλί		Α	Low
131	05/08/1971	Τ ράρωνας		Α	Low
132	08/02/1973	Πόλη Αμμορώστου		Α	Very Low

153	04/10/1979	Παλλουριώτισσα,		Α	Low
154	04/10/1979	Καιμακλί		Α	Low
155	29/01/1981	Ύ ψωνας		ΑΚ	Low
156	29/01/1981	Φασούρι-Τσερκέζοι,		ΑΚ	Low
157	29/01/1981	Τ ραχώνι		ΑΚ	Low
158	29/01/1981	Πόλη Λάρνακας		ΑΚ	Low
159	25-26/3/1981	Παλαιομέτοχο	Ποταμός Κατούρης	Τ	Medium
160	25-26/3/1981	Παλλουριώτισσα		Α	Medium
161	25-26/3/1981	Καιμακλί		Α	Medium
162	15/06/1981	Αγία Άννα,	Τρέμιθος	Π	Low
163	15/06/1981	Αραδίππου	Ποταμοί Αρχάγγελος, Καμμίτσης	Π	Low
164	15/06/1981	Λειβάδια	Ποταμοί Αρχάγγελος, Καμμίτσης	Π	Low
165	15/06/1981	Δεκέλεια-Λά ρνακα		Π	Low
166	15/06/1981	Κοφίνου		Π	Low
167	15/06/1981	Μοσφιλωτή		Π	Low
168	15/06/1981	Κλαυδιά		Π	Low
169	27/11/1981	Σωτήρα		Κ	Low
170	27/11/1981	Δασάκι της Άχνας		Κ	Low
171	27/11/1981	Λιοπέτρι		Κ	Low
172	27/11/1981	Φρέναρος		Κ	Low
173	10/06/1983	Λύμπια		Κ	Very Low
174	10/06/1983	Λειβάδια		Κ	Very Low
175	1-2/11/1984	Αραδίππου	Ποταμός Αρχάγγελος	Τ	Medium
176	1-2/11/1984	Λειβάδια		Τ	Medium
177	1-2/11/1984	Πόλη Λάρνακας		Α	Medium
178	04/11/1984	Πόλη Λάρνακας		Α	Medium

133	12/06/1973	Λεμεσός		Α	Low
134	12/06/1973	Τσέρι		Α	Very
135	08-11/10/1973	Αμμόρωστος		Α	Very Low
136	12/10/1973	Πόλη Λεμεσού		Α	Very Low
137	30-31/10/1973	Αμμόρωστος		Α	Very Low
138	23/09/1975	Πόλη Λευκωσίας		Α	Very Low
139	23/09/1975	Άγιοι Ομολογητές		Α	Very Low
140	08/12/1977	Πόλη Λεμεσού		Α	Very Low
141	11/12/1978	Πόλη Λευκωσίας		Α	Very Low
142	11/12/1978	Πόλη Λάρνακας,		Α	Very Low
143	11/12/1978	Άχνα		Α	Very Low
144	11/12/1978	Πόλη Λεμεσού		Α	Very Low
145	07/02/1979	Πόλη Λευκωσίας		Α	Very Low
146	30/10/1979	Αγίοι Ομολογητές,		Α	Very Low
147	30/10/1979	Παλλουριώτισσα		Α	Very Low
148	02/10/1979	Πόλη Λευκωσίας		Α	Very Low
149	04/10/1979	Έγκωμη		Α	Low

179	04/11/1984	Λειβάδια	Ποταμός Αρχάγγελος	Π	Medium
180	04/11/1984	Πύλα		Τ	Medium
181	04/11/1984	Ορόκλινη		Τ	Medium
182	04/11/1984	Στρόβολος		ΚΤ	Low
183	23/12/1984	Λάρνακα		Α	Very Low
184	1984	Συλίκου		Τ	Very Low
185	06/03/1987	Πόλη Λεμεσού		Α	Very Low
186	06/03/1987	Πόλη Λάρνακας		Α	Very Low
187	15/02/1988	Σωτήρα		Κ	Low
188	15/02/1988	Λιοπέτρι		Κ	Low
189	15/02/1988	Παραλίμνι		Κ	Low
190	15/02/1988	Δερύνεια		Κ	Low
191	15/02/1988	Φρέναρος		Κ	Low
192	28/10/1988	Πόλη Λάρνακα		Α	Low
193	01/12/1991	Πόλη Λάρνακα		Α	Very Low
194	08/12/1991	Αραδίππου		Κ	Very Low

A/A	**Date**	**Region Name**	**River Name**	**Type of flood**	**Severity of flooding**
195	16/06/1992	Στρόβολος		Α	Low
196	16/06/1992	Παλλουριώτισσα		Α	Low
197	16/06/1992	Άγιος Δομέτιος		Α	Low
198	16/06/1992	Μακεδονίτισσα-Έγκωμη		Α	Low
199	16/06/1992	Καιμακλί		Α	Low
200	16/06/1992	Άγιος Παύλος		Α	Low
201	16/06/1992	Αρχάγγελος		Α	Low
202	03/11/1994	Πόλη Λευκωσίας		Α	Low

A/A	**Date**	**Region Name**	**River Name**	**Type of flood**	**Severity of flooding**
241	28/09/2000	Αραδίππου,		Κ	Very Low
242	28/09/2000	Κόσιη,		Κ	Very Low
243	28/09/2000	Αθηαίνου,		Κ	Very Low
244	28/09/2000	Άγιος Θεόδωρος		Κ	Very Low
245	28/09/2000	Λειβάδια		Κ	Very Low
246	09/10/2000	Αλάμπρα		Τ	Very Low
247	09/10/2000	Δάλι		Τ	Very Low
248	22/11/2000	Πόλη Λάρνακας		ΑΤ	Very Low
249	22/11/2000	Λειβάδια	Ποταμός Αρχάγγελος	ΑΤ	Very Low
250	22/11/2000	Αραδίππου		ΑΤ	Very Low

203	03/11/1994	Λεμεσός (Άγιος Αθανάσιος)		A	Very Low
204	03/11/1994	Τσέρι		AK	Low
205	03/11/1994	Γέρι		AK	Low
206	03/11/1994	Λατσιά		AK	Low
207	03/11/1994	Παλουριώτισσα		AK	Low
208	03/11/1994	Λακατάμεια		AK	Low
209	21/11/1994	Τσέρι	Πεδιαίος, Βασιλικός	A	Very Low
210	21/11/1994	Λατσιά		A	Very Low
211	21/11/1994	Λακατάμεια		Π	Very Low
212	21/11/1994	Μακεδονίτισσα-Έγκωμη		Π	Very Low
213	21/11/1994	Ανθούπολης		A	Very Low
214	21/11/1994	Πόλη Λάρνακας		A	Very Low
215	21/11/1994	Μοσφιλωτή		Π	Very Low
216	21/11/1994	Αθηένου		A	Very Low
217	21/11/1994	Καλαβασός		Π	Very Low
218	21/11/1994	Πόλη Λεμεσού		A	Very Low
219	21/11/1994	Γερμασόγεια		A	Very Low
220	21/11/1994	Πόλη Πάφου		A	Very Low
221	04/04/1995	Λατσιά		T	Very Low
222	09/07/1995	Αγ. Δομέτιος	Ποταμός Κλήμος	A	Low
223	09/07/1995	Αγ. Παύλος		A	Low
224	09/07/1995	Αγλαντζιά		A	Low
225	09/07/1995	Παλουριώτισσα		A	Low
226	03/01/1996	Πόλη Λευκωσίας	Πεδιαίος	AT	Very Low
227	03/01/1996	Πόλη Λάρνακας		AT	Very Low
228	03/01/1996	Πόλη Λεμεσού		AT	Very Low
229	10/10/1996	Πάφος		K	Very Low
230	10/10/1996	Λεμεσός		K	Very Low
231	20/11/1996	Πόλη Λεμεσού		A	Low
232	26/11/1996	Άγιος Παύλος		A	Very Low

251	28/11/2000	Μανδριά		T	Very Low
252	28/11/2000	Τίμη		T	Very Low
253	28/11/2000	Αχέλεια		T	Very Low
254	28/11/2000	Νικόκλεια		T	Very Low
255	28/11/2000	Λακατάμεια		K	Low
256	28/11/2000	Αρχάγγελος		K	Low
257	28/11/2000	Λατσιά		K	Low
258	28/11/2000	Ψημολόφου		K	Low
259	28/11/2000	Γέρι		K	Low
260	28/11/2000	Πόλη Λεμεσού		K	Low
261	13/03/2001	Στρόβολος		A	Low
262	13/03/2001	Έγκωμη-Μακεδονίτισσα		A	Low
263	13/03/2001	Άγιος Δομέτιος		A	Low
264	13/03/2001	Αρχάγγελος		A	Low
265	13/03/2001	Κάτω Μονή		T	Low
266	13/03/2001	Μένοικο		T	Low
267	19/03/2001	Έγκωμη-Μακεδονίτισσα		A	Very Low
268	14/05/2001	Έγκωμη-Μακεδονίτισσα	Πεδιαίος	A	Medium
269	14/05/2001	Στρόβολος		A	Medium
270	14/05/2001	Άγιος Δομέτιος		A	Medium
271	14/05/2001	Άγιος Παύλος		A	Medium
272	14/05/2001	Λακατάμεια		A	Medium
273	14/05/2001	Τσέρι		A	Medium
274	14/05/2001	Αρχάγγελος		A	Medium
275	02/12/2001	Πάφος		AT	Very Low
276	02/12/2001	Χλώρακα		T	Very Low
277	02/12/2001	Έμπα		T	Very Low
278	02/12/2001	Μεσόγη		T	Very Low
279	02/12/2001	Πόλη Λάρνακας		A	Low
280	03/12/2001	Αραδίππου		A	Very Low

233	26/11/1996	Άγιος Δομέτιος		Α	Very Low
234	26/11/1996	Έγκωμη	Πεδιαίος	Α	Very Low
235	18-22/10/97	Τρούλλοι	Ποταμός Ορόκλινης	Π	High
236	04/09/1998	Δάλι	Γιαλιάς, Αλμυρός	Τ	Very Low
237	10/11/1998	Ζακάκι		Α	Very Low
238	27/09/2000	Έγκωμη-Μακεδονίτισσα,		Α	Very Low
239	27/09/2000	Παλλουριώτισσα,		Α	Very Low
240	27/09/2000	Άγιος Παύλος		Α	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
290	14/05/2002	Έγκωμη-Μακεδονίτισσα,		Α	Very Low
291	14/05/2002	Στρόβολος		Α	Very Low
292	14/05/2002	Άγιος Δομέτιος		Α	Very Low
293	14/05/2002	Άγιος Παύλος		Α	Very Low
294	14/05/2002	Αγλαντζιά		Α	Very Low
295	14/05/2002	Άγιος Ανδρέας		Α	Very Low
296	14/05/2002	Άγιοι Ομολογητές		Α	Very Low
297	14/05/2002	Λατσιά		Α	Very Low
298	03/12/2002	Πόλη Λευκωσίας		Α	Very Low
299	03/12/2002	Άγιος Δομέτιος		Α	Very Low
300	03/12/2002	Ανθούπολη		Α	Very Low
301	03/12/2002	Στρόβολος	Πεδιαίος	Π	Very Low
302	08/12/2002	Αθηαίνου		ΚΤ	Very Low
303	19/12/2002	Πόλη Λάρνακας		Α	Low
304	12-13/2/2003	Στρόβολος,	Πεδιαίος	Π	Very Low
305	12-13/2/2003	Αρχάγγελος,		Π	Very Low

281	03/12/2001	Λειβάδια		Α	Very Low
282	08/12/2001	Ποταμιά	Γιαλιάς	Π	Very Low
283	08/12/2001	Πέρα Χωριό		Κ	Very Low
284	08/12/2001	Λύμπια		Κ	Very Low
285	08/12/2001	Δάλι		Κ	Very Low
286	08/12/2001	Πόλη Λευκωσίας		Α	Very Low
287	08/12/2001	Λακατάμεια		Α	Very Low
288	08/12/2001	Στρόβολος	Πεδιαίος	Π	Very Low
289	08/12/2001	Αγλαντζιά		Α	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
329	3-4/12/2003	Καλό Χωριό		Α	Very Low
330	3-4/12/2003	Αραδίππου		Α	Very Low
331	04/12/2003	Πόλη Πάφου		Α	Very Low
332	04/12/2003	Έμπα		Α	Very Low
333	04/12/2003	Μεσόγη		Α	Very Low
334	04/12/2003	Πόλη Λευκωσίας		Α	Very Low
335	04/12/2003	Λατσιά		Α	Very Low
336	04/12/2003	Γέρι		Α	Very Low
337	04/12/2003	Άγιος Αντώνιος		Α	Very Low
338	15/12/2003	Πόλη Λάρνακας		Α	Low
339	11/01/2004	Λεμεσός		ΑΚ	Low
340	11/01/2004	Ζακάκι		ΑΚ	Low
341	11/01/2004	Άγιος Ιωάννης,		ΑΚ	Low
342	11/01/2004	Κάτω Πολεμίδια		ΑΚ	Low
343	11/01/2004	Πόλη Λάρνακας		Α	Very Low
344	11/01/2004	Κάτω Μονή		ΑΤ	Very Low
345	11/01/2004	Αγία Μαρίνα Ξυλιάτου		ΑΤ	Very Low
346	12/01/2004	Κάτω Πολεμίδια		ΑΚ	Medium

306	12-13/2/2003	Παλαιομέτορο	Ποταμός Κουτής	Τ	Low
307	12-13/2/2003	Αγίοι Τριμιθιάς		Τ	Low
308	12-13/2/2003	Δάλι		Π	Low
309	12-13/2/2003	Πέρα Χωρίο Νήσου	Γιαλιάς	Π	High
310	12-13/2/2003	Πόλη Λάρνακας		Α	Medium
311	12-13/2/2003	Πυργά		Α	Medium
312	12-13/2/2003	Ζακάκι		Α	Medium
313	12-13/2/2003	Πολεμίδια		Α	Medium
314	12-13/2/2003	Πόλη Πάφου		Α	Medium
315	31/05/2003	Αγλαντζιά		Α	Very Low
316	31/05/2003	Αγίοι Ομολογητές		Α	Very Low
317	31/05/2003	Στρόβολος		Κ	Very Low
318	31/05/2003	Πέρα Χωριό Νήσου		Κ	Very Low
319	01/10/2003	Π. Λεύκαρα		Κ	Very Low
320	02/10/2003	Ζακάκι		Κ	Very Low
321	02/10/2003	Τ ραχώνι		Κ	Very Low
322	02/12/2003	Δάλι	Ποταμός Αλμυρός, (Γιαλιάς)	Τ	Medium
323	02/12/2003	Νήσου	Γιαλιάς	Τ	Very Low
324	02/12/2003	Δάλι		Τ	Very Low
325	02/12/2003	Στρόβολος,	Πεδιαίος	Τ	Very Low
326	02/12/2003	Λακατάμια,	Πεδιαίος	Τ	Very Low
327	02/12/2003	Ψημολόφου		Τ	Very Low
328	3-4/12/2003	Πόλη Λάρνακα		Α	Very Low

347	12/01/2004	Ζακάκι		ΑΚ	Medium
348	12/01/2004	Άγιος Ιωάννης		ΑΚ	Medium
349	12/01/2004	Άγιος Γεώργιος		ΑΚ	Medium
350	12/01/2004	Ύψωνας		ΑΚ	Medium
351	12/01/2004	Τ ραχώνι		ΑΚ	Medium
352	12/01/2004	Κοτσιάτης	Γιαλιάς	Τ	Very Low
353	12/01/2004	Αγία Βαρβάρα		Τ	Very Low
354	12/01/2004	Πέρα Χωρίο Νήσου		Τ	Very Low
355	12/01/2004	Πόλη Λάρνακας,		Α	Medium
356	12/01/2004	Κοφίνου		Α	Medium
357	12/01/2004	Αραδίππου		Α	Medium
358	12/01/2004	Ορόκλινη		Α	Medium
359	12/01/2004	Αλεθρικό	Τρέμιθος	Α	Medium
360	12/01/2004	Ξυλοφάγου		Κ	Low
361	12/01/2004	Δερύνεια		Κ	Low
362	12/01/2004	Αυγόρου,		Κ	Low
363	12/01/2004	Λιοπέτρι		Κ	Low
364	12/01/2004	Σωτήρα		Κ	Low
365	12/01/2004	Παραλίμνι		Κ	Low
366	12/01/2004	Πόλη Πάφου,		Τ	Very Low
367	12/01/2004	Πόλις Χρυσοχούς		Τ	Very Low
368	12/01/2004	Τίμη		Τ	Very Low
369	12/01/2004	Μανδριά		Τ	Very Low
370	12/01/2004	Στρόβολος	Πεδιαίος	ΑΤ	Low
371	12/01/2004	Παλαιχώρι	Μαρούλλενα	ΑΤ	Low
372	31/5-1/6/2005	Αγίοι Τριμιθιάς		Τ	Very Low
373	31/5-1/6/2005	Παλαιομέτοχο		Τ	Very Low
374	31/5-1/6/2005	Πόλη Λάρνακας		ΑΚ	Very Low
375	31/5-1/6/2005	Ορόκλινη		ΑΚ	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
376	31/5-1/6/2005	Αγλαντζιά	Πεδιαίος	AT	Medium
377	31/5-1/6/2005	Λακατάμια		AT	Medium
378	31/5-1/6/2005	Στρόβολος		AT	Medium
379	31/5-1/6/2005	Έγκωμη		AT	Medium
380	31/5-1/6/2005	Εργάτες		AT	Medium
381	31/5-1/6/2005	Καμπιά		AT	Medium
382	31/5-1/6/2005	Ψημολόφου		AT	Medium
383	31/5-1/6/2005	Δευτερά		AT	Medium
384	31/5-1/6/2005	Πέρα Ορεινής		AT	Medium
385	31/5-1/6/2005	Αρεδιού		AT	Medium
386	31/5-1/6/2005	Τσέρι		AT	Medium
387	18/11/2005	Ζακάκι		A	Medium
388	18/11/2005	Ομόνοια		A	Medium
389	18/11/2005	Άγιος Αθανάσιος		A	Medium
390	18/11/2005	Ύψωνας		A	Medium
391	11/01/2006	Αγία Νάπα		K	Medium
392	11/01/2006	Παραλίμνι		K	Medium
393	11/01/2006	Λιοπέτρι		K	Medium
394	11/01/2006	Αυγόρου		K	Medium
395	11/01/2006	Άχνα		K	Medium
396	11/01/2006	Σωτήρα		K	Medium
397	11/01/2006	Ξυλοφάγου		K	Medium
398	27/03/2006	Έγκωμη-Μακεδονίτισσα,		A	Low
399	27/03/2006	Στρόβολος,		A	Low
400	27/03/2006	Αγλαντζιά		A	Low
401	27/03/2006	Άγιοι Ομολογητές		A	Low
402	27/03/2006	Αρχάγγελος		A	Low
403	05/07/2006	Στρόβολος,		A	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
428	22/12/2008	Μανδριά		A	Low
429	30/01/2009	Πέγεια	Άσπρος	T	Very Low
430	30/01/2009	Πόλις της Χρυσοχούς		T	Very Low
431	30/01/2009	Κελοκέδαρα		T	Very Low
432	26/02/2009	Κοράκου	Κλάριος	Π	Very Low
433	26/02/2009	Πόλη Πάφου,	Εζούσας	AK	Low
434	26/02/2009	Γεροσκήπου,		AK	Low
435	26/02/2009	Επισκοπή		AK	Low
436	27/10/2009	Αλάμπρα	Γιαλιάς, Γέρος	Π	Medium
437	27/10/2009	Αγία Βαρβάρα,		Π	Medium
438	27/10/2009	Πέρα Χωρίο Νήσου		Π	Medium
439	27/10/2009	Λύμπια		Π	Medium
440	27/10/2009	Δάλι		Π	Medium
441	27/10/2009	Μοσφηλωτή		Π	Medium
442	28/10/2009	Έγκωμη-Μακεδονίτισσα		A	Very Low
443	28/10/2009	Άγιος Δομέτιος		A	Very Low
444	28/10/2009	Άγιος Παύλος		A	Very Low
445	28/10/2009	Άγιος Ανδρέας		A	Very Low
446	02/11/2009	Πόλη Πάφου		A	Very Low
447	02/11/2009	Τίμη		A	Very Low
448	02/11/2009	Μανδριά		A	Very Low
449	18/01/2010	Λεμεσός		A	Very Low
450	18/01/2010	Ζακάκι		A	Very Low
451	18/01/2010	Νατά		Π	Very Low
452	18/01/2010	Χολέτρια		Π	Very Low
453	18/01/2010	Πόλη Λευκωσίας		AT	Medium
454	18/01/2010	Έγκωμη-Μακεδονίτισα		AT	Medium
455	18/01/2010	Ακάκι,		AT	Medium

404	05/07/2006	Λακατάμεια		Α	Very Low
405	05/07/2006	Παλλουριώτισσα		Α	Very Low
406	05/07/2006	Καιμακλί		Α	Very Low
407	13/10/2006	Πόλη Πάφου		Α	Medium
408	30/10/2006	Πόλη Πάφου		ΚΤ	High
409	30/10/2006	Κισσόνεργα		ΚΤ	High
410	30/10/2006	Έμπα		ΚΤ	High
411	30/10/2006	Τάλα		ΚΤ	High
412	30/10/2006	Χλώρακα		ΚΤ	Low
413	30/10/2006	Πέγεια		ΚΤ	Low
414	31/10/2006	Κίτι	Τρέμιθος	Τ	Very Low
415	31/10/2006	Λειβάδια	Αρχάγγελος	Τ	Very Low
416	3-5/2/2007	Πόλη Λάρνακας		Α	Very Low
417	3-5/2/2007	Ευρύχου	Ποταμός Κλάριος	Π	Very Low
418	3-5/2/2007	Κοράκου		Π	Very Low
419	22/10/2008	Πόλη Λευκωσίας		Α	Very Low
420	22/10/2008	Αγλαντζιά		Α	Very Low
421	22/10/2008	Αρχάγγελος,		Α	Very Low
422	22/10/2008	Στρόβολος		Α	Very Low
423	22/12/2008	Ζακάκι		Α	Low
424	22/12/2008	Αναρίτα		Α	Low
425	22/12/2008	Ορόκλινη		Α	Low
426	22/12/2008	Ασώματος		Α	Low
427	22/12/2008	Κούκλια		Α	Low

456	18/01/2010	Λακατάμεια		ΑΤ	Medium
457	18/01/2010	Αστρομερίτης	Κομίτης	ΑΤ	Medium
458	18/01/2010	Περιστερώνα	Κομίτης	ΑΤ	Medium
459	18/01/2010	Ορούντα		ΑΤ	Medium
460	18/01/2010	Στρόβολος	Πεδιαίος	ΑΤ	Medium
461	18/01/2010	Πέρα Χωρίο Νήσου		ΑΤ	Medium
462	18/01/2010	Αρχάγγελος,		ΑΤ	Medium
463	18/01/2010	Φλάσου,	Κλάριος, Κομήτης	ΑΤ	Medium
464	18/01/2010	Δάλι		ΑΤ	Medium
465	18/01/2010	Κοράκου	Κλάριος, Κομήτης	ΑΤ	Medium
466	22/04/2010	Πόλη Λεμεσού		ΑΚ	Medium
467	22/04/2010	Άγιος Αθανάσιος		ΑΚ	Medium
468	03/01/2011	Πόλη Λάρνακας		Α	Low

*Sources of the historic flood events	**Type of flood
1. Systematic check of newspaper archive 2. Published in Newspaper: «Κυπριακός Φύλαξ» (1934 - 1936) 3. Published in the weekly Newspaper ΕΝΩΣΙΣ 4. Published in the weekly Newspaper ΑΛΗΘΕΙΑ 5. Published in the Newspaper ΦΩΝΗ ΤΗΣ ΚΥΠΡΟΥ 6. Published in the weekly Newspaper ΣΑΛΠΙΞ 7. Published in the weekly Newspaper ΕΥΑΓΟΡΑΣ 8. Published in the Newspaper ΚΥΠΡΟΣ 9. Published in the Newspaper ΕΛΕΥΘΕΡΙΑ 10. Annual reports WDD 11. Published in the Newspaper «Ο Φιλελεύθερος» 12. Meteorological Department 13. Fire Department 14. Theses Ε. Χρίστου 1995 15. Photo archive of hydrology department 16. Archive of hydrology department 17. Published in the Newspaper «Η Σημερινή» 18. Published in the Newspaper «Ο Αγών» 19. Published in the Newspaper «Πολίτης» 20. Letter from the president of Sylikou 3/11/2010	Θ = coastal flooding Τ= rapid response Π = river flood Α = urban flood Κ = deluge flooding Υ = Flood of underground water

Analysis of flood models

Two of the main steps in accomplishing the obligations towards the European Union with regard to the implementation of the European Directive 2007/60/EC on the assessment and management of flood risks and the relevant law of Cyprus Law N. 70 (i)/2010 which provides for the evaluation, management and treatment of flood risks, are the hydrologic and hydraulic models of the most vulnerable to flooding areas in Cyprus. This modeling helps in the creation of the flood hazard and risk maps.

This report contains information taken by projects from private companies worked on the modelling of flood risks in Cyprus under the instructions of Water Development Department who sponsored of the projects.

Hydrological rainfall – runoff models

The development of hydrological models was performed by using the HEC-HMS software and the HEC-GeoHMS as an additional toolbar in the ESRI products ArcGIS.

The model parameters were divided into two categories. Those which are directly measurable and those that are estimated according to the characteristics of the area. The former includes:

- the extent of the basin
- the mean slope of the basin
- length of watercourses

The parameters belonging in the second category are the indirect ones:

- The CN (Curve Number) number which was determined though ArcMAP using the available geographic data (soil characteristics and land use)
- The initial humidity
- The cross section of the river at sites that were considered to be natural streams or arranged with a non-lined cross section was considered trapezoidal. In positions where there were arrangements with open or close lined section, the corresponding cross section was considered (usually rectangular).
- The dimensions of the stream
- The Manning roughness coefficient
- The slope of the stream

Examples of the sub-basin and stream parameters used are given in the following tables.

Table 17. Example of the parameters used for the sub-basins of the Kalogeros river (Source: Water Development Department)

A/A	Name	Area	Average slope	CN Number	Initial Losses	24hr Rainfall 2Yrs	Inflow time	Lag time
		(km2)	(%)		(mm)	(in)	(hr)	(hr)
1	W240	0.354	6.75	85.2	8.83	1.457	0.29	0.17
2	W250	0.987	5.73	89.5	5.96	1.457	0.79	0.48
3	W260	0.612	6.79	88.8	6.39	1.457	0.68	0.41
4	W280	0.619	6.18	82.2	11.01	1.457	0.89	0.53

A/A	Name	Area	Average slope	CN Number	Initial Losses	24hr Rainfall 2Yrs	Inflow time	Lag time
		(km2)	(%)		(mm)	(in)	(hr)	(hr)
5	W290	0.255	6.50	84.5	9.29	1.457	0.29	0.17
6	W310	1.940	4.37	85.8	8.40	1.483	0.93	0.56
7	W320	1.901	5.59	79.0	13.46	1.648	1.04	0.62
8	W330	1.099	7.64	78.9	13.60	1.675	0.85	0.51
9	W360	0.832	4.53	88.7	6.46	1.457	0.70	0.42
10	W380	2.751	4.96	79.7	12.95	1.586	0.98	0.59
11	W410	3.803	15.77	67.3	24.70	1.700	1.10	0.66
12	W420	1.059	10.81	75.0	16.90	1.700	0.80	0.48
13	W440	2.646	17.45	67.6	24.34	1.700	1.23	0.74
14	W490	3.046	14.24	70.5	21.31	1.673	1.34	0.80
15	W530	3.099	7.23	74.7	17.17	1.700	1.48	0.89
16	W540	1.305	8.51	85.5	8.64	1.700	0.32	0.19
17	W580	0.033	4.44	74.2	17.69	1.457	0.12	0.07
18	W630	0.450	7.33	84.1	9.61	1.510	0.47	0.28
19	W640	2.464	4.46	83.9	9.75	1.679	1.23	0.74
						Area (Km2) =		29.26
						Inflow time (hrs) Tc=		4.32
						Area Reduction Factor =		**0.98**

Table 18. Example of the parameters used for the streams of the Kalogeros river (Source: Water Development Department)

A/A	Name	Length	Upstream elevation	Downstream elevation	Slope	Cross section	Width	Lateral slope	Manning Coefficient	Time of Tavel
		(m)			(m/m)		(m)	(h:v)		(hrs)
1	R20	330.52	158.89	158.89	0.004000	Trapezoid	6.0	1.5	0.050	0.14
2	R30	644.41	161.63	158.89	0.004260	Trapezoid	6.0	1.5	0.040	0.21
3	R60	1199.33	169.48	161.63	0.006546	Trapezoid	6.0	1.5	0.070	0.55
4	R50	323.85	171.60	169.48	0.006549	Trapezoid	6.0	1.5	0.040	0.08
5	R70	763.41	175.39	171.60	0.004952	Trapezoid	6.0	1.5	0.070	0.40
6	R150	2649.78	196.61	175.39	0.008008	Trapezoid	10.0	1.5	0.040	0.64
7	R110	845.27	170.28	161.63	0.010230	Trapezoid	3.0	1.5	0.070	0.30

8	R160	1590.89	184.56	170.28	0.008975	Trapezoid	3.0	1.5	0.025	0.22
9	R140	164.50	197.59	196.61	0.005960	Trapezoid	10.0	1.5	0.030	0.03
10	R230	3979.10	243.22	197.59	0.011469	Trapezoid	5.0	1.5	0.035	0.68
11	R550	1608.09	266.85	243.22	0.014691	Trapezoid	3.0	1.5	0.035	0.24
12	R90	331.78	182.26	175.39	0.020716	Trapezoid	2.0	1.5	0.030	0.04
13	R610	708.55	187.06	182.26	0.006781	Trapezoid	2.0	1.5	0.030	0.13

Design storms

Rainfall (IDF) curves produced by the Cyprus Meteorological Service were used for the formation of the design storms. For each station that affects the particular basin, three hyetographs (graphical representation of rainfall over time) were constructed (one for each return period T=20 years, T=100 years and T=500 years).

The rainfall heights of the hyetographs were such that they ensure that the resulting tensions for selected durations (e.g. 5min, 10min, 1min, 30min, 1hr, 2hr, 6 hr, 24 hr) will be equal to those of the corresponding rainfall for each of the return periods. The method proposed to be used is the Alternating Block method as described in the relevant bibliography (Applied Hydrology, 1988, V.T. Chow, D.R. Maidment and L.W. Mays).

As an example, the following tables were used for the formation of design storms in the case of the Kalogeros River.

Table 19. Influence of the weather stations on each sub-basin of the Kalogeros river (Source: Water Development Department)

Watershed (basin)	Weather Station	Area of influence (km2)	Weight
W240	666	0.438	0.999
W250	666	1.174	0.999
W260	666	0.612	0.999
W280	666	0.619	0.999
W290	666	0.255	0.999
W310	583	0.133	0.068
W310	640	0.670	0.344
W310	666	1.146	0.588

Watershed (basin)	Weather Station	Area of influence (km2)	Weight
W320	583	1.498	0.788
W320	666	0.402	0.212
W330	583	0.987	0.898
W330	666	0.111	0.102
W360	666	0.831	0.999
W380	583	1.462	0.532
W380	666	1.288	0.468
W410	583	3.800	0.999
W420	583	1.058	0.999
W440	583	2.644	0.999
W490	580	0.341	0.112
W490	583	2.661	0.873
W490	597	0.043	0.014
W530	583	3.165	0.999
W540	583	1.304	0.999
W580	666	0.033	0.999
W630	583	0.086	0.191
W630	640	0.102	0.227
W630	666	0.261	0.582
W640	583	2.178	0.902
W640	640	0.236	0.098
W640	666	0.000	0.000

Table 20. Example of calculation of the watersheds' time of travel for the Kalogeros river (Source: Water Development Department)

Watershed Name	W240	W250	W260	W280	W290	W580	W310	W320	W330	W360
Watershed ID	24	25	26	28	29	58	31	32	33	36
Sheet Flow Characteristics										
Manning's Roughness Coefficient	0.011	0.011	0.011	0.06	0.011	0.06	0.011	0.06	0.06	0.011
Flow Length (ft)	100	100	100	100	100	99.9999	99.9999	99.9998	100	100.0001
Two-Year 24-hour Rainfall (in)	1.457	1.457	1.457	1.457	1.457	1.457	1.483	1.648	1.675	1.457
Land Slope (ft/ft)	0.0453	0.016	0.0752	0.0175	0.0058	0.0815	0.1069	0.1802	0.0177	0.0131
Sheet Flow Tt (hr)	0.02	0.03	0.02	0.12	0.05	0.07	0.02	0.05	0.11	0.04
Shallow Concentrated Flow Characteristics										

Surface Description (1 - unpaved, 2 - paved)	2	2	2	1	2	1	2	1	1	2
Flow Length (ft)	3092	7021	4705	4902	2899	196.4087	7593.813	6477.444	1269.676	4673.506
Watercourse Slope (ft/ft)	0.0332	0.0187	0.0191	0.0126	0.0331	0.0337	0.018	0.0323	0.0458	0.0174
Average Velocity - computed (ft/s)	3.70	2.78	2.81	1.81	3.70	2.96	2.73	2.90	3.45	2.68
Shallow Concentrated Flow Tt (hr)	0.23	0.70	0.47	0.75	0.22	0.02	0.77	0.62	0.10	0.48
Channel Flow Characterisitics										
Cross-sectional Flow Area (ft2)	22.02	18.02	22.02	22.02	22.02	18.02	22.02	18.02	26.02	19.02
Wetted Perimeter (ft)	17.78	13.78	17.78	17.78	17.78	13.78	17.78	13.78	21.78	14.78
Hydraulic Radius - computed (ft)	1.24	1.31	1.24	1.24	1.24	1.31	1.24	1.31	1.19	1.29
Channel Slope (ft/ft)	0.006	0.0067	0.0036	0.0118	0.004	0.0156	0.0177	0.0116	0.0078	0.0121
Manning's Roughness Coefficient	0.05	0.025	0.04	0.07	0.04	0.025	0.07	0.05	0.04	0.07
Average Velocity - computed (ft/s)	2.66	5.83	2.58	2.67	2.72	8.90	3.27	3.84	3.70	2.77
Flow Length (ft)	348	1251	1803	151	197	1024.33	1680.256	5124.672	8470.322	1816.877
Channel Flow Tt (hr)	0.04	0.06	0.19	0.02	0.02	0.03	0.14	0.37	0.64	0.18
Watershed Time of travel (hr)	0.29	0.79	0.68	0.89	0.29	0.12	0.93	1.04	0.85	0.70

Reinfall losses

The loss model used is the Curve Number model (CN) of SCS (SCS National Engineering Handbook, Section 4, 1985) which is used empirically in hydrology for the prediction of direct runoff or infiltration due to rainfall (United States Department of Agriculture (1986). Urban hydrology for small watersheds. Technical Release 55 (TR-55) (Second ed.). Natural Resources Conservation Service, Conservation Engineering Division). The existing Corine 2006 map was used to determine the combination of territorial coverage and processing. The matching of the SCS tables was based on the closest resemblance to the descriptions of the Corine map and the SCS TR-55 tables. A relevant work in southern Italy was also taken into account.

Basin response-Reinfall Runoff relationships

The model used is the SCS (Soil Conservation Service) unit model, which is an event model, a single, empirical, parameterized identifier that is assessed by the properties of the watershed. It is fully consistent with the available data and the type of rainfall in Cyprus (generally individual events).

The data required for the construction of the SCS model result from the characteristics of the basin such as:

- The area of the basin and

- The concentration time, which is the time required to reach the farthest hydraulic drop in the basin output position. This time can be allocated to the following components:
    - The time needed in the slopes of the basin
    - The route time as shallow flow and
    - The time of travel in the main stream

Routing of hydrographs through pipelines

Routing of the flow is the process of determining the hydrography at a point of the water stream from a known or hypothetical hydrograph to one or more upstream points.

The basic data required for the implementation of Routing models are:

- The description of the water stream, is either in indirect ways or in usual terms of bottom width, cross section etc.
- The parameters of energy loss models e.g. Manning roughness coefficient
- The initial conditions of the basin
- Limit conditions. The marginal conditions are the upstream influx, the lateral inputs, input hydrographs of the confluences etc.

The model that has been used is the Muskingum-Cunge model.

Reservoirs

Reservoirs in Cyprus do not, always, work to cover the needs of flood protection. The modelling of the existing reservoirs was made considering that at the beginning of the rainfall their level is not below the maximum normal level.

Storage - water level relationships in the reservoir and water level – flow supply from Spillway were taken from the Water Development Department.

Calibration of hydrological models

In the 7 out of the 19 regions there are flow data. These areas are the Pediaios river with 2 stations, the Kalogeros river with 1 station, the inflow River of Paralimni Lake with 1 station, the Gialias river with 2 stations, the Archangelos – Kammitsis river with 3 stations, the Germasogeia river with 2 stations and the Garyllis river with 1 station. After calibration, the parameters of the models were adjusted in order to represent (model) satisfactorily two recent historical floods and to satisfactorily approach the expected value of the runoff for each of the 3 recovery periods.

Consequences and impact assessment

In 2014, Water Development Department (WDD), created hazard and risk maps the most vulnerable, to flooding, areas in Cyprus given in Task 4.1 of this project. The purpose of this deliverable is to specify the methodology followed by the WDD to produce the flood hazard maps as well as the flood risk maps. The hazard maps produced, show the impact of the flood, including the area covered by the overflow as well as the water depth, while, on the other hand, the risk maps produced depict the potential negative effects of the floods. The information was taken from both procedures shoed in Tasks 4.1 and 4.2. The creation of such maps helped in fulfilling Cyprus's obligations towards the European Union regarding the implementation of the European Directive 2007/60/EC on the assessment and management of flood risks and the relevant Law of Cyprus Law N. 70 (I) / 2010.

This report contains information taken by projects from private companies worked on the modelling of flood risks in Cyprus under the instructions of Water Development Department who sponsored of the projects.

Areas vulnerable to flooding in Cyprus

The following Table 21 determines the 19 areas vulnerable to flooding in Cyprus, presented in Task 4.1.

Table 21. Areas of potential flooding in Cyprus (Source: WDD)

A/A	Area Code	Name of River / Stream	Length of river (m)
1	CY-APSFR01	Pediaios	25 310
2	CY-APSFR02	Klimos	5 740
3	CY-APSFR03	Merikas (tributary)	3 250
4	CY-APSFR04	Kalogeros	5 630
5	CY-APSFR05	Merikas	5 690
6	CY-APSFR06	Almiyros-Alikos	7 750
7	CY-APSFR07	Paralimni	3 290

8	CY-APSFR08	Gialias	5 810
9	CY-APSFR09	Ormidia	4 960
10	CY-APSFR10	Archangelos	11 300
11	CY-APSFR11	Kamares	6 640
12	CY-APSFR12	Kosinas	8 770
13	CY-APSFR13	Limnarka	3 380
14	CY-APSFR14	Germasogeia	6 070
15	CY-APSFR15	Vathias	7 700
16	CY-APSFR16	Garyllis	13 730
17	CY-APSFR17	Marketou	3 760
18	CY-APSFR18	Komitis	3 600
19	CY-APSFR19	Vasilikos	7 790

Data used

The following data was used during the map production:

- Aerial photographs 2008 provided by the Department of Lands and Surveys.
- Satellite images available from ArcGIS Online for areas not covered by the 2008 backgrounds.
- Bare Earth Digital Terrain Model in Triangular Irregular Network (TIN) format resulting from LIDAR data.
- A geospatial file with the land uses in the areas under consideration and a Table 4.with building and coverage factors per use given by WDD.
- A geospatial database with site locations that may cause accidental pollution in the event of a flood.
- The population density values (area per person).
- The results of the hydraulic modelling solutions for each area.

Flood Hazard and Risk Maps produced

Table 22 summarises all the hazard and risk maps produced for all of the areas of consideration.

Table 22. Total hazard and risk maps produced

A/A	Name of River / Stream	Hazard maps					Risk maps				Totals
		Summary	Flood possibility			Total	Flood possibility			Total	
			Low	Medium	High		Low	Medium	High		
1	Pediaios	8	8	8	8	**32**	8	8	8	**24**	**56**
2	Klimos	2	2	2	2	**8**	2	2	2	**6**	**14**
3	Merikas (tributary)	1	1	1	1	**4**	1	1	1	**3**	**7**
4	Kalogeros	2	2	2	2	**8**	2	2	2	**6**	**14**
5	Merikas	2	2	2	2	**8**	2	2	2	**6**	**14**
6	Almiyros-Alikos	1	1	1	1	**4**	1	1	1	**3**	**7**
7	Paralimni	1	1	1	1	**4**	1	1	1	**3**	**7**
8	Gialias	2	2	2	2	**8**	2	2	2	**6**	**14**
9	Ormidia	2	2	2	2	**8**	2	2	2	**6**	**14**
10	Archangelos	2	2	2	2	**8**	2	2	2	**6**	**14**
11	Kamares	2	2	2	2	**8**	2	2	2	**6**	**14**
12	Kosinas	2	2	2	2	**8**	2	2	2	**6**	**14**
13	Limnarka	1	1	1	1	**4**	1	1	1	**3**	**7**
14	Germasogeia	3	3	3	3	**12**	3	3	3	**9**	**21**
15	Vathias	2	2	2	2	**8**	2	2	2	**6**	**14**
16	Garyllis	3	3	3	3	**12**	3	3	3	**9**	**21**
17	Marketou	2	2	2	2	**8**	2	2	2	**6**	**14**
18	Komitis	1	1	1	1	**4**	1	1	1	**3**	**7**
19	Vasilikos	3	3	3	3	**12**	3	3	3	**9**	**21**
Totals		**42**	**42**	**42**	**42**	**168**	**42**	**42**	**42**	**126**	**294**

In cases of river basins that could not be showed by a single sheet of paper, more than one sheets were numbered appropriately.

Creation of hazard maps

1. Extraction of the maximum water level using HEC-RAS

Only the maximum water level section (MaxWS) results were extracted from HEC-RAS per cross section. Hydraulic model resolutions were made for non-steady flow conditions with a five (5) minutes step and a fifteen (15) minutes output.

2. Conversion of the file into XML formatting

In order to import digital data into a GIS environment, the file extracted from HEC-RAS (SDF formatting) has to be converted to XML. The conversion is performed through HEC-GEORAS tools.

3. Import of the XML file into GIS

The above file is imported into a GIS environment using HEC-GEORAS tools. In more detail, a File Geodatabase is created where the vector data is imported as a minimum: a) the XS Cut Lines of the hydraulic model and b) the polygon in which the flooding will be shown, (Bounding Polygon) is depicted. During this phase, the digital model (TIN) of the bare ground is also converted to a mosaic file (dtmgrid). The pixel size has been set at two (2) meters for all models. The size is small since highly analysed data is available due to the LIDAR flood area. This size also determines the pixel size of the flow-rate file to be generated in the next steps.

4. Editing of the vector data

The processing of the above mainly consists from the expansion of the polygon flood imaging to cross sections in the positions wherein set levees point in hydraulic model and in small areas which are flooded but are not described by the cross sections. In the cross sections of the levees, the polygon produced is limited to these positions which affect the extent of the flooding in the cross sections before and after these positions.

5. Production of a triangular digital model of maximum water level

Using a HEC-GEORAS tool (Water Surface Generation) and based on the maximum water level contained in the hydraulic model cross sections already introduced into the GIS, the triangular model of maximum water level (t Max WS) is produced.

6. Production of a mosaic file of depths flow and flood boundaries

The triangular water surface model created in step e. is firstly converted to a mosaic file with a pixel size defined when the data is entering the GIS database (see step 3). The depth flow-rate mosaic is then produced by subtracting for each pixel the value of the terrain altitude from the value the maximum water level. Finally, the flood boundary is generated as the outline of the above depths flow mosaic file.

7. Editing of the flood limit

Then the flood limit is edited in a GIS environment. Normalization of points that were not consistent with the overall picture of the terrain.

8. Editing of the flood mosaic file

For the filling of small soil islets within the flood limits, applied automated methods in Arc GIS Toolbox (Nibble) were used.

9. Cut off a segment of a depth flow file within the processed flood limit

Finally, with the ArcGIS Toolbox (Raster Clip) tools, the processed mosaic depth flow file was cut off within the processed flood limit.

10. Creation of Hazard maps

A geodatabase and a map file (mxd) for each study area and each return period were created. The background of the depth flow record, the flood limit, the cross sections and the cross-sectional boundary were inserted on each map. Then the cross sections whose elements will be visualized are selected. It is noted that due to the high cross-sectional density required in the hydraulic models for solving under non-steady flow conditions, it was not possible to visualize all the cross-sections.

Flood scenarios in Cyprus

The three scenarios that were created to show the flooding events are the ones that are shown on **Error! Reference source not found.**, i.e. low flood possibility (return period of 500 years), medium flood possibility (return period of 100 years) and high flood possibility (return period of 20 years) scenarios. The following maps represent the 3 scenarios for Pediaios river. Each scenario is separated into hazard and risk maps. There are 8 flood hazard maps showing all three return periods and 24 flood risk maps (8 flood risk maps * 3 return periods - T).

The population affected by the flooding of each one of the 19 vulnerable to flooding areas is shown in the next two Figures.

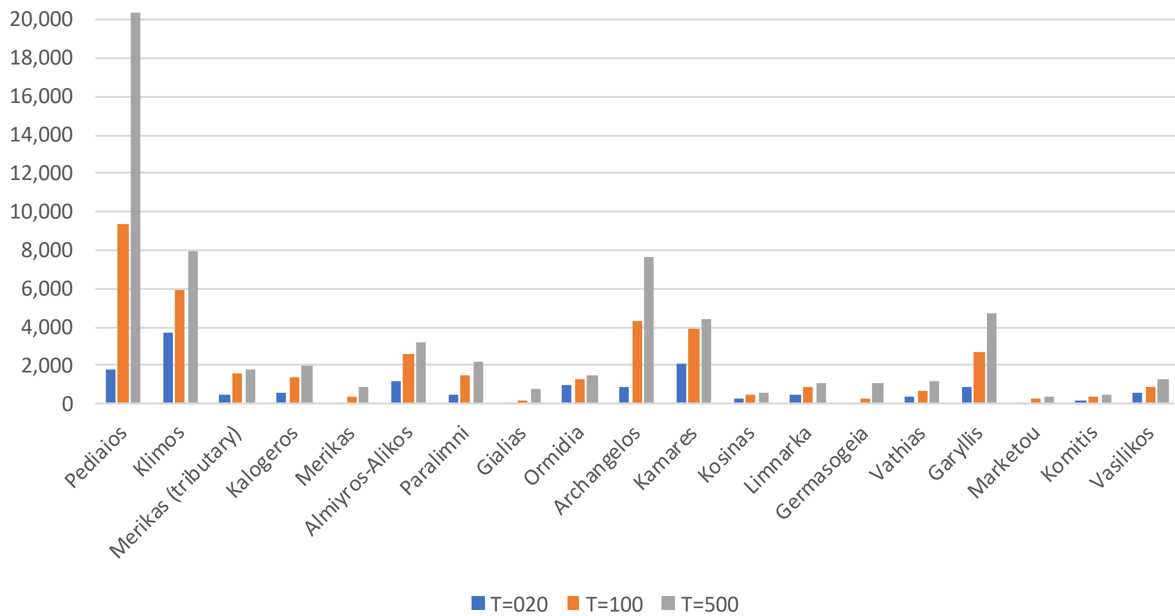

Figure 55 – Estimated population affected by flooding in full development of the river area (WDD)

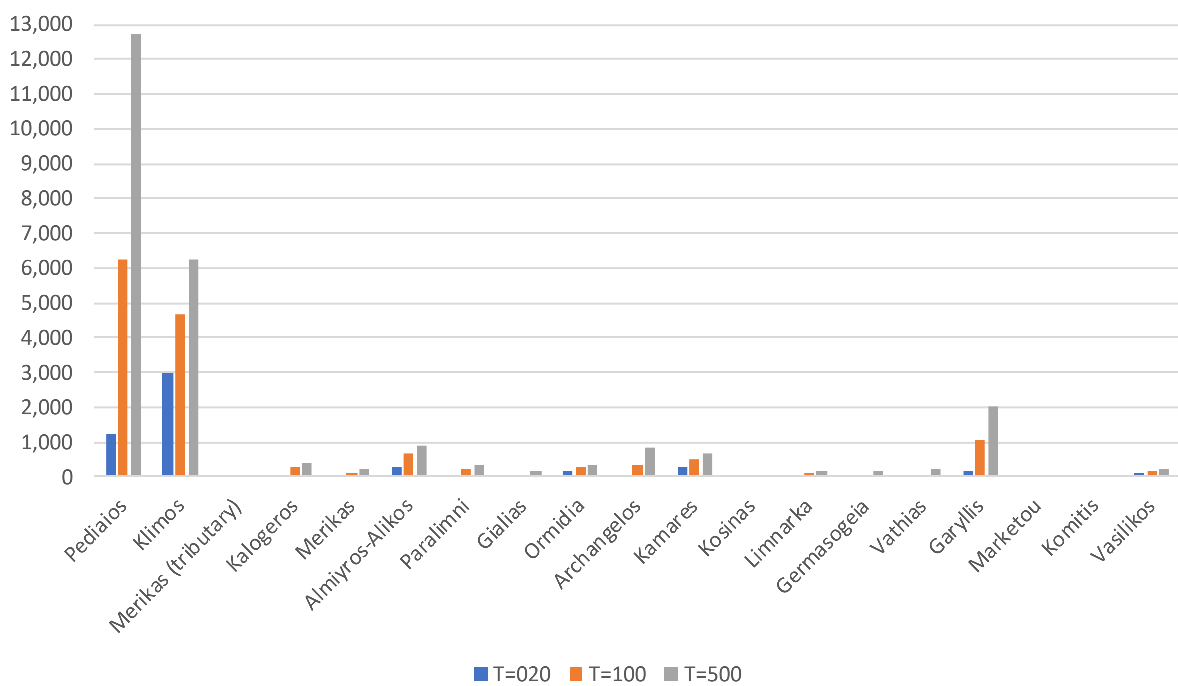

Figure 56 – Estimated population (in river area) affected by flooding in 2014 (WDD)

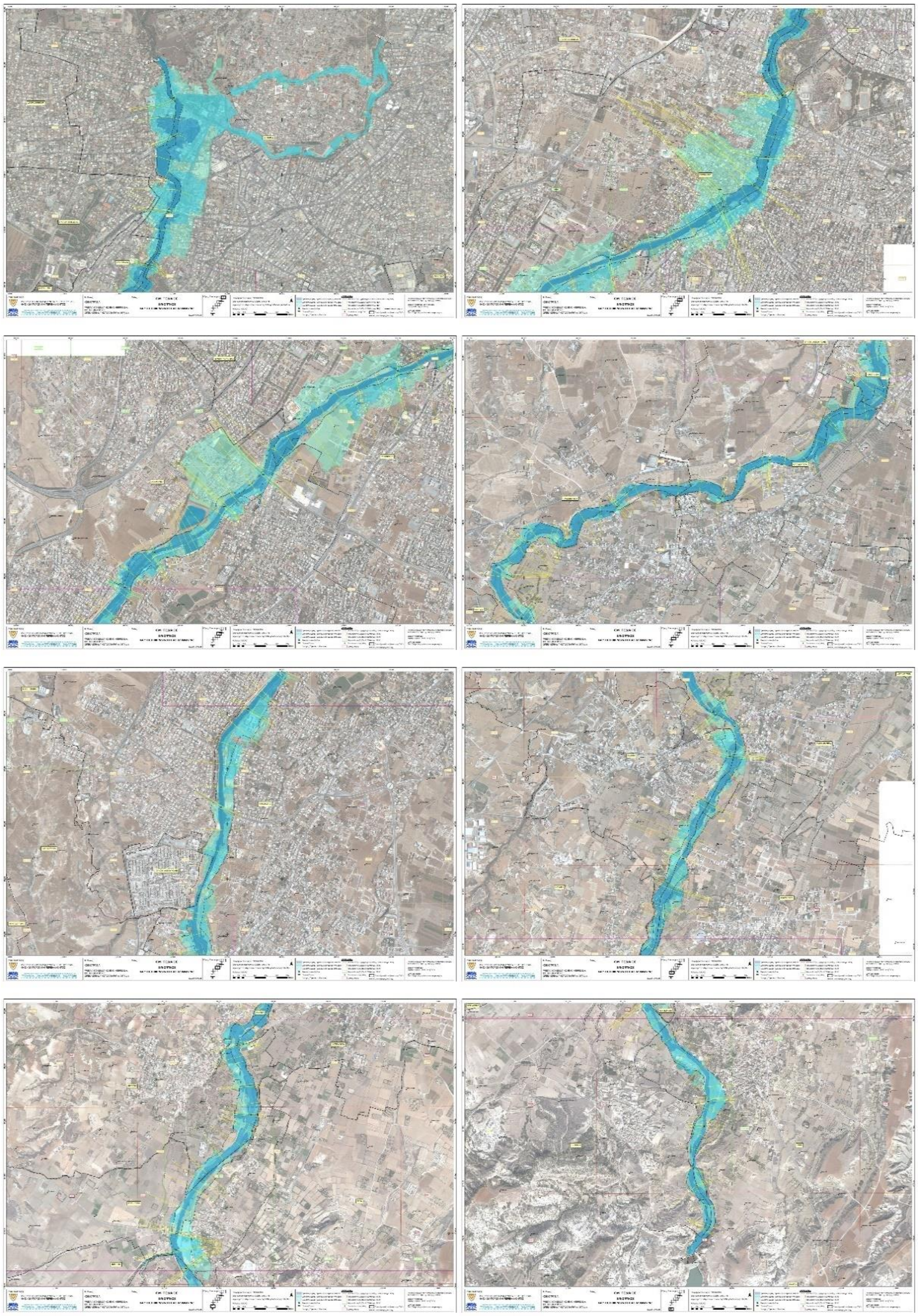

Figure 57 – Flood Hazard map of Pediaios river – 20, 100 and 500 restoration periods – 1-8 (WDD)

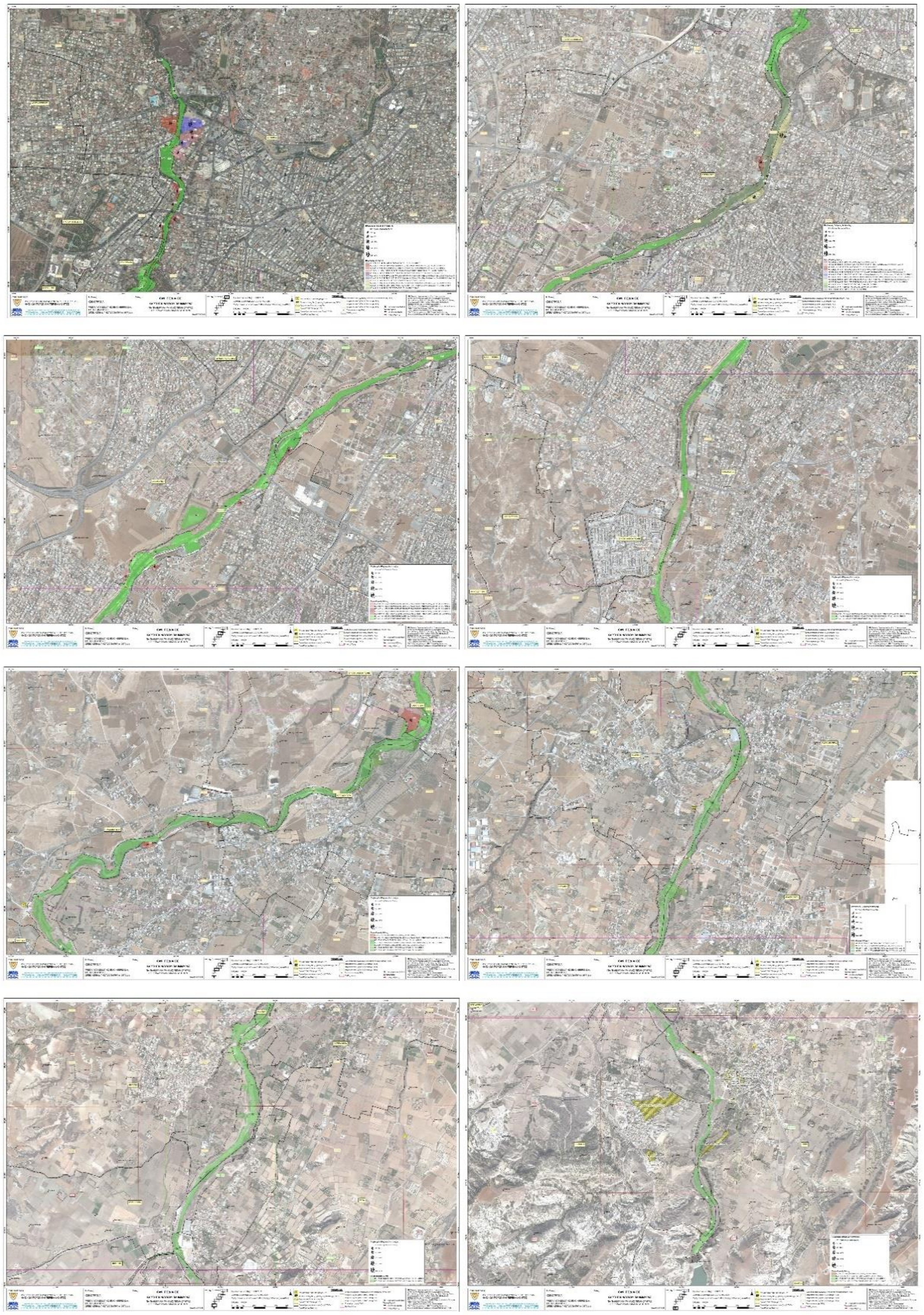

Figure 58 – Flood Risk map of Pediaios river – 20 years restoration period – 1-8 (WDD)

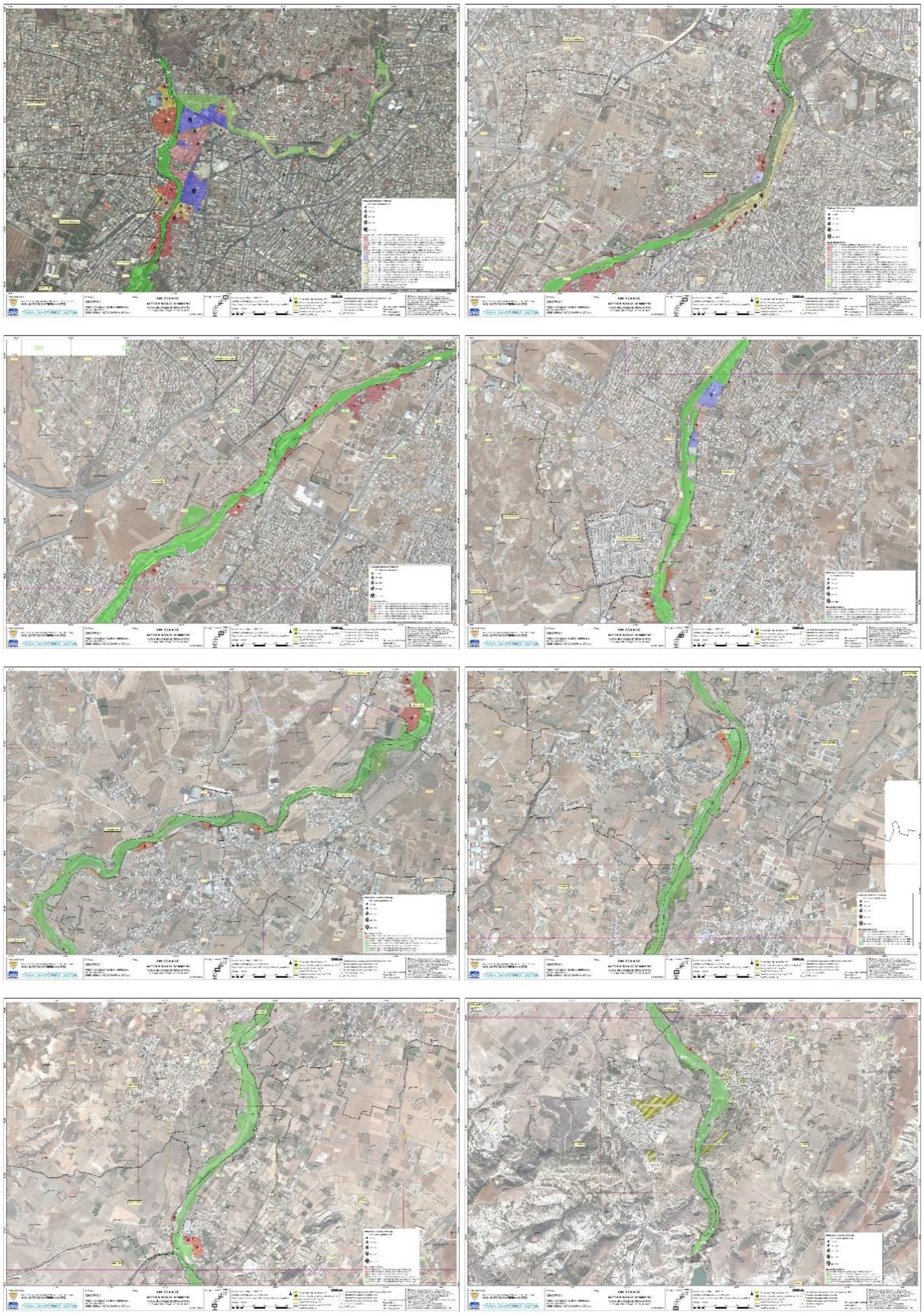

Figure 59 – Flood Risk map of Pediaios river – 100 years restoration period – 1-8 (WDD)

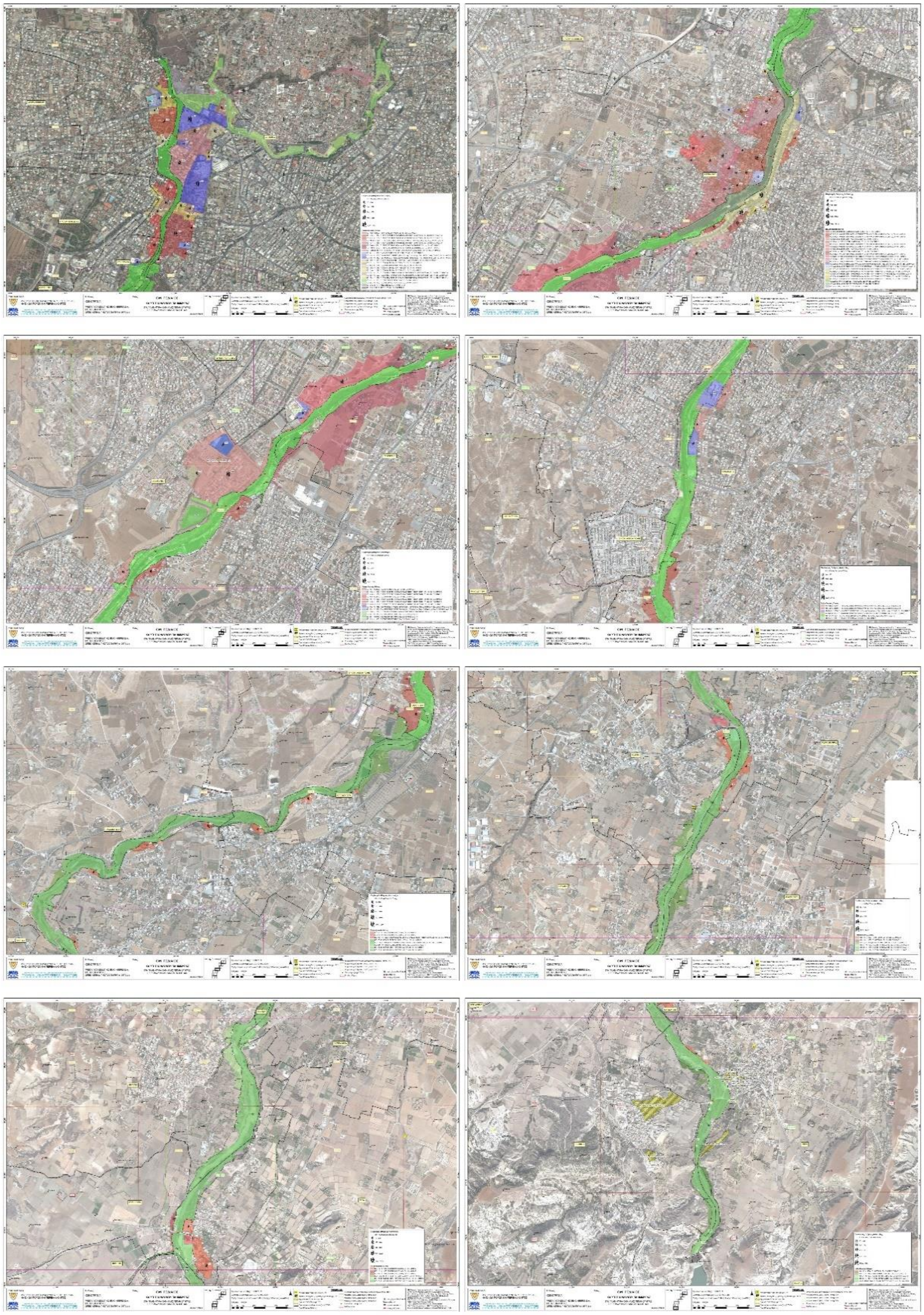

Figure 60 – Flood Risk map of Pediaios river – 500 years restoration period – 8/8 (WDD)

Early warnings system for floods in Cyprus

The aim of this task is to describe an Early warning tool produced by an EU funded project that supports decision makers in the prediction of flood events according to the flood models created in Task 4.3. This tool is connected to a geodatabase created in a Geographic Information System (GIS) environment and through interpolation according to the intensity of precipitation. It is a tool, which links the maximum intensity precipitation to areas which can lead to potentials floods.

The Early Warning tool was produced during a project that received funding from the European Union's Directorate-General humanitarian aid and civil protection (DG-ECHO) under Grant Agreement ECHO/SUB/2015/713788/PREP02. The name of the project was "Use of SDSS and MCDA to prepare for disasters Or Plan for multiple hazards" while "DECATASTROPHIZE" was its acronym. The information of this task was taken from the DECATASTROPHIZE project.

The Decision Support System (DSS) Tool

This tool is a platform for the dissemination of geospatial data and information about hazards, including floods, for emergency management purposes. The basic features of the tool are:

- Basic GIS visualization. The tool performs in a GIS environment i.e. it displays vector and raster data which overlay over high resolutions background, it displays layers legends, there is scale control and mouse lat/long coordinates, maps printing and measuring tools are applicable.
- Geospatial data integration. Different GIS tools can be used by different authorized personnel in monitoring the same or different hazard/event
- Web GIS editing tools to harmonize feedback. The user can to annotate a map in order to describe the current status of an area where a disaster is recently happened.
- Visualization of time-dependent layers. The tool can provide time-dependent visualization on the map.
- Integration of existing Hazard Models. The tool can work, after integration and adaptation, with different existing hazard models. This can be performed either by full model integration or using precomputed scenarios or using manual execution of external models or by having loose platform integration.

It consists of three different sections, that are interconnected to each other to form a recursive workflow stopping at the end of an emergency. These three different sections support the main phases of the emergency management: Early Warning, Impact Assessment and Mitigation of Impact plus a few modules that provide generic supports needed by the three phases. The DSS with its modules and processes are described in the following Figure 61.

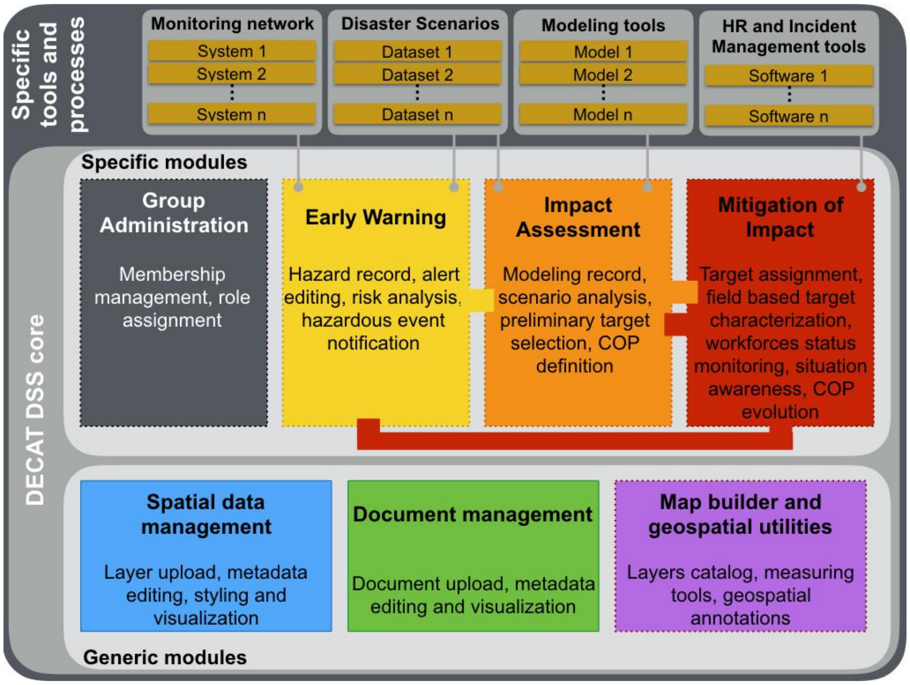

Figure 61 – Functional decomposition of the DSS platform (Damalas et al. 2018)

The Early Warning phase, aimed to collect the hazardous event occurring in a certain area to provide early warnings to the disaster management team. It provides the operator with wizards helping in editing and updating events (ex. flooding events) occurring inside the area of interest. in these wizards, the operator can edit point features and record ancillary information for the characterization of a hazardous event, i.e. the level of the hazard. As Figure 62 shows, the event is firstly promoted to the DSS platform, and then the other phases are enabled enableing the impact and manage of the emergeny.

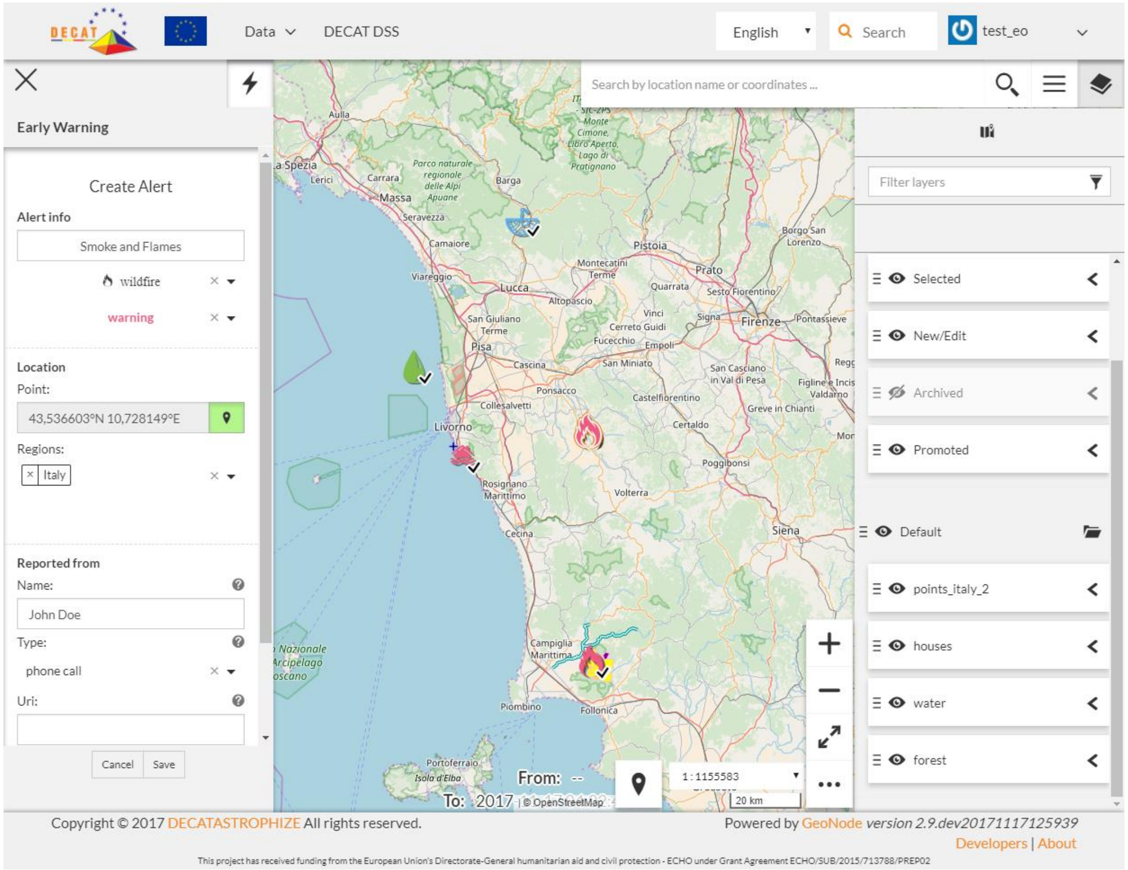

Figure 62 – User Interface for Event Operator (Damalas et al. 2018)

The impact assessment phase is where all context data in the area of interest and the hazardous event are analyzed by modeling or pre-formulated scenario analyses, additional spatial information, reports and documents useful to properly identify and locate specific needs of rescue and recovery interventions. The aim of the phase is to evaluate at an early stage the distribution and magnitude of potential losses due to a disaster. It is designed to permit the creation and update of the Common Operating Picture (COP) for the emergency managers. The COP can be the reference map created by the impact assessor which can be used to show multi-hazard modeling together with geospatial information related to emergency plan implementation like hospital locations and targets needing urgent intervention. Figure 63 shows some symbols (for fire hazard) that were used to visualize the hazard. These symbols can be changed accordingly for many hazards, including floods. The COP can then be frozen and shared with the emergency managers, responsible to assign rescue or recovery targets to work-force teams.

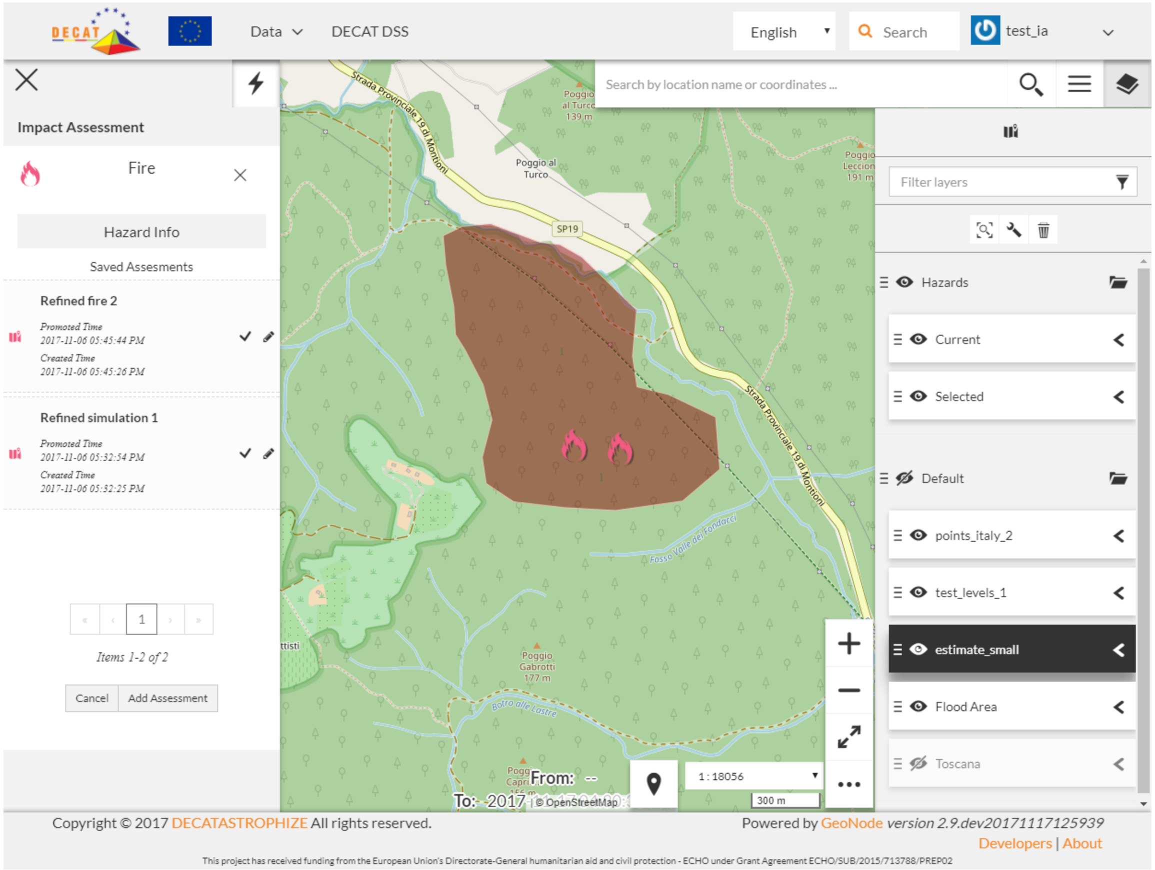

Figure 63 – User Interface for Impact Assessor (Damalas et al. 2018)

The mitigation of the impact phase assists the tactical level by: a) prioritizing the mitigation actions and rescue operations in the area of interest, b) recording the allocation of relief workforces and incident management evolution and c) using feedbacks from the field to update the assessment or to notify unexpected events, occurred in the crises area, significantly influencing the disaster evolution. It provides to the emergency managers the ability to work together and manage online the COP. This is performed by allocating the working teams by means of the workforce they belong. Figure 64 shows the mitigation of the impact phase where the geospatial features can be updated in real-time to capture the status of the resources engaged in rescuing operation on field.

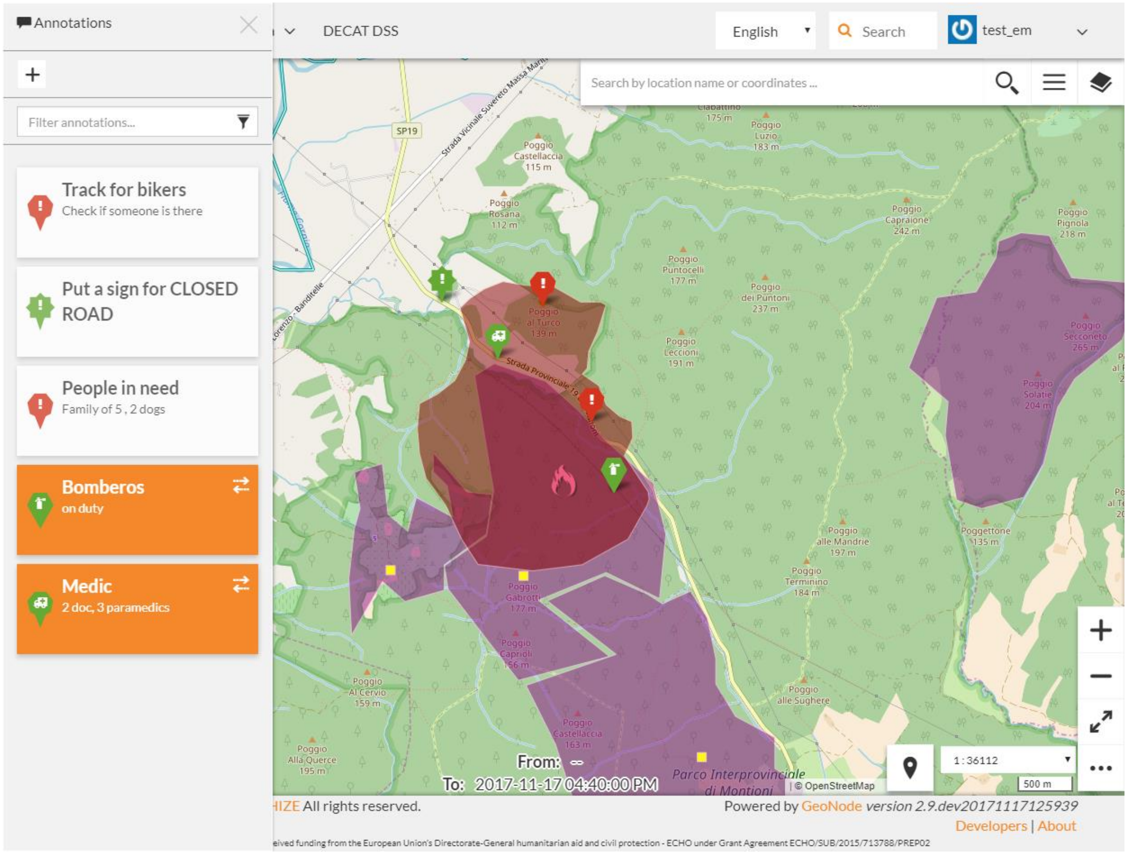

Figure 64 – User Interface of the Emergency Manager – mitigation of the impact (Damalas et al. 2018)

The management of hazards on DSS tool, is managed as a workflow. Different types of Operators, with different expertise, capabilities and responsibilities, are involved on the different phases of the management of the impact event and its mitigation. The main objective is to provide to the users involved only the tool and information they really need, helping them to take action quickly and in an intuitive way. Figure 65 shows the three phases and the roles of each phase user.

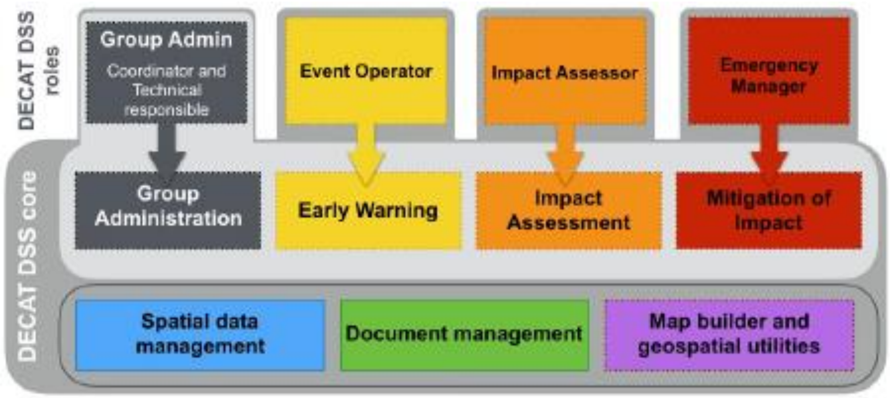

Figure 65 – Roles of the operators of each phase

In other words, the whole tool is designed in a way to make procedures simple and speed up the sharing of the geospatial information. Also, it disseminates the geospatial representation of the COP progression by supporting a workflow of repeated communication among Early Warning updates, Impact Assessment re-evaluations and Emergency management evolution. Tools like the one described in this task, can help managers and event operators to prepare and prevent from the flood hazard, but also in the event of a multi-hazard scenario.

11 FIRES IN FORESTS AND RURAL AREAS

Hazard scenario identification

Forest and rural vegetation classification, based on elaboration and analysis of satellite imagery, grey literature data and field visits will allowing for the identification and mapping fire hazard potential across the country. Forest (vegetation) fuel characterization and relative mapping will be implemented for assessing the respective component of the geographic distribution of hazard. Meteorological patterns and relevant regimes (wind) during the fire season will be studied in particular in statistically high-risk areas. Climate change projections over the next decade will be further used to identify intensity and frequency patterns and support mid-term fire prevention policy decisions and eventual fire management investments. Basic and extreme hazard scenarios will be prepared and analyzed based on relevant vegetation and climate patterns.

Introduction

Forest fires (also including megafies, WUI, etc) have been considered a major hazard in the EU domain[i]. On an annual basis half a million hectares of forest and natural lands is burned on average. The spatial characteristics and recurrence period of forest fires heavily depends on local meteorological conditions and dead biomass burning/accumulation, which is exacerbated by changing climate patterns.

The likelihood and characteristics of forest fires vary depending on the types of forest, topography, climatic conditions and preparedness to respond and contain early-on localised sources of fire. In fact, a large majority of forest fires are initiated by malicious or unintended human action. Forest fires can have major disruptive impacts on the environment, human lives health, cultural heritage and the economy, considering the particularly significant environmental, financial and well-being value of forests in Europe. When combined with extreme climate conditions and non-optimal emergency response, forest fires result to deaths (e.g. 49 in Portugal 2017, 99 in Greece 2018) and injuries, environmental and ecosystem degradation, extensive property damage, disruption to critical infrastructure services (electricity, transportation, water, telecoms), businesses and private assets. Secondary effects are also of importance due to high concentration of air pollutants (PM2.5, PM10, dioxins, CO, etc…) that could cause adverse health effects and contribute to global warming.

It should be noted that, WP7 relies on data that will be provided by the Department of Forestry and the Department of Meteorology. At the moment the research team anticipates delivery of data from the Department of Forestry. There is a fee for the Meteorological data provided by the Department of Meteorology, and we are in the process of finding a solution.

Description of Forest (vegetation) fuel characterization and relative mapping in Cyprus

According to the FAO, 18.7% or about 173,000 ha in Cyprus are covered by forests. In the period between 1990 and 2010, Cyprus lost an average of 600 ha or 0.37% per year. In total, between 1990 and 2010, Cyprus gained 7.5% of its forest cover or around 12,000 ha (Cyprus Forest Information and Data). Forests in Cyprus are classified in two groups (a) forests and (b) other wooded land. These two major forest types account for about 42% of the total land area[1]. About 40% of this land is of state ownership. High forests account for 45% of the total forest area and lower vegetation for the rest 55% (Figure 66). Plantations account only for 2.3% and were mainly planted in the past for fuelwood production, sand dune stabilisation and swamp drainage.

Forest ecosystems are established across the Troodos and Pentadaktylos ranges as well as along the coastal belt. It should be noted that there is no forest in the central Mesaoria plain, which is in general characterised as a climatic semi-arid zone with a prolonged drought period. Over the last decades there has been observed a small increase in forest cover due to afforestation of state land and abandonment of private land. Forest ownership status plays an important role in the quality of forest management. State forests are managed by the Department of Forests (DoF) and are under a systematic management and protection status, with almost 80% of this land use type registered in the Natura 2000 network**.** Private forest are usually fragmented small parts of land with an average size of 2-4 ha, growing at the borders of state forests.

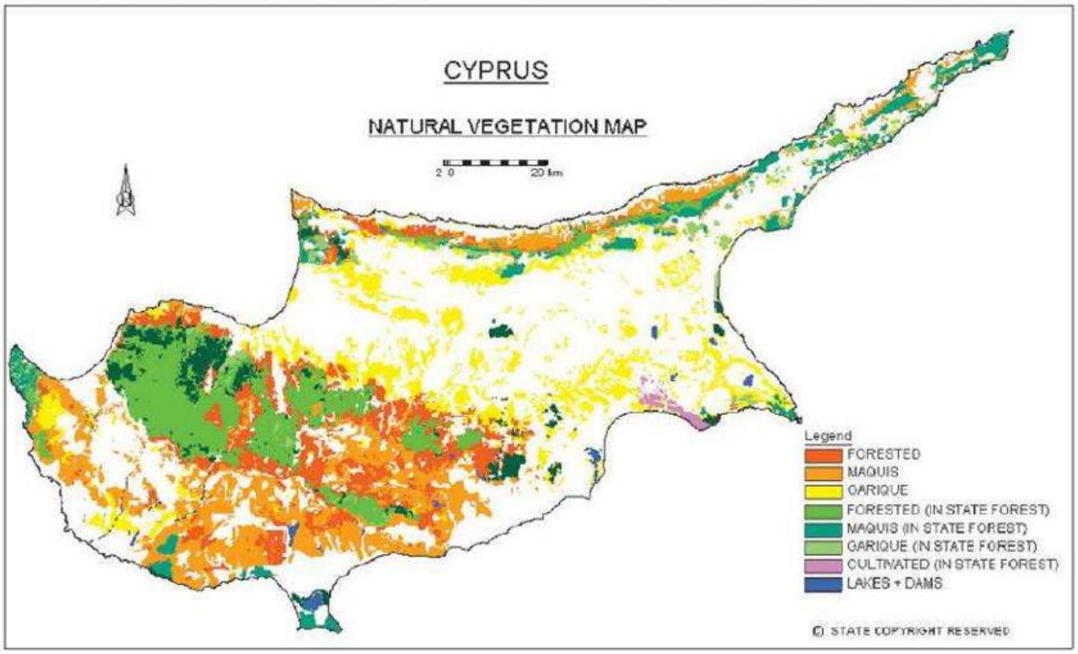

Figure 66 – Natural Vegetation Map of Cyprus (Source: ECHOES Cost Action 2009)

The main state forests occupy the two mountainous ranges of south Troodos and northern Pentadactylos. Conifers and broadleaved tree species such as pines, cedars, cypress and oaks are the dominant elements of vegetation. The most common species is *Pinus*, which is the most productive species found up to 1400m above sea level (asl). *Pinus nigra* subsp. *pallasiana* dominates the higher elevations of the Troodos mountain up to 1950m asl. *Cedrus brevifolia* (endemic), *Juniperus foetidissima, Juniperus oxycedrus* and *Juniperus excelsa* are also found at higher elevations. The endemic *Quercus alnifolia* is usually found at the understory of conifer stands or in pure stands above 700m asl across the Troodos mountain range. Lowland forests (8% of total forested area) are dominated by *Juniperus phoenicea, Olea europaea, Ceratonia siliqua, Pistacia lentiscus, Pistacia terebinthus* and scattered *Pinus brutia.* **Table 23** provides information of the area covered by the most dominant tree species Cyprus. Sclerophyllus species such as *Quercus alnifolia, Crataegus azarolus*, *Pistacia lentiscus, Pistacia terebinthus, Olea europaea, Ceratonia siliqua, Sarcopoterium spinosum, Thymus capitatus and Ziziphus* lotus dominate the maqui and phryganic ecosystems that cover a large area in Cyprus (213.000 ha).

Pinus brutia is the only commercial species in Cyprus. The total area covered by *P. brutia* is around 138.000 ha, with only 30% characterised as productive. Due to the low growth rate and the existence of under stocked areas, the annual cut covers only 2% of the local demand for wood. Thus, forestry contribution to the economy of Cyprus is negligible.

Cypriot forests are an important resource that provides non-wood forest products and services (NWFPs). These services include soil and water protection and regulation, support of biological diversity, carbon sinks and mitigation of global warming and various recreational and touristic activities. **Table 24** provides a summary of some key ecosystem services provided by the common forest species in Cyprus. These services accounted for in management and climate change adaptation policies. In terms of biodiversity conservation, **Table 25** presents a list of the endemic trees and shrubs found in Cyprus. These species are of particular ecological value, which should be taken into account in management and climate change adaptation policies.

Table 23. Area Covered by the dominant forest species in Cyprus (Source: DoF 2006)

Community	State	Private	Total
Pinus brutia	88.790	48.954	137.744
Juniperus phoenicia	5.350	2.940	8.290
Cupressus sempervirens		7.270	7.270
Pinus brutia- Quercus alnifolia	5.870		5.870
Ceratonia siliqua - Olea europaea		5.720	5.720
Pinus nigra	2.640		2.640
Pinus brutia - Pinus nigra	2.330		2.330
Platanus - Alnus spp	430	610	1.040
Eucalyptus spp	137	260	397
Cedrus brevifolia	130		130
Cedrus brevifolia - Pinus brutia	120		120
Quercus infectoria subsp. *veneris*		60	60

Table 24. Ecosystem services provided by common forest species (Source: DoF 2011)

Species	Soil and Water Conservation	Biodiversity Conservatio n	Cultural Values	Aestheti c Values
Pinus brutia	X	X		X
Pinus nigra	X	X	X	X
Cedrus brevifolia	X	X	X	X
Juniperus foetidissima	X	X		X
Juniperus excelsa	X	X		X

Species	**Soil and Water Conservation**	**Biodiversity Conservatio n**	**Cultural Values**	**Aestheti c Values**
Juniperus phoenicea	X	X		X
Cupressus sempervirens	X	X	X	X
Quercus infectoria subsp. *veneris*	X	X	X	X
Quercus alnifolia	X	X		X
Platanus orientalis	X	X	X	X
Alnus orientalis	X	X		X
Eucalyptus spp.	X	X		X

Table 25. Endemic forest & woody species in Cyprus (Source: DoF 2011)

Forest Trees and Other Woody Species Which Are Endemic In Cyprus			
1	*Acinos troodi*	27	*Onosma caespitosa*
2	*Alyssum akamasicum*	28	*Onosma fruticosa*
3	*Alyssum chondrogynum*	29	*Onosma troodi*
4	*Alyssum troodi*	30	*Origanum cordifolium*
5	*Anthemis plutonia*	31	*Origanum majorana* var *tenuifolium*
6	*Anthemis tricolor*	32	*Origanums yriacum* ssp. *bevanii*
7	*Arabis cypria*	33	*Phlomis brevibracteata*
8	*Arabis purpurea*	34	*Phlomis cypria* var. *cypria*
9	*Asperula cypria*	35	*Phlomis cypria* var. *occidentalis*
10	*Astragalus echinus* ssp. *chionistrae*	36	*Pterocephalus multiflorus* ssp. *multiflorus*
11	*Astragalus macrocarpus* ssp. *lefkarensis*	37	*Pterocephalus multiflorus* ssp. *obtusifolius*
12	*Ballota integrifolia*	38	*Ptilostemon chamaepeuce* var. *cyprius*
13	*Bosea cypria*	39	*Quercus alnifolia*
14	*Carlina pygmaea*	40	*Rosa chionistrae*
15	*Cedrus brevifolia*	41	*Rubia laurae*
16	*Centaurea akamantis*	42	*Salvia willeana*
17	*Dianthus cyprius*	43	*Saponaria cypria*
18	*Dianthus strictus* var. *troodi*	44	*Scabiosa cyprica*
19	*Erysimum kykkoticum*	45	*Sideritis cypria*

Forest Trees and Other Woody Species Which Are Endemic In Cyprus			
20	*Genista sphacelata* ssp. *crudelis*	46	*Teucrium cyprium* ssp. *cyprium*
21	*Hedysarum cyprium*	47	*Teucrium cyprium* ssp. *kyreniae*
22	*Helianthemum obtusifolium*	48	*Teucrium divaricatum* ssp. *canescens*
23	*Micrimeria cypria*	49	*Teucriumm icropodioides*
24	*Micromeria chionistrae*	50	*Thlaspi cyprium*
25	*Nepeta troodi*	51	*Thymus integer*
26	*Odontites cypria*		

Major threats for forest ecosystems in Cyprus are briefly described below.

Forest Fires are the most catastrophic agent for both forests and other wooded lands in Cyprus. As in most Mediterranean biomes fire risk and hazard is greater during the summer period. Abandonment of agricultural land contributes to increase of fire hazard through the increase of flammable vegetation components. The mean number of fires for the period between 2002 and 2014 was 198 with the mean area burned around 2100 ha per year. The highest number of fire events was recorded in 2013 and was associated with an increased burned area.

Grazing and in particular **overgrazing** is an important problem in some of the state forests in Cyprus. Overgrazing leads to vegetation degradation and soil erosion.

Climate Change. Over the last century, a strong increase in the mean summer temperature was recorded for the Eastern part of the Mediterranean basin from the 1950s, followed by a cooling until the mid-1970s. Subsequently a strong warming was observed with 2003 being the hottest summer[1]. A strong decline in precipitation, starting from the early 1960s is evident. These climate changes are associated with over 6000 ha of dieback and secondary insect infestations in Cyprus forests (DoF 2011).

Land use and Land use changes, mainly associated with unsustainable touristic development affect private forestland.

According to the CYSTAT data[1] the gross output of forestry recorded a significant increase reaching to €3.4 million in 2011, while in 2012 recorded a decrease of 16.4% and dropped to €2.8 million. Timber production recorded a decrease from 6,177 cubic metres in 2011 to 5,572 cubic meters in 2012. In addition, charcoal production increased significantly to 1,217 tons in 2012 from 662 tons in 2011. The long-term patterns of timber and charcoal production are presented in Figure 67. A rather stable rate is observed for the 2002-2014 period.

As far as other forest products are concerned, a decrease was observed in fuel wood production, which dropped to €241,100 in 2012. The value of production of plants, seeds, Christmas trees etc.

increased significantly and reached from €263,392 in 2010 to €1,544,000 in 2011, while the same value of production decreased by 43% and dropped to €879,200 in 2012. Reforestation increased by 22.8% in 2012 compared to 2011.

The Value added of the forestry subsector to the agricultural sector[1] decreased from 0.6% in 2011 to 0.5% in 2012. Agricultural sector's contribution to GDP was 2% in 2011 and 1.9% in 2012 and rose to 2.5 in 2013 (CYSTAT 2014, 2015a, 2015b).

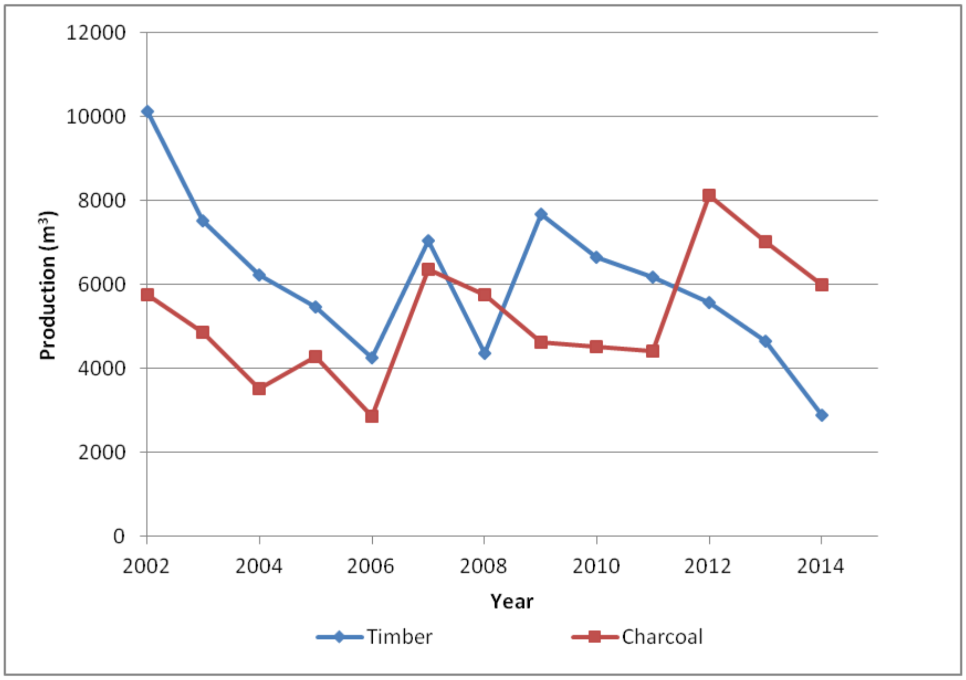

Figure 67 – Timber and charcoal production during the 2002-2014 period (data source: DoF annual reports)

[1] includes crop, livestock, forestry, fishing and ancillary production

Description of wind dynamic in Cyprus

Over the eastern Mediterranean generally surface winds are mostly westerly or southwesterly in winter and northwesterly or northerly in summer. Usually of light or moderate strength, they rarely reach gale force.

Over the island of Cyprus, winds are quite variable in direction with orography and local heating effects playing a large part in determination of local wind direction and strength. Differences of temperature between sea and land, which are built up daily in predominant periods of clear skies in summer cause considerable sea and land breezes. Whilst these are most marked near the coasts they regularly penetrate inland in summer reaching the capital, Nicosia, often bringing a reduction of temperature and also an increase in humidity[1].

Gales are infrequent over Cyprus but may occur especially on exposed coasts with winter depressions. Small whirlwinds are common in summer appearing mostly near midday as "dust devils" on the hot dry central plain. Very rarely vortices, approaching a diameter of 100 metres or so and with the characteristics of water spouts at sea and of small tornadoes on land, occur in a thundery type of weather. Localized damage caused by these has been reported on a few occasions but in general Cyprus suffers relatively little wind damage.

Kleanthous et al[1] provide an analysis of air pollution characteristics for Cyprus. Data from four monitoring stations of the network of the Air Quality Section of the Department of Labour Inspection[1] had been used in this study. The stations are (a) the rural inland Agia Marina station (35.04N–33.06E, 532 m a.s.l.), (b) the rural-marine Inia (34.99N–32.40E, 672 m a.s.l.) to the east of Cyprus, (c) the lower altitude and more exposed to sea-breeze circulation rural Cavo Greco (35.02N–34.09E, 23 m a.s.l.) to the west of Cyprus, and (d) the rural-Stavrovouni (34.89N, 33.44E, 650 m a.s.l.). Agia Marina, is additionally part of the European Monitoring and Evaluation Programme[1]. The Agia-Marina station started operation in 1997[1].

The wind climatology shows a prevalence of north and north-westerly winds during the entire year, bringing continental air from Turkey and Eastern/Central Europe; their most frequent occurrence is observed during the dry period (May to September). Especially in summer, northerlies account for the largest fraction (80%) of the overall wind regime. Toward the wet season (October to April), their contribution is smaller mainly due to the enhancement of the southerlies (Africa) and westerlies (clean maritime air).

Table 26. Basic statistics of observed daily mean chemical and meteorological parameters at the Agia Marina (EMEP) monitoring station including their minimum and maximum values

Station	Data (units)	Period	Range	Average ± std	Median	Min	Max
Agia Marina (EMEP)	Ozone (ppbv)	1997–2012	26.0–76.7	47.5 ± 8.2	47	26	76.7
	NO (ppbv)	2007–2012	0.0–1.4	0.2 ± 0.2	0.2	0	1.4
	NOy (ppbv)	2007–2012	0.4–9.7	1.8 ± 0.9	1.6	0.6	8.5
	CO (ppbv)	2011–2012	77.2–250.0	145.5 ± 27.6	142.2	77.2	250

	Temperature (°C)	1997–2012	1.3–35.7	18.9 ± 7.2	19	− 1.3	35.7
	Relative humidity (%)	2007–2012	12.8–91.6	55.0 ± 14.3	57.3	12.8	91.2
	Wind speed (m s− 1)	1997–2012	0.8–9.7	2.9 ± 1.0	2.6	0.8	9.7
	Solar radiation flux (W m− 2)	1997–2012	0.0–850.5	211.9 ± 99.5	209.4	0	387

Easternmost Mediterranean Sea; and especially maritime areas offshore of Middle East and Cyprus where the current 30 year mean wind speed value is below 6 m s1 revealing the lower wind power amounts (400 W m2), with negative future change at the middle and the near end of 21st century (100 to 200 W m2 , respectively). Additionally, almost all ensemble members agree that the wind power potential would decrease by more than 5%.

Parameters defining the framework (used to estimate probability, vulnerability and exposure)

Such parameters may be included to the general National Forest Fire Management system. Such parameters provide insight on the level of preparedness, that can play a critical role in defining the severity of an event as well as exposure and vulnerability of socioeconomical parameters.

Legislation

In Cyprus there are 2 laws concerning forest fires and their management:

(a) The Forest Law of 2012

(b) The Law for the Prevention and Control of Fires in Rural Areas of 1988.

Effective legislation actually defined the National Fire management Plan.

A number of Government agencies are involved in the extinguishment of fires, namely the Fire Service, the Forest Service and the Civil Defense Force. In case a fire breaks out in the areas falling under the British Sovereign Bases jurisdiction, the above are assisted by the relevant British authorities and in those cases that a fire incident occurs in the “green line” the UN authorities are getting involved. Each agency is involved according to the fire classification criteria as follows:

<u>Forest Fires:</u> The primary responsibility rests on the Department of Forest of the Ministry of Agriculture, Natural Resources and Environment.

<u>Rural Fires:</u> The Cyprus Fire Service which comes under the jurisdiction of the Ministry of Justice and Public Order through the Police is responsible to fight all rural fires which are up to the distance

of 1km from forests boundaries. It is important to mention that the Civil Defense Force is acting in support of both in case of an emergency.

Prevention plans

The obligation for the preparation and implementation of fire prevention plans within the state forests and a zone of 2km from the state forest boundaries, lies on the Department of Forests. For other areas, the Department of Forests is involved only for the preparation of such plans. There are two major fire action plans: "Ifestos" and "Pyrsos". Effective prevention plans can affect the severity of an event and consequently the probability of having a major event.

Volunteers

A number of volunteers are involved in the forest fire management. They may contribute in fire detection (patrolling and observation) and in fire-fighting operations, as well as for the restoration of burnt areas. Training of volunteers may be an issue that can raise several concerns. The use of volunteers can increase the level of preparedness assist in dealing with an event, however, lack of adequate training can increase the probability of serious injuries and/or human losses (for them or for civilians).

Challenges of forest fire management due to geopolitical reasons (imported/exported fires, fires in the border)

Cyprus is an island, as such there are no imported or exported fires. Almost 40% of Cyprus is under occupation since the illegal invasion of Turkish troops in 1974. The Republic of Cyprus first response is in collaboration within and along the buffer zone, with the United Nations.

Firefighting Resources

The firefighting resources of the Department of Forests include:

(a) *Personnel:* 1.000 people (forest officers, fire fighters and fire watchers)

(b) *Ground and air means:* 2 firefighting airplanes, 83 fire engines of different types, 13 bulldozers, 4 trucks, 1 coordination vehicle and 185 personnel carrier vehicles.

(c) *Infrastructure:* 28 forest stations, 1 flight unit, 1 coordination center, 39 fire lookout stations, 215 watertanks, 38 helispots, 1 automatic fire detection system, network of forest roads and firebreaks.

Cooperation with other countries (Israel, Greece, ERCC)

The Republic of Cyprus enjoys the benefits of participating as a full member in the European Union since 2004. This fact provides the competent services of the Republic with directives, European instruments, joint committees, European authorities from which the Republic can draw a wealth of tools in terms of forest fires and disasters in general. The population of our country is 0.2% of the total EU population, area-wise Cyprus is 26th out of the 28 EU Member States. The purpose of the above comparison is to highlight the fact that the Republic- due to size - is a special case in relation to the structure of its State Agencies.

The Republic has a functioning public service system. In the field of forest fires, the main "actors" are:

- Department of Forests

- Fire Service

- Civil defence

- Prosecutor

- Wildlife Fund

- National Guard

- Police

Financial data

Regarding the economic dimension, to date, of the cost of firefighting in the Republic of Cyprus, it should be mentioned the following:

- The Government spends approximately 0.02% of the State Budget on fire-related expenditure (i.e. wages and benefits, rental costs, maintenance), based on data from 2010 - today

- This figure is gradually decreasing to around 0.019% in the years of the economic crisis

- Based on Geneva Fire Statistics, there are countries that spend comparable rates of GDP (eg Singapore 0.02%, Romania 0.05%) but these are at the lower end of the spectrum

- Countries like Portugal or the United Kingdom spend about 0.2% of their GDP at similar costs and are at the top end

Livestock and grazing data information

Grazing within the State forest is prohibited, unless a license is granted, according to the Forest Law. However, in certain areas like Akamas, Pegeia, Oreites and Radhi forests and to a lesser extent in the Machera, Lythrodontas, Aetomoutti, Xylia and Kakorazia forests, illegal grazing is practiced. According to the Annual Report, during 2016 totally 9.078 ha of State forests were disturbed by grazing.

Boundaries and fire culture

The areas related to an increased probability of forest fires are those at the boundaries between forest and rural areas in which there are forms of human activities. Although illegal, the use of fire as a vegetation management tool is still practiced in Cyprus, mostly by farmers for agricultural land clearing and by shepherds for pasture regeneration purposes. Other uses of fire are engaged to recreational activity (setting barbecues and campfires), residential activities (cooking, heating, grass burning, etc) and garbage burning at illegal waste dumps.

Training of fire fighters and forest fire managers

Forest Officers attend training sessions in the fire management methods and techniques, which are performed by external experts. Forest fire fighters, throughout the fire season are trained in the firefighting techniques and in the use of firefighting equipment.

Forest fuel management programs

The Department of Forests designs and implements an annual forest fuel management program, aiming at reducing the risk of fire outbreaks as well as the spreading of forest fires. This program includes different silvicultural measures such as pruning, thinning and cleaning of the vegetation, mainly along forest and public roads and in places where there is a high risk of fire ignition (picnic and camping sites, garbage dumps, military training fields etc).

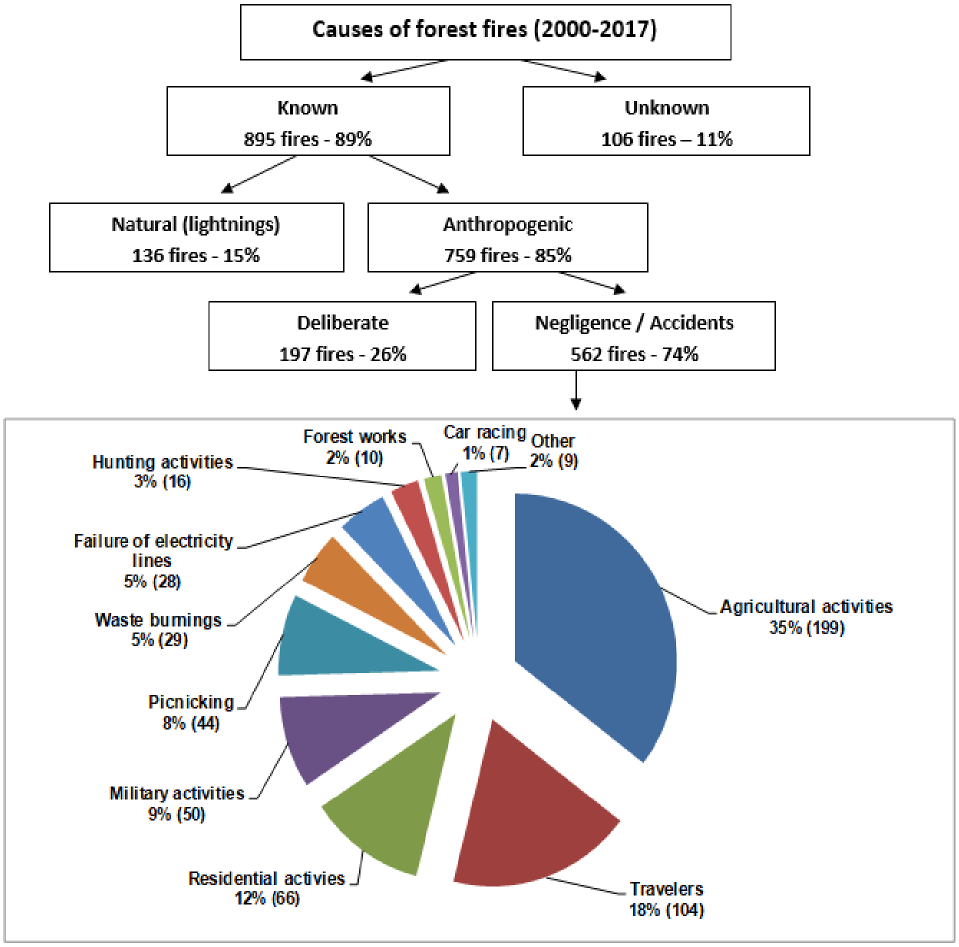

Figure 68 – Causes of forest fires for the period 2000-2017

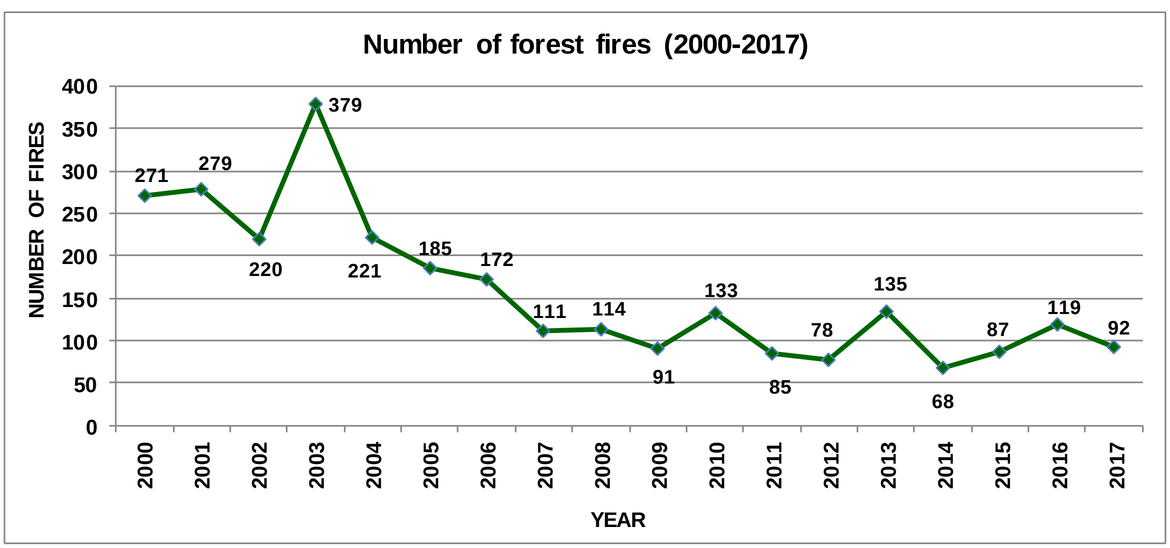

Figure 69 – Annual number of forest fires in Cyprus for the period 2000-2017

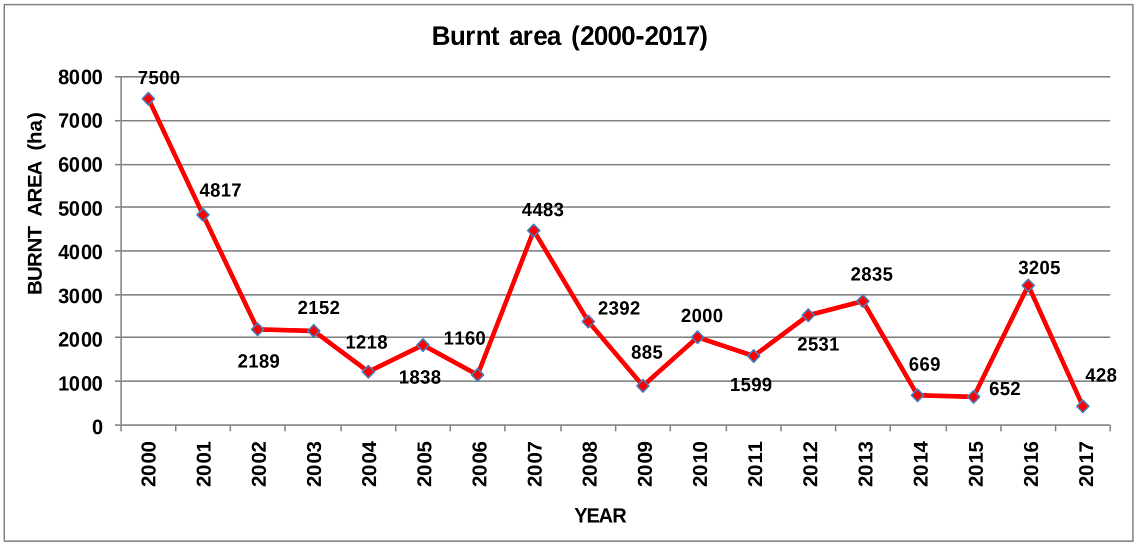

Figure 70 – Annual burnt area in Cyprus for the period 2000-2017

Technological aspects

A number of available technologies are already used or are intended to be used in near future. Such technologies include:

- **GIS**

  Technology in use.

  Objective of the use: Burnt area mapping, rapid fire damage assessment, preparation of fire protection maps, etc.

- **UAV**

  Technology not in use at the moment but it will be used in the near future.

- **Remote sensing**

  Technology in basic use.

- **Automatic fire detection systems**

  Technology in use.

  Objective of the use: Early fire detection.

- **Wireless sensors (including meteo stations)**

  Technology in use.

Objective of the use: A network of automatic meteo stations exists, which is supporting the fire managers for the prevention and suppression of forest fires.

- **Modeling**

  Technology not in use.

- **Cellular phones**
- Technology in use.

  Objective of the use: Mobile phone apps are an efficient monitoring and decision support tool in fire management.

- **Fleet management**

  Technology in use.

  Objective of the use: A GPS based software was developed which is used for better management of the vehicle fleet of the Department of Forests and more specifically for increasing their performance during the fire suppression operations.

- **Social media**

  Technology in use.

  Objective of the use: Facebook software is used in order to facilitate the dissemination of information concerning forest fires and other forest management related issues.

Risk Communication

A fire danger rating system is applied in Cyprus by the forest service. Risk is mainly communicated through the media. There are five (5) fire danger classes in use: Low, Moderate, High, Very High and Extremely High.

Defining more parameters that will be used for calculating Risk and build scenarios

Fire season

For the case of Cyprus, the fire season starts in May and ends in October, but occasionally it starts in April and is extended up to November, according to the prevailing weather conditions. The most dangerous period of the fire season to start a fire is June to September.

Usual causes for fire start

Most frequent human activities that may cause a fire ignition are related to agriculture, residential activities, throw of burning cigarette butts or matches from travelers, camp fires, use of electrical machinery that produces sparks, military exercises, waste burnings, car racings, electric faults from powerlines, hunting activities, forest works etc.

Specific places

Forest fires in Cyprus usually starts along the state forest boundaries, mostly in regions with increased human activity.

Specific hours

The most critical hours for a forest fire to start is from 11:00am to 16:00pm

Meteorological conditions

The combination of prolonged drought period, high temperature, low relative humidity and strong wind, is the worst case scenario for a forest fire ignition.

Number of different fires that would start simultaneously

In many cases the Department of Forests had to deal with the suppression of multiple forest fires in a day. Not rarely, resources of the Department of Forests are involved in the suppression of 6-8 fire incidents in a single day.

Exposure and vulnerability of socioeconomical parameters

In this task, the **impact on human, economics & environment and political/society**, will be analysed in terms of <u>vulnerability and exposure</u>. Therefore, in this stage using a semi-quantitative approach when possible, for the hazard of fires in forest and rural areas, the exposure and vulnerability in these three categories will be determined using numerical rating scales.

Damages for the economy or the society suffered by forest fires the last decades in Cyprus

Every summer, year after year enormous blazes destroy thousands of acres of forests. The Mediterranean for a number of reasons is prone to such catastrophes. According to JRC[1] in the five Southern most affected European States (Greece, Italy, Spain, France, and Portugal) fires burned 323,896 hectares of land in 52,795 fires. According to the same publication between 1980 and 2009, 14,367,304 hectares were burnt in 1,501,409 fires, again in these five states.

Forest Fires have a lasting impact on *social*, *environmental* and *financial* level. In a social level the impacts of catastrophic fires are enormous. Human lives are lost, livelihoods and villages are destroyed, creating a lasting effect in a collective and individual level[1].Forest fires, especially mega fires can cause psychopathologogical disturbances to survivors[1]. Forest fires can cause psychopathological disturbances to fire fighters[1].

Novel techniques[1] used in environmental pollution analysis clearly show how the air quality is affected in the short term. In their paper Liu et al (2009) indicate a big increase in the number of particles in the atmosphere during the 2007 fires in Greece. Forest fires have long term environmental implications. Moreira et al argue that previously burned areas have an increased tendency to be burnt again creating, therefore, a vicious circle that intensifies the catastrophes. In addition to the above, forest fires increase the total carbon footprint. As early as 1994, Holeman[1] (1994) based on Crutzen[1] (1990) and Andrae[1] (1990) quantified carbon emissions due to the various forms of wildland fire to 4.08x 10^{15} tons of emitted carbon through biomass fuel burning. At that time and based on the same calculations, the overall carbon global emissions were estimated to be 13.28×10^{15} tons, therefore making biomass fuel burning 40% of the total.

In a financial level, wildland fires bear high costs. Prevention, suppression, costs to the medical system, additional costs to the pension system, insurance costs are only some of the measurable costs. Two critical factors though cannot be estimated: cost of human lives and loss in the added value for the country in general.

Tourism, especially in the Mediterranean is based upon an offer of sea, sun, culture, and nature. While sea and sun will continue existing even after a severe wildland fire catastrophe, cultural monuments and nature can suffer heavy losses. For instance, the tragic incident of the fires of 2007 in Peloponnese harmed the archaeological site of Olympia, the birthplace of the Olympic Games.

The large fire at Solea region in 2016, is responsible for the worst damages by forest fires in Cyprus during the last decades. This fire claimed the lives of two forest fire-fighters and caused the injury of 9 others, villages were seriously threatened and needed to be evacuated, private properties were destroyed, fire engines and other vehicles and equipment were damaged and 19 km^2 of pine forest was turned into ashes.

Probabilistic scenarios analysis / consequences and impact assessment

At this step, the probability of occurrence of each hazard scenario will be determined along with the associated consequences. Therefore, (taking into account all three categories of impacts) the risk will be estimated as a function of the probability of hazard’s occurrence (p), vulnerability (V) and exposure (E) as shown below,

Risk=R=*f* (p*E*V)

Quantification of existing treatment measures and suggestions for adaption and mitigation measures

In this final step, there will be a comparison of the results of the risk analysis with risk criteria to determine whether the risk and/ or its magnitude is acceptable or tolerable and whether a risk will be accepted or treated as part of the national level risk assessment. The risk for hazard will be evaluated against specified criteria that will be the terms of reference against which the significance of a risk will be analysed and evaluated. The risk criteria will include associated socioeconomic and environmental factors etc.

Criteria can be based on sources such as:

- agreed process objectives,
- criteria identified in specifications and national guidelines,
- research data from local universities and research institutions,
- Generally accepted industry criteria such as safety integrity levels.

Damages for the economy or the society suffered by forest fires the last decades in Cyprus

The large fire at Solea region in 2016, is responsible for the worst damages by forest fires in Cyprus during the last decades. This fire claimed the lives of two forest fire-fighters and caused the injury of 9 others, villages were seriously threatened and needed to be evacuated, private properties were destroyed, fire engines and other vehicles and equipment were damaged and 19 km² of pine forest was turned into ashes.

Scenarios

The definition of fire scenarios is a dynamic, spatial and integrative concept. The parameters that were described above, determining fire behavior (climatic, physiographic, biological, and social) may have different weighting. We can summarize the main components of forest fire scenarios as follows:

1. Fuels (ecosystems; plant communities):
2. Territorial dynamics and land-use changes:
3. Settlements

Fire history

The impact criteria will be assessed against three hazard scenarios that will be those scenarios were selected from the range of possible scenarios, having different limits /types for the comparison to be meaningful and fall into the following categories:

A. **Worst-case scenario.** Plausible with upper risk limit/level: assessed considering both impact and likelihood.

According to the worst-case scenario, during August, after a prolonged drought period, with high temperature, low relative humidity and strong wind there are two or more large scale forest fire outbreaks, close to a rural area at 16:00. Available means are not enough to face effectively limit the fires while due to the strong wind every minute counts and firefighting means from neighbouring countries will take some time to arrive. Thus, the fires would affect a large area, burning a significant area of forest, while evacuation plans may need revising for a significant number of citizens since fire could reach and probably burn villages from different directions, rural areas or even cities' borders. Power lines could be destroyed and critical infrastructures could be affected. Dangerous substances included in smoke and fumes would be released in the atmosphere. Psychological issues would arise for a large percentage of the population such as stress, insecurity, etc.

B. Best case/mild scenario-Plausible with lower risk limit

According to that scenario, during June, there is one large scale forest fire. Weather conditions are mild since there were some showers during the previous days. A number of available means is used to effectively limit the fire. No assistance is required from neighbouring countries. The fire would affect a limited forest area, while no evacuation plans are activated since fire is not close to rural areas.

Expected scenario – Analysis – Risk Matrix

According to historical data, there is one such fire every 8-10 years. Thus, the probability of considered to be high since such a scenario is likely to happen. In case that likelihood also consider the exposure and vulnerability of the potential target(s), it can be given a score of 4.

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