Disasater Risk Profile for Jamaica

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ABSTRACT[1]

One of the key strategic activities of disaster risk management at country level is the assessment of disaster risk. However, few methods allow analysis of the disaster risk for two reasons. One is due to the lack of information that allows building a robust database to describe the exposure values. The other is due to the lack of methodologies for modeling the hazardous risk, the vulnerability function, the exposed values and the risk calculation in an integrated manner. The aim of the study Disaster Risk Profile for Jamaica is to assess the country's disaster risk for Jamaica, using an appropriate probabilistic technique that takes into account the uncertainty of the process, the inevitable limitations on information and the available electronic computing capacity. The study focuses on the two principal hazards of the country; earthquake and hurricane winds. The result of the study indicates that the country would lose more than US$2 billion in value of public infrastructures when 500 years return period scale seismic event hits the county; that is more than 10% of public infrastructure in the country. Furthermore, the country is at risk of more than US$2.4 billion infrastructure loss when a hurricane of once every 250 years scale hits the country.

JEL Code: Q54 (Climate; Natural Disasters; Global Warming)

Keywords: Probabilistic risk assessment; probable maximum loss; average annual loss; earthquake; hurricane; Jamaica

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INTRODUCTION

One of the key strategic activities of disaster risk management at country level is the assessment of the risk of disaster or of extreme events, which requires the use of reliable methodologies that allow an adequate estimation and quantification of potential losses in a given exposure time. However, although they have been developed internationally diverse methodologies for detailed risk assessment for different types of natural hazards, few methods allow analysis at country level for two main reasons: first, the lack of detailed information that prevents the formation of a robust database to describe the exposure and, secondly, the lack of methodologies for an integrated modeling of the threats, the vulnerability of the exposed elements and the risk from their convolution.

To achieve, then the overall goal of identifying and quantifying the catastrophe risk, it is necessary to use and even develop a method that takes account the natural hazards in an integrated manner that includes the total and detailed exposure of infrastructure assets with their main features. This in order to take into account the specific vulnerability of each component of the infrastructure and to evaluate risk assessment using an appropriate probabilistic technique that takes into account the uncertainty of the process, the inevitable limitations on information and the electronic computing capacity available.

In most cases it is necessary to use certain approaches and criteria for simplification and for aggregation of information due to a lack of data or the inherent low resolution of the information. This fact sometimes means sacrificing some scientific or technical and econometric characteristics, accuracy and completeness that are desirable features when the risk evaluation is the goal of the process.

This report presents the catastrophe risk assessment for Jamaica taking into account that hurricanes and earthquakes are the natural events that represent the main hazard for the country. The probabilistic methodology used is considered the most robust for this type of

modeling and identifies the most important aspects of catastrophe risk from financial protection perspective in according to the fiscal responsibility of the State. In addition, the results of the analysis may be particularly useful in guiding the priorities of the country's disaster risk management in general. The methodological and technical foundations of this risk assessment are the models made by this consultant group for the development of ERN-**CAPRA** (Comprehensive Approach for Probabilistic Risk Assessment); an open architecture platform designed with support of the IDB, the World Bank and the UN International Strategy for Disaster Reduction. Details of the model and its implementation are available at www.ecapra.org.

This report provides relevant inputs for the formulation and updating of the financial strategy to protect the country against the catastrophe risk. This report in addition to the report related to the alternative mechanisms of risk retention and transfer are useful for the country and the Bank to estimate the order of magnitude of the contingent liabilities due to extreme disasters and to explore financing feasible alternatives to design the coverage of the country's fiscal responsibility.

Nomenclature

AAL	Annual average loss
AME	Hazard files (array of events)
Com	Commercial buildings
DDI_{MCE}	Desater deficit index based on maximum considered event (MCE)
DDI_{CE}	Desater deficit index based on capital expenditure (CE)
Gov	Government buildings
GIS	Geografic information system
Ind	Industrial buildings
LEC	Loss exceedance curve
PML	Probable máximum loss
PriEdu	Private Education buildings
PriHealth	Private Health buildings
PRM	Probabilistic risk module
PubEdu	Public Education buildings
PubHealth	Public Health buildings
ResHP	Residential buildings of high socioeconomic level
ResLP	Residential buildings of low socioeconomic level
ResMP	Residential buildings of medium socioeconomic level

1 METHODOLOGY AND SCOPE

The objective of this risk evaluation is to provide robust analysis that will identify important disaster risk issues in the context of the country's development priorities and will orient the setting of risk management priorities. In doing so, these assessments will serve as the basis for the formulation and updating of the Bank's country strategies and programming dialogue with the country.

The frequency of catastrophic events is mainly low by definition, reason why the historic information is generally very limited. Considering the probabilities of high destructive capacity events occurring, the risk estimate must concentrate on probabilistic models which use the limited historic information available to forecast, in the best possible manner, the consequences of futures events considering at the same time unavoidable high uncertainties involved in the analyses.

A country may be suffert the consequences of different types of natural events; however, for the present evaluation only earthquake hazards are considered and the hazard of hurricane-winds when it is relevant. Without discarding the possibility of other types of hazards may also generate devastating events, the present analysis is concentrated on threats that have demonstrated in the past that can generated critical events and that in most cases their losses evolve or would be bigger than other small events or events that have not possibilities to occur in the future.

The risk estimate must be prospective, anticipating scientifically possible events that may occur in the future. For the case of seismic events, seismological and engineering bases are used to develop earthquake forecasting models that allow estimating damages, losses and effects as a result of catastrophic events. For the case of hurricane-winds, the hydrometeorologic information available of the historic hurricanes that have affected the area of study is used and, jointly with engineering methodologies, the effects of these

phenomena upon the exposed assets are estimated. Due to the high uncertainties inherent to the models of analysis regarding the severity and frequency of occurrence of the events, the risk model is based on probabilistic formulations incorporating said uncertainty in the risk evaluation. The probabilistic risk model (PRM) constructed as a sequence of modules quantifies the potential losses that arise from a given event, as illustrated in Figure 1.1

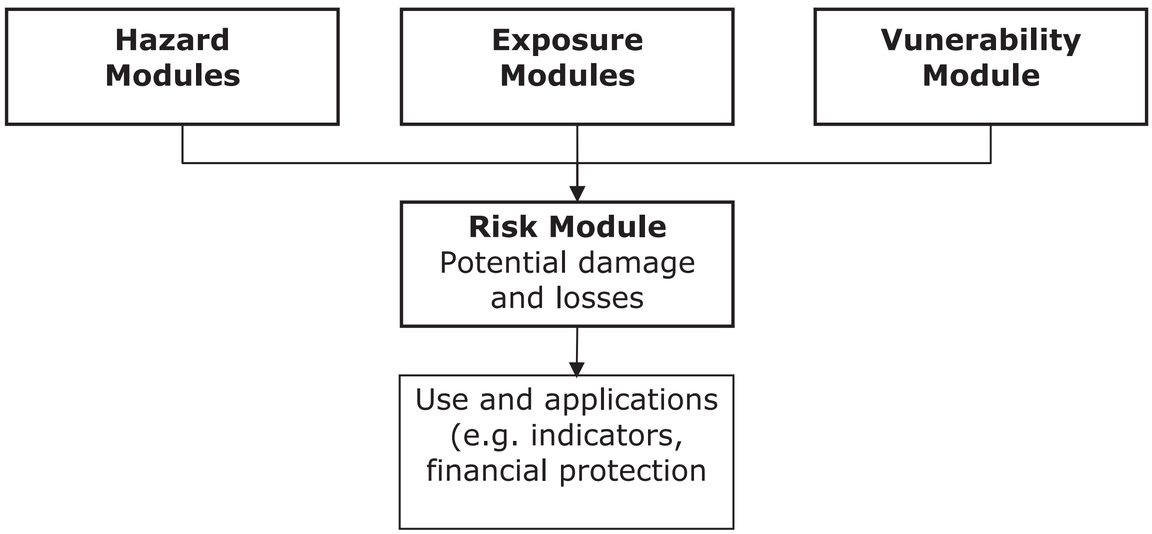


Figure 1.1 General scheme of the probabilistic risk analysis

The suggested analysis modules have the following specific functions:

- Hazards module: This module allows calculating the threat associated to all possible events that could occur, to a group of selected events, or even to a single relevant event. For each type of natural phenomenon, using the module, it is possible to calculate the probable maximum value of the intensity that characterized for different rates of occurrence or return period. In this module is produced for each type of threat, an AME file type (.ame from *amenaza* in Spanish), which include multiple grids, on the studied territory, of the different parameters of intensity of the considered phenomena. Each grid is a scenario of the intensity level obtained from historical or stochastic generated events, with their frequency of occurrence. For

this case the parameter of seismic intensity selected is the spectral acceleration. In the case of hurricanes, we used the maximum wind speed.

- Exposure Module: This module deals with the description of the exposed elements or assets that may be affected. It is based on files in "shape" format corresponding to the exposed infrastructure that will be included in the risk analysis. The information required for these files is the following:

    - Identification
    - Location
    - Exposure value
    - Vulnerability function associated to each type of hazard

  In this case the exposure module was developed based on a proxy model or simplified and aggregated description of the exposed assets.

- Vulnerability Module: This module allows the generation of vulnerability functions based on the direct use or modification of existing functions chosen from a library of functions, or by generating new functions from specific information of construction class of the exposed asset o element that has to resist or cope with the phenomenon. The assignement of the vulnerability function to each element is carried out on the shape format file processed in the exposure module.

- Risk Module: This module performs the convolution of the threat with the vulnerability of the exposed elements in order to assess risk or the potential effects or consequences. Risk can be expressed in terms of damage or physical effects, absolute or relative economic loss and / or effects on the population.

Once the expected physical damage has been estimated (average potential value and its dispersion) as a percentage for each of the assets or infrastructure components included in

the analysis, one can make estimates of various parameters or metrics useful for the proposed analysis as result of obtaining the Loss Exceedance Curve (LEC). This study focuses, then, in the risk assessment of the country (overall, by sector and by geographic units) due to the hurricanes and earthquake hazards, using as measurement the Probable Maximum Loss (PML) for different return periods and the Average Annual Loss (AAL) or technical risk premium. Based on these results, it is estimated the specific risk at the country level and the concentration of risk and can be calculated the indicators of contingent liabilities (as are the figures currently used by the Disaster Deficit Index, DDI and DDI'). The values of PML and AAL are the main results of this report. These measures or metrics are of particular importance for the future design of risk retention (financing) or risk transfer intruments, and therefore they will be a particularly valuable contribution to further studies to define a strategy for financial protection to cover the fiscal liability of the State. Within this project also presents an overview of the financial protection alternatives that could be explored and which are available internationally.

2 ASSETS EXPOSURE MODEL

2.1 MODEL DEVELOPMENT

The information on exposure to natural events concerns the inventory of buildings and infrastructure that can be affected. This is expressed in terms of assets and population. It is an essential component in the risk analysis or evaluation, and the degree of accurancy of the results depends on its level of resolution and detail. There are different resolution levels, and when there is no enough detailed information available, like the coverage of public services or the characteristics of infrastructure available, it is necessary to carry out estimations of the exposed inventory of assets based on coarse grain data or on expert opinions. This is referred as the *proxy* exposure model.

Figure 2.1 shows the general procedure carried out to develop a simplified model of exposed assets for the country.

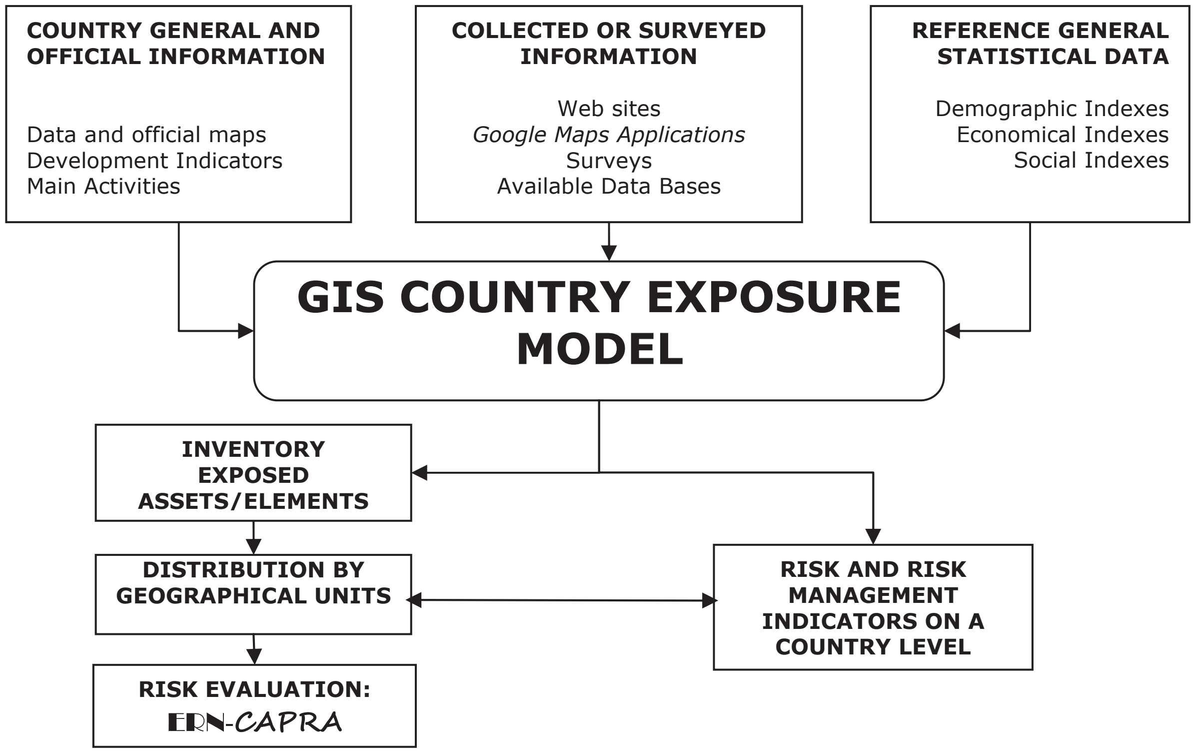


Figure 2.1 Simplified Model of the inventory assets for risk evaluation

The objective of the country's exposure model *proxy* is also to create a suitable distribution for the inventory, in terms of geographic national units or political divisions, like Parishes in the case of Jamaica, in such a way that it represents, in general, the location of the exposed assets and population. The exposure is provided by the different elements at risk and their geographic location, the assigned restoration value, the estimated occupancy in terms of people and other characteristics allowing the assignment of vulnerability functions to the different hazards with the purpose of risk assessment. These bases of exposure are indicators related to the type of country and city infrastructure, its economic appraisal and its human occupancy. The model also provides information for the formulation of risk indicators. The diagram of the Figure 2.1 illustrates the model used, in which the

information is stored in a database for its subsequent analysis and future utilization. The *proxy* exposure model requires the following definitions:

(a) Geographical and political division: the model is presented by means of a categorization in the following units:

   i. Parishes (sub national units)

   ii. Municipalities and main towns belonging to the parishes

   iii. The municipalities would also be separated in rural area and urban area.

(b) To characterize the different urban areas, a zoning assessment is set out in homogeneous zones in terms of infrastructure characteristics, population concentration, economic activity, socioeconomic conditions, topographic characteristics, and institutional importance, amongst others.

(c) In addition, the different rural zones of the municipalities are also characterized if it is necessary for the analysis.A zoning on homogeneous areas can be defined for this purpose in terms of land use characteristics, density of constructions, population concentration, economic activity, and topographic characteristics, amongst others.

More detailed geographical areas can be used if it is required for the analysis; for example, in cities, the suburbs could be included depending on the information available.

In general, it is important to mention that usually for the representation of the exposure it is not possible to have information element by element (for example building by building) because there are not available catastral data. In most cases a proxy is developed using indirect variables and correlations. The construction of the proxy how it was decribed in this Annex 2 depends of the existing information that can be treated by levels. In the Annex 2 are included figures that describe the levels of resolution of de exposure.

In summary, the scope of this study is to develop the catastrophe risk assessment using a proxy. This because the cost implications of a high resolution evaluation but also because

the detailed information in the country in general is not available, updated and reliable. Some institutions have data difficult to obtain but this information neither is of quality, building by building, nor clearly classified by sectors and with appropriate reposition property values.

2.2 GENERAL INFORMATION OF THE COUNTRY

2.2.1 Setup of the Database for Risk Analysis

The exposure figures or indicators are developed with the objective of representing the physical, economic and human information of a country or a city in geographical terms. In order to develop these indicators, the following main categories are established:

- Building area in main cities
- Relevant urban infrastructure
- National infrastructure

The methodology also allows for the inclusion of other exposed elements such as crops, environmental elements and in general any type of component susceptible of suffering any damage caused by the hazard events. The exposure indicators are developed using a spreadsheet: **Proxy-Jamaica.xls** (See Annex 3)**.**

2.2.2 Geographical Description and Political Division of the Country

Jamaica is one of the island states comprising the Greater Antilles. It is located in the Caribbean Sea and is divided into 14 political regions called Parishes. Jamaica has an area of 10,991 km^2 and a population of 2,693,681 inhabitants. Figure 2.2 presents the political division and/or geographical distribution of the political regions, the Parishes.

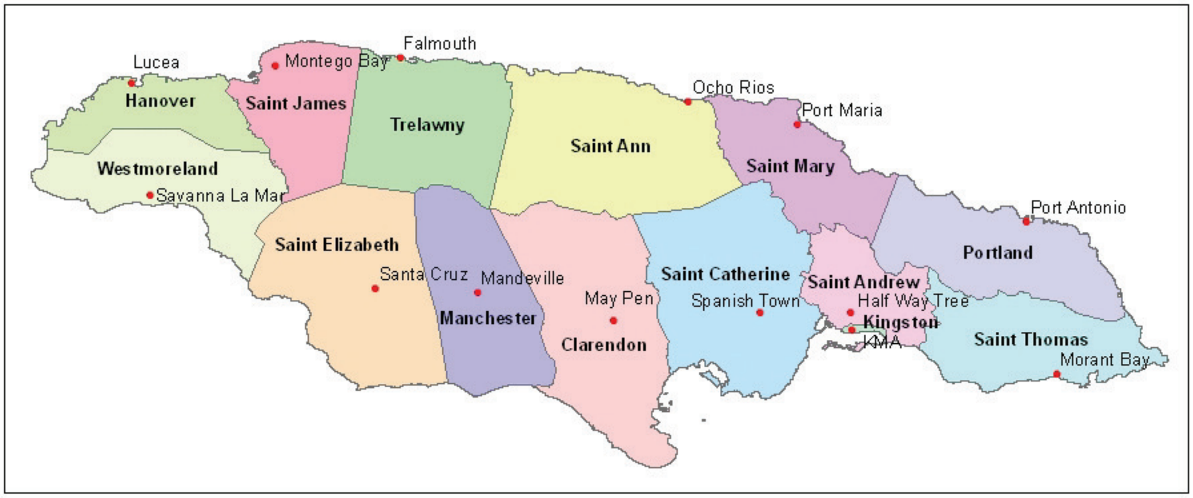


Figure 2.2 Country's political division (main regions and urban centres),
Ref: http://www.diva-gis.org/gData (Data for Jamaica)

The geographical information collected is organized as shown in the Table 2.1. This table presents the country's main regions and the code used for their identification. For illustrative purposes, some of the data included in the table is presented herein. The complete information is included in the file mentioned in Annex 3. Table 2.2 presents a list of the main urban centres of the country and their corresponding political sub national unit or Parish (see Annex 3). Each one of this cities were selected according to population, socio economic level and quality and cover of public services

Table 2.1 Distribution of country's sub national units

Parish	ID Parish	Parish
1	1	Clarendon
2	2	Hanover
3	3	Kingston
4	4	St Andrew
5	5	Manchester
6	6	Portland
7	7	St Ann
8	8	St Catherine
9	9	St Elizabeth
10	10	St James
11	11	St Mary
12	12	St Thomas
13	13	Trelawny
14	14	Westmoreland

Table 2.2 Characteristics of main urban centres

ID City	City	ID Parish	ID
1	KMA	3	1
2	Spanish town	8	1
3	Portmore	8	1
4	Montego Bay	10	1

Note: KMA= Kingston Metropolitan Area

2.2.3 Distribution of Population

The total population of the country is 2,693,681 inhabitants (projected to the year 2008, as included in the 2001 Census, with an annual growth rate of 0.3% in 2002 and 0.5% for the subsequent years, according to ECLAC), with 52% of the population residing in urban centres (1,400,060 inhabitants) and 48% in rural areas (1,293,625 inhabitants). The population is distributed as follows: 32% are children and adolescents, (861,978 inhabitants, 0-14 years), 60.6% are teenagers and adults (1,632,371 inhabitants, 15–64 years), and 7.4% are persons older than 65 years (199,333 inhabitants, senior citizens).

Approximately 42.4% of the population (1,142,685 inhabitants) is economically active, with 18.2% of this being engaged in the agricultural sector, 7% in the industrial sector and 74.8% in the service sector.

Considering the different levels of development of the various segments of the population, a classification is established in accordance with the level of complexity or degree of development. This classification enables the differentiation of the various indexes used in the formulation of the complexity indicators such as urban population densities, prices per square meter of real estate, occupancy levels, types and costs of public services, etc.

2.3 DATABASE OF BUILDINGS

2.3.1 Methodology and Scope

With the objective of identifying the exposure value of the constructions in the country, an inventory of the urban centres in each Parish was carried out. The most realiable parameter for this analysis is the official population reported for each political and administrative sub national unit (i.e. Parishes in this case). The official population and a set of indicators such as employment, students, health facilities, amongst others, are used to estimate the number and type of buildngs located in each urban centre. Subsequently, the same population information is used to establish hypothetical scenarios of occupancy for each building of the city being analized.

The building classes and the occupancy are estimated according to the diverse economic sectors presented and the basic needs of the population, such as education and health facilities, amongst others. The class (use) and size (m^2) of the buildings are estimated using the housing census classified in the following categories:

(a) Residential LP: low-income housing
(b) Residential MP: medium-income housing

(c) Residential HP: high-income housing

(d) Commercial

(e) Industrial

(f) Private Health

(g) Private Educational

(h) Public Health

(i) Public Educational

(j) Governmental

For the elaboration of this analysis, it is necessary to estimate the built areas per inhabitant, per type of uses and levels of complexity, the economic value of each square meter of building per type of use and level of complexity, and the occupancy level of each type of building in a certain given scenario, expressed in terms of square meter of built area per type of use and level of complexity.

The Table 2.3 shows the range of urban population that is used for each level of complexity, and Table 2.4 shows the percentages of people belonging to different economic levels and depending on the level of complexity. PB means low income population, PM means medium income population and PA means high income population. Poverty data were obtained for each Parish from "Jamaica Survey of Living Condition, Parish report 2002".

Table 2.3 Level of Complexity

Level of Complexity	Population in the urban zone [V 2]
High - 1	>100,000
Medium - 2	20,000 to 100,000
Low - 3	<20,000

Table 2.4 Poverty indicators

Economic capability	Population LP	Population MP	Population HP
	[V 4]		
High	13%	71%	16%
Medium	26%	60%	14%
Low	26%	60%	14%

The analysis of bulding exposure in urban centres was carried out for a total of 14 Parishes, with an overall total urban population of over 1.4 million of inhabitants.

For information concerning infrastructure characteristic values, the extrapolation was performed on the basis of regional information as it is mentiones in paragraph 2.8 of this report.

2.3.2 Building Database Setup

Using the abovementioned information and considering the urban population, the database of built areas can be set up using the exposure values and typical occupancy levels for the different types of uses in each Parish. A summary of the information included in the database is given in Table 2.5 to Table 2.8.

Table 2.5 Distribution of built areas per parish and building use group

ID Parish	Parish	ID	m^2 Built Infrastructure Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov	Total
			(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)	(m^2x10^3)
1	Clarendon	1-1	257.3	1,757.6	749.2	1,553.3	364.5	0.1	114.6	1.1	458.2	63.3	5,319
2	Hanover	2-1	53.0	460.4	194.7	439.3	103.1	0.0	0.0	0.2	133.1	17.9	1,402
3	Kingston	3-1	64.7	1,050.0	406.9	629.5	147.7	0.4	202.0	0.7	202.0	25.6	2,730
4	St. Andrew	4-1	374.6	6,075.8	2,354.6	3,642.6	854.7	2.6	532.8	4.3	532.8	148.4	14,523
5	Manchester	5-1	201.7	1,377.7	587.3	1,217.6	285.7	0.2	66.8	1.9	267.1	49.6	4,056
6	Portland	6-1	63.4	550.9	232.9	525.6	123.3	0.0	0.0	0.4	135.3	21.4	1,653
7	St. Ann	7-1	181.0	1,236.6	527.1	1,092.9	256.4	0.1	67.7	1.1	270.9	44.5	3,678
8	St. Catherine	8-1	325.1	5,272.2	2,043.2	3,160.8	741.7	0.9	532.9	1.5	532.9	128.7	12,740
9	St. Elizabeth	9-1	158.9	1,085.6	462.8	959.5	225.1	0.1	62.4	0.5	249.8	39.1	3,244
10	St. James	10-1	190.1	1,298.6	553.6	1,147.7	269.3	0.2	75.2	1.9	300.8	46.7	3,884
11	St. Mary	11-1	121.0	826.5	352.4	730.5	171.4	0.1	44.9	0.9	179.7	29.8	2,457
12	St.Thomas	12-1	99.4	679.3	289.6	600.3	140.9	0.1	38.4	0.7	153.4	24.4	2,026
13	Trelawny	13-1	57.7	501.8	212.2	478.8	112.4	0.0	0.0	0.2	129.5	19.5	1,512
14	Westmoreland	14-1	150.8	1,030.3	439.2	910.6	213.7	0.1	62.5	0.8	250.2	37.1	3,095
		Total	2,299	23,203	9,406	17,089	4,010	5	1,800	16	3,796	696	
				62,320									

The methodology adopted for estímate building area is explained in 1.1 a 1.7 from Aneex 2, based on indexes of Table A2-1, population and labor force by sector, the quantity of building area for regular buildings is estimated.

Table 2.6 Distribution of exposure values per parish and building use group

ID Parish	Parish	ID	Values of Structures										
			Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov	Total
			(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)	(US$x10⁶)
1	Clarendon	1-1	22.51	307.58	196.68	271.83	95.68	0.03	20.05	0.24	80.19	11.07	1,006
2	Hanover	2-1	3.31	57.55	36.50	54.92	19.33	0.00	0.00	0.02	16.64	2.24	191
3	Kingston	3-1	8.09	262.49	152.59	157.37	55.39	0.17	50.50	0.22	50.50	6.41	744
4	St. Andrew	4-1	46.83	1,518.96	882.99	910.65	320.53	0.97	133.20	1.29	133.20	37.09	3,986
5	Manchester	5-1	17.65	241.11	154.17	213.09	75.00	0.06	11.69	0.39	46.75	8.68	769
6	Portland	6-1	3.96	68.86	43.67	65.70	23.13	0.00	0.00	0.06	16.92	2.68	225
7	St. Ann	7-1	15.84	216.40	138.38	191.25	67.32	0.03	11.85	0.24	47.40	7.79	696
8	St. Catherine	8-1	40.64	1,318.04	766.19	790.19	278.13	0.34	133.22	0.46	133.22	32.18	3,493
9	St. Elizabeth	9-1	13.91	189.98	121.48	167.90	59.10	0.02	10.93	0.11	43.71	6.84	614
10	St. James	10-1	16.63	227.25	145.32	200.85	70.69	0.06	13.16	0.40	52.64	8.18	735
11	St. Mary	11-1	10.59	144.64	92.49	127.84	45.00	0.03	7.86	0.18	31.45	5.21	465
12	St.Thomas	12-1	8.70	118.87	76.01	105.06	36.98	0.02	6.71	0.15	26.85	4.28	384
13	Trelawny	13-1	3.61	62.73	39.78	59.85	21.07	0.00	0.00	0.03	16.18	2.44	206
14	Westmoreland	14-1	13.20	180.31	115.30	159.35	56.09	0.02	10.95	0.16	43.78	6.49	586
		Total	225	4,915	2,962	3,476	1,223	2	410	4	739	142	
			14,098										

Once the build area was estimated, the value of these buildings can be calculated according on numeral 2 from Annex 2, with that methodology were obtained the values of Table 2.6.

Table 2.7 Distribution of typical occupancy levels per parish and building use group (day scenario)

ID Parish	Parish	ID	Occupancy of Structures (Day)										
			Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov	Total
			(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)
1	Clarendon	1-1	5,789	47,455	16,858	74,560	6,561	20	9,165	172	36,658	12,653	209,890
2	Hanover	2-1	954	10,360	3,504	17,573	928	0	0	15	5,325	2,863	41,522
3	Kingston	3-1	2,039	37,798	12,817	35,251	3,988	89	24,240	149	24,240	6,153	146,766
4	St Andrew	4-1	11,801	218,730	74,171	203,986	23,078	517	63,936	863	63,936	35,605	696,625
5	Manchester	5-1	4,538	37,199	13,215	58,447	5,143	32	5,343	280	21,370	9,918	155,486
6	Portland	6-1	1,141	12,395	4,192	21,025	1,110	0	0	37	5,413	3,425	48,738
7	St Ann	7-1	4,073	33,387	11,861	52,458	4,616	19	5,418	168	21,671	8,902	142,573
8	St Catherine	8-1	10,240	189,798	64,360	177,004	20,025	183	63,947	305	63,947	30,896	620,705
9	St Elizabeth	9-1	3,576	29,312	10,413	46,054	4,052	9	4,996	80	19,982	7,815	126,289
10	St James	10-1	4,277	35,062	12,456	55,089	4,848	33	6,017	287	24,066	9,349	151,484
11	St Mary	11-1	2,723	22,317	7,928	35,063	3,085	15	3,594	128	14,378	5,950	95,180
12	St Thomas	12-1	2,237	18,340	6,515	28,816	2,536	13	3,068	108	12,273	4,890	78,796
13	Trelawny	13-1	1,039	11,291	3,819	19,153	1,011	0	0	23	5,178	3,120	44,636
14	Westmoreland	14-1	3,394	27,819	9,882	43,708	3,846	13	5,004	114	20,015	7,417	121,212
		Total	57,822	731,262	251,992	868,186	84,827	944	194,727	2,731	338,454	148,957	
			2,679,902										

Table 2.8 Distribution of typical occupancy levels per parish and building use group (night scenario)

ID Parish	Parish	ID	Occupancy of Structures (Night)										
			Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov	Total
			(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)	(Pop)
1	Clarendon	1-1	12,865	105,455	37,462	27,960	3,645	20	0	172	0	0	187,579
2	Hanover	2-1	2,119	23,022	7,786	6,590	515	0	0	15	0	0	40,048
3	Kingston	3-1	4,532	83,997	28,483	13,219	2,216	89	0	149	0	0	132,685
4	St Andrew	4-1	26,225	486,067	164,825	76,495	12,821	517	0	863	0	0	767,813
5	Manchester	5-1	10,085	82,665	29,366	21,918	2,857	32	0	280	0	0	147,203
6	Portland	6-1	2,535	27,544	9,316	7,884	617	0	0	37	0	0	47,933
7	St Ann	7-1	9,051	74,194	26,357	19,672	2,564	19	0	168	0	0	132,026
8	St Catherine	8-1	22,756	421,772	143,023	66,376	11,125	183	0	305	0	0	665,540
9	St Elizabeth	9-1	7,946	65,137	23,140	17,270	2,251	9	0	80	0	0	115,834
10	St James	10-1	9,505	77,916	27,679	20,658	2,693	33	0	287	0	0	138,773
11	St Mary	11-1	6,050	49,592	17,618	13,149	1,714	15	0	128	0	0	88,265
12	St Thomas	12-1	4,972	40,756	14,478	10,806	1,409	13	0	108	0	0	72,541
13	Trelawny	13-1	2,310	25,092	8,487	7,183	562	0	0	23	0	0	43,656
14	Westmoreland	14-1	7,542	61,819	21,961	16,391	2,137	13	0	114	0	0	109,976
		Total	128,493	1,625,027	559,981	325,570	47,126	944	0	2,731	0	0	
			2,689,872										

Estimation of occupancy both on at day scenario as at night scenario was made according to quantity of build area previously estimated. Table A.2.4 from Anexo 2 presents the indexes used to estimate occupancy. These values were adjusted acording to build area and population assigned by sector.

2.4 DATABASE FOR URBAN INFRASTRUCTURE

2.4.1 Methodology and Scope

With the objective of identifying the exposure value of the urban infrastructure in the country, and using the inventory of the urban centres completed for each of the parishes, an estimation of the coverage of public utilities and valuation of networks (water, sewage, and telecommunications), bridges, airports and ports is carried out.

The public utilities and transport infrastructure coverage is estimated using the information included in the housing census classified in the following categories:

(a) Bridges in urban areas
(b) Airports
(c) Ports

(d) Energy substations and adjacent network

(e) Telecommunication substations and antennas

(f) Water and sewage network

(g) Water treatment plants

(h) Gas network.

In case that the necessary information of coverage of public services and infrastructure unit values is not available, the estimation is carried out according to the typical values of other countries in the region, based on the level of complexity of the Parish and the population density and coverage level of each of these services.

2.4.2 Urban Infrastructure Database Setup

The available information allows the consolidation of all the data related to transportation and public utilities infrastructure in urban centres, and therefoer to estimate the exposure values in each of the sectors analyzed. Table 2.9 presents the results of this estimation.

Table 2.9 Exposure values of transportation systems, public services and networks

ID Parish	Parish	ID	Airports				Ports				Bridges	
			m^2 Const	Const. Value	km Airstrip	Value of Airstrip	m^2 Const	Const. Value	m^2 Wharf	Value of Wharf	Num. Bridges	Value
			(m^2)	(US$x10^6)	(km)	(US$x10^6)	(m^2)	(US$x10^6)	(m^2)	(US$x10^6)	Und	(US$x10^6)
1	Clarendon	1-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
2	Hanover	2-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
3	Kingston	3-1	44,340	88.68	2.7	27.16	248,090	248.09	82,945	248.84	11	22.00
4	St. Andrew	4-1	2,291	4.58	0.9	9.15	0	0.00	0	0.00	0	0.00
5	Manchester	5-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
6	Portland	6-1	212	0.13	1.0	2.61	0	0.00	0	0.00	0	0.00
7	St. Ann	7-1	1,031	1.03	0.9	4.58	19,391	15.51	3,819	7.64	0	0.00
8	St. Catherine	8-1	0	0.00	0.0	0.00	0	0.00	0	0.00	14	28.23
9	St. Elizabeth	9-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
10	St. James	10-1	55,623	55.62	2.7	13.31	49,191	39.35	16,069	32.14	3	2.75
11	St. Mary	11-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
12	St.Thomas	12-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
13	Trelawny	13-1	0	0.00	0.0	0.00	0	0.00	0	0.00	0	0.00
14	Westmoreland	14-1	146	0.15	0.7	3.30	0	0.00	0	0.00	0	0.00
		Total	103,644	150	9	60	316,672	303	102,832	289	28	53

Table 2.9 Exposure values of transportation systems, public services and networks (second part)

ID Parish	Parish	ID	Electric Substations	Communication Substations	Dams	Plants and tanks	Networks		
							Aqueducts	Sewage systems	Gas networks
			(US$x10^6)	(US$x10^6)	(US$x10^6)	(US$x10^6)	(US$x10^6)	(US$x10^6)	(US$x10^6)
1	Clarendon	1-1	1.18	1.59	0.00	0.64	1.28	1.34	0.67
2	Hanover	2-1	0.01	0.02	0.00	0.02	0.04	0.04	0.02
3	Kingston	3-1	7.99	6.01	0.00	2.40	3.43	3.90	1.95
4	St. Andrew	4-1	40.17	30.24	0.00	12.07	17.24	19.61	9.80
5	Manchester	5-1	1.03	1.38	0.00	0.56	1.11	1.16	0.58
6	Portland	6-1	0.02	0.05	0.00	0.05	0.11	0.11	0.05
7	St. Ann	7-1	0.74	0.99	0.00	0.40	0.80	0.83	0.42
8	St. Catherine	8-1	29.59	22.28	0.00	8.89	12.70	14.45	7.22
9	St. Elizabeth	9-1	0.35	0.47	0.00	0.19	0.38	0.39	0.20
10	St. James	10-1	1.59	2.13	0.00	0.86	1.72	1.80	0.90
11	St. Mary	11-1	0.38	0.51	0.00	0.21	0.41	0.43	0.22
12	St.Thomas	12-1	0.43	0.57	0.00	0.23	0.46	0.48	0.24
13	Trelawny	13-1	0.02	0.04	0.00	0.04	0.08	0.08	0.04
14	Westmoreland	14-1	0.59	0.79	0.00	0.32	0.64	0.67	0.33
		Total	84	67	0	27	40	45	23
			1,141						

2.5 NATIONAL INFRASTRUCTURE DATABASE

2.5.1 Methodology and Scope

The inventory of information collected at Parish and urban centre levels in addition to the information related to the coverage of power, water, gas and waste supply, were used to quantify the value of infrastructure exposed at a national level. Based on this data, an estimation of the services coverage and an assessment of infrastructure components, such as hydroelectric power plants, national telecommunications network, pipelines and national road network, were performed.

The national infrastructure is then classified in the following categories:

(a) Main Road Network
(b) Secondary Road Network
(c) Hydroelectric Power Plants
(d) Dams
(e) Thermal Power Plants

(f) Energy Substations and Networks

(g) Telecommunications Substations and Antennas

(h) Fuel and Gas Substations and Networks

The assignment of values to the infrastructure previously described was done using the estimation of the population that has coverage of the services corresponding to each type of infrastructure: the country's energy generation, the amount of phone lines, and the level of exploitation of hydrocarbons. These values are then distributed geographically according to the population density and the production centres.

2.5.2 National Infrastructure Database Setup

The available information allows the consolidation of all the data related to national transport and public utilities infrastructure, thus the estimations of the exposure values in each of the sectors analyzed.
Table 2.10 and Table 2.11 present the results of this estimation.

Table 2.10 Exposure values of national roads

ID Parrish	Parrish	ID	Primary Roads		Secondary Roads		Primary Roads		Secondary Roads	
			km of road	Value of Roads	km of road	Value of Roads	km of bridges	Value of bridges	km of bridges	Value of bridges
			(km)	(Cost US$ x 10^6)	(km)	(Cost US$ x 10^6)	(km)	(Cost US$ x 10^6)	(km)	(Cost US$ x 10^6)
1	Clarendon	1-1	47.32	123.03	142.33	46.26	0.15	3.09	0.36	5.46
2	Hanover	2-1	78.18	203.28	12.53	4.07	1.13	22.50	0.21	3.11
3	Kingston	3-1	79.41	206.45	52.59	17.09	0.03	0.59	0.36	5.43
4	St. Andrew	4-1	46.11	119.89	24.03	7.81	0.17	3.45	0.36	5.47
5	Manchester	5-1	33.81	87.89	76.88	24.99	0.02	0.31	0.27	4.00
6	Portland	6-1	78.69	204.59	33.39	10.85	0.46	9.25	0.58	8.67
7	St. Ann	7-1	61.22	159.16	122.86	39.93	0.17	3.33	0.09	1.29
8	St. Catherine	8-1	41.98	109.15	57.57	18.71	0.26	5.12	0.57	8.50
9	St. Elizabeth	9-1	58.17	151.25	36.35	11.81	0.08	1.51	0.16	2.41
10	St. James	10-1	48.88	127.09	0.00	0.00	0.06	1.25	0.30	4.53
11	St. Mary	11-1	154.15	400.79	56.71	18.43	0.57	11.41	0.78	11.68
12	St.Thomas	12-1	66.74	173.54	0.00	0.00	0.34	6.78	0.57	8.49
13	Trelawny	13-1	35.65	92.69	71.19	23.14	0.03	0.68	0.09	1.30
14	Westmoreland	14-1	74.46	193.60	47.51	15.44	0.11	2.27	0.26	3.97
		Total	905	2,352	734	239	4	72	5	74
				2,737						

Table 2.11 Exposure values of national infrastructure

ID Parish	Parish	ID	Power generation				Energy distribution		Communications		Hydrocarbons	
			Hydroelectric infrastructure		Power Plants							
			Dam	Power houses	Thermal	Geothermal	Substations	Power lines	Fixed lines	Mobile lines	Derivatives	Gas
			(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)	(US$ x 10^6)
1	Clarendon	1-1	7.04	3.70	19.99	0.00	2.02	2.02	0.69	0.65	0.00	8.11
2	Hanover	2-1	2.01	1.05	5.70	0.00	0.58	0.58	0.20	0.20	0.00	2.88
3	Kingston	3-1	3.43	1.80	9.74	0.00	0.98	0.98	0.50	0.28	100.00	4.56
4	St. Andrew	4-1	20.15	10.58	57.22	0.00	5.74	5.74	3.69	1.65	0.00	26.65
5	Manchester	5-1	5.74	3.02	16.32	0.00	1.65	1.65	0.73	0.51	0.00	7.19
6	Portland	6-1	2.45	1.29	6.96	0.00	0.70	0.70	0.32	0.24	0.00	3.34
7	St. Ann	7-1	5.30	2.78	15.04	0.00	1.52	1.52	0.58	0.45	0.00	6.62
8	St. Catherine	8-1	16.18	8.49	45.95	0.00	4.64	4.64	2.91	1.34	0.00	22.12
9	St. Elizabeth	9-1	4.06	2.13	11.54	0.00	1.16	1.16	0.39	0.42	0.00	5.02
10	St. James	10-1	5.76	3.02	16.35	0.00	1.65	1.65	0.82	0.50	0.00	8.12
11	St. Mary	11-1	3.40	1.78	9.65	0.00	0.97	0.97	0.38	0.32	0.00	4.54
12	St.Thomas	12-1	2.81	1.47	7.98	0.00	0.81	0.81	0.42	0.28	0.00	3.67
13	Trelawny	13-1	2.16	1.13	6.13	0.00	0.62	0.62	0.25	0.22	0.00	2.74
14	Westmoreland	14-1	4.19	2.20	11.91	0.00	1.20	1.20	0.36	0.42	0.00	5.69
		Total	85	44	240	0	24	24	12	7	100	111
				649								

2.6 GENERAL SUMMARY OF EXPOSURE INDICATORS

The information collected and described in the previous sections was organized and classified in a spread sheet (See Annex 3). All data related to Parish, population, buildings, urban and national infrastructure was found. This spread sheet includes also a summary of the different indexes of the country and the exposure values of each estimated portafolio of assets. Table 2.12 and

Table 2.13 present a summary of the final values for the indexes and physical, economical and human exposure.

Table 2.12 Summary of indicators of the model of assets: Proxy indicators

Population	
Urban	1,400,060 Hab
Rural	1,293,625 Hab
Total	2,693,681 Hab

	Unit	Value	Value per capita	1/BIP per Capita
Built area				
Urban built area	m^2	62,320 x10³	44.5	-
Density of urban constructions	m^2/m^2 urban lands	0.24	-	-
Infrastructure Assessment				
Urban constructions	USx10^6$	14,098	5,234	1.09
Rural constructions	USx10^6$	-	-	-
Urban infrastructure	USx10^6$	1,141	815	0.17
National infrastructure	USx10^6$	3,386	1,257	0.26
Total Infrastructure for the country	**USx10^6$**	**18,625**	**6,914**	**1.44**

Table 2.13 Summary of indicators of the model of assets: Exposure values

Sector	Unit	Unit per capita country	Unit per capita sector	Value	Value per capita country
Urban constructions	**[m^2x10^3]**	**[m^2 / Pop]**		**[USx10^6$]**	**[US$ / Pop]**
Residential LP	2,299	0.9	1.64 [Hab Urb]	225	84
Residential MP	23,203	8.6	16.57 [Hab Urb]	4,915	1,825
Residential HP	9,406	3.5	6.72 [Hab Urb]	2,962	1,099
Commercial	17,089	6.3	20 m²/FL	3,476	1,290
Industry	4,010	1.5	50 m²/FL	1,223	454
Private Health	5	0.00	1.8 m²/1000Hab	2	1
Private Education	1,800	0.7	3.4 m²/Est	410	152
Public Health	16	0.01	6.0 m²/1000Hab	4	1
Public Education	3,796	1.4	7.2 m²/Est	739	275
Government	696	0.3	5 m²/EP	142	53
Total	**62,320**	**23.1**		**14,098**	**5,234**

Sector	Occupancy Day	Occupancy Night
Urban constructions	**[Population]**	**[Population]**
Residential LP	57,822	128,493
Residential MP	731,262	1,625,027
Residential HP	251,992	559,981
Commercial	868,186	325,570
Industry	84,827	47,126
Private Health	944	944
Private Education	194,727	0
Public Health	2,731	2,731
Public Education	338,454	0
Government	148,957	0
Total	**2,679,902**	**2,689,872**

Table 2.13 Summary of indicators of the model of assets: Exposure values (second part)

Sector	Unit	Unit per capita Urban	Value	Value per capita Urban	Value per Unit
Urban Infrastructure			[US$x10^6]	[US$ / Pop]	
Electric Substations	-	-	84	60	-
Communication Substations	-	-	67	48	-
Dams	-	-	0	0	-
Plants and tanks	-	-	27	19	-
Aqueducts	-	-	40	29	-
Sewage systems	-	-	45	32	-
Gas networks	-	-	23	16	-
Airports (Terminal)	103,644 m²	74.0	150	107	1,449 USD / m²
Airports (Airstrips)	9 km	0.0	60	43	7 USDx10^6 / km
Ports (Cellars)	316,672 m²	226.2	303	216	957 USDx10^6 / m²
Ports (Wharfs)	102,832 m²	73.4	289	206	2,807 USDx10^6 / m²
Urban Bridges	28 und	0.0	53	38	2 USD / und
Total			1,141	815	

Sector	Unit	Value	Value per capita National	Value per Unit
National Infrastructure	[km]	[US$x10^6]	[US$ / Pop]	[US$x10^6 / km]
Main roads (Roads)	905	2,352	873	2.6
Secondary roads (Roads)	734	239	89	0.33
Main roads (Bridges)	4	72	27	20
Secondary roads (Bridges)	5	74	28	15
Hydroelectric infrastructure (Dams)	-	85	31	-
Hydroelectric infrastructure (Power house	-	44	17	-
Thermal power plants	-	240	89	-
Geothermal power plants	-	0	0	-
Electric Energy distribution (Substations)	-	24	9	-
Electric Energy distribution (Power lines)	-	24	9	-
Communications (Fixed phone lines)	-	12	5	-
Communications (Mobile phone lines)	-	7	2.8	-
Hydrocarbons (Derivatives)	-	100	37	-
Hydrocarbons (Gas)	-	111	41	-
Total	-	3,386	1,257	-

2.7 GRAPHICAL PRESENTATION OF THE MODEL OF EXPOSURE

To understand the relative distribution of the exposure values at geographical level and the distribution by economic, development and use sectors, the following paragraphs present the most important parameters of the model.

2.7.1 Urban constructions in function of built area, value per parish and sectors

Figure 2.3 to Figure 2.5 show the area (km²), the population and the population density (urban, rural, and total) for the 14 parishes of the country.

Figure 2.3 shows that Parishes with more area are: Clarendon, St. Ann, St. Catherine and St. Elizabeth. Figure 2.4 shows that Parishes with more total and urban population are St. Andrew and St. Catherine, and the Parish with more rural population is Clarendon. Figure 2.5 shows that the Parish with the more population density is Kingston follow by St. Andrew.

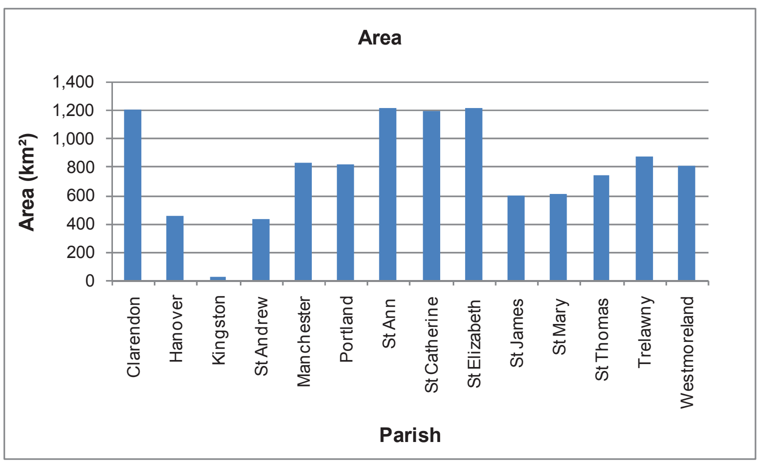


Figure 2.3 Area of the territory

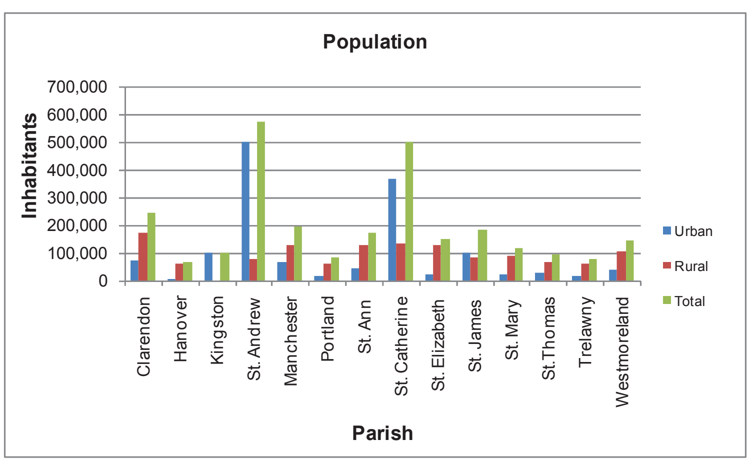


Figure 2.4 Population per parish

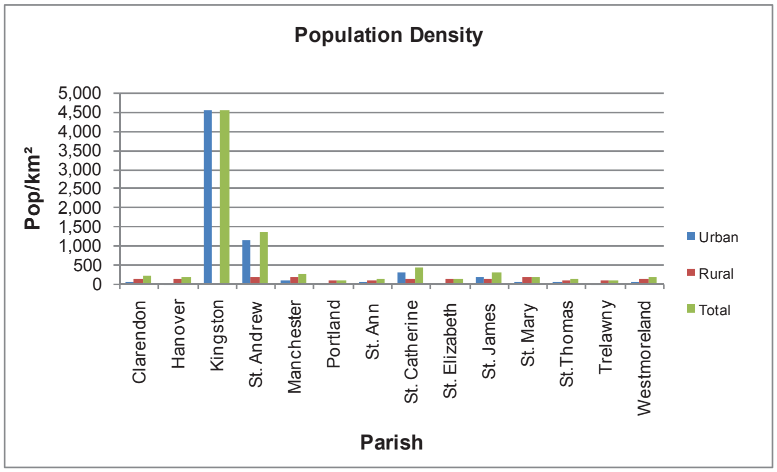


Figure 2.5 Population density per parish

Figure 2.6 and Figure 2.7 show the estimated values of urban built area (m²) and exposure value for each Parish of the country. These Figures show that the Parishes with more built area are St. Andrew and St. Catherine, and for this reason they have the higher building exposed value.

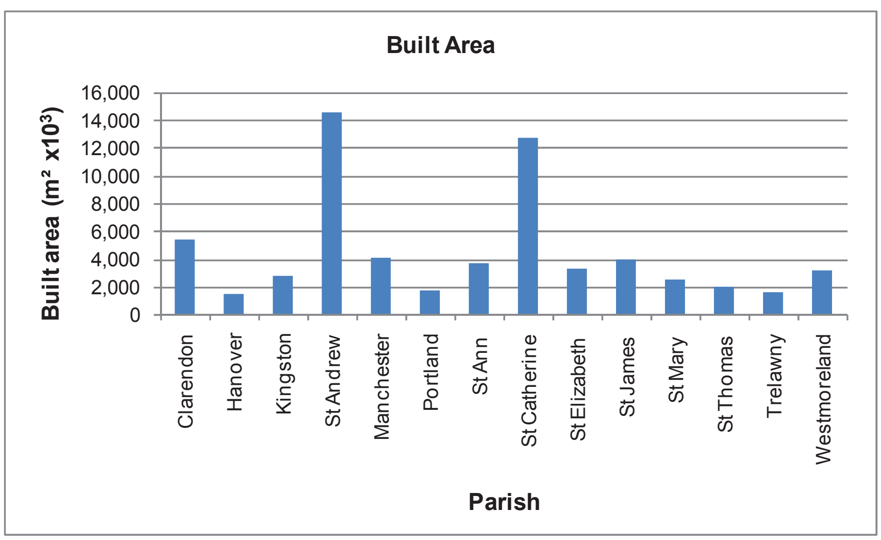


Figure 2.6 Built area per parish

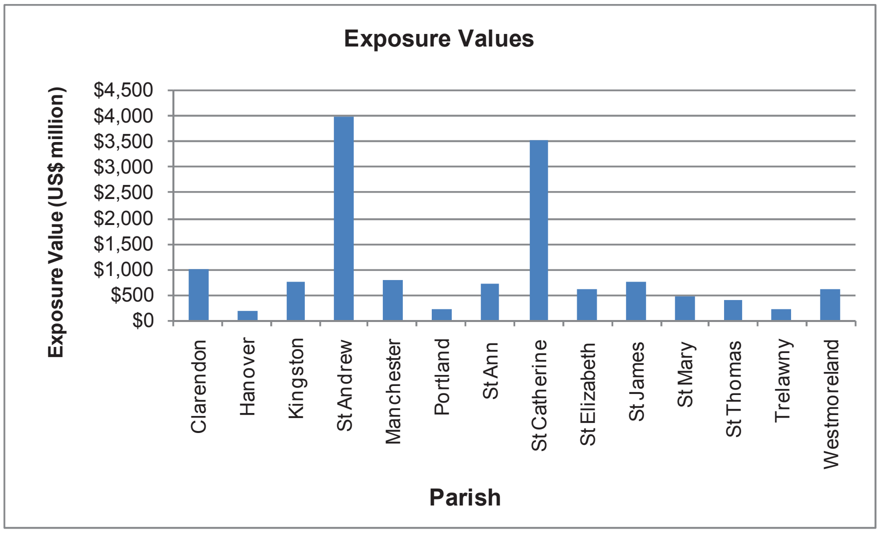


Figure 2.7 Exposure values of regular constructions per parish

Figure 2.8 and Figure 2.9 show the information about approximated built area and exposure values for the use sectors analyzed. These Figures show that the sector uses with high built area are Residential PM and Commertial, therefore they have the higher exposed value.

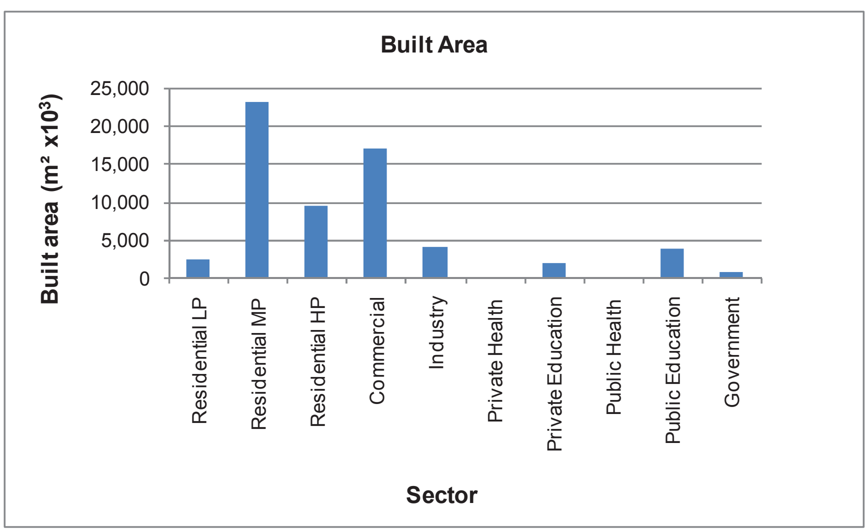


Figure 2.8 Built area per use sector

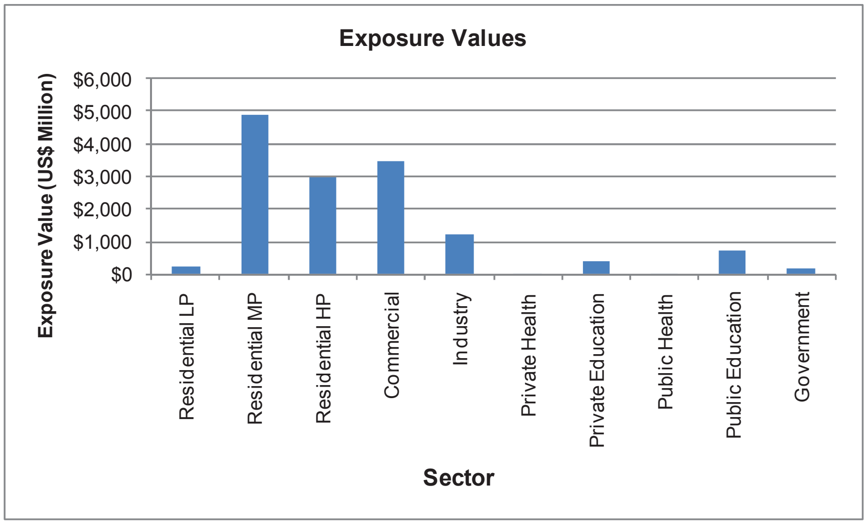


Figure 2.9 Exposure values per use sector

The information showed above is combined to produce the three-dimensional graphs (Figure 2.10 and Figure 2.11). The Figuress show built areas and exposure values in accordance with the Parishes and the use sectors defined.

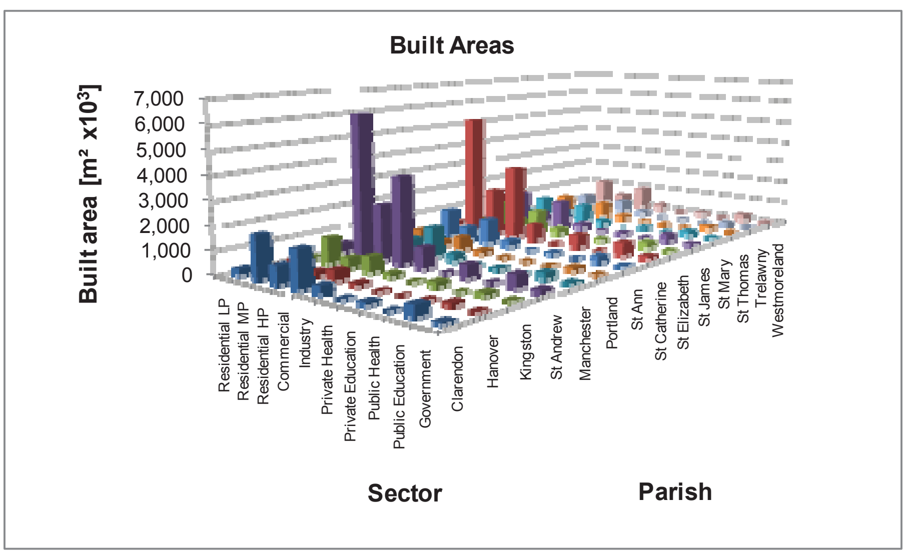


Figure 2.10 Built area per parish and use sector

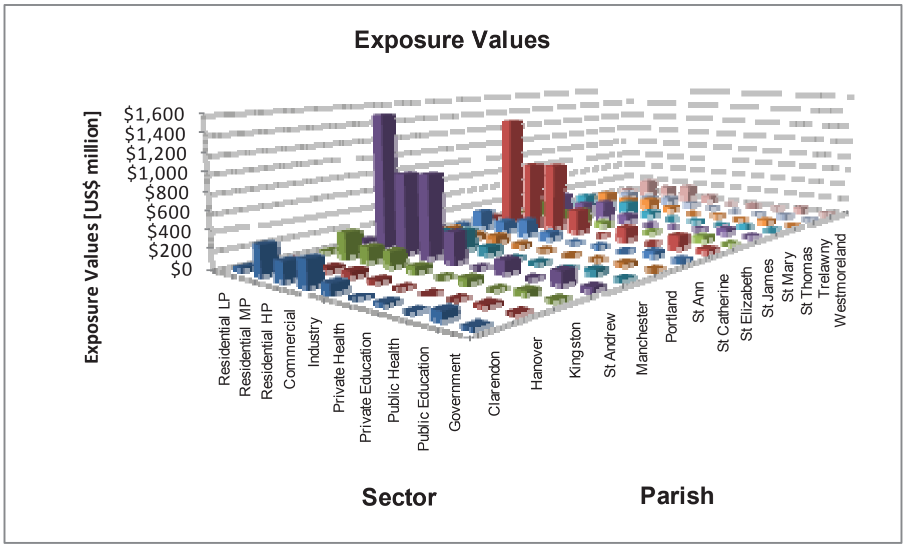


Figure 2.11 Exposure values per parish and use sector

2.7.2 Urban infrastructure in function of values per Parish and sectors

Figure 2.12 and Figure 2.13 show the exposure values of urban infrastructure, including ports, airports, power distribution systems, telecommunications, water and sewage systems, water treatment plants and gas systems. The information is showed by Parish and sector. Figure 2.12 shows that the Parish with the higher exposed value in urban infrastructure is Kingston and Figure 2.13 shows that the sector related to ports has the higher exposed value.

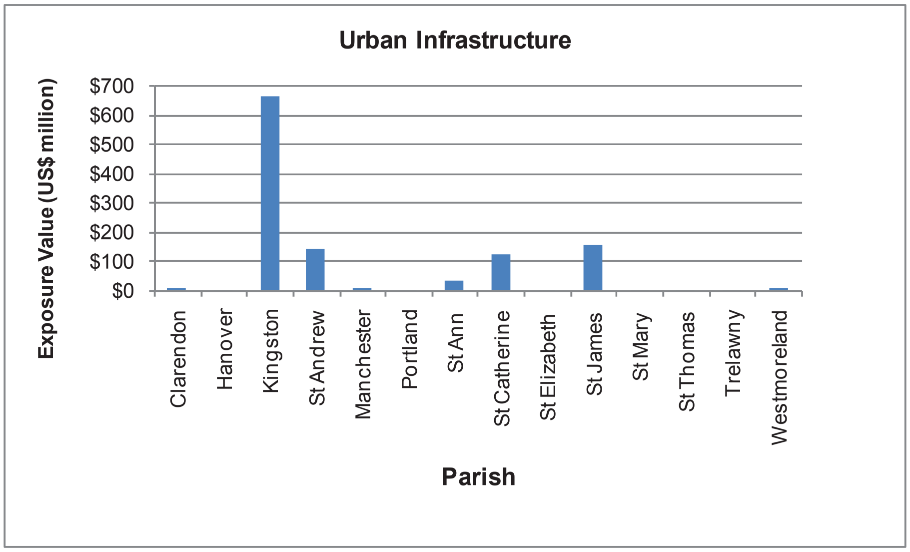


Figure 2.12 Exposure value of urban infrastructure per parish

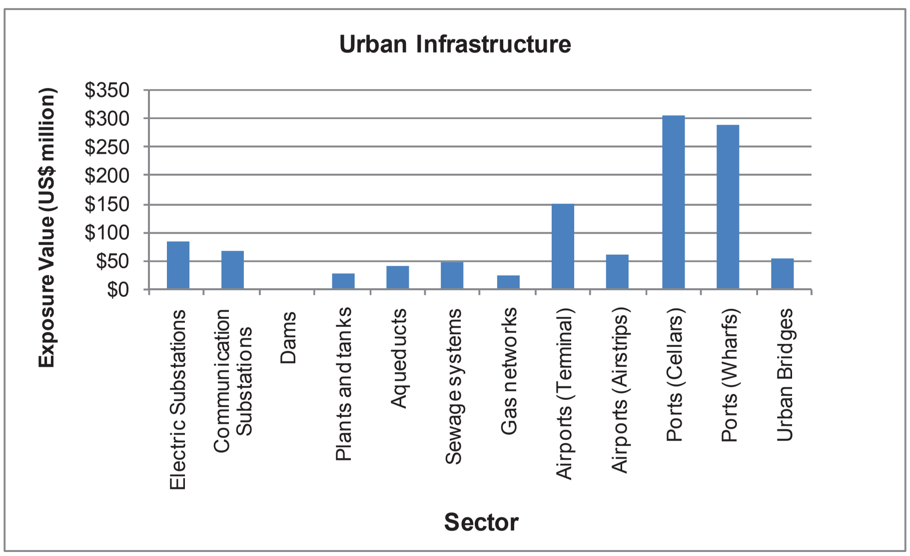


Figure 2.13 Exposure value of urban infrastructure per sector

Figure 2.14 shows the same information presented above in a three-dimensional graph.

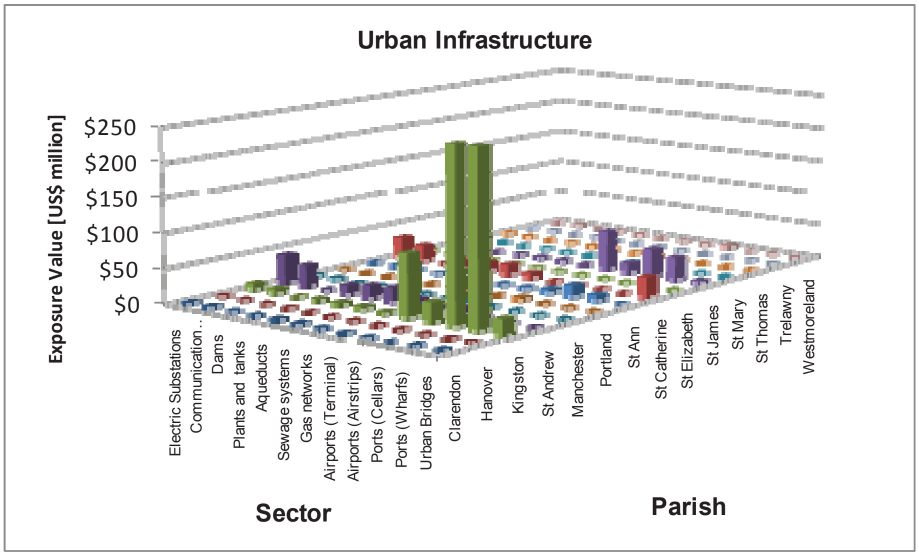


Figure 2.14 Exposure value of urban infrastructure per parish and sector

2.7.3 National infrastructure in function of values per parish and sector

Figure 2.15 and Figure 2.16 show the exposure values for national infrastructure. This topic includes the main and secondary road network, bridges, hydroelectric power plants, dams, thermal power plants, power substations, telecommunications substations, fuel and gas substations and networks. The information is showed per Parish and sector. Figure 2.15 shows that the exposed value of national infrastructure is distributed in all Parishes, but the Parish with the higher exposed value is St. Mary and Figure 2.16 shows that the sector of higher exposed value, in this case, is the main road network.

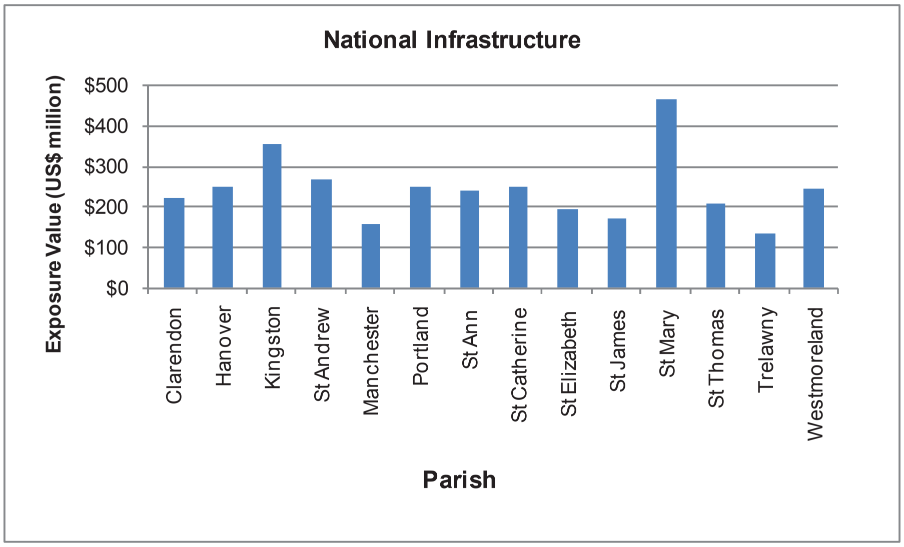


Figure 2.15 Exposure value of national infrastructure per parish

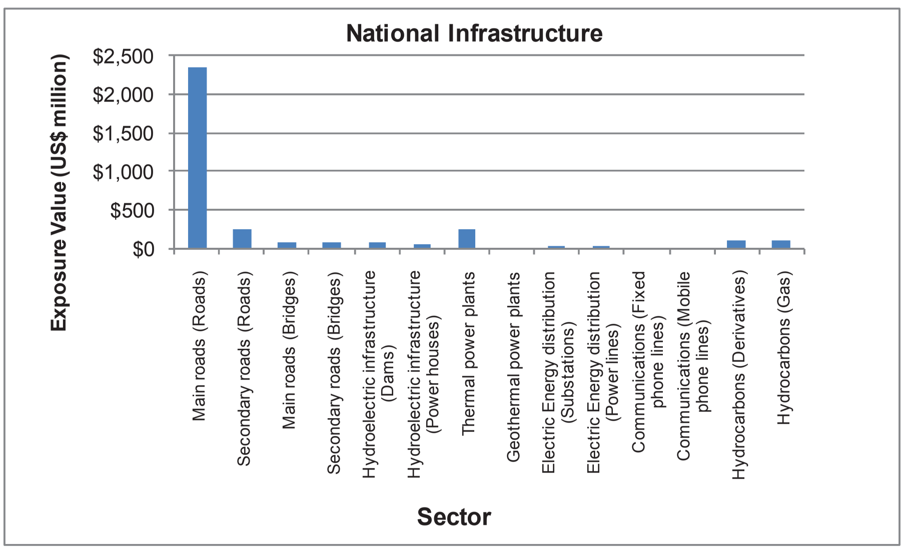


Figure 2.16 Exposure value of national infrastructure per sector

Figure 2.17 shows the same information presented above in a three- dimensional graph.

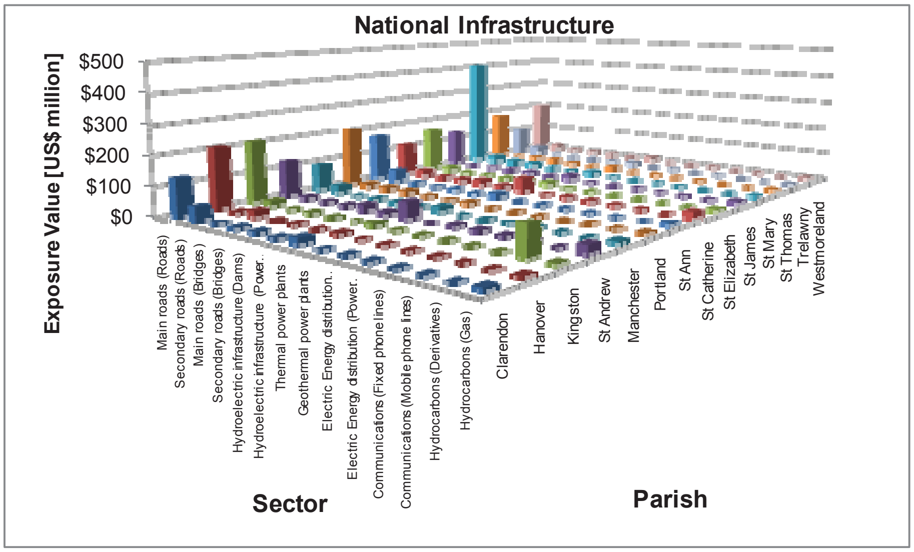


Figure 2.17 Exposure value of national infrastructure per parish and sector

2.7.4 Summary of Total Exposure Values per Parish and Sector

Figure 2.18 and Figure 2.19 show the summary of the total exposure values obtained by the addition of urban buildings, urban and national infrastructure per each Parish and sector. In the categories of use sectors, all these types were considered. Figure 2.18 shows that the Parishes with the higher exposed values are St. Andrew and St. Catherine, and Figure 2.19 shows the use sector with the higher expoed value is the private constructions or buildings.

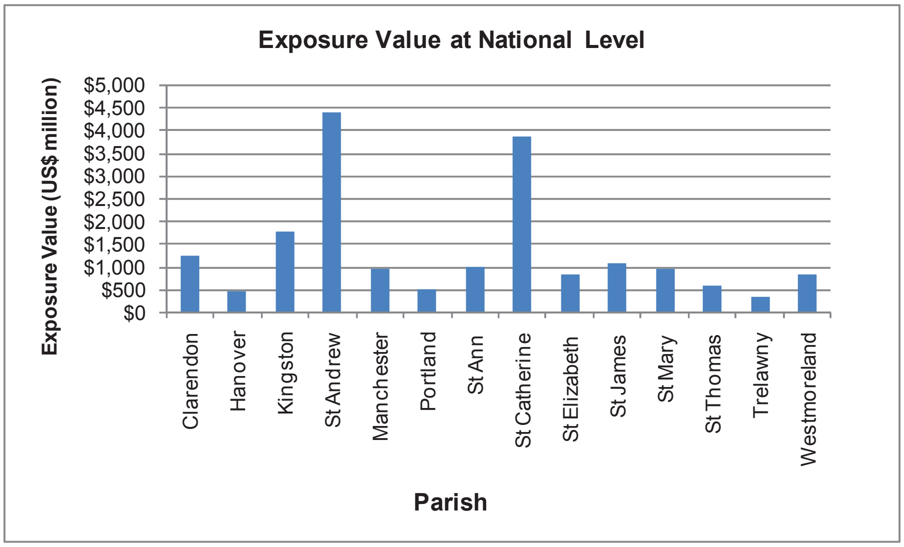


Figure 2.18 Total exposure values of national infrastructure per parish

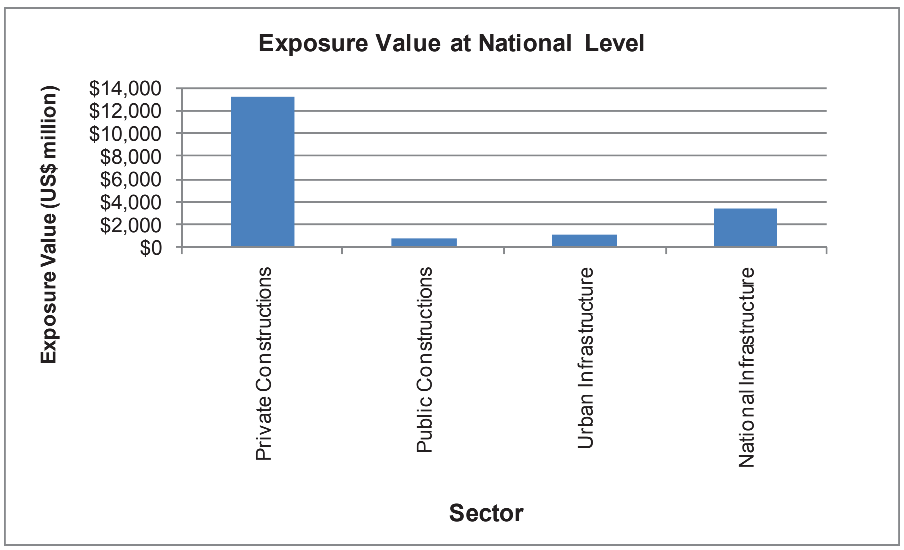


Figure 2.19 Total exposure value of national infrastructure per sector

Figure 2.20 shows the information presented above in a three-dimensional graph.

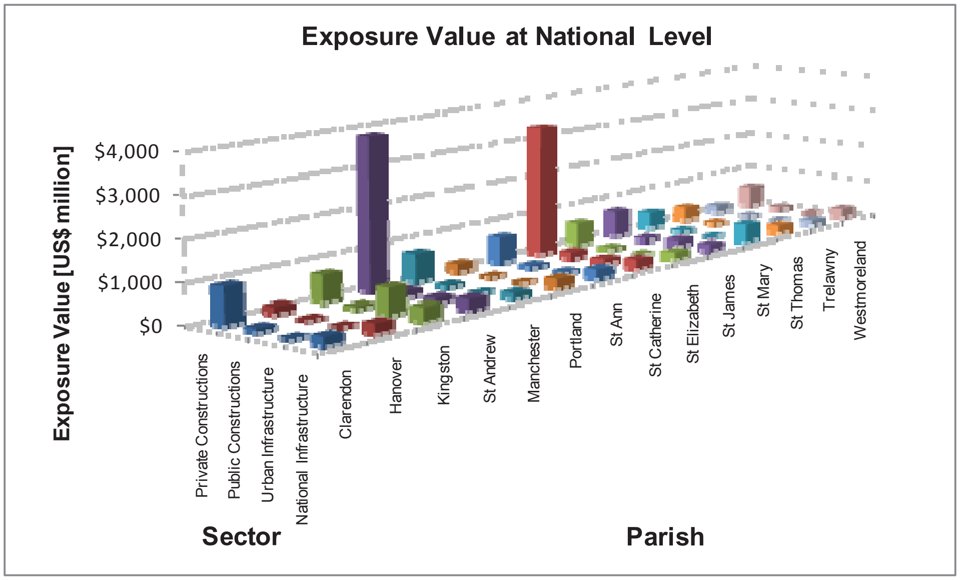


Figure 2.20 Total exposure value of national infrastructure per parish and sector

Figure 2.21 shows the national exposed values for the sectors of urban and rural constructions (buildings) and the urban and national infrastructure, and addition it shows the total exposed valur of the country. Clearly, it is posible to see that the urban constructions have the higher exposed value of the country.

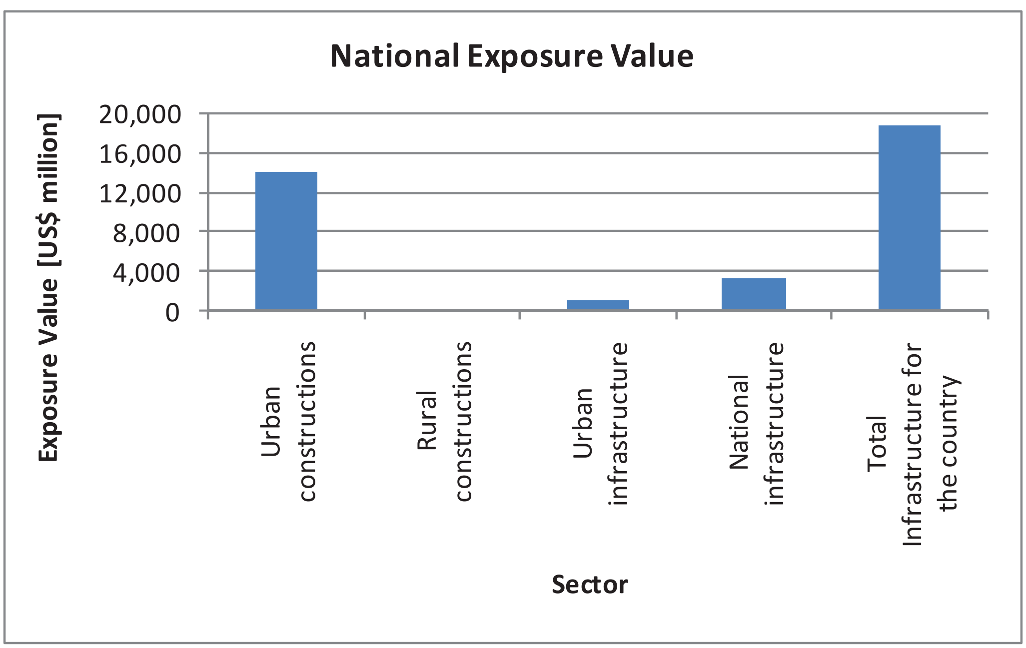


Figure 2.21 National exposure value per sector

2.7.5 Summary of conclusions

- Parishes with more land area are Clarendon, St.Ann, St.Catherine and St.Elizabeth.
- Parishes with more total and urban population are St. Andrew and St. Catherine reason why these Parishes have more built area and have the higher building exposed value.
- Parish with more rural population is Clarendon.
- Parish with the more population density is Kingston follow by St. Andrew.
- Sector uses with more built area are Residential PM and Commertial, therefore these Parishes have the more exposed value.
- Kingston has the higher exposed value on urban infrastructure. In the same way the ports sector is who has the higher exposed value.
- At national level, the sector of road networks has the higher exposed value on national infrastructure. At the same time, St. Mary has the higher exposed value on national infrastructure.
- St. Andrew and St. Catherine are Parishes with the higher exposed values, and the sector with the higher exposed value is private buildings.

2.7.6 Information in Descriptive Maps

Figure 2.22 to Figure 2.29 show the maps of information per Parish, for each of the following variables: population, distribution of built area and distribution of exposure value.

- Figure 2.22 shows that the population of Jamaica is concentrated in the South of the country, mainly in the Parishes of Kingston, Saint Andrew and Saint Catherine.
- Figure 2.23 Show that the Parishes with higher population density are Kingston, Saint Andrew and Saint Catherine. They encompass the Metropolitan Area of Kingston.
- Figure 2.24 Shows that the Parishes with higher built area are Kingston, Saint Andrew and Saint Catherine. In theses Parishes are living the most people of the country. Accordingly in these Parishes are located the higher expose values in contructions, as it is showed in Figure 2.25.

- Figure 2.26, shows that the higher exposed value in urban infrastructure is located in the Parishes of Kingston, Saint Andrew, Saint Catherine and Saint James. In these Parishes are located the main ports and airports of the country.
- Figure 2.27 Shows that the Parishes with the higher exposed value in national infrastructure are Hanover, Saint Mary and Westmoreland, due to the partipation of the transportation infrastructure.
- Figure 2.28 Shows that the Parishes with the higher total exposed value are Kingston, Saint Andrew and Saint Catherine. They have the high exposed values in private constructions.
- Figure 2.29, shows that in most Parishes the expoed values by sector are concentrated mainly in prívate constructions and national infrastructure. Kingston presents higher exposed value in urban infrastructure.

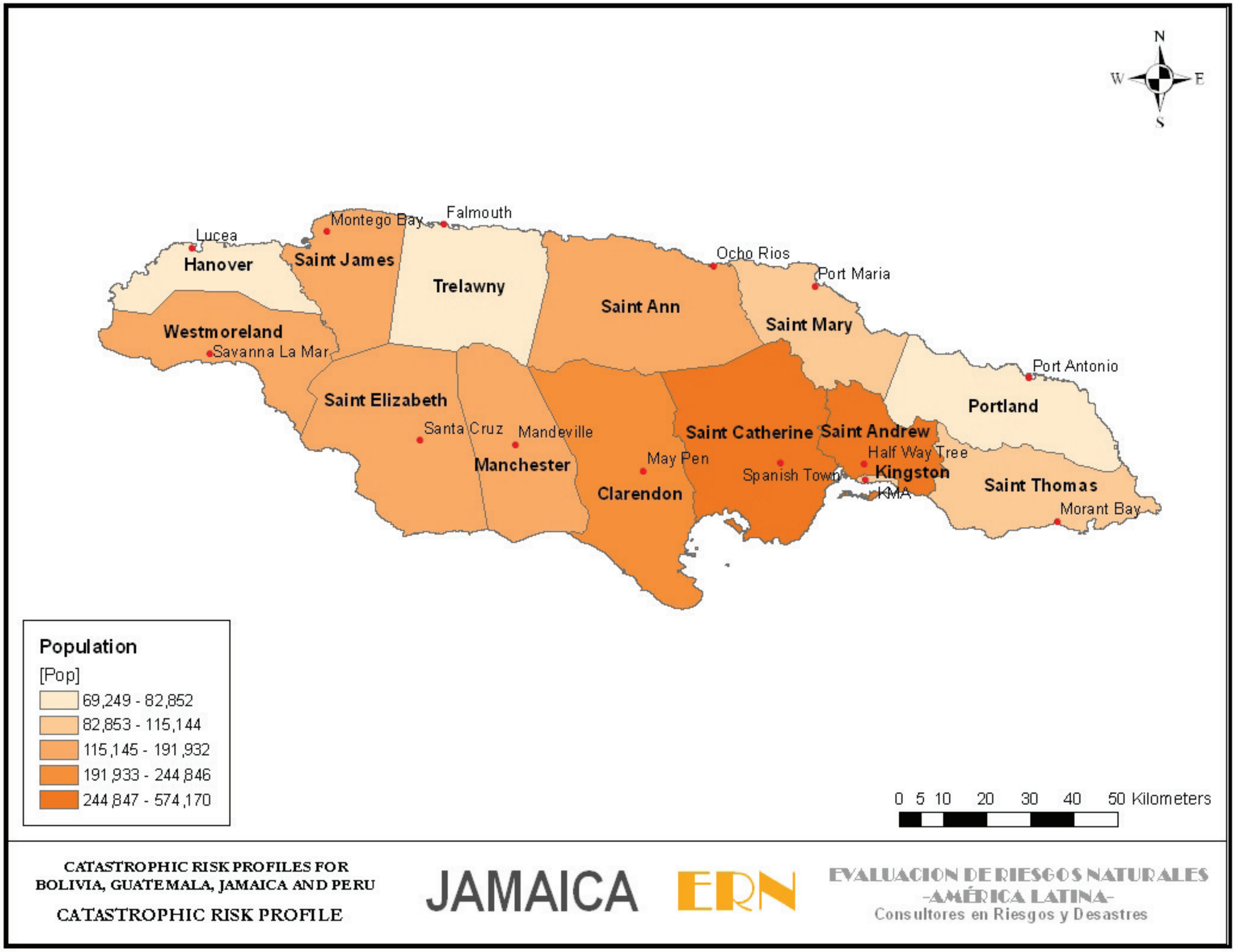


Figure 2.22 Distribution of population per parish

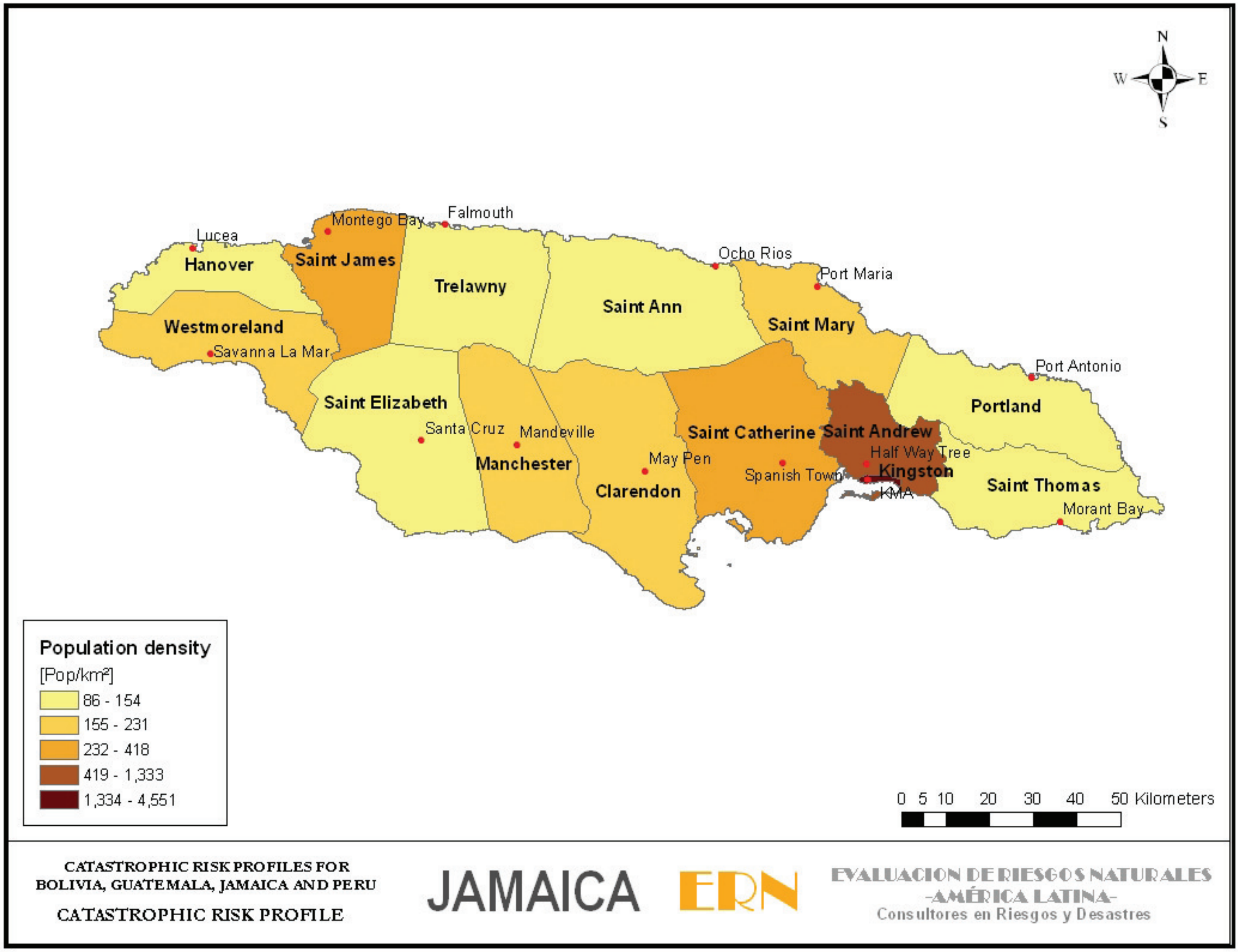


Figure 2.23 Population density per parish

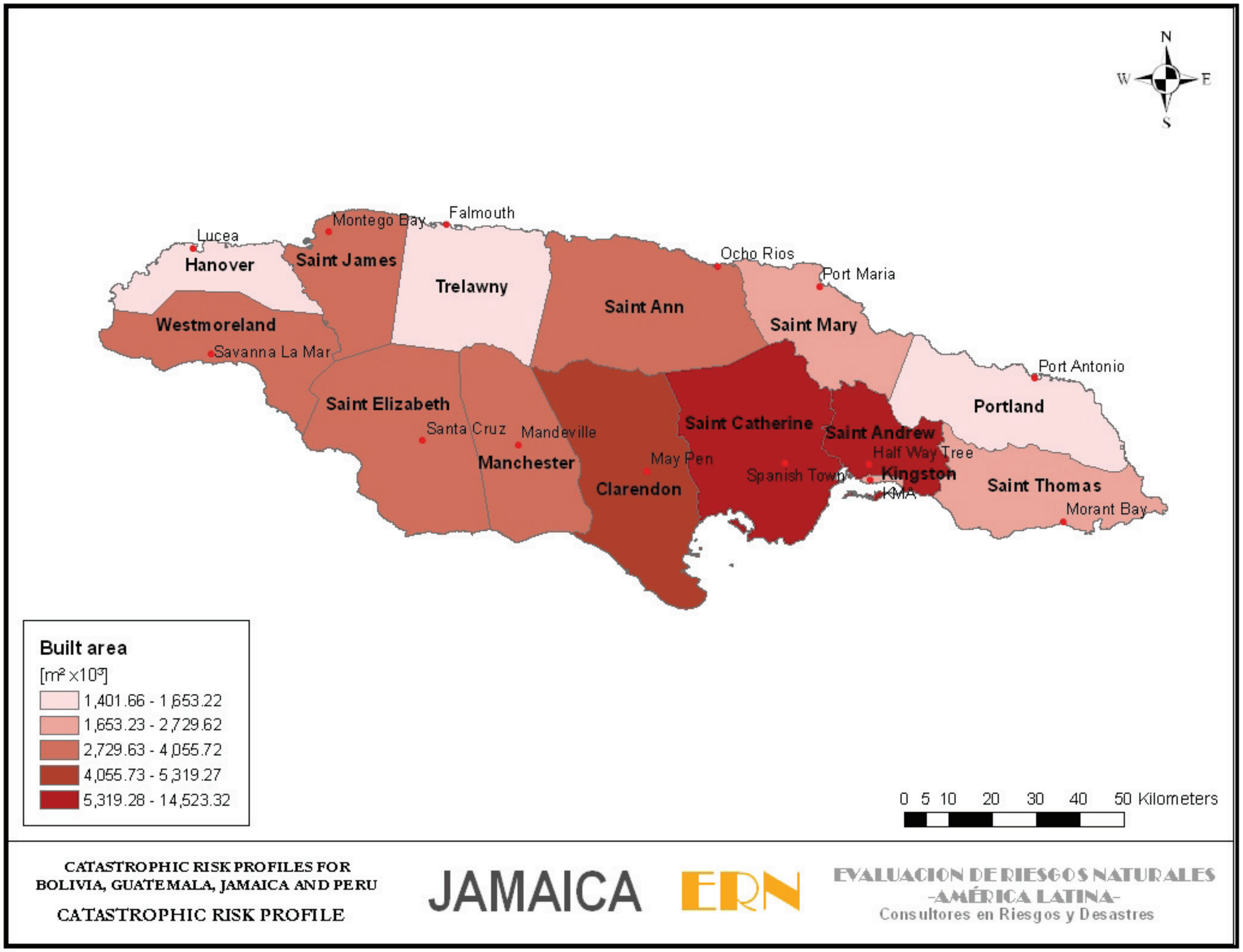


Figure 2.24 Distribution of built area per parish

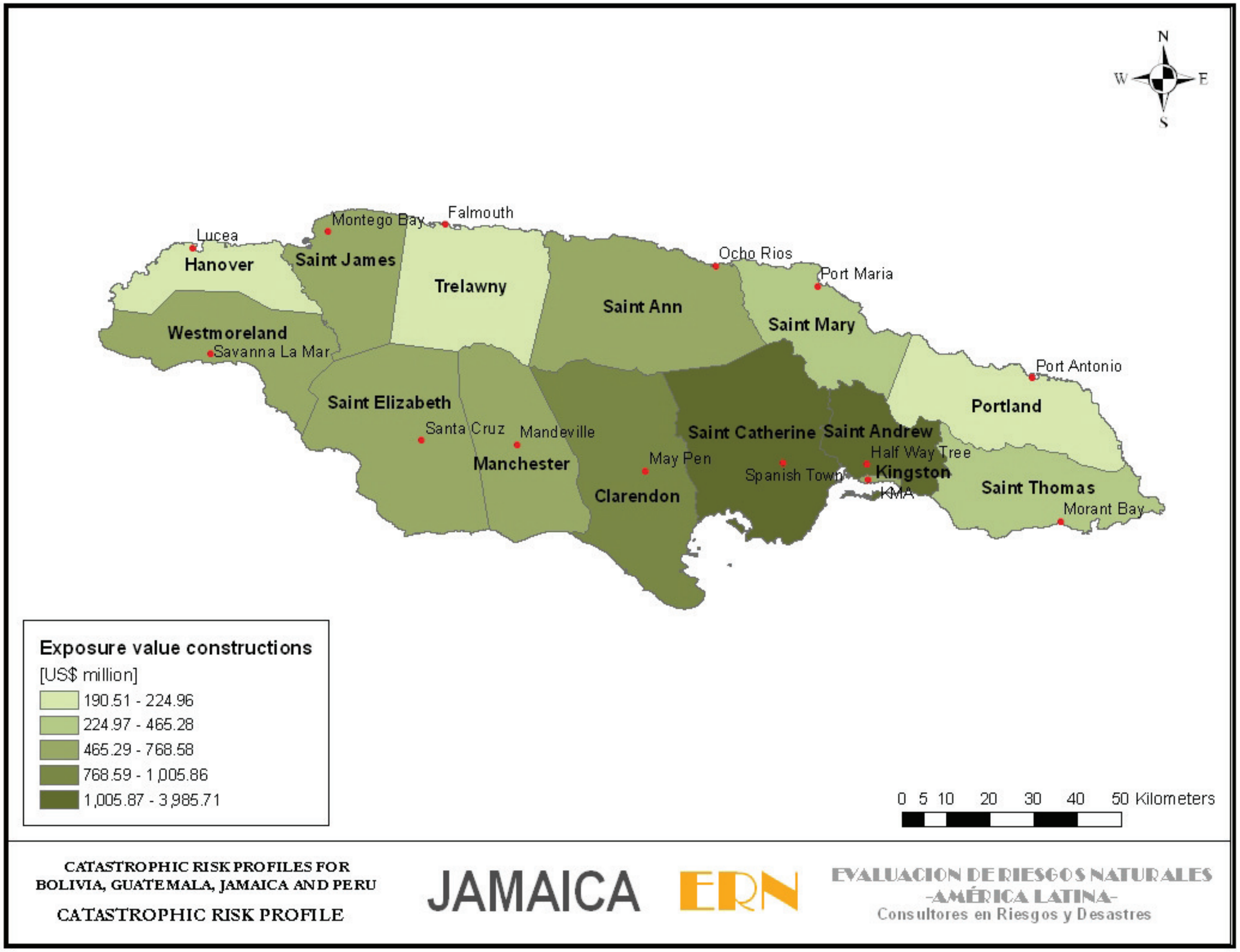


Figure 2.25 Distribution of exposure value in regular constructions per parish

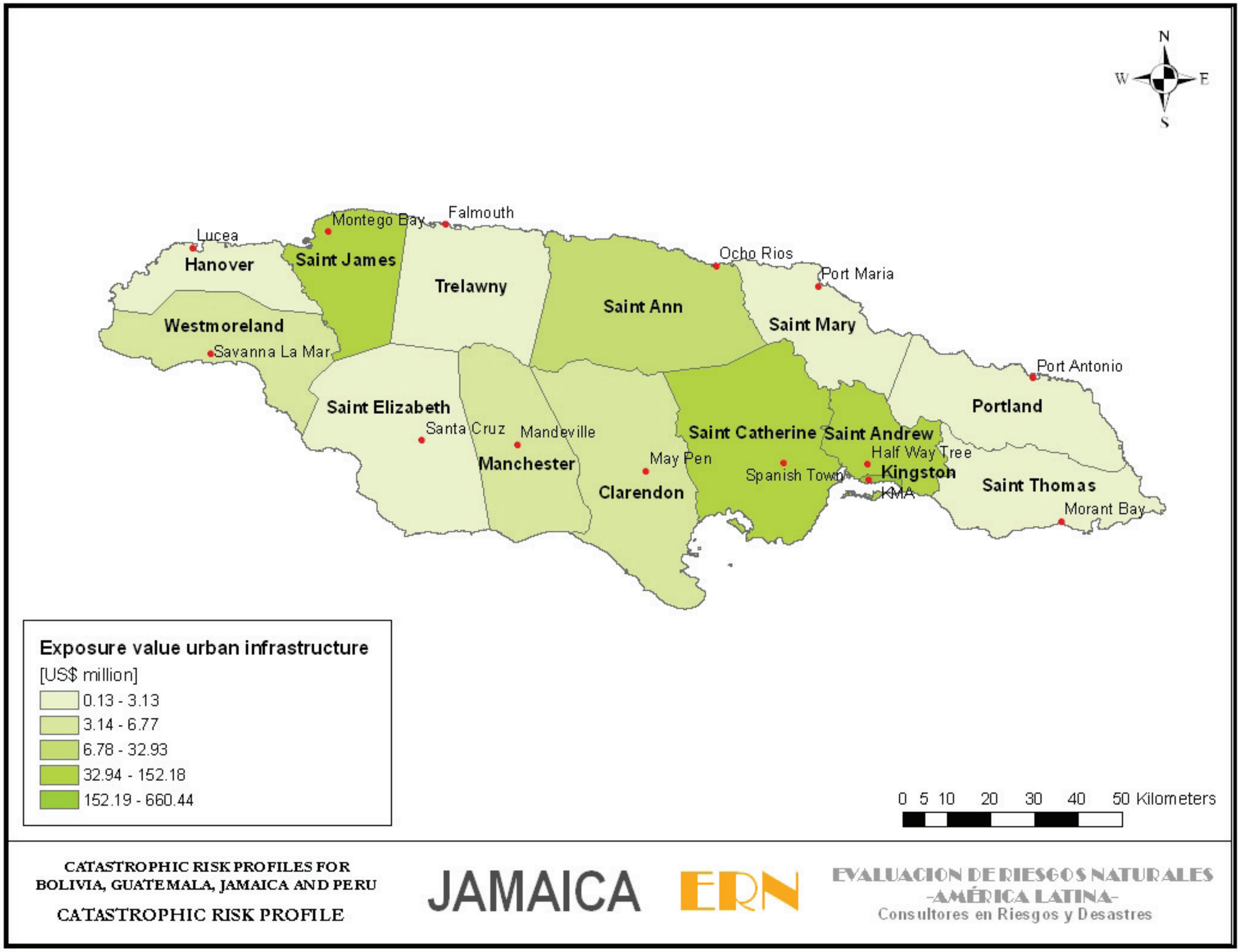


Figure 2.26 Distribution of exposure value of urban infrastructure per parish

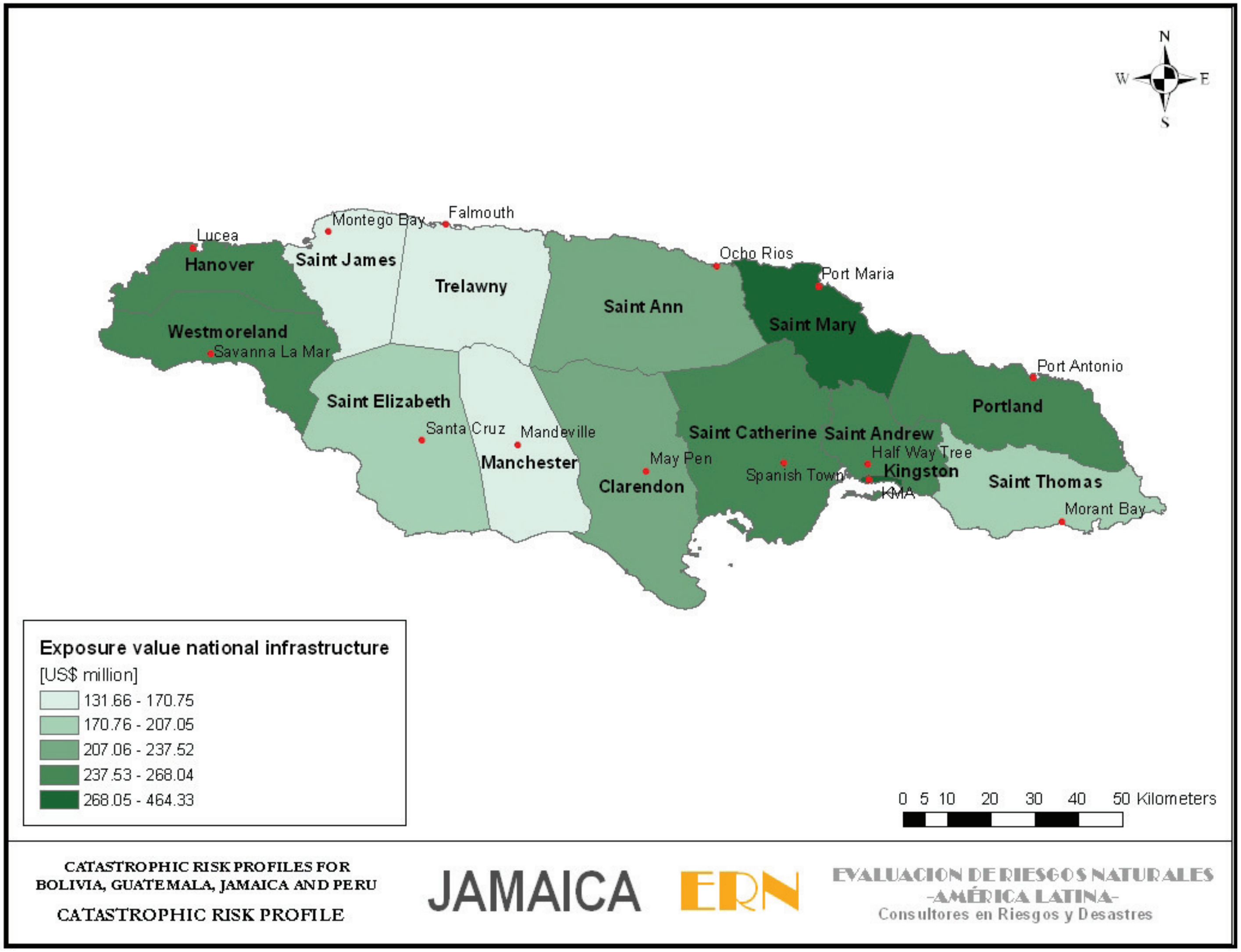


Figure 2.27 Distribution of exposure value of national infrastructure per parish

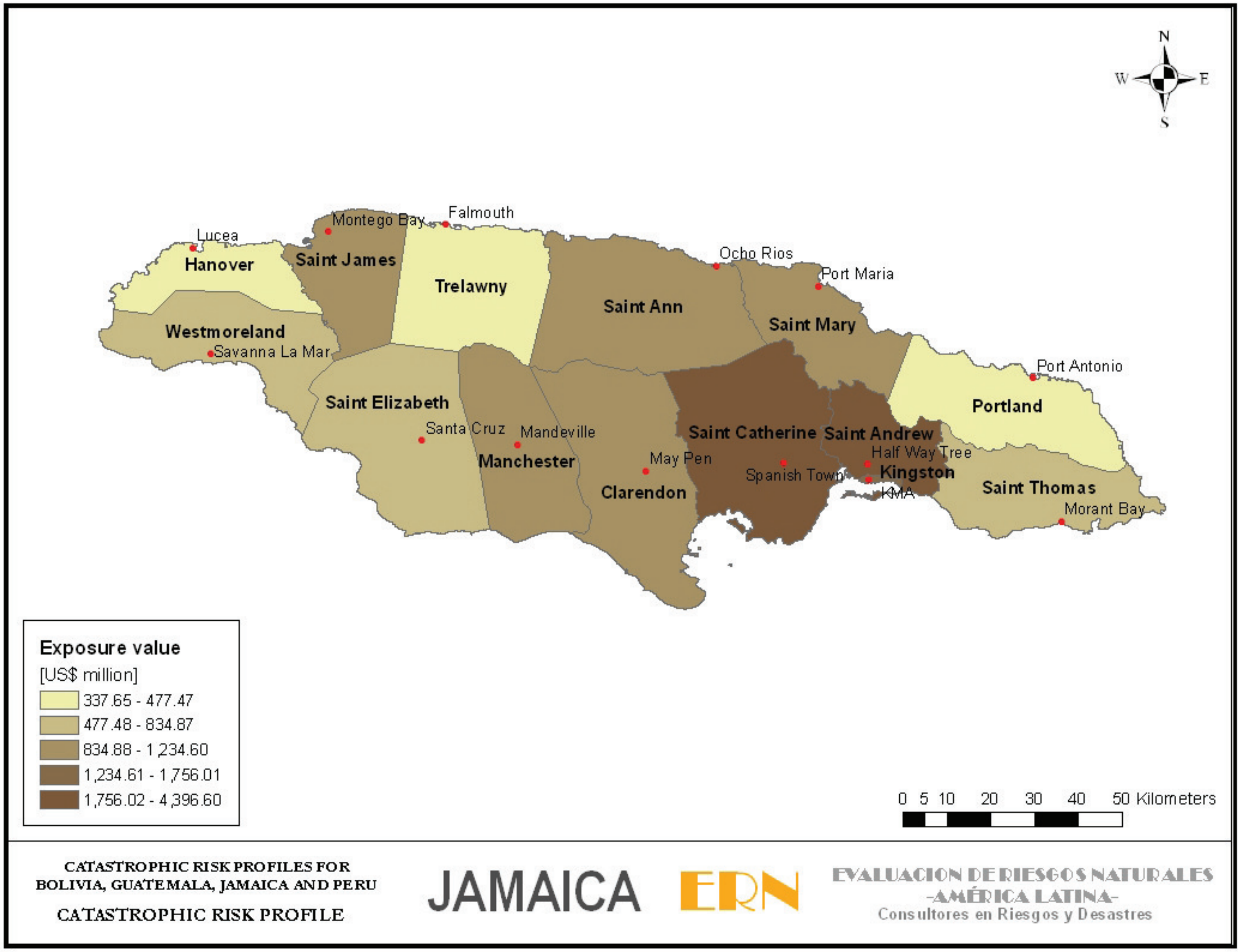


Figure 2.28 Distribution of total exposure value per parish

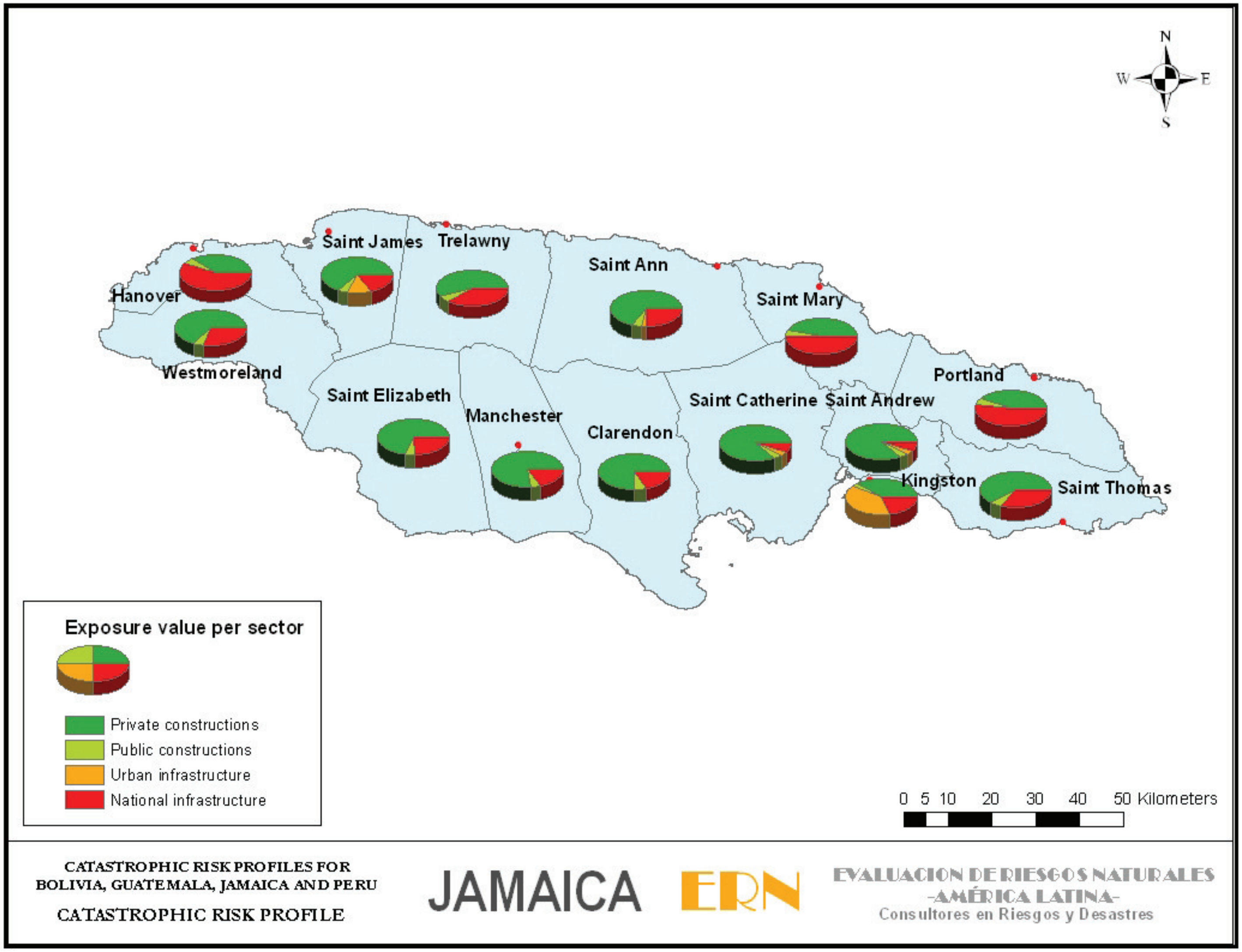
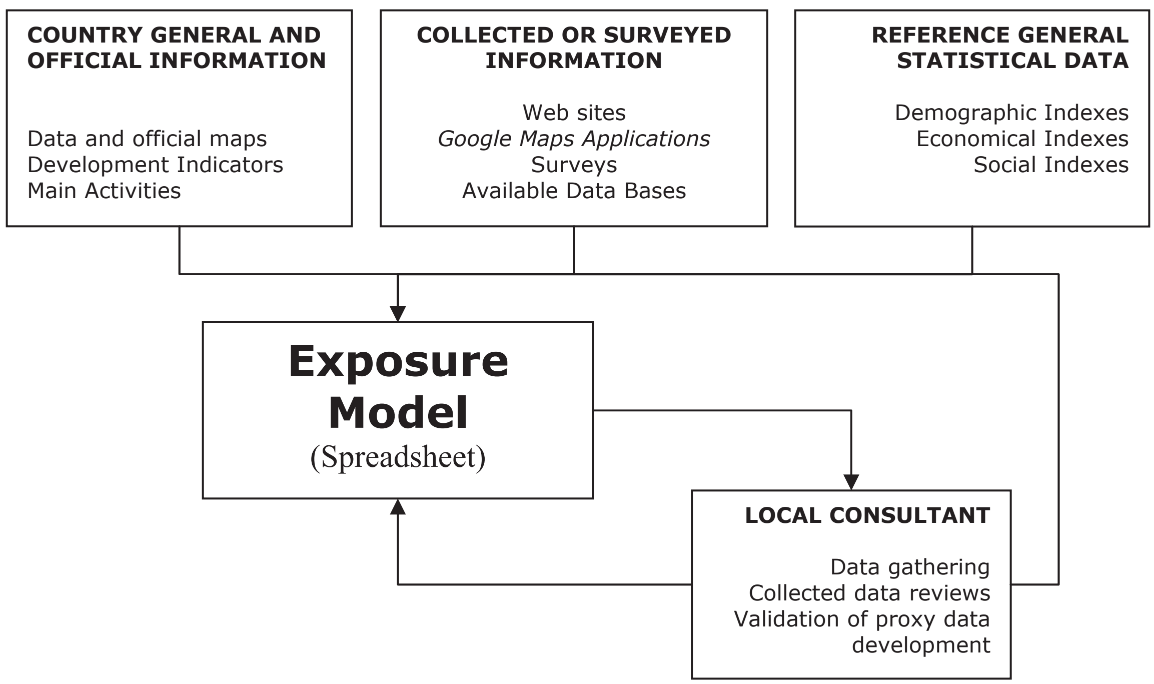


Figure 2.29 Relative distribution of exposure values for each sector per parish

2.8 VALIDATION PROCESS

After gathering information described in 2.1 of this report, that information becomes an input of the exposure model, all information has been arranged on a spreadsheet that performs all estimations described in Annex 2. Once the exposure model has been formed, it is remitted to the local consultant who reviewed and validated the input information and the corresponding exposure result values. This validation process is carried out iteratively until accomplish with adjusted exposure model.



Samples of different buildings are collected in distinct places to check characteristics of construction and predominant types. Specific forms are used for information gathering. According to this technical procedure a special software program is used for vulnerability adjustment.

2.9 MAIN SOURCES OF INFORMATION

- ◊ Statistical Institute of Jamaica, 2001, Population Census, http://www.statinja.com
- ◊ Ministry of Education 2006 -2007, School Profiles, http:// www.moec.gov.jm/schools_website/PROFILE%202006-2007.
- ◊ Ministry of Health Government of Jamaica, 2006, Jamaica Annual Report, http://www.moh.gov.jm/
- ◊ Ministry of Transport and Works. 2005 - 2006, Annual transport statistics report: Jamaica in figures, http://www.mtw.gov.jm/general_information/reports/reports.aspx
- ◊ Ministry of Energy, Minning and Telecommunications. http://www.mct.gov.jm/
- ◊ http://www.aircraft-charter-world.com/airports/centralamerica/guatemala.htm
- ◊ http://rangeland.tamu.edu (Data about Jamaica)
- ◊ http://geography.about.com/library/cia/blcjamaica.htm
- ◊ http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=JM
- ◊ https://www.jpsco.com/site.nsf/web/newsmain.htm
- ◊ Grace A. Daley Williams, An Evaluation Of The Low-Income Housing Sector In Jamaica,(http://etd.gatech.edu/theses/available/etd-11192006231412 /unrestricted/williams_grace_d_200612_mast.pdf.pdf)
- ◊ https://www.cia.gov/library/publications/the-world-factbook/
- ◊ Comisión Económica para América Latina y el Caribe, 2007, Statistical Yearbook for Latin America and the Caribbean, http://www.eclac.org/cgi-bin/getProd.asp?xml=/publicaciones/xml/8/32598/P32598.xml&xsl=/deype/tpl/p9f.xsl&base=/tpl/top-bottom.xslt
- ◊ http://www.presidencia.gov.co/sne/2005/mayo/14/05142005.htm
- ◊ http://www.invias.gov.co/invias/hermesoft/portalIG

◊ http://www.el-exportador.com/012002/mercados/n49_articulo.pdf

◊ http://www.centralamericadata.com

◊ http://www.portjam.com/

◊ http://www.ern-la.com/aplicaciones_capra/aplicaciones_capra.htm

◊ http://www.nwcjamaica.com/WaterSupplyFacilities.asp

◊ http://www.nwcjamaica.com/PDFs/FinancialStatements/NWC%20Audited%20Financial%20Statements%2031%20March%202006.pdf

◊ http://www.nwcjamaica.com/PDFs/Website(PUBLICATIONS)%20-%20Water%20Distribution.pdf

◊ http://www.jis.gov.jm/health/index.asp

3 EARTHQUAKE CATASTROPHE RISK

3.1 SEISMIC HAZARD ASSESSMENT

3.1.1 General Aspects

The usual form of representing seismic hazard is by exceedance rates of given intensities. It can also be represented by maps of land accelerations, velocities and displacements for different return periods or specific seismic scenarios. When the seismic demand on each element that forms part of the inventory of the country's assets is acknowledged, it is possible to estimate the response, regarding the potential seismic activity and assessing probable effects, damage or economic losses.

Seismic hazard assessment in Jamaica is relatively recent. In 1980 Shepherd & Aspinall estimated maximum horizontal acceleration values with an exceedance probability of 30% in 50 years, for the complete Jamaican territory, based on earthquake history and the macroseismic Modified Mercalli Intensity (MMI). Said task was adopted in the Jamaican National Building Code, published in 1983.

In 1999, Shepherd used updated seismic information from the Panamerican Institute of Geography and History[2] to update intensity values associated to seismic hazard.

In 2001, the USAID Office for Assistance to Foreign Disasters, published the Assessment Study of the Seismic Hazard in Kingston's Metropolitan Area, as a part of the Project for Mitigation of Disasters in the Caribbean area[3]. Said study assessed the level of seismic

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[2] Specialized agency of the Organization of American States - OAS

[3] Caribbean Disaster Mitigation Project. 1999

hazard existing in the capital of Jamaica, including site effects, and design advice was given for new constructions in the city.

From the revision of the seismic hazard models used in the studies previously mentioned, a national seismic hazard model was developed, based on the classic seismological theory that allows estimation of the exceedance probability of relevant intensities in the behavior of structures for different exposure periods.

The seismic hazard was calculated using the Hazard Module of ERN-**CAPRA.** Details of the model of seismic hazard assessment are presented at: http://www.ecapra.org/es/ (wiki – amenazas).

3.1.2 Results of Seismic Hazard

3.1.2.1 *Contribution of Seismic Sources to Hazard*

Assessment of seismic hazard on a representative point of the country indicates the contribution of the nearest seismogenic sources. Figure 3.1 presents the relative contribution in terms of the exceedance rates of each of the main seismogenic sources and the global hazard given for the integration of the sources' hazards, in this case for the city of Kingston.

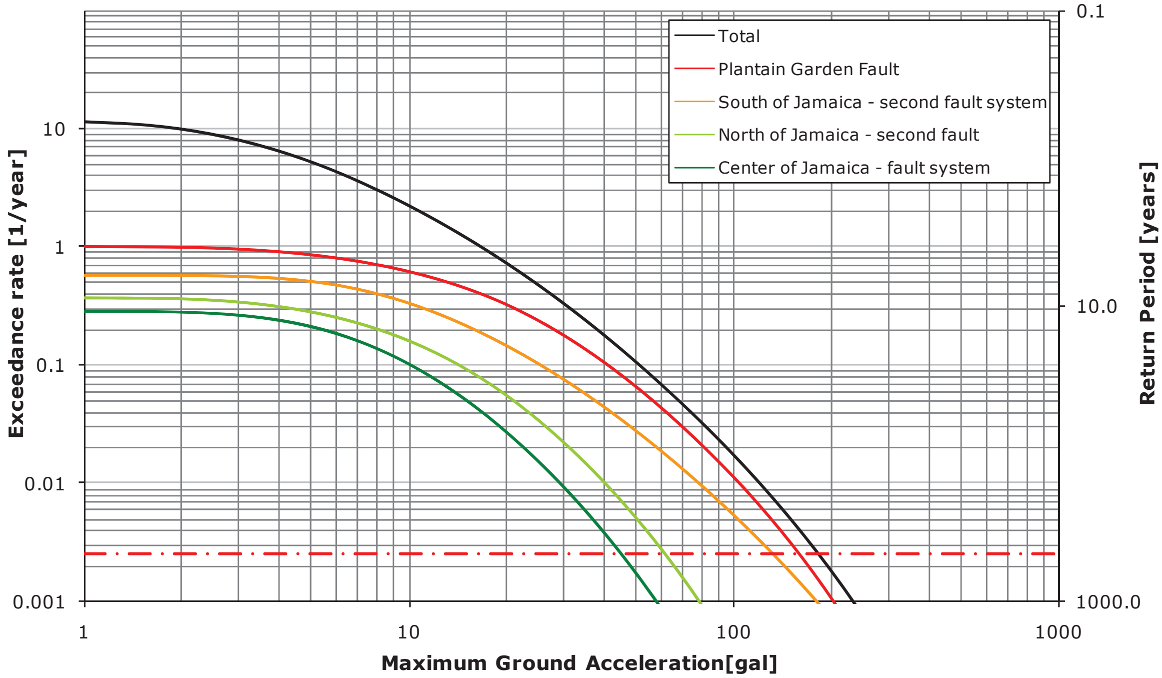


Figure 3.1 Exceedance rates of maximum acceleration for Kingston

If upon the Figure 3.1 an exceedance rate is chosen for a specific functional condition, it is possible to draw horizontal lines that intercept the rate curves of the different sources contributing to the regional hazard. For example, when establishing a return period of 500 years (rate of 0.002/year), it is possible to find the points of maximum acceleration for each source on the area of study. In addition, following the classic theory of seismic hazard, it is possible to calculate the total hazard as result from the contribution of all the sources (see Figure 3.2). For a return period of 500 years, a probable maximum acceleration on the bedrock of the order of 19% of gravity (190 gal) is obtained.

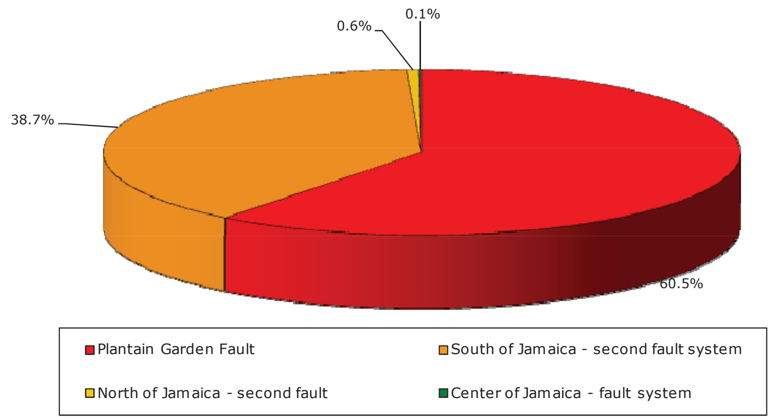


Figure 3.2 Percentage of participation for seismic sources in the Kingston's hazard, 500 years of return period

(Seismic sources Plantain Garden and South Jamaica fault systems provide together about the 99 % of the seismic hazard)

Extending the procedure described for different spectral ordinates, it is possible to build uniform hazard spectra, for which all calculated seismic intensity values have the same exceedance probability. Spectral uniform acceleration, velocity and displacement on bedrock for a given point on the area of study, are presented in Figure 3.3.

A

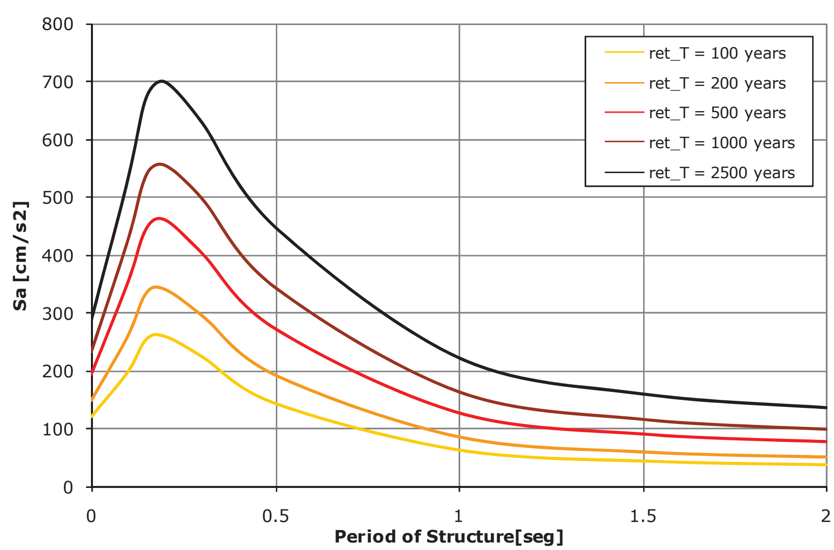
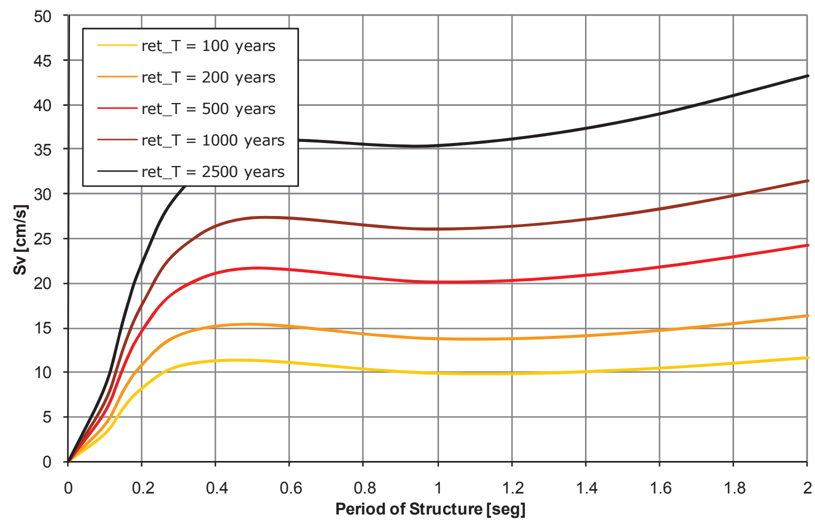


Figure 3.3 Uniform hazard spectrums for different seismic intensities A: acceleration [cm/s²], B: velocity [cm/s], C: displacement [cm]

(The Uniform Hazard Spectra shown represents the top motion intensities, in terms of acceleration, velocity and displacement, for different kind of structures)

B



C

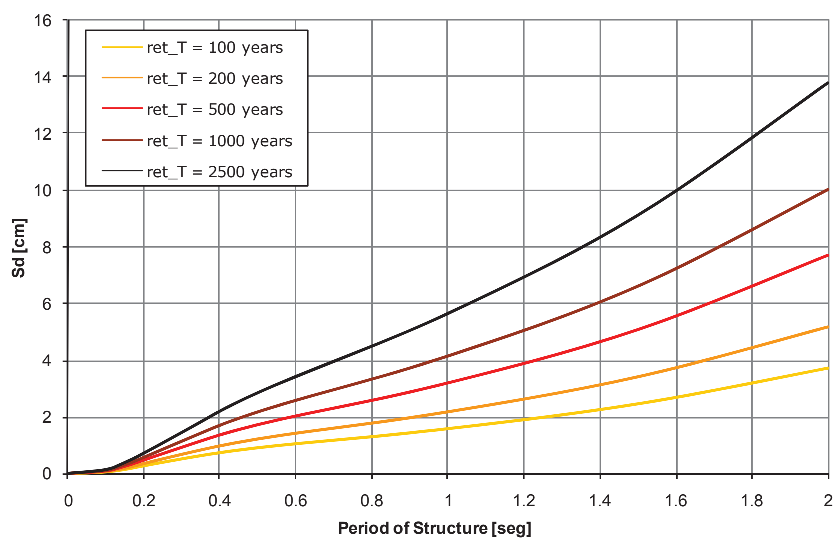


Figure 3.3 Uniform hazard spectrums for different seismic intensities A: acceleration [cm/s²], B: velocity [cm/s], C: displacement [cm] (part two)

3.1.2.2 *Regional Seismic Hazard on Bedrock*

The results of seismic hazard on bedrock for the whole country taking into consideration all the seismic sources are presented as follows.

Figure 3.4 shows the seismic hazard maps in terms of spectral acceleration for the 500-year return period, for selected structural periods. Figure 3.5 shows the seismic hazard maps for maximum land acceleration for different return periods (Ret-T).

The hazard maps presented correspond to the expected response of the geological formations of the bedrock, with shear wave velocities of the order of 800m/s or more. When these strata are reached and for the areas where soft soil deposits of considerable thickness are present, the seismic wave will propagate within the superficial subsoil, generally less rigid, until the structure's foundations, or simply the ground level are reached.

For this evaluation, calculations are performed directly using the hazard parameters obtained at firm ground level, and the effects of local seismic response due to specific soil deposits on the different points are not taken into account.

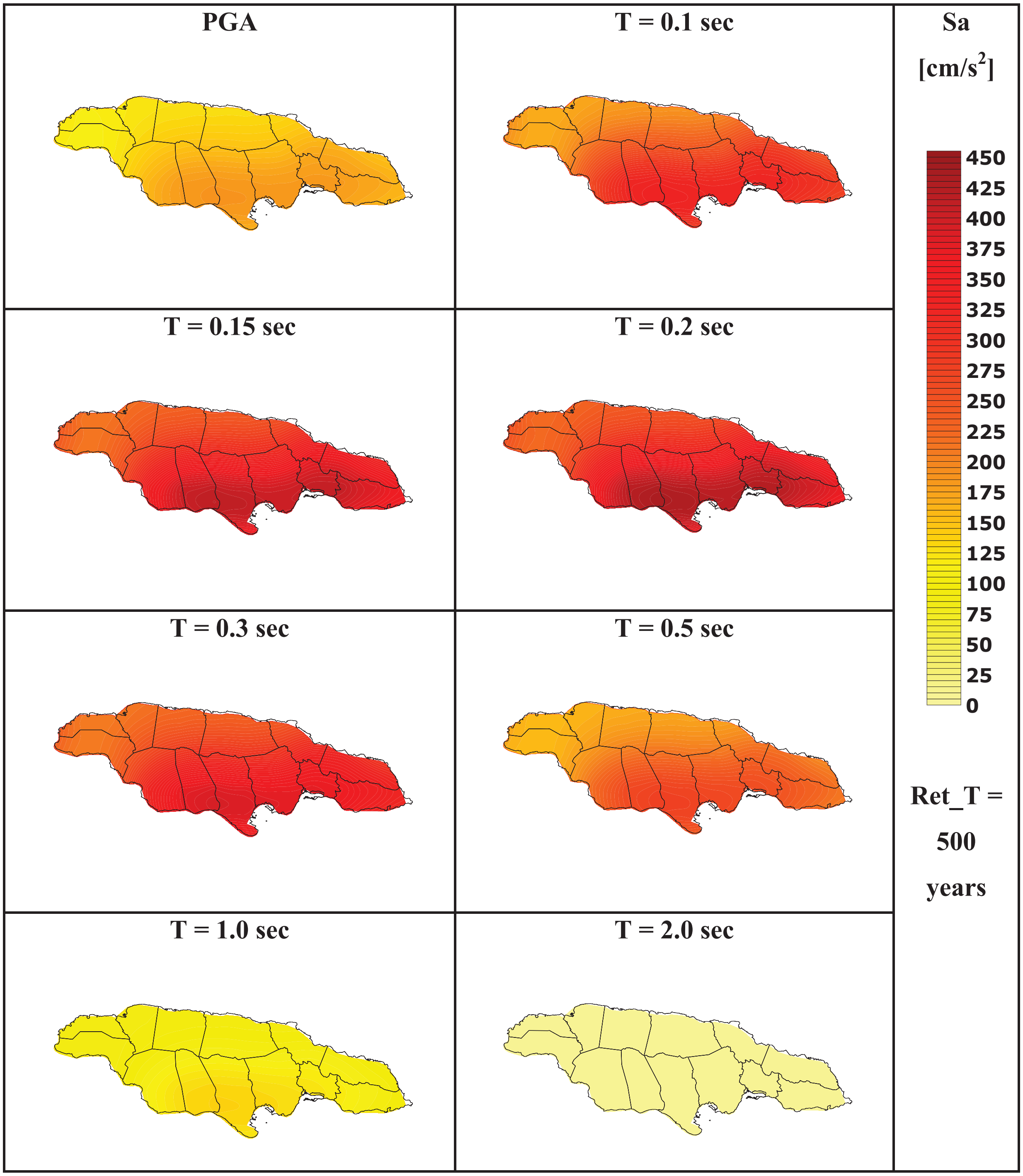


Figure 3.4 Spectral acceleration maps [cm/s²] at the bedrock (Ret_T=500 years)

(Seismic hazard in Jamaica is concentrated south of the country, near the Plantain Garden Fault system. Note how the acceleration value increases for some of the structural periods, reaching the highest values in periods representing buildings between 1 to 5 stories)

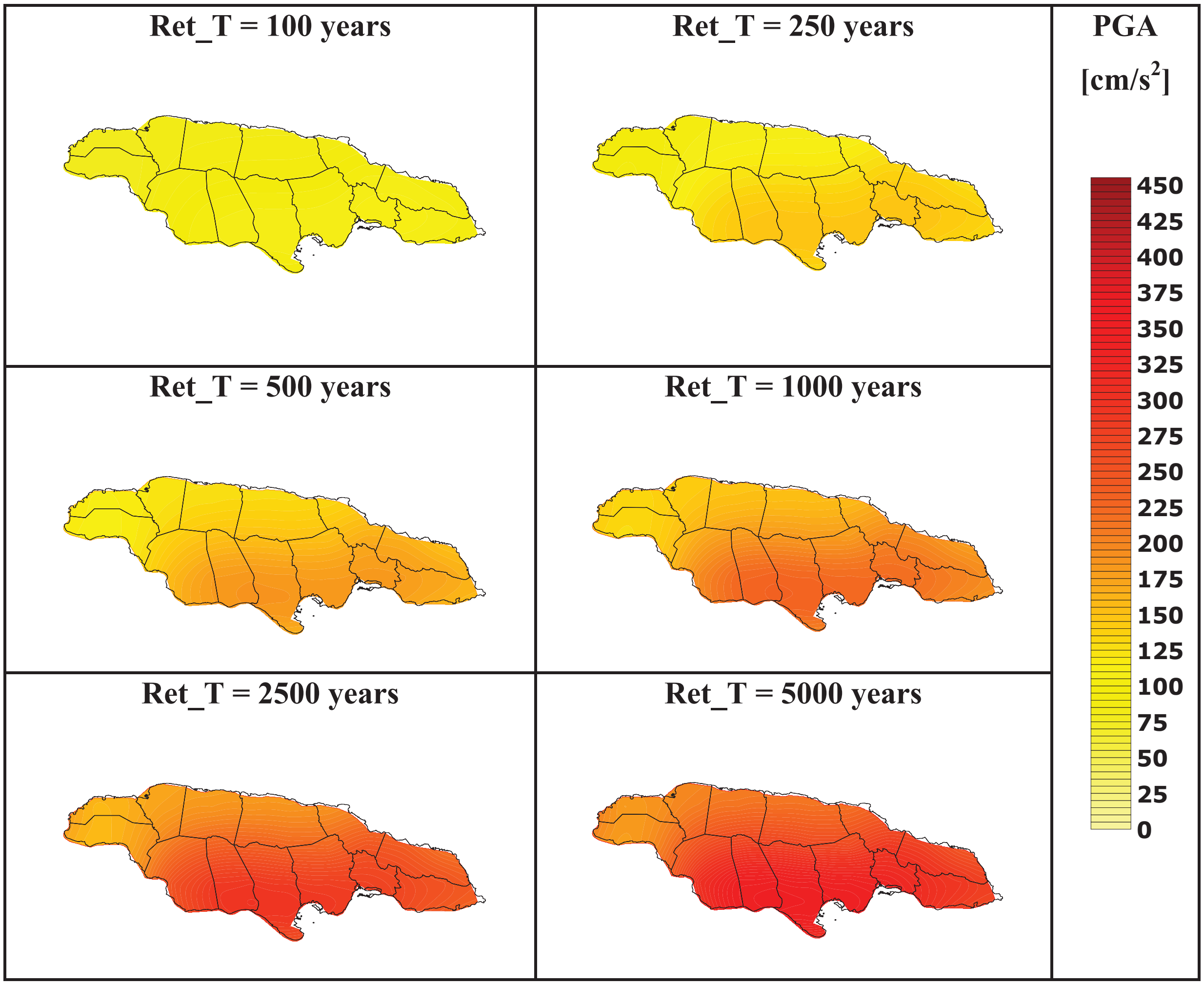


Figure 3.5 Peak ground acceleration maps [cm/s²] for different return periods

(Note how the PGA values increase with the return period, wich indicates that these intensity values have a lower exceedence probability on any given time frame)

3.1.2.3 *Stochastic events for hazard analysis*

When conducting probabilistic risk analyses, a series of stochastic events that represent in an adequate manner the effects of any feasible earthquake location and magnitude that could arise in the area of influence are simulated. The set of generated scenarios must represent all possible hypocentres and the whole range of possible magnitudes associated to a specific hypo-central location. Each of these events or scenarios will have a specific associated frequency of occurrence. Naturally, the scenarios associated to low magnitude

earthquakes will have a higher probability of occurrence, than those scenarios associated to high magnitude earthquakes, which will have a relatively low probability of occurrence.

The procedure for calculating probabilities comprises evaluating the desired risk parameters, such as damage percentage, associated economic losses, effects on the population and others, for each of the hazard scenarios, and then, using the occurrence frequencies of each earthquake scenario, integrating the obtained results. For the case of Jamaica, a total of 2,412 seismic hazard scenarios were generated, similar to the illustrated in Figure 3.6 and Figure 3.7.

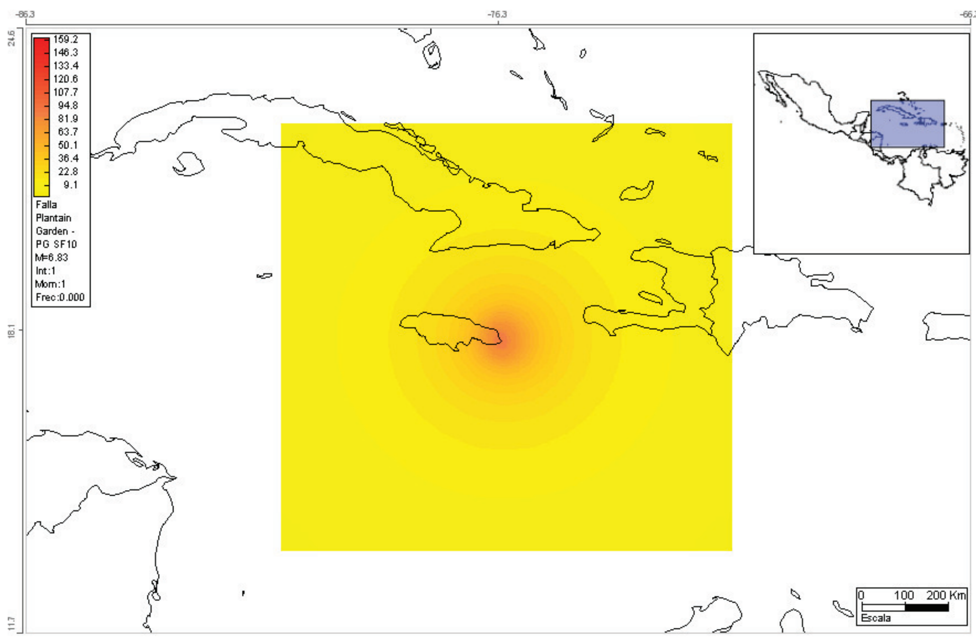


Figure 3.6 Peak ground acceleration map for a 6.8-magnitude earthquake, occurring in the Plantain Garden Fault
(Obtained with the platform ERN-CAPRA-GIS)

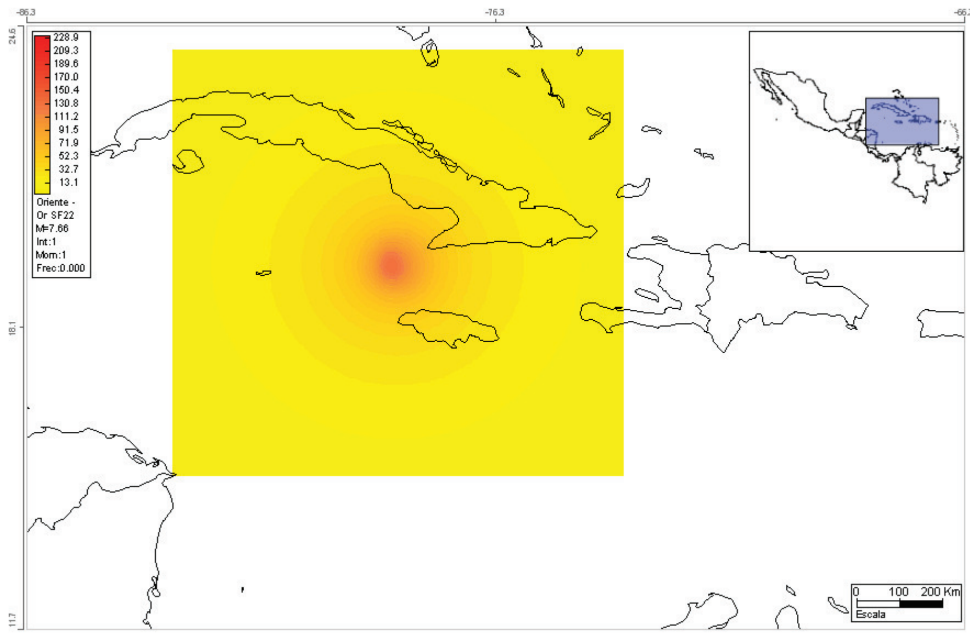


Figure 3.7 Peak ground acceleration map for a 7.6-magnitude earthquake, occurring in the East fault

(Obtained with the platform* ERN-CAPRA-GIS*)

3.2 SEISMIC VULNERABILITY OF ASSETS

3.2.1 General Aspects

Seismic vulnerability is the ratio between any measure of intensity of the phenomenon (acceleration, velocity, displacement or any other, whichever shows the best correlation) and the level of damage of the physical exposed element to such seismic intensity. For example, for the case of several floor building constructions, the seismic intensity that best correlates to the expected damages is the drift or angular distortion between floors (related to the structural deformation due to earthquake forces). For other types of constructions, such as smaller buildings made of masonry or adobe, the maximum ground acceleration is used as correlation parameter regarding damage. In other cases, such as buried piping systems, it is more convenient to use the maximum ground velocity as an intensity parameter.

The procedure for classifying seismic vulnerability of the different exposed elements is the following:

(a) Typification of the more representing and predominant constructions classes of the portfolio of exposed elements, based on existing information and the opinions and criteria obtained in the local level.
(b) Calculation of the vulnerability functions of characteristic construction classes. For this purpose, several analytical models have been developed and some previously published applicable functions have been used, according to preceding national or international experiences.
(c) Conformation of the database of constructions and main elements representing the national inventory of assets.
(d) Assignment of a characteristic construction class and an associated vulnerability function to each element of the exposed inventory of assets.

Once the vulnerability function of each element is assigned, a seismic risk analysis is conducted.

A summary of the vulnerability functions used for the different exposed elements is presented. These curves are based either on the behavior of equivalent typical components obtained from previous studies or from specific analysis on design and construction conditions of the modeled elements.

3.2.2 Seismic Vulnerability Functions

Typical constructions of several stories include constructions of several structural systems such as momentum resistant frames, combined or dual systems, building systems with structural walls, prefabricated systems and others and, in general, constructions that share the characteristic of the major damage being mainly dependant on the relative story displacement. The vulnerability functions for these construction or building classes are

graphically represented as the *damage percentage vs. the maximum story-drift of the building*.

On the other hand, for construction systems such as masonry structural walls, minor constructions built in adobe, tapia and local materials, and isolated structures such as retaining walls, tanks and the like, the vulnerability functions are best correlated to parameters such as maximum ground acceleration. In this case, the vulnerability functions are best represented as the *percentage of damage vs. the maximum spectral acceleration of the construction*.

The functions of vulnerability are generated in the Vulnerability Module of the ERN-**CAPRA,** based on information available at http://www.ecapra.org/es/ (wiki - vulnerability).

3.2.3 Vulnerability Functions for Exposed Elements

The analysis demands vulnerability functions for each element comprised within the national asset inventory. These include:

Typical urban and rural constructions

(a) Residential LP: low income
(b) Residential MP: medium income
(c) Residential HP: high income
(d) Commercial
(e) Industrial (structures with a big built area)
(f) Health - Private
(g) Education - Private
(h) Health - Public
(i) Education - Public
(j) Governmental

Urban infrastructure

a) Power substations and annex networks
b) Communication substations and antennas
c) Dams/reservoirs, tanks and water and sewage plants
d) Water supply and sewage networks
e) Gas supply network
f) Airports
g) Ports
h) Urban bridges

National infrastructure

(a) Primary road network (roads and bridges)
(b) Secondary road network (roads and bridges)
(c) Hydroelectric power stations (dams and machinery sites)
(d) Thermal and geothermal power stations
(e) Power substations and annex networks
(f) Communication substations and antennas
(g) Fuel and gas substations and annex networks

The vulnerability functions for each of these components are calculated using the Vulnerability Module of the ERN-**CAPRA.** The functions are generated in terms of spectral acceleration or in terms of structural drift and are then unified in terms of spectral acceleration, as previously explained. The curves are modified with factors that take into account particular aspects of local construction classes, such as material quality, general condition of constructions, typical design and construction practices and, in general, specific characteristics of predominant structural types.

At the link http://www.ecapra.org/es/ (wiki – vulnerability) are showed the vulnerability functions used in the analysis. Figure 3.8 shows the functions in terms of structural drift, while Figure 3.9 shows the functions in terms of spectral acceleration for each case.

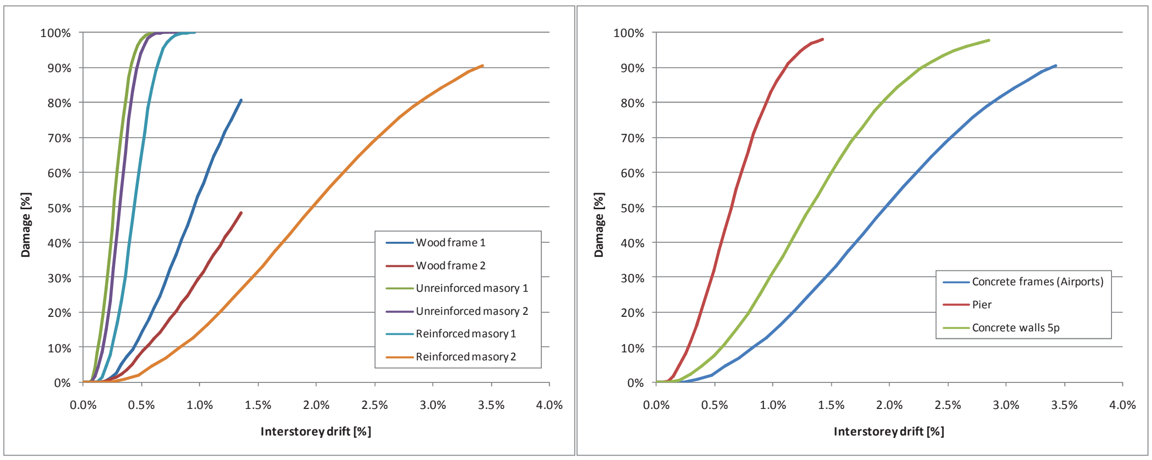


Figure 3.8 Vulnerability functions (based on drift) for earthquake

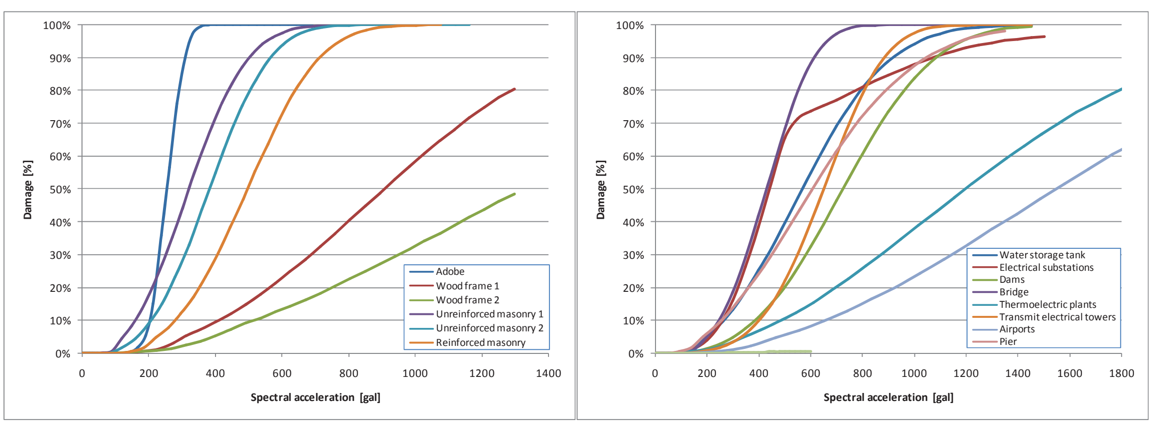


Figure 3.9 Vulnerability functions (based on spectral acceleration) for earthquake

Given the fact that each of these functions is associated to a specific characteristic structural class, Table 3.1 summarizes the representative structural periods of each structural class, based on which the corresponding seismic intensity assignment to be used on the analysis is done.

Table 3.1 Types of vulnerability functions, structural types and period of vibrations

Vulnerability Function for structural type	Representative period of vibration
AD – Adobe	0.15 sec
MD1 – Wood frame	0.50 sec
MD2 – Wood frame	0.50 sec
MS1 – Unreinforced Masonry	0.07 sec
MS2 – Unreinforced Masonry	0.10 sec
MR1 –Reinforced Masonry	0.15 sec
MR2 – Reinforced Masonry	0.20 sec
PCR – Reinforced concrete frame	0.75 sec

Table 3.1 Types of vulnerability functions, structural types and period of vibrations (part two)

Vulnerability Function for structural type	Representative Period of vibration
Electrical Substation	0.10 sec
Communications Substation	0.75 sec
Dams	0.30 sec
Plants and Tanks	0.00 sec
Water Supply Network	0.00 sec
Sewage Network	0.00 sec
Gas Network	0.00 sec
Airports (Terminal)	0.75 sec
Ports (Warehouses)	0.75 sec
Ports (Pier)	0.50 sec
Urban Bridges	0.20 sec

Vulnerability Function for structural type	Representative Period of vibration
Primary road network (Bridges)	0.20 sec
Secondary road network (Bridges)	0.20 sec
Hydroelectric power stations (dams)	0.30 sec
Hydroelectric power stations (machinery sites)	0.75 sec
Thermal power stations	0.86 sec
Geothermal power stations	0.86 sec
Power distribution (Substations)	0.10 sec
Power distribution (Networks)	0.30 sec
Communications (Fixed lines/phones/numbers)	0.75 sec
Communications (Mobile lines)	0.75 sec
Hydrocarbon Derivates	0.86 sec
Hydrocarbons (Gas)	0.86 sec

At the link http://www.ecapra.org/es/ (wiki – vulnerabilidad) are showed the vulnerability functions used in the analysis and the explanation of the different damage levels expected for each specific structural type.

3.3 SEISMIC RISK ASSESSMENT

3.3.1 General Aspects

Based on the proposed probabilistic hazard models and on the exposed assets inventory and appraisal of exposed assets with respective vulnerability functions, a probabilistic risk analysis model is developed for the country.

As previously explained, the probabilistic risk analysis is done based on a series of hazard scenarios that adequately represent the effects of any event of feasible magnitude that can occur on the area of influence. Each of these scenarios has an associated specific frequency or probability of occurrence. The probabilistic calculation procedure comprises the assessment using appropriate metrics, in this case the economic loss, for each exposed asset considering each of the hazard scenarios with their frequency of occurrence, and the probabilistic integration of the obtained results.

Seismic risk was calculated using the platform ERN-**CAPRA.** The methodology of evaluation is described in the link http://www.ecapra.org/es/ (wiki – riesgo).

3.3.2 Total Losses at National Level

Table 3.2 is presented with the consolidated information for the all country in terms of total exposure value, the expected annual loss in value and in thousands (also known as technical risk premium) and indicative values of probable maximum loss for different return periods.

Table 3.2 General results of PML for earthquake

Results		
Exposure Value	US$ x10^6	$18,625
Average Annual Loss	US$ x10^6	$30
	‰	1.6
PML		
Return Period	**Loss**	
Years	**US$ x10^6**	**%**
50	$381	2.0%
100	$774	4.2%
250	$1,455	7.8%
500	$2,013	10.8%
1000	$2,583	13.9%

Figure 3.10 shows the loss exceedance curves for the country.

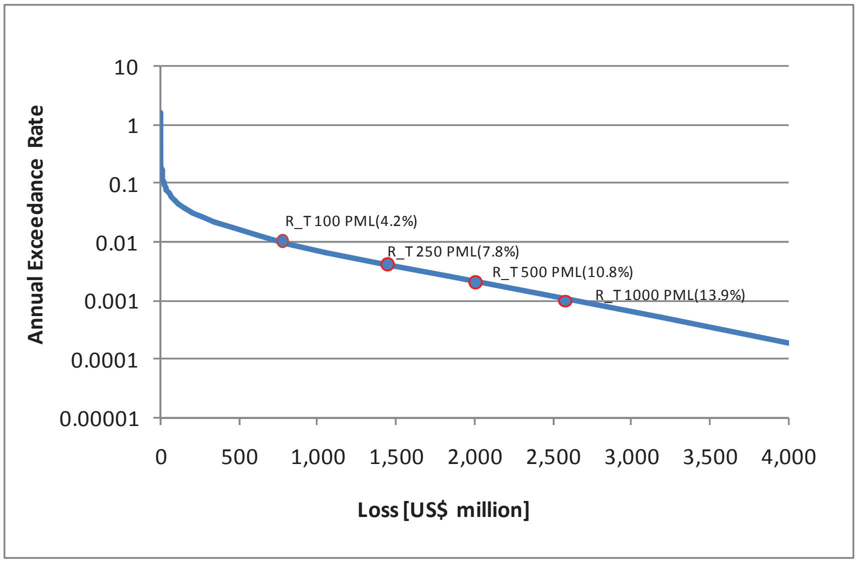


Figure 3.10 Loss exceedance for earthquake

Figure 3.11 presents the probable maximum loss curve, as value and percentage for different return periods. Also, the exceedance probability curves for different PML percentage values for different exposure periods, specifically 20, 50, 100 and 200 years, are presented in Figure 3.12.

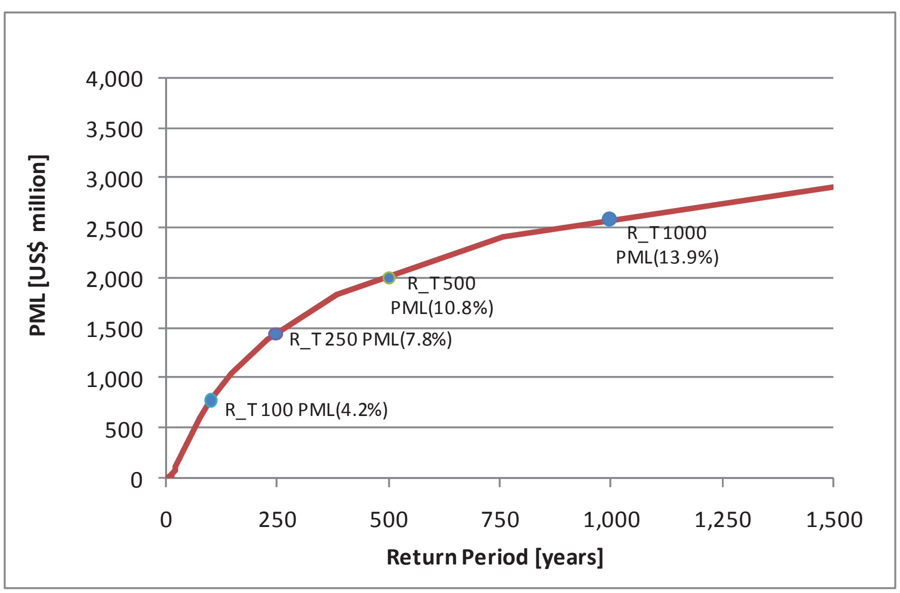


Figure 3.11 PML curve for earthquake

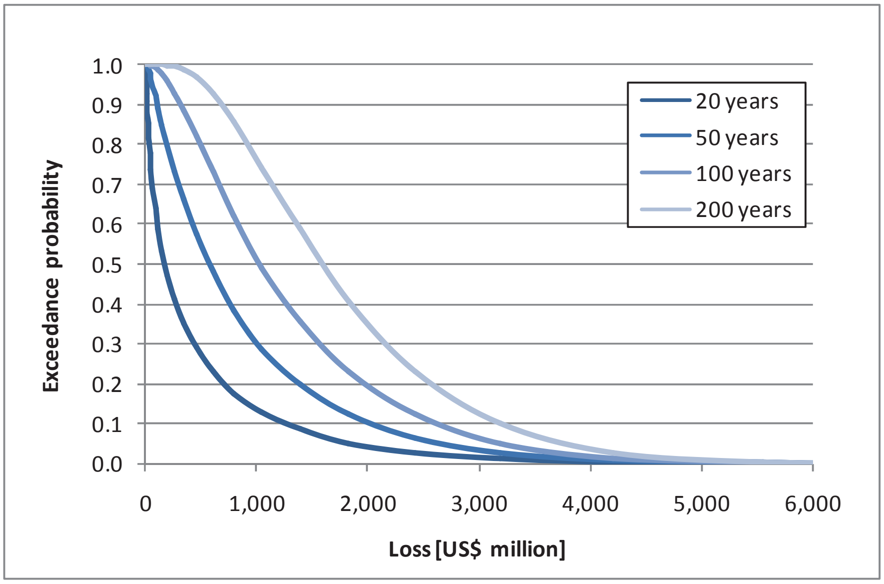


Figure 3.12 Earthquake exceedance probability curves for different PML values for different exposure periods

The Table 3.3 summarizes the critical scenarios resulting from the analysis, that is, the scenarios resulting with the highest expected economic losses.

Table 3.3 Critical scenarios from earthquake analysis

N°	Scenario		Loss		Frequency	Ret. Period scenario [years]
	Seismic sources	Magnitude	[US$ x 10^6]	%		
1494	South of Jamaica - second fault system - JS2	7.2	2,909.61	18.21%	2.46E-05	40676
1500	South of Jamaica - second fault system - JS2	7.8	2,685.37	16.81%	2.04E-04	4905
1493	South of Jamaica - second fault system - JS2	7.3	2,594.40	16.24%	4.23E-05	23633
1499	South of Jamaica - second fault system - JS2	7.3	2,396.98	15.01%	3.51E-04	2850
1488	South of Jamaica - second fault system - JS2	7.8	2,257.29	14.13%	1.24E-04	8034
1492	South of Jamaica - second fault system - JS2	6.8	2,014.41	12.61%	7.28E-05	13731
1487	South of Jamaica - second fault system - JS2	-	2,009.88	12.58%	2.14E-04	4668
1498	South of Jamaica - second fault system - JS2	-	1,843.09	11.54%	6.04E-04	1656
1524	South of Jamaica - second fault system - JS2	7.8	1,737.56	10.88%	8.33E-05	12008
1602	Plantain Garden Fault - PG_SF4	6.8	1,548.80	9.70%	3.73E-04	2684

3.4 CONCENTRATION OF SEISMIC RISK

The risk concentration analysis is carried out for parishes and by sector for public and private sectors of use, as well for main components of the national infrastructure.

3.4.1 Comparison of Losses by Parish

Losses are assessed by parish as a geographic unit. Figure 3.13 shows a comparison between the different parishes.

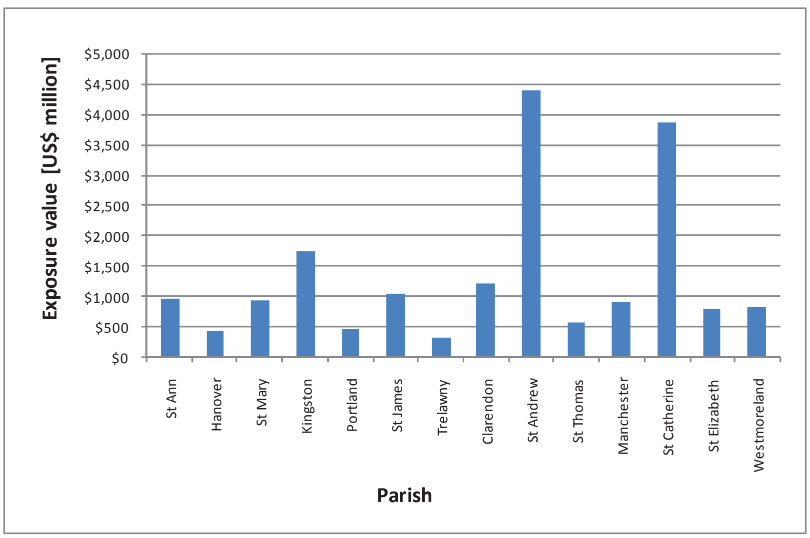


Figure 3.13 Exposure values per parish

For each parish, a complementary individual analysis is carried out. This allows estimating the probable maximum loss level and the individual premium level by parish. Figure 3.14 shows an example of the presentation format[4] used for individual parish results. Individual

[4] The probability of exceed certain loss in a return period in a time of exposure do not depend on the loss value itself but only from return period and time of exposure according with this equation: P(p)=1-exp(-T_exposure/T_return). Where: P(p): is the

results for the other parishes are presented in Annex 3. In each case, results are presented as follows:

- Table summarizing average annual loss (AAL) and probable maximum loss (PML)
- Loss exceedance rate curves and PML with the corresponding return periods
- Bar diagram with AAL figures in value and thousand, discriminated for each sector of use.

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probability of exceed a certain loss, T_exposure: is the time in which the building will be exposed, T_return: is the return period to calculate the probability of exceed a certain loss. That is the reason why the values on tables are equal for diferent parishes or sectors. On the form presents the loss probabilities for exposed time of 20, 50, 100 and 500 years and for return periods of 100, 250, 500 y 1000 years.

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Kingston		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$62.02	3.53%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$1,756.02	250 years	$138.06	7.86%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$2.38	500 years	$205.03	11.68%	3.92%	9.52%	18.13%	63.21%
	‰	1.36	1000 years	$273.31	15.56%	1.98%	4.88%	9.52%	39.35%

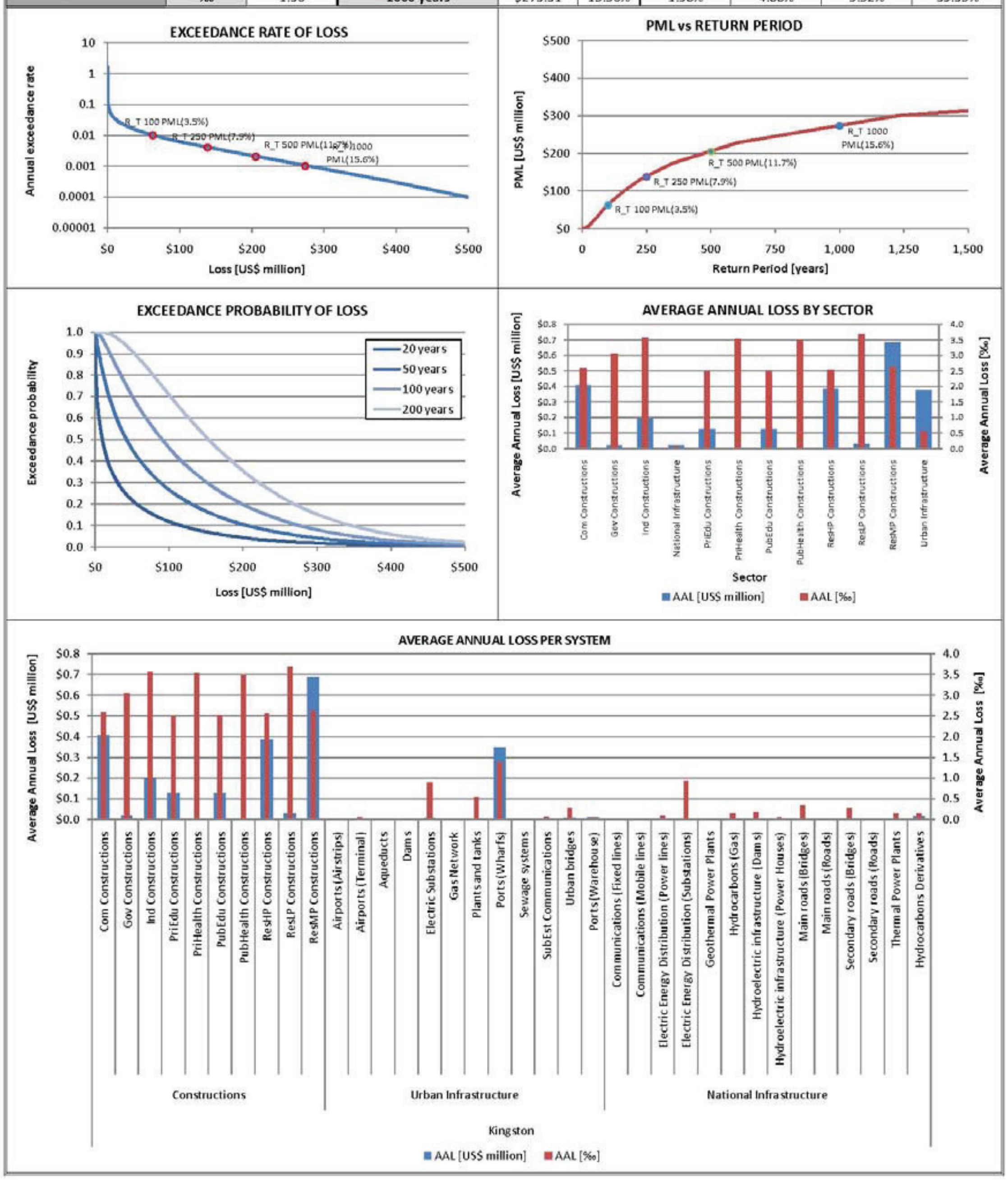


Figure 3.14 Individual results of each Parish for earthquake

Figure 3.15 summarizes PML values for return periods of 250, 500 and 1000 years for each parish in values as well as in percentages.

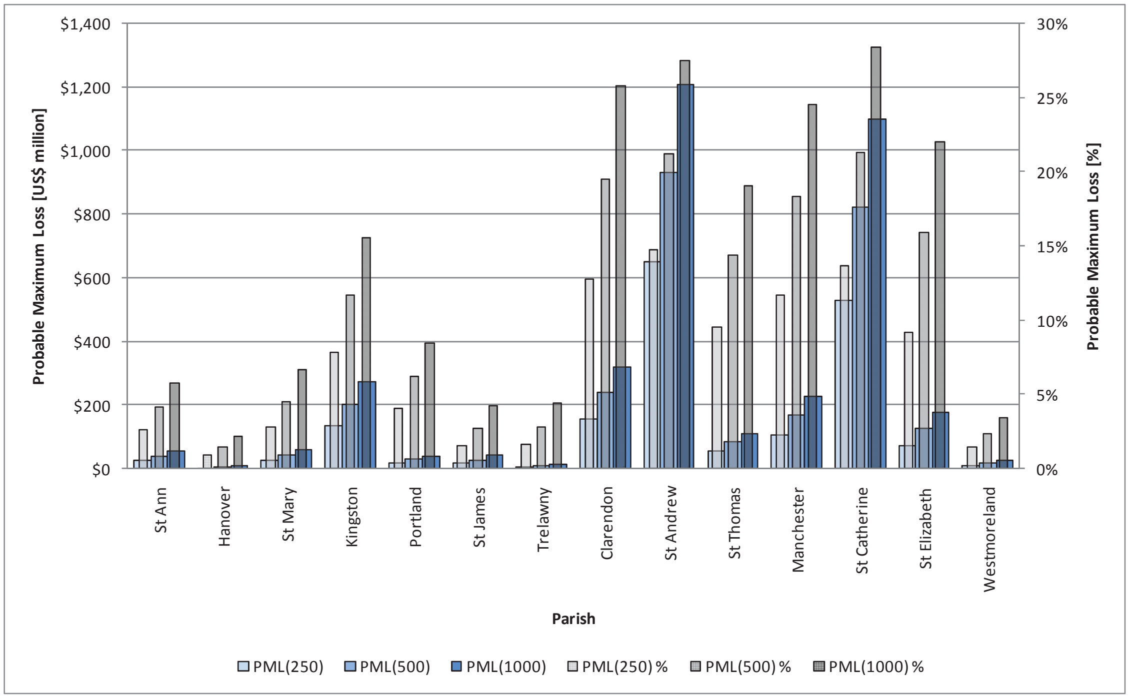


Figure 3.15 PML values for earthquake and for different return periods

On the other hand, Figure 3.16 displays values corresponding to average annual loss in value and thousands.

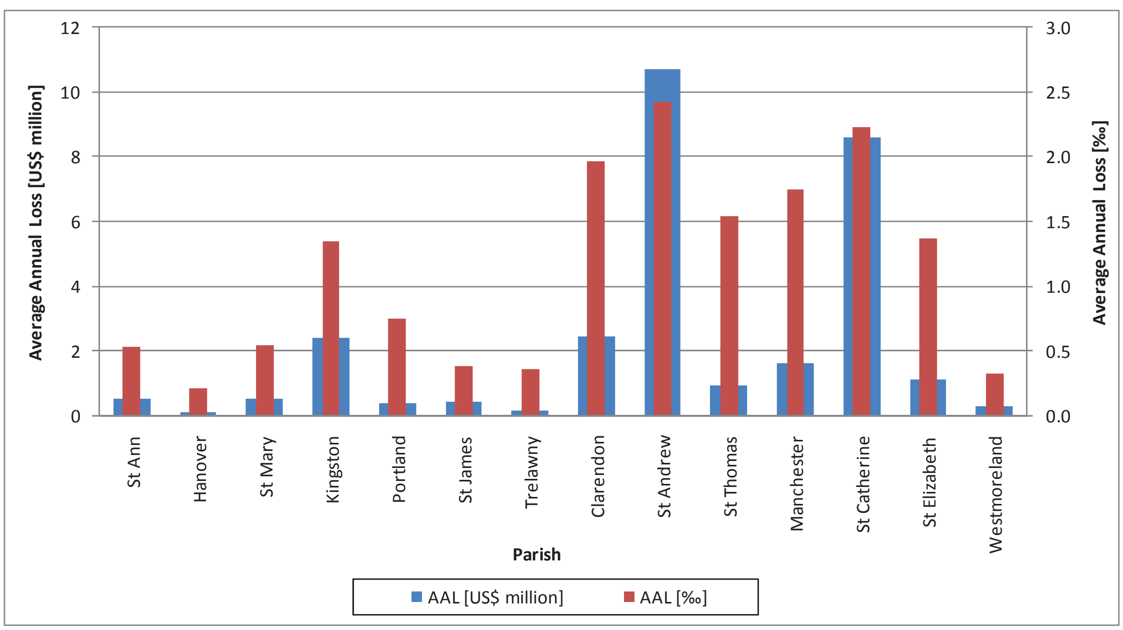


Figure 3.16 Values of AAL for earthquake per parish

Figure 3.17 shows the average annual loss by sectors for each parish. Urban constructions, urban infrastructure and national infrastructure associated with each parish are considered.

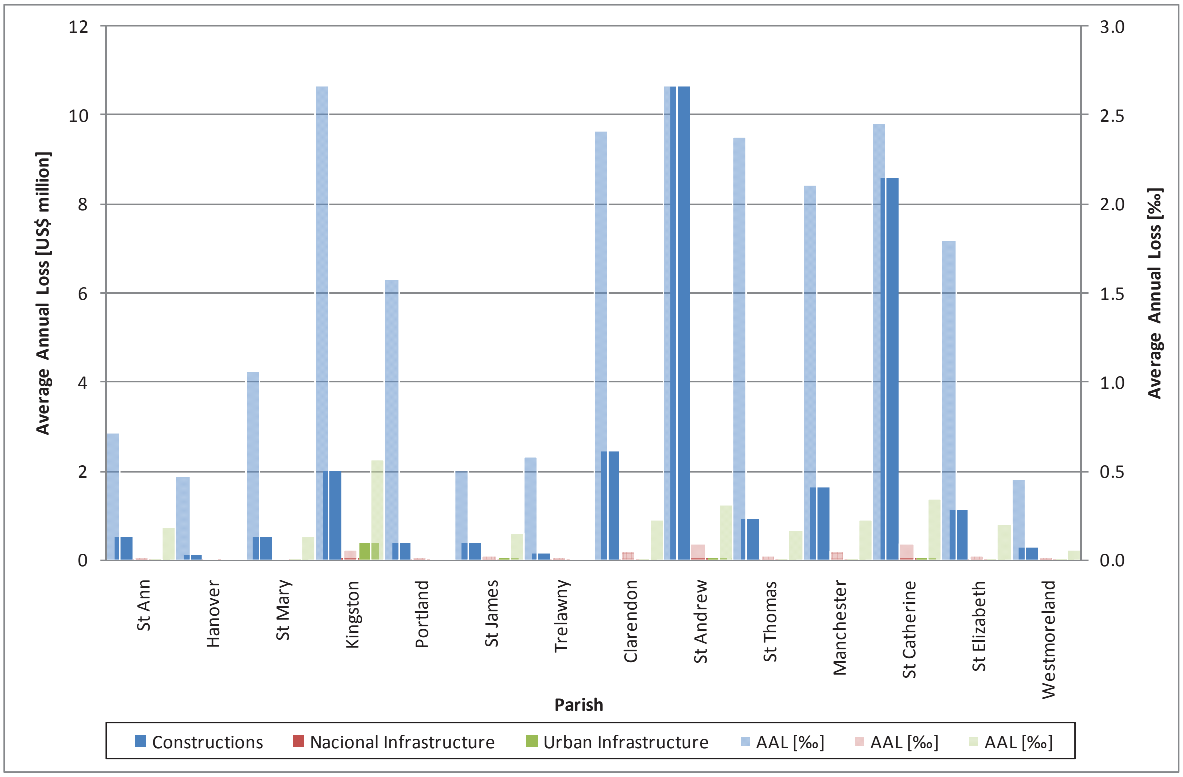


Figure 3.17 Values of AAL for earthquake, per parish and for each use sector

Finally Figure 3.18 and Figure 3.19 present the geographic distribution of the average annual losses for each parish. Figure 3.20 and Figure 3.21 show the values of the probable maximum loss for each parish.

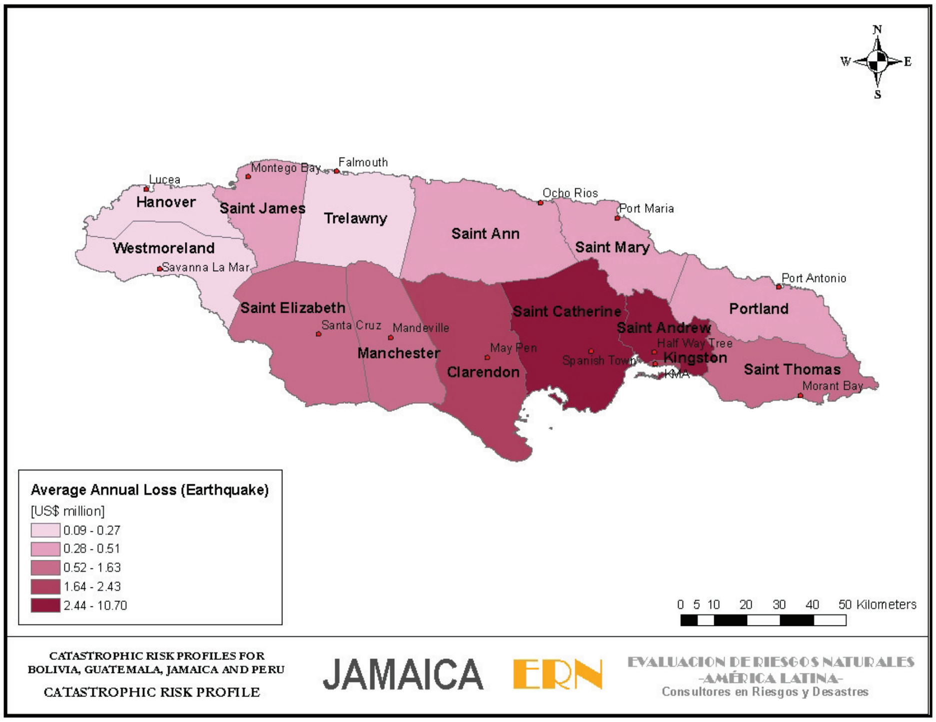


Figure 3.18 Geographic distribution of AAL (value) for earthquake per parish

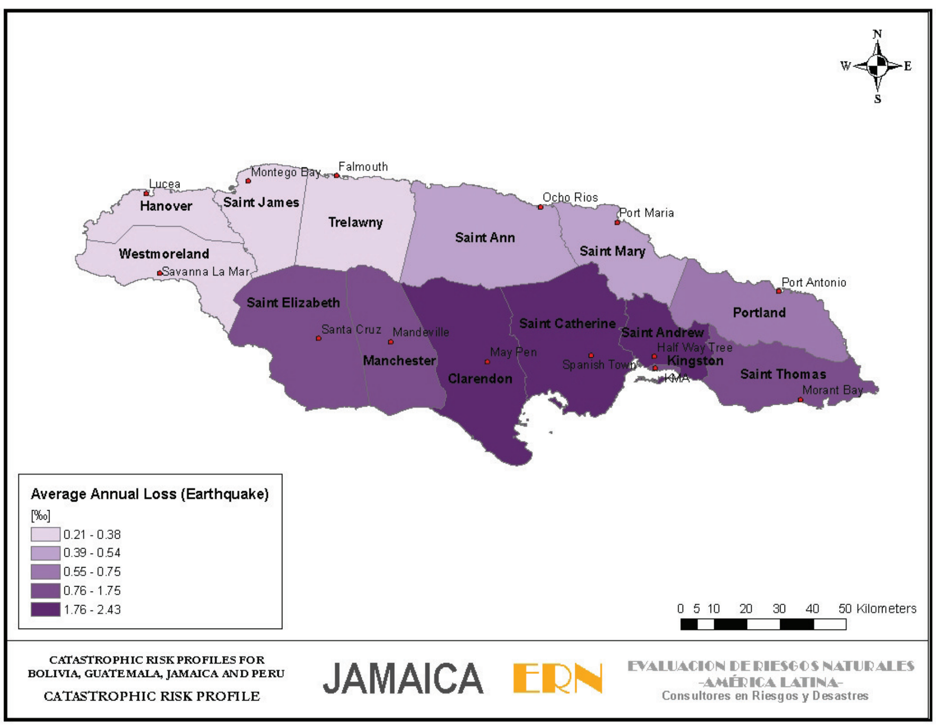


Figure 3.19 Geographic distribution of AAL (‰) for earthquake per parish

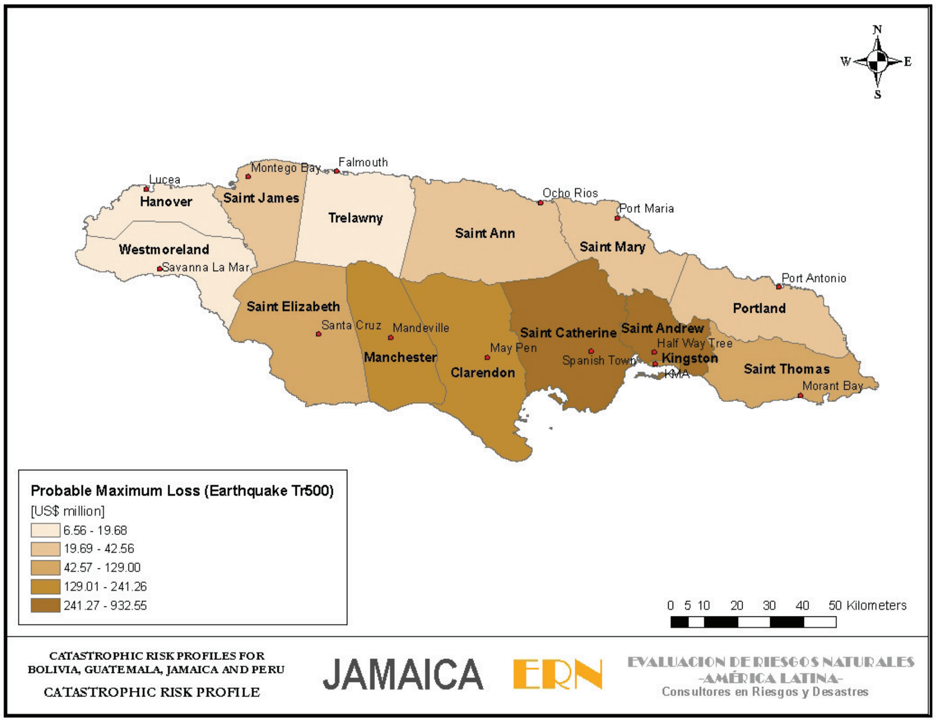


Figure 3.20 Geographic distribution of PML (value) for earthquake per parish

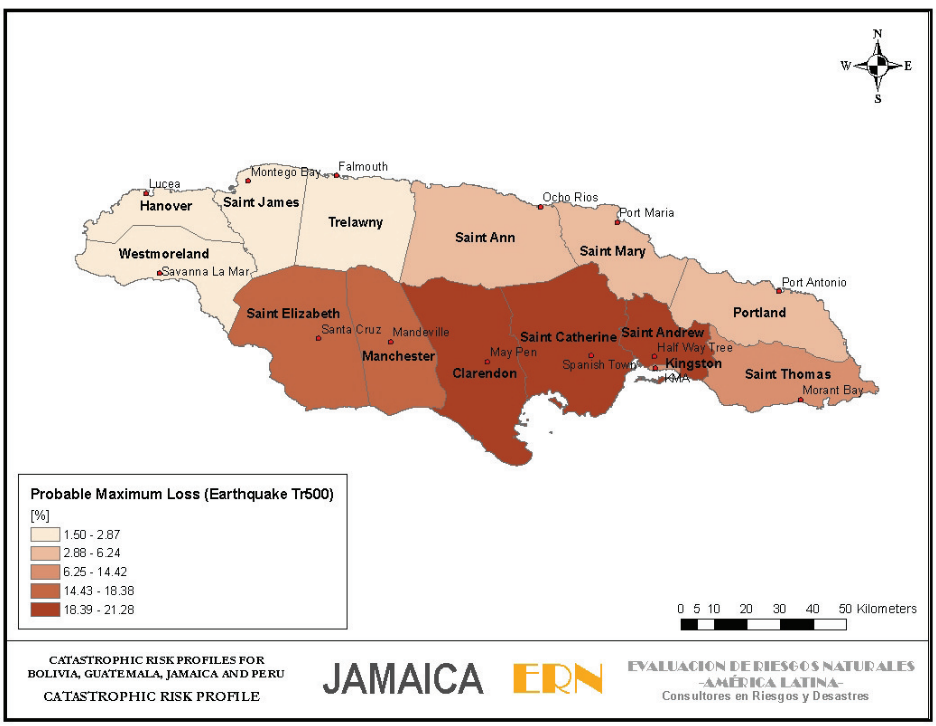


Figure 3.21 Geographic distribution of PML (%) for earthquake per parish

3.4.2 Comparison of Losses by Sector

Figure 3.22 presents a comparison of the relative exposure values by sector at national level.

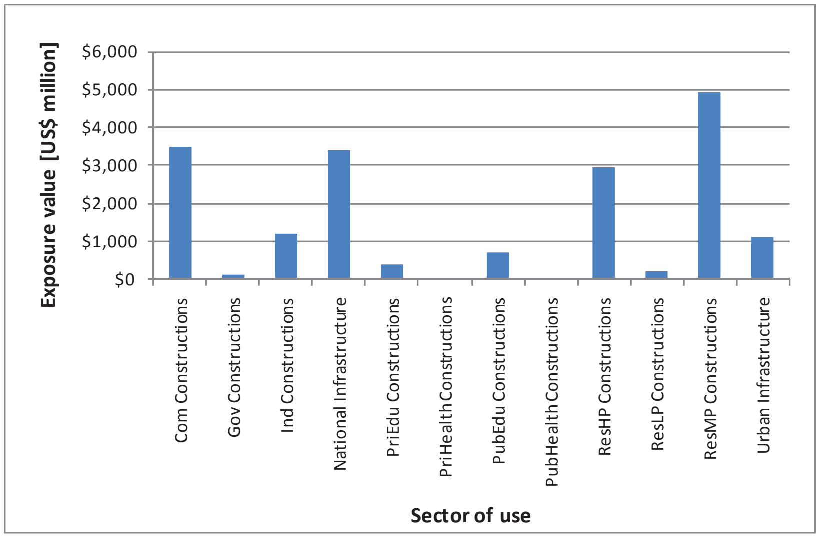


Figure 3.22 Exposure values per sector

The Figure 3.23 includes the total average annual loss in value and thousands for each sector of use and for the country as a whole.

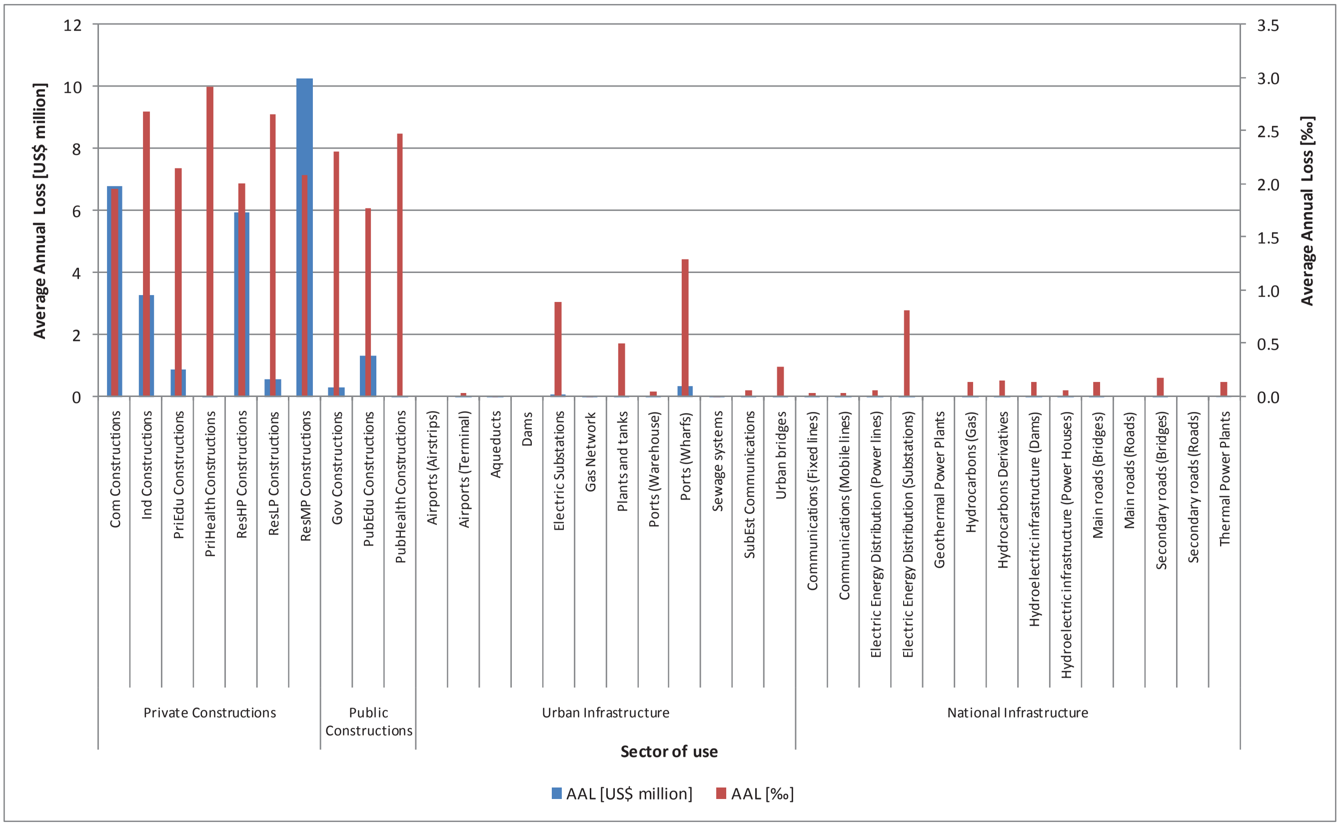


Figure 3.23 Values of AAL for earthqauke and per sector

On the other hand and more specifically, Figure 3.24 presents the AAL results including the total results for the three main sectors of use: urban constructions, urban infrastructure and national infrastructure.

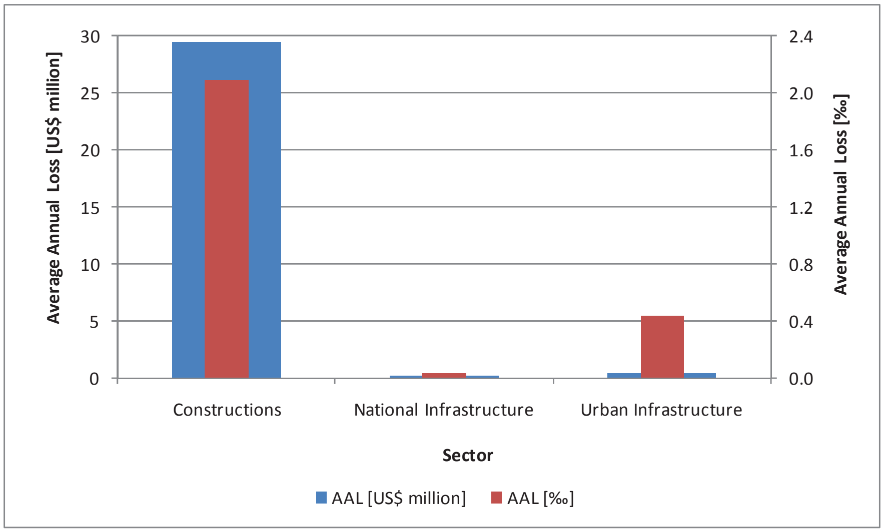


Figure 3.24 Summary for values of AAL for earthquakes and per sector

3.4.3 Probable Maximum Loss for Public and Private Sectors

To assess the probable maximum loss for public and private sectors it is necessary to conduct analyses for each portfolio, because these types of results depend on the relative geographic distribution of the exposure values.

The public sector includes public urban constructions (health, educational –when they are property of the State- and government buildings) and the entire infrastructure. In turn, the private sector includes residential, commercial and industrial constructions, and the corresponding health and education constructions.

The Figure 3.25 shows the exposure values of the public and private sectors in the country.

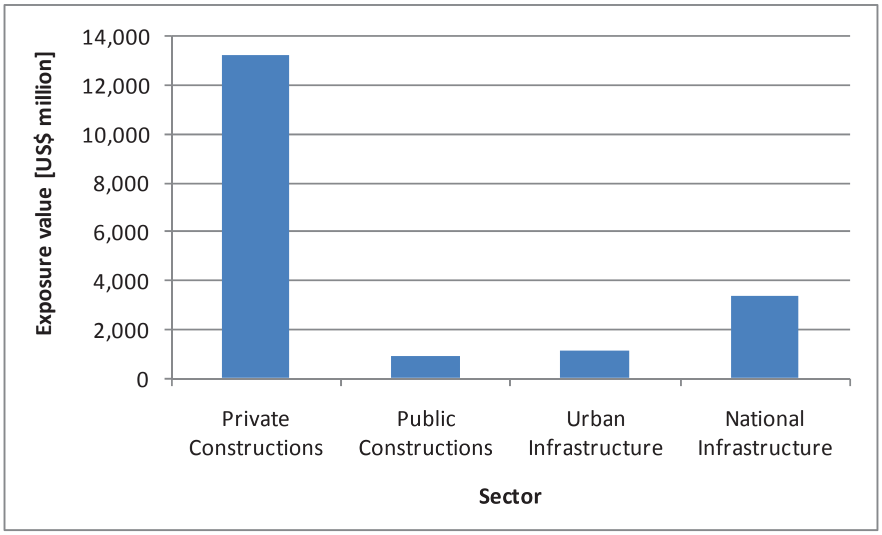


Figure 3.25 Exposure values per sector

Figure 3.26 and Figure 3.27 present the PML curve for each of these sectors.

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Public Constructions		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$42.84	4.84%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$884.92	250 years	$79.34	8.97%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$1.65	500 years	$108.91	12.31%	3.92%	9.52%	18.13%	63.21%
	‰	1.86	1000 years	$139.38	15.75%	1.98%	4.88%	9.52%	39.35%

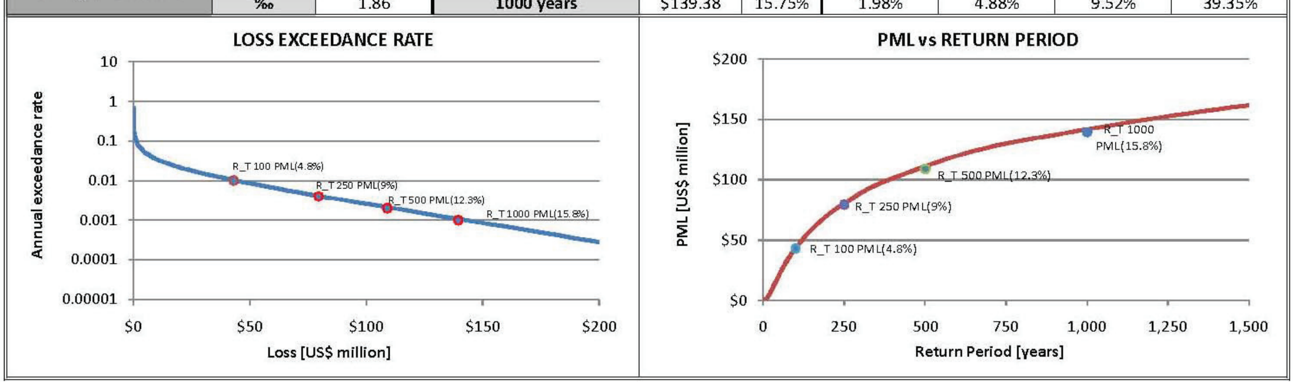


Figure 3.26 Loss exceedance and PML curve for earthquake and for public constructions

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Private Constructions		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$718.84	5.44%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$13,213.17	250 years	$1,355.23	10.26%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$27.76	500 years	$1,895.16	14.34%	3.92%	9.52%	18.13%	63.21%
	‰	2.10	1000 years	$2,410.52	18.24%	1.98%	4.88%	9.52%	39.35%

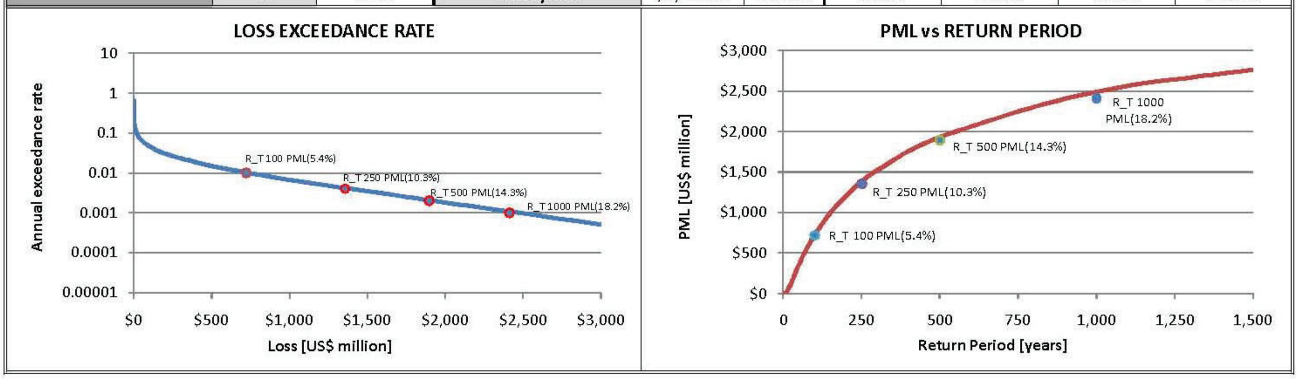


Figure 3.27 Loss exceedance and PML curve for earthqueke and for private constructions

3.4.4 Probable Maximum Loss for the National Infrastructure

A similar analysis to the previous one is carried out for the national infrastructure sector taking into account that individual analyses can be performed for:

- Power generation and distribution
- Communications
- Transportation (roads and bridges)
- Hydrocarbons

The results for the PML curves for each of these sectors are presented together with the return period and the global values of AAL, in value and thousands. Figure 3.28 to Figure 3.31 summarize such results.

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Production and distribution (Energy)		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.65	0.16%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$418.08	250 years	$1.60	0.38%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.07	500 years	$3.03	0.72%	3.92%	9.52%	18.13%	63.21%
	‰	0.17	1000 years	$5.25	1.26%	1.98%	4.88%	9.52%	39.35%

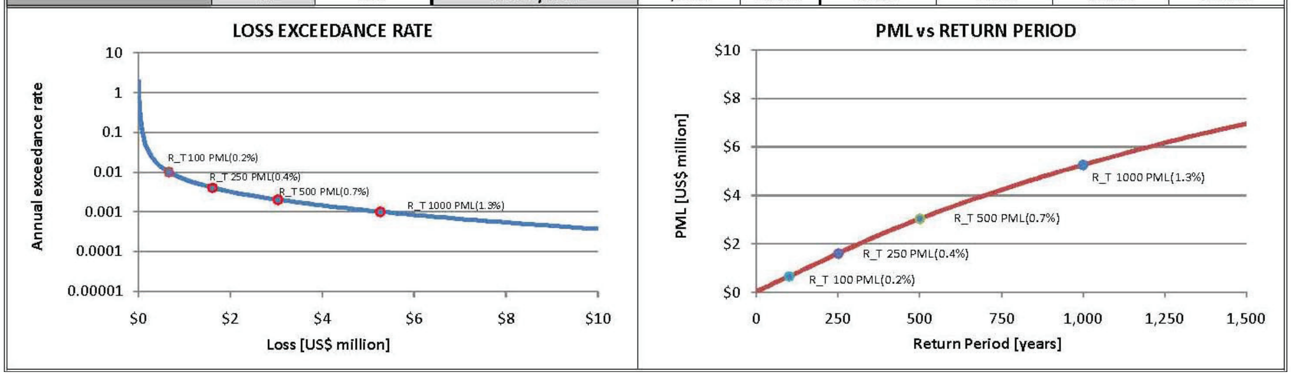


Figure 3.28 Loss exceedance and PML curve for earthquake for the energy sector

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Communications		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.01	0.03%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$19.72	250 years	$0.02	0.08%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.00	500 years	$0.04	0.18%	3.92%	9.52%	18.13%	63.21%
	‰	0.00	1000 years	$0.07	0.37%	1.98%	4.88%	9.52%	39.35%

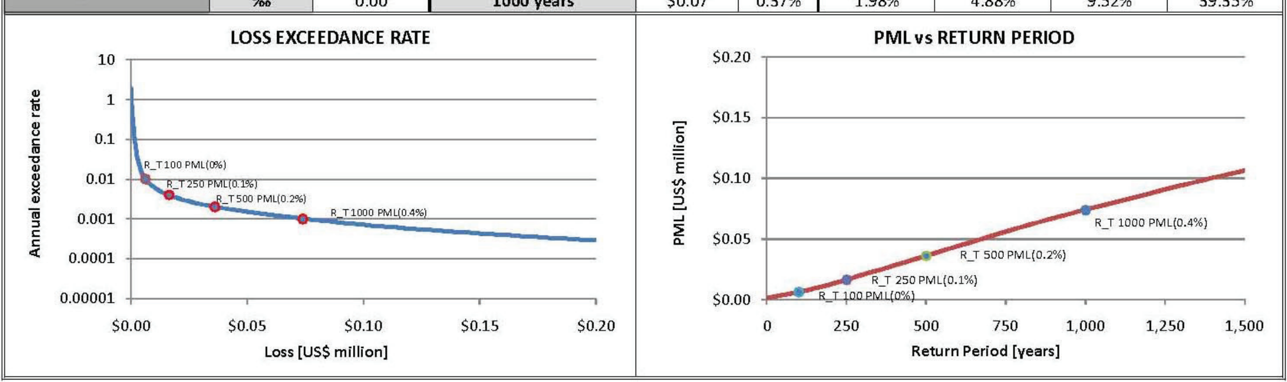


Figure 3.29 Loss exceedance and PML curve for earthquake for the communication sector

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	National Roads		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$0.23	0.01%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$2,736.78	250 years	$0.86	0.03%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.02	500 years	$2.06	0.08%	3.92%	9.52%	18.13%	63.21%
	‰	0.01	1000 years	$4.14	0.15%	1.98%	4.88%	9.52%	39.35%

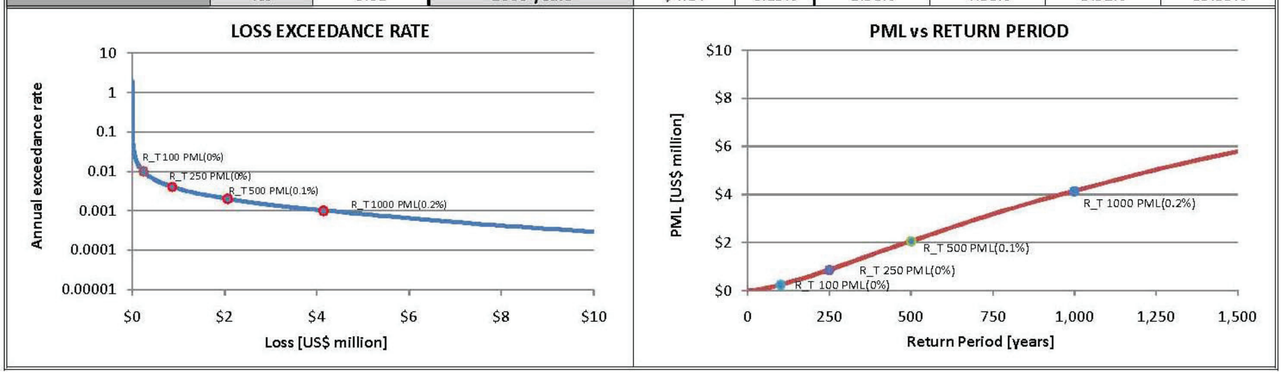


Figure 3.30 Loss exceedance and PML curve for earthquake for the transportation sector

COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Hydrocarbons		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$0.22	0.10%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$211.25	250 years	$0.55	0.26%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.03	500 years	$1.16	0.55%	3.92%	9.52%	18.13%	63.21%
	‰	0.14	1000 years	$2.24	1.06%	1.98%	4.88%	9.52%	39.35%

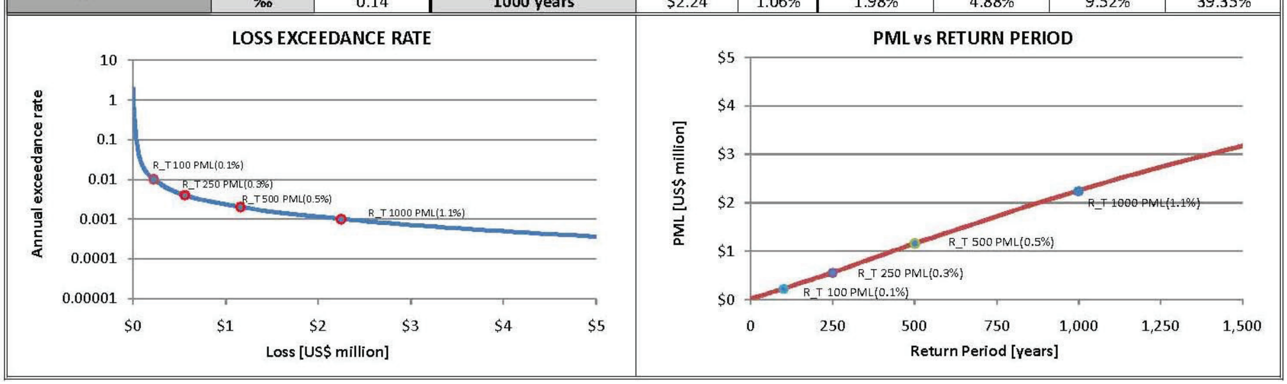


Figure 3.31 Loss exceedance and PML for earthquake for the hydrocarbon sector

4 HURRICANE CATASTROPHE RISK PROFILE

4.1 HURRICANE WIND HAZARD

4.1.1 General Aspects

Despite the frequency of hurricane occurence being relatively high at this region (i.e. at the Caribbean), its frequency of occurrence for a specific country or small island in the Caribbean remains low, especially when considering catastrophic events. According to this and considering the possibilities of high destructive capacity events in the future, the risk estimation should be approached using probabilistic models, which, in turn, use the available historical information to forecast, as accurately as possible, scenarios of future events or intensities and maximum feasible losses, considering the high uncertainties involved in the analysis; a management equivalent to the process carried out for earthquakes.

The risk analysis model for hurricane winds includes the hazard assessment, considering a set of stochastic events or scenarios, each with its own frequency of occurrence, assigned according to available historical records, the distribution of vulnerability functions by the maximum speed of the wind for each of the exposed elements of infrastructure and the probabilistic risk assessment, as explained above.

The impact of hurricanes in general be modeled taking into account the effects of strong winds that can occur, the storm surge resulting from the low pressure over the sea, the waves due to the wind, and the flooding on the coast that can affect the exposed elements prone to the action to these phenomena. The ERN-**CAPRA** platform used in this study can estimate the effects of three effects independently or simultaneously, which implies that the expected total annual loss is obtained from the sum of the independent average annual losses. Unfortunately, despite the computing capacity of the platform neither threre are detailed information on the bathymetry and topography of the coast, nor on the elements

located in the strip that could be affected or are prone to storm surge, waves and flooding. For this reason the estimate is based on the wind action, which for the purposes of this study is quite sufficient to cover not only the coast line but the internal areas of the country.

The most adequate way to represent hurricane-force wind hazard involves the consideration of the maximum wind velocities that can be generated at a specific site, according to the different trajectories of each hurricane or tropical storm. In other words, a hurricane-force wind is obtained from the consideration of the scenarios of hurricane winds and is defined as the maximum velocity field that can arise, independently of the hurricane's eye position and its velocity of movement. The non-simultaneous occurrence of wind peak velocity values is considered irrelevant for the hazard analysis.

The usual hazard representation is performed with maximum velocity exceedance rates. It can also be accomplished using intensity maps for different return periods or for specific scenarios. When the maximum incident velocity on each element comprising the country's assets inventory is acknowledged, it is possible to estimate the response of these elements to the imposed wind action and to assess its effects in terms of probable damages or economic losses.

A hurricane wind hazard model was developed natiowide, allowing the estimation of peak velocity exceedance probability for different exposure periods. The evaluation was made using the Hazard Module of the ERN-**CAPRA.** At the link http://www.ecapra.org/es/ (wiki – hazards) are presented details of the model for the hurricane hazard assessment.

4.1.2 Hurricane hazard results

4.1.2.1 *Nationwide hurricane hazard*

Results for hurricane hazard are presented for the whole country considering all the historic trajectories and the simulation of other feasible obtained from the stochastic trajectory

generation associated to the historial registers. Figure 4.1 shows the maximum hurricane wind velocity maps for different return periods.

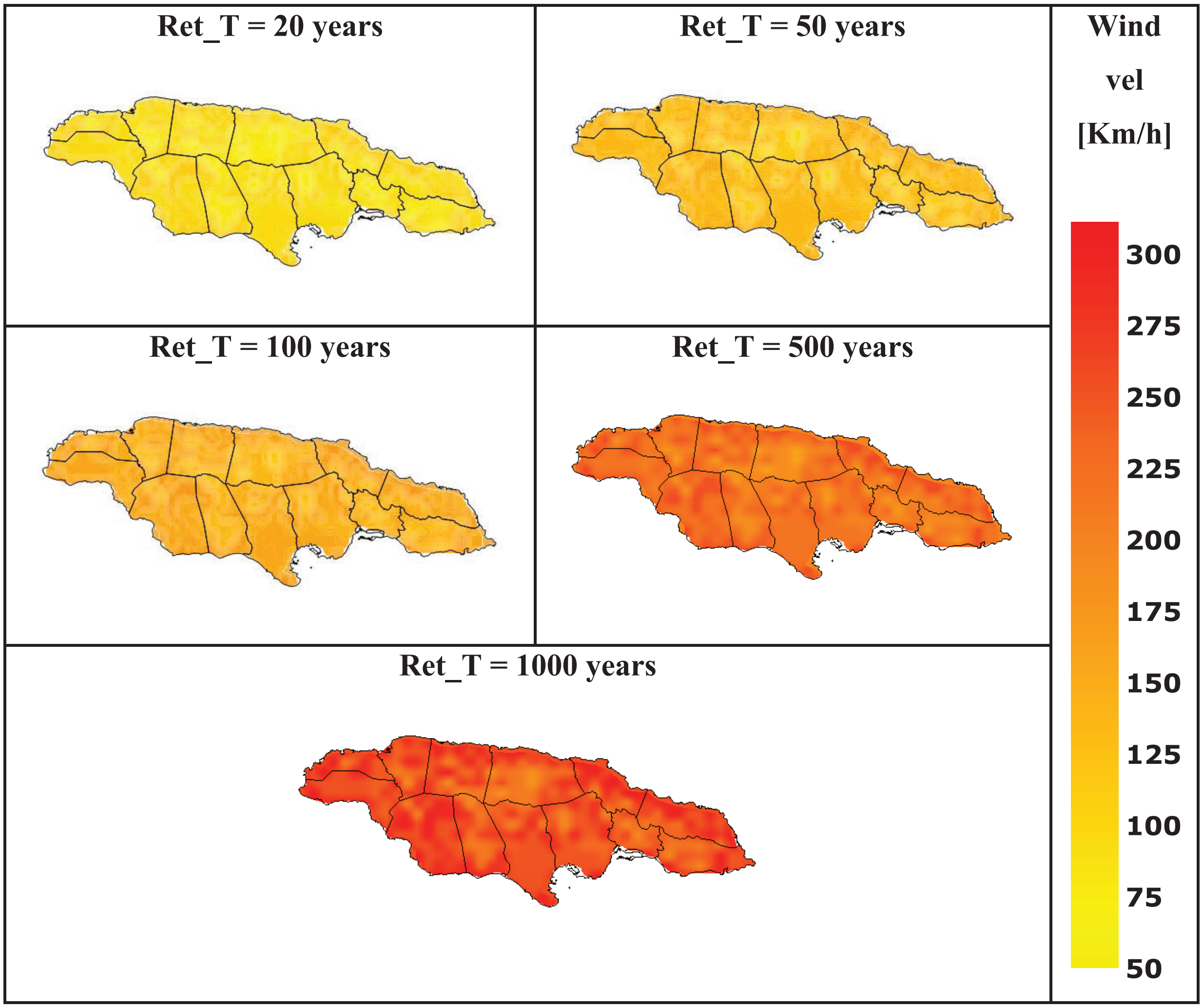


Figure 4.1 Maximum wind velocity maps [Km/h] for different return periods

(Note how the wind velocity values increase with the return period, wich indicates that these intensity values have a lower exceedence probability on any given time frame)

4.1.2.2 *Stochastic events for hazard analysis*

A series of stochastic events that adequately represent the effects of any feasible hurricane in the area of influence, incluiding its trajectory and belonging to any given hurricane

category, are simulated for the probabilistic risk analysis. The set of scenarios generated must adequately represent all the possible combinations of trajectory and category. Each of these events or scenarios will have an associated occurrence frequency.

The procedure of probabilistic calculation consist of the assessment of the desired risk parameters, such as damage percentages, associated economic losses, effects on the population and any other, for each of the hazard scenarios and then the probabilistic integrations of the obtained results, using each hurricane's occurrence frequencies. For the case of Jamaica, 100 simulations for 121 historic hurricane scenarios were done, for a total of 12,100 modeled events. The group of 100 simulations for each historic hurricane represents a "family" of the historic hurricane. Each simulation has similar characteristics to the original hurricane. Figure 4.2 to Figure 4.4 present some examples of the expected value for the maximum wind velocity in some "families" of historic scenarios.

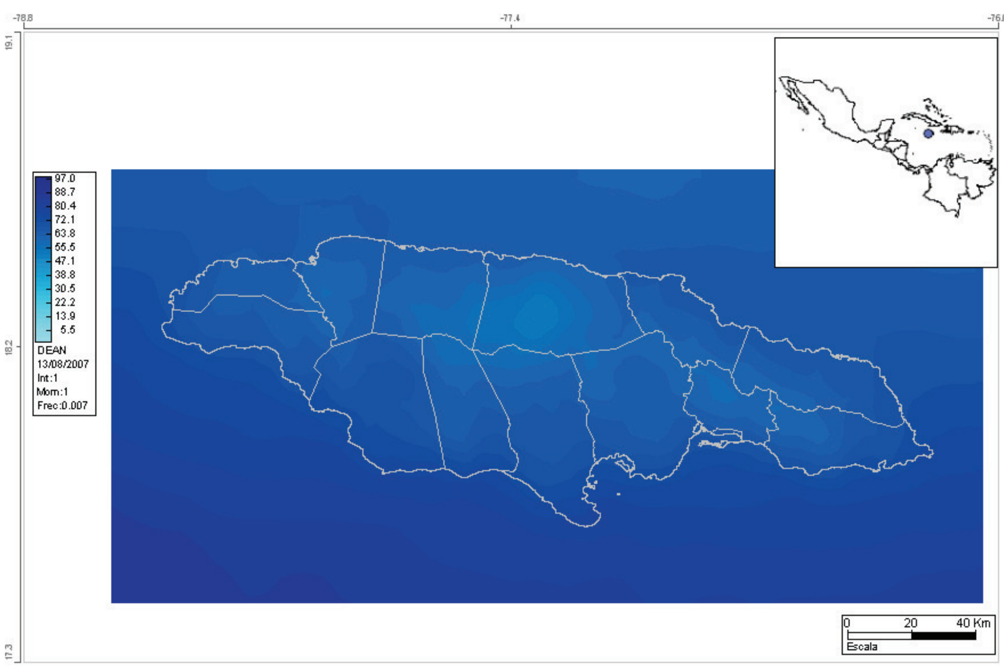


Figure 4.2 Map of distribution of the expected value of maximum wind velocity for the group of simulations of the hurricane Dean (August 13th 2007) (Obtained with the platform ERN-CAPRA-GIS)

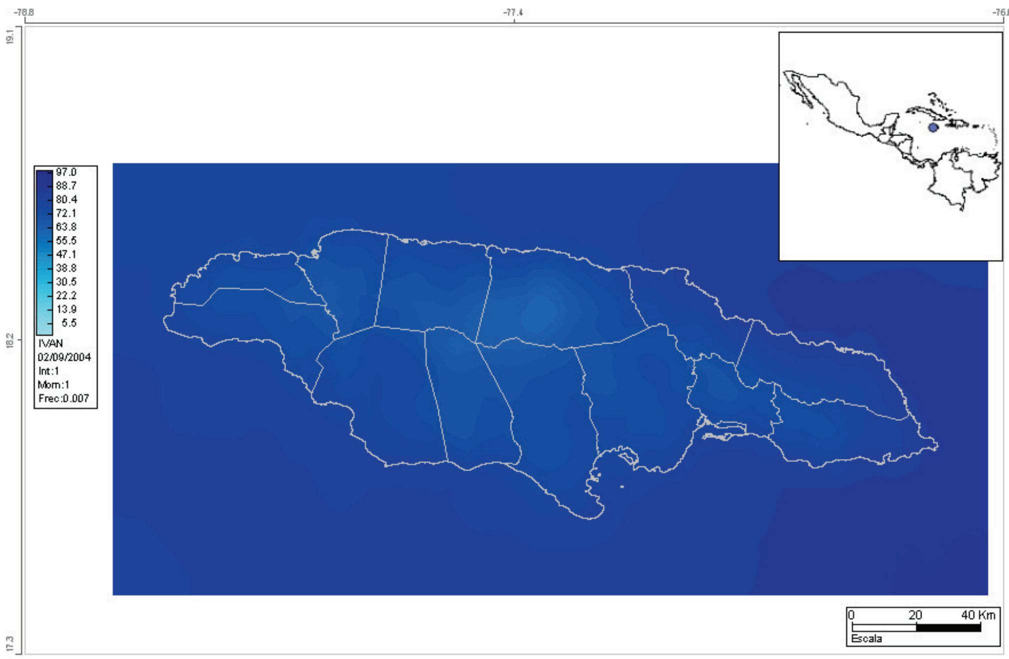


Figure 4.3 Map of distribution of the expected value of the maximum wind velocity for the groupof simulations of the hurricane Ivan (September 2nd 2004) (Obtained with the platform* ERN-CAPRA-GIS*)

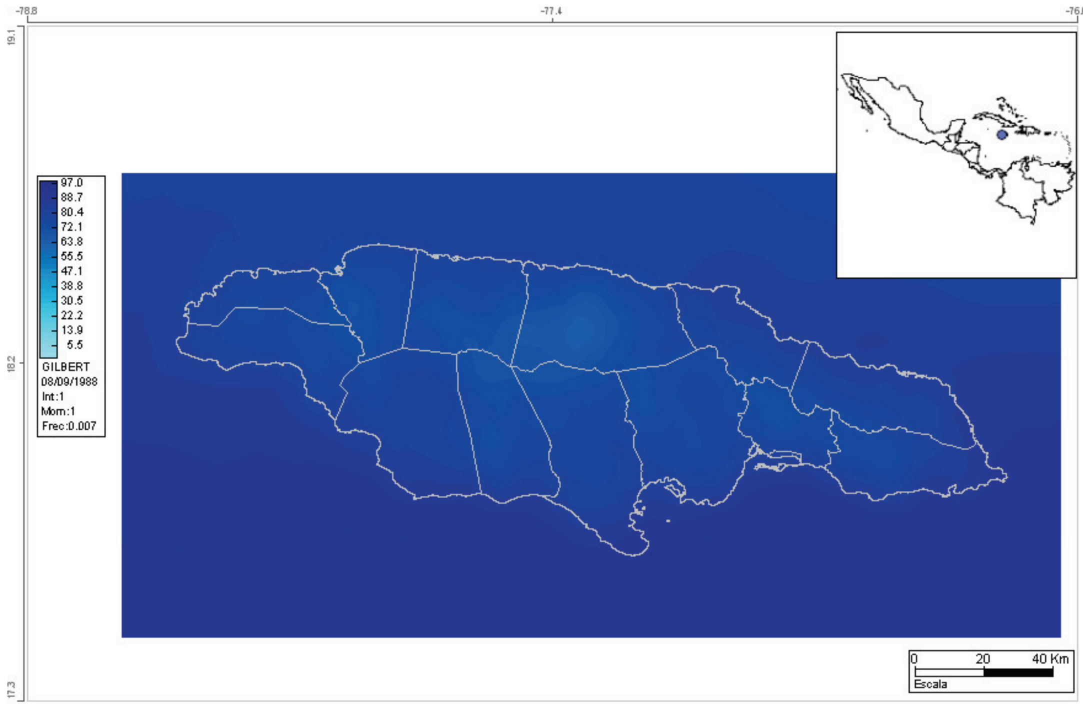


Figure 4.4 Map of distribution of the expected value of maximum wind velocity for the group of simulations of the hurricane Gilbert (September 8th 1988)
(Obtained with the platform* ERN-CAPRA-GIS*)

4.2 VULNERABILITY OF ASSETS TO HURRICANE WINDS

4.2.1 General Aspects

For the case of hurricane-force winds, vulnerability is suggested to be the relationship between the maximum wind velocity in the location of the analyzed exposed element and the level of damage to the physical that can present associated to that maximum wind velocity.

(a) Typification of the more representing and predominant constructions classes of the portfolio of exposed elements, based on existing information and the opinions and criteria obtained in the local level.

(b) Calculation of the vulnerability functions of characteristic construction classes. For this purpose, several analytical models have been developed and some previously published applicable functions have been used, according to preceding national or international experiences.

(c) Conformation of the database of constructions and main elements representing the national inventory of assets.

(d) Assignment of a characteristic construction class and an associated vulnerability function to each element of the exposed inventory of assets.

Once the vulnerability function of each element is assigned, a hurricane risk analysis is conducted.

A summary of the vulnerability functions used for the different exposed elements is presented. These curves are based either on the behavior of equivalent typical components obteined from previous studies or from specific analysis on design and construction conditions of the modeled elements regarding wind forces.

4.2.2 Vulnerability Functions to Wind Action

The vulnerability functions for the different construction types of the buildings exposed to the wind actions depend on several factors, such as:

- Main structural system
- Shape of the structure, percentage of openings in the section, size of main spans and other geometric characteristics.
- Elements that make up the front of the structure and type of connection with the structural elements.
- Parts that make up the windows, doors and their fastening systems to other elements.
- Roof system and elements of fastening and connection to the roof structure.

The evaluation of vulnerability of exposed elements to wind forces must be assessed through the weighing of the effects that can occur on the different components of the construction and its structure.

The generation of the vulnerability function is carried out in the Vunerability Module of the ERN-**CAPRA** and based on the information available. In the link http://www.ecapra.org/en/ (wiki – vulnerability) is presented the calculation methodology for vulnerability, according to the dominating national constructive types.

4.2.3 Vulnerability Functions for exposed elements

The analysis demands vulnerability functions for each one of the types of elements that make up the national inventory of assets. The types of elements are the following:

Characteristic urban and rural constructions

(a) Residential LP: low economic capacity
(b) Residential MP: moderate economic capacity
(c) Residential HP: high economic capacity
(d) Commercial
(e) Industrial
(f) Private health
(g) Private education
(h) Public health
(i) Public education
(j) Governmental

Urban infrastructure

a) Energy substations and annexed networks
b) Communication substations and antennas
c) Dams, tanks and aqueduct plants and sewage
d) Aqueduct networks, sewage
e) Gas networks
f) Airports
g) Ports
h) Urban bridges

National infrastructure

(a) Primary roads network (roads and bridges)
(b) Secondary roads network (roads and bridges)
(c) Hydroelectric plants (dams and machinery sites)
(d) Thermal and geothermal plants
(e) Energy substations and annexed networks
(f) Communication substations and antennas
(g) Fuel and gas substations and annexed networks

The vulnerability functions for each one of these components are calculated using the Vulnerability Module of the ERN-**CAPRA.** The functions are generated in terms of maximum wind velocity. The curves are modified with factors that take into account particular aspects of the local constructive types such as material quality, general condition of constructions, design practices and characteristic construction, and in general the specific characteristics of the predominant structural types. It must be emphasized that several infrastructure components such as hydroelectric plants, pipe systems, road networks and others are in general lightly susceptible to the direct effect of the wind, reason why their vulnerability is assumed as null for the analysis. Figure 4.5 shows the vulnerability

functions used for the analysis. At the link http://www.ecapra.org/es/ (wiki - vulnerabilidad) are presented the mentioned functions.

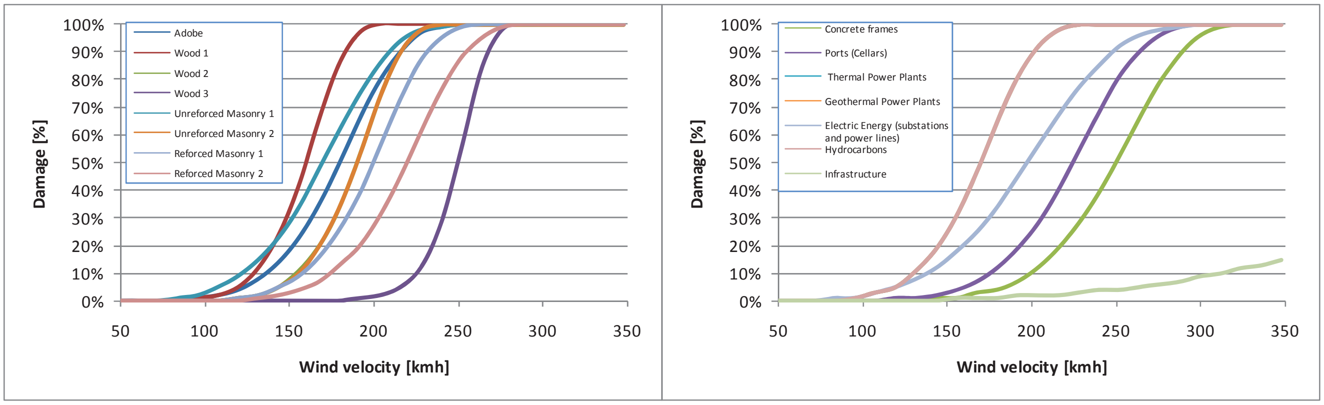


Figure 4.5 Vulnerability Functions for hurricane winds

4.3 HURRICANE RISK EVALUATION

4.3.1 General Aspects

Based on the probabilistic hazard models proposed and on the inventory and assessment of exposed assets, with their corresponding vulnerability functions, a probabilistic risk modeling was developed for hurricane winds in the country using the Hazard Module of the ERN-**CAPRA**.

The calculation risk methodology follows the same methodology as the one used for the case of earthquakes, for further reference see the link http://www.ecapra.org/es/ (wiki – risk).

4.3.2 Total Losses at National Level

First of all, Table 4.1 shows the consolidated information nationwide, with the total exposure value, the average annual loss in value and in thousands (also known as technical

risk premium) and the values that indicate probable maximum loss for different return periods.

Table 4.1 General results of PML for hurricane winds

Results		
Exposure Value	US$ x10^6	$18,625
Average Annual Loss	US$ x10^6	$105
	‰	5.6
PML		
Return Period	Loss	
Years	US$ x10^6	%
50	$1,075	5.8%
100	$1,574	8.5%
250	$2,424	13.0%
500	$3,148	16.9%
1000	$3,801	20.4%

Figure 4.6 shows the exceedance curves of losses at country level due to hurricane winds

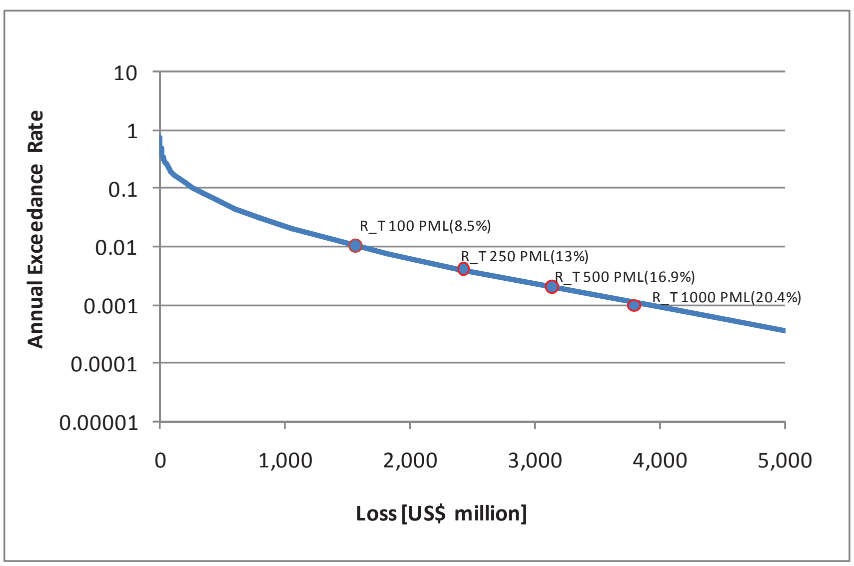


Figure 4.6 Loss exceedance due to hurricane winds

Figure 4.7 shows the curve of probable maximum loss showing values and percentages for different return periods. Similarly, the probability exceedance curves of different PML values are presented in percentage for different exposure periods, in particular 20, 50, 100 and 200 years (Figure 4.8).

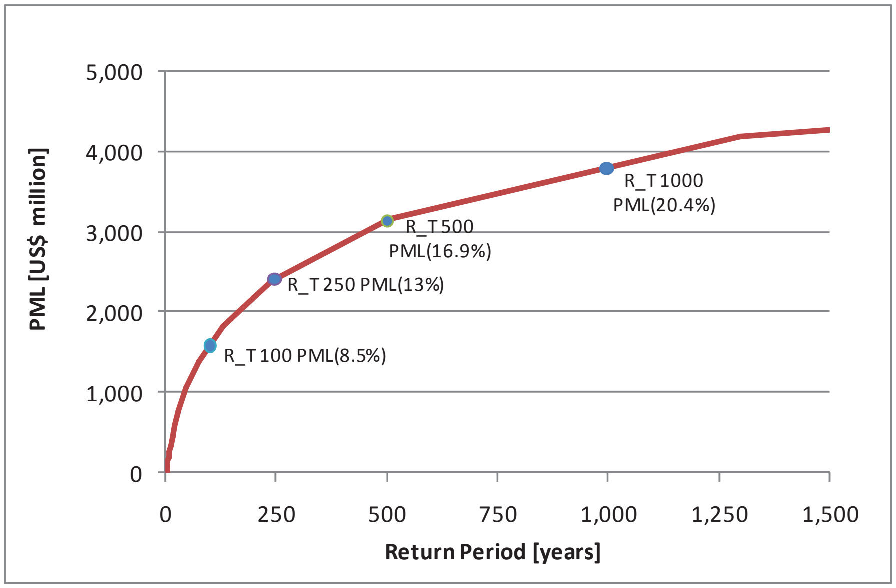


Figure 4.7 PML curve for hurricane winds

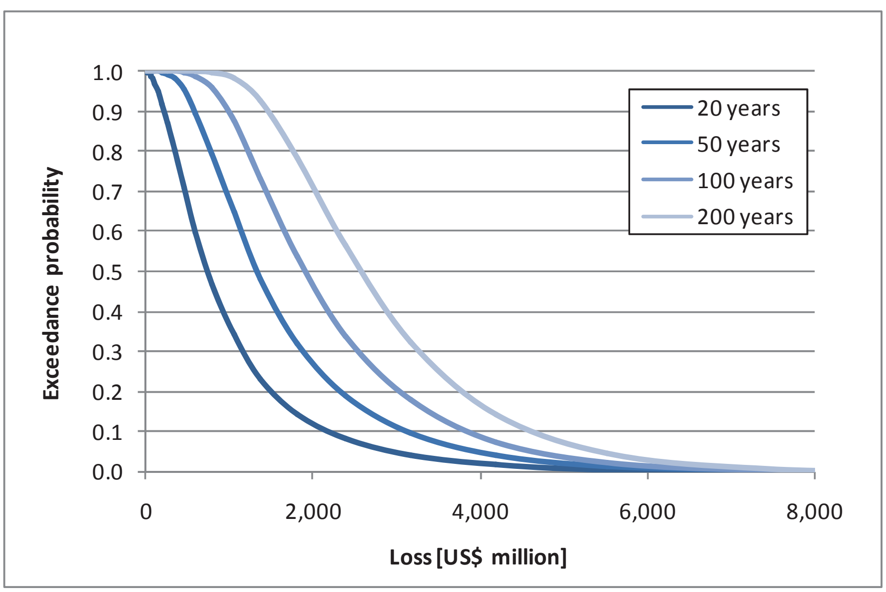


Figure 4.8 Exceedance probability curves of different PML values for different times of exposition for hurricane winds

Table 4.2 summarizes the resulting group of simulations or “family” of critical scenarios, that is, the scenarios resulting in the greater economic losses expected for effects of hurricane winds.

Table 4.2 Group of simulations of the critical scenarios of analysis for hurricane winds

N°	Scenario	Loss		Frequency	Ret. Period scenario [years]
		[US$ x 10^6]	%		
114	IVAN_02/09/2004	1,261.29	7.95%	6.58E-03	152
97	ALLEN_31/07/1980	1,048.43	6.61%	6.58E-03	152
116	EMILY_10/07/2005	996.63	6.28%	6.58E-03	152
119	DEAN_13/08/2007	959.95	6.05%	6.58E-03	152
101	GILBERT_08/09/1988	688.80	4.34%	6.58E-03	152
83	JANET_21/09/1955	571.08	3.60%	6.58E-03	152
32	NOT NAMED_06/08/1903	499.64	3.15%	6.58E-03	152
87	CLEO_20/08/1964	485.98	3.06%	6.58E-03	152
44	NOT NAMED_11/11/1912	463.97	2.92%	6.58E-03	152
121	PALOMA_05/11/2008	449.46	2.83%	6.58E-03	152

4.4 CONCENTRATION HURRICANE RISK

The analysis of risk concentration is carried out at parish level, for the different sectors of use for the public and private sectors and as well for the main components of infrastructure at national level.

4.4.1 Comparison of Losses per Parish

Losses are evaluated by parish as geographical units of analysis. Figure 4.9 shows a comparison of exposure values between the different parishes.

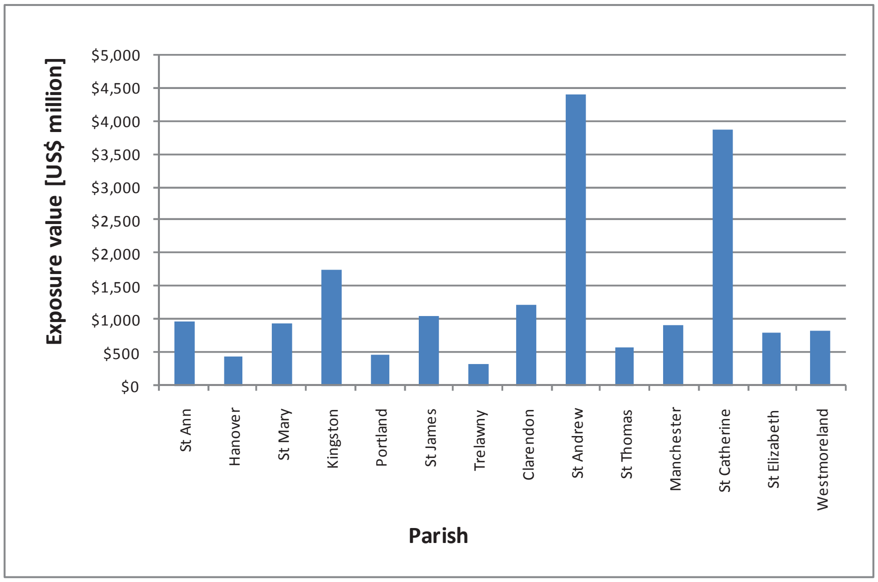


Figure 4.9 Exposure values per parish

For each parish, a complementary individual analysis is conducted, that allows estimating the probable maximum loss level and the individual premium level by parish. Figure 4.10 shows an example of the format[5] used to present individual results for each parish. Annex 3 shows individual results for the other parishes. For each case, results are presented as follows:

- Summary table of average annual loss (AAL) and probable maximum loss (PML)
- Curves of loss exceedance rates and PML with return period
- Bar diagrams showing the AAL in values and thousands, discriminated for each sector of use.

Figure 4.10 shows an example of the format used to present individual results for each parish. Annex 3 shows individual results for the other parishes.

5 The probability of exceed certain loss in a return period in a time of exposure do not depend on the loss value itself but only from return period and time of exposure according with this equation: P(p)=1-exp(-T_exposure/T_return). Where: P(p): is the probability of exceed a certain loss, T_exposure: is the time in which the building will be exposed, T_return: is the return period to calculate the probability of exceed a certain loss. That is the reason why the values on tables are equal for diferent parishes or sectors. On the form presents the loss probabilities for exposed time of 20, 50, 100 and 500 years and for return periods of 100, 250, 500 y 1000 years

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Kingston		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$168.00	9.57%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10⁶	$1,756.02	250 years	$261.76	14.91%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10⁶	$9.90	500 years	$344.67	19.63%	3.92%	9.52%	18.13%	63.21%
	‰	5.64	1000 years	$430.26	24.50%	1.98%	4.88%	9.52%	39.35%

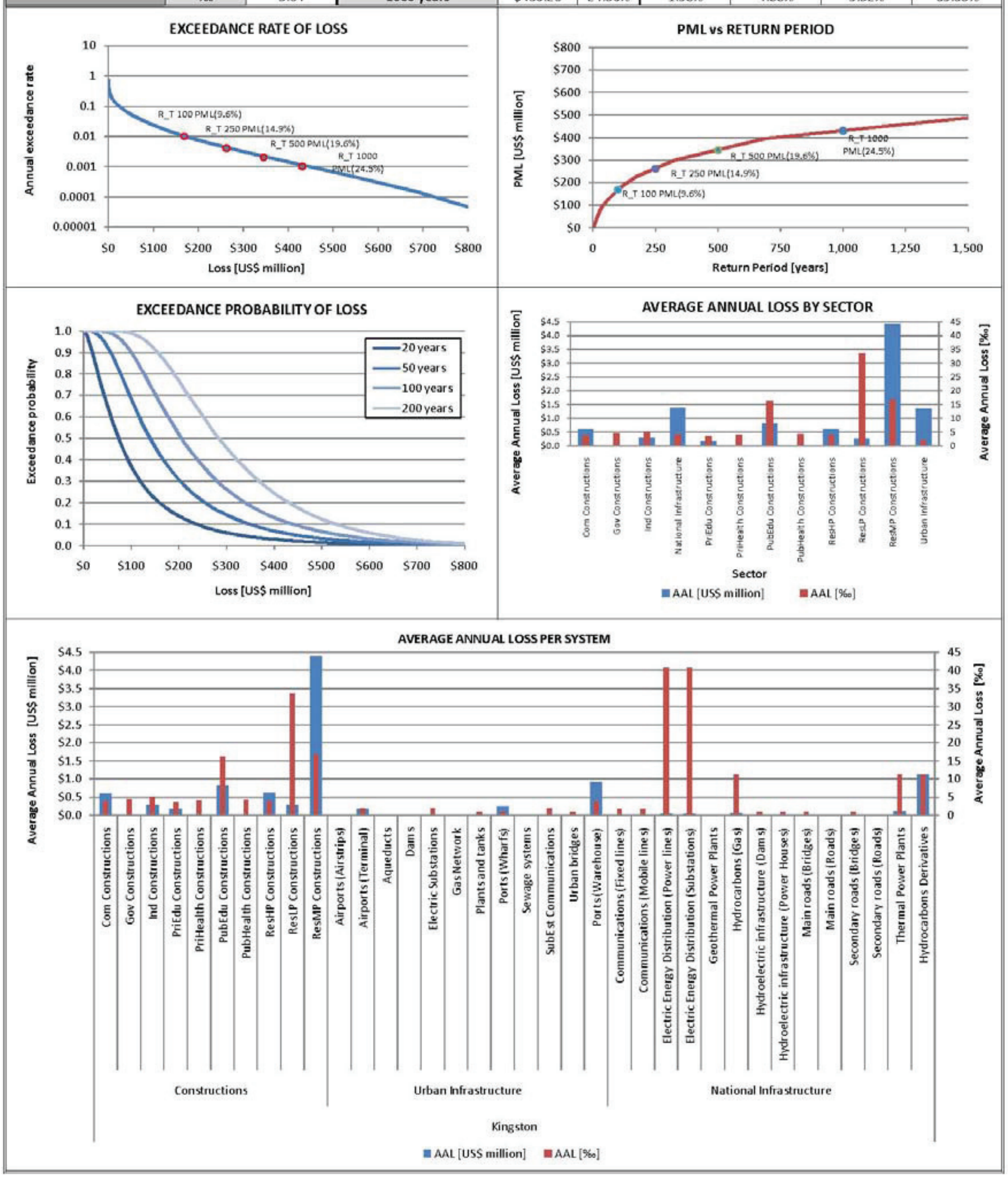


Figure 4.10 Example of results for Kingston for hurricane winds

Figure 4.11 summarizes PML values for return periods of 250, 500 and 1000 years for each parish in values as well as in percentage.

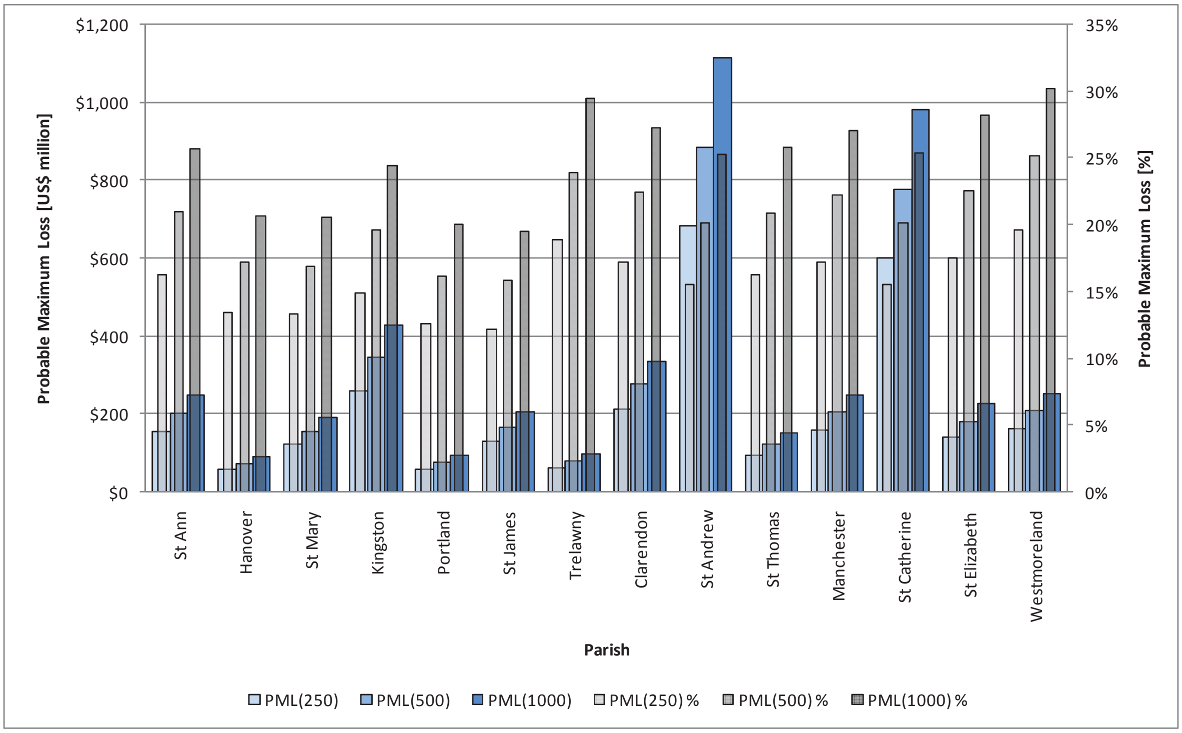


Figure 4.11 PML values for several return periods for hurricane winds per parish

On the other hand, Figure 4.12 shows the values corresponding to AAL showing in values and thousands.

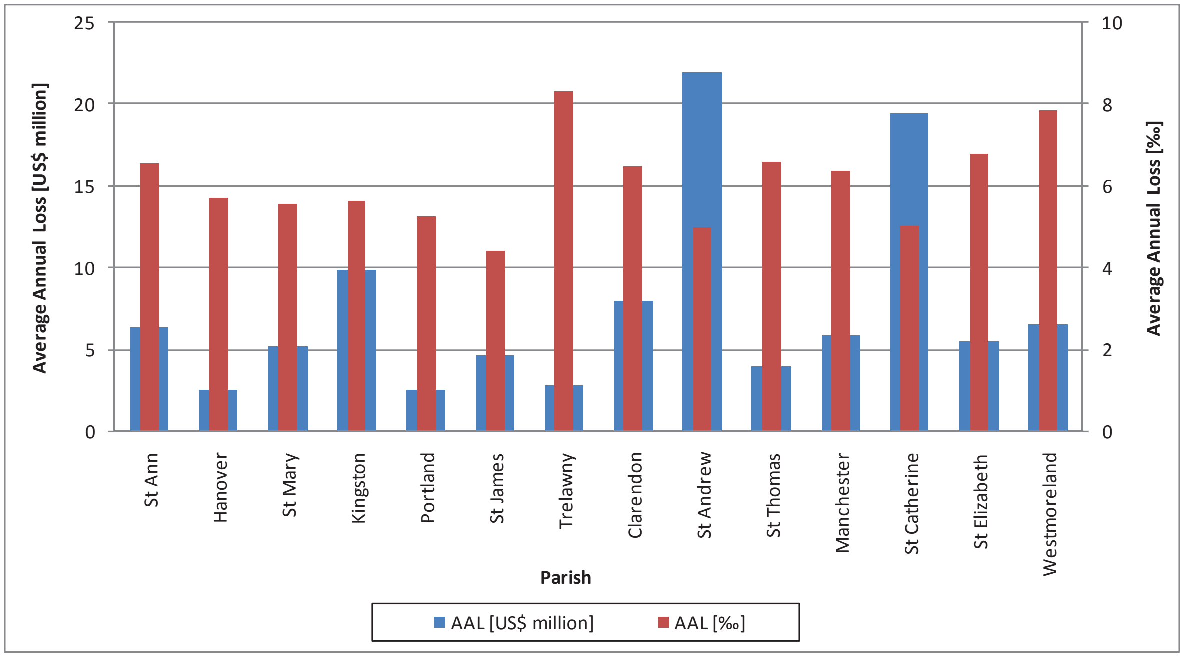


Figure 4.12 Values of AAL per parish for hurricane wind

Figure 4.13 also shows the expected annual losses by sectors for each parish. Urban constructions, urban infrastructure and the national infrastructure associated to each parish are considered.

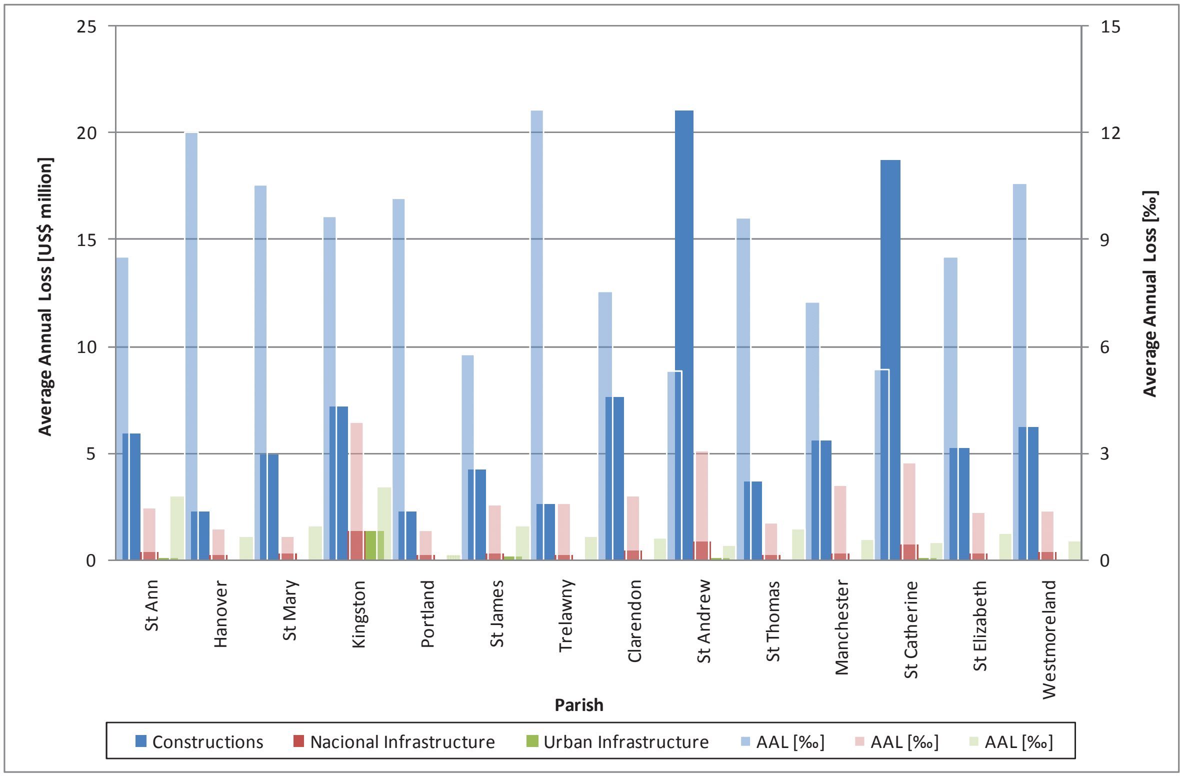


Figure 4.13 Values of AAL per parish discriminated by sectors of use for hurricane winds

Finally, Figure 4.14 and Figure 4.15 show the geographical distribution of average annual losses in value and in thousands, for each parish. Figure 4.16 and Figure 4.17 show probable maximum losses in value and in percentage, for each parish.

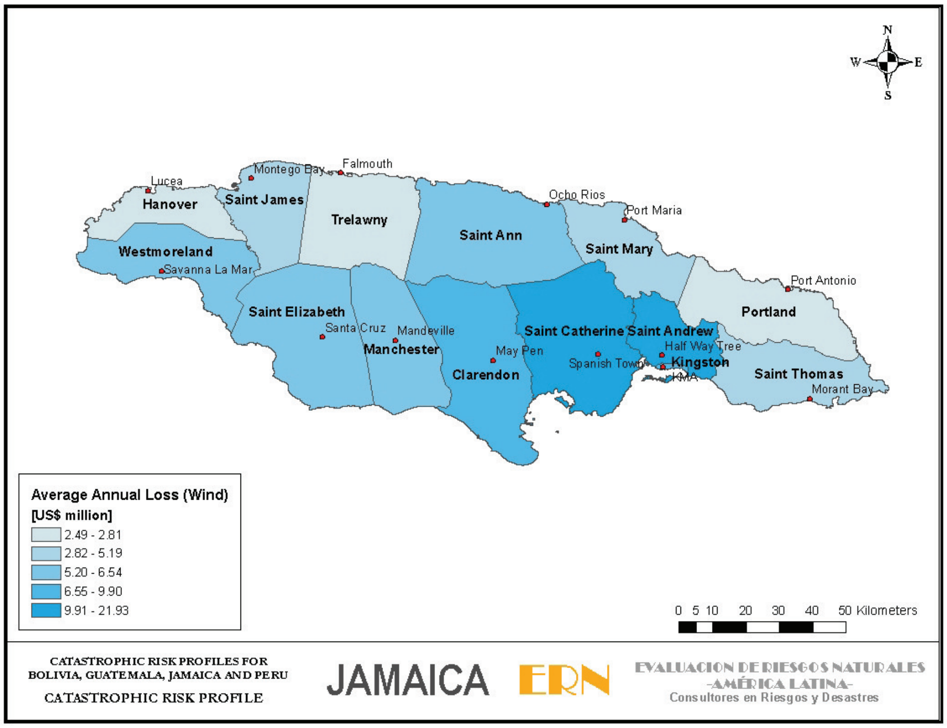


Figure 4.14 Geographical distribution of AAL (values) per parish for hurricane winds

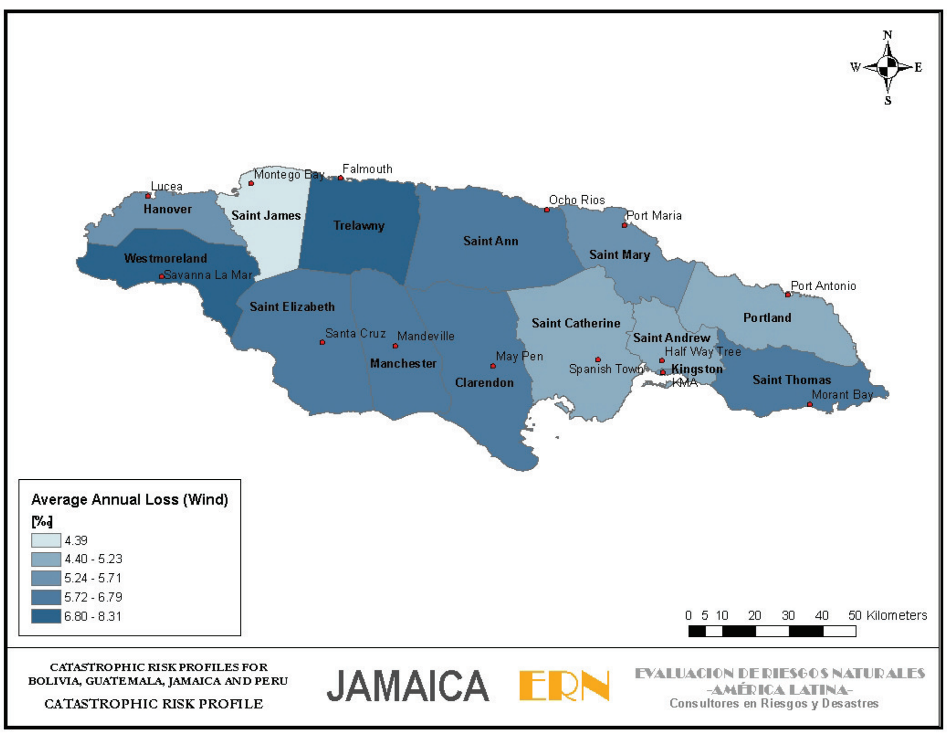


Figure 4.15 Geographical distribution of AAL (‰) per parish for hurricane winds

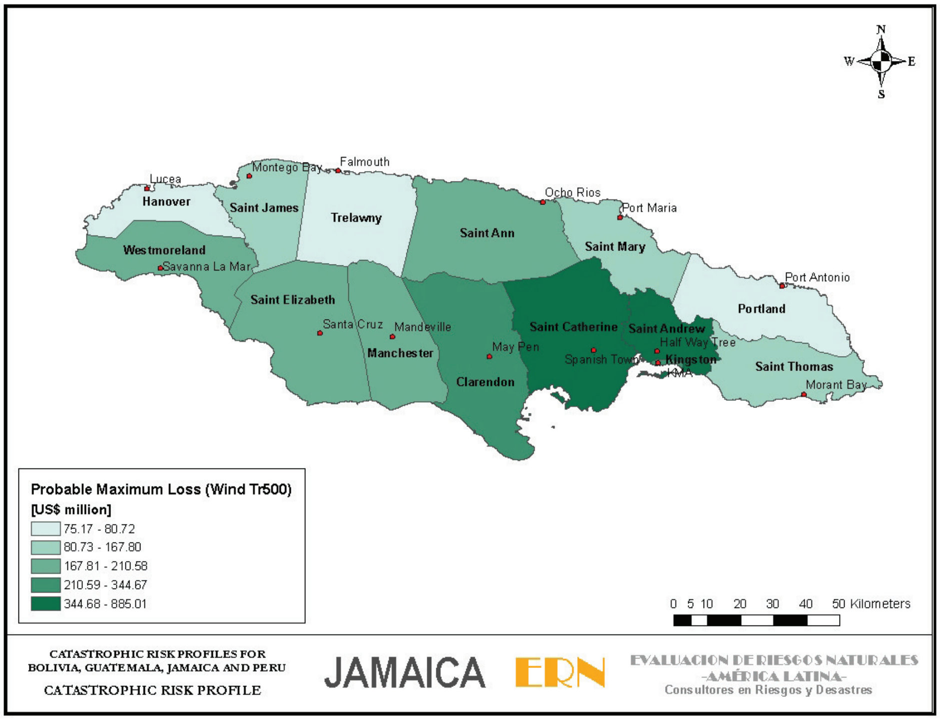


Figure 4.16 Geographical distribution of PML (value) per parish for hurricane winds

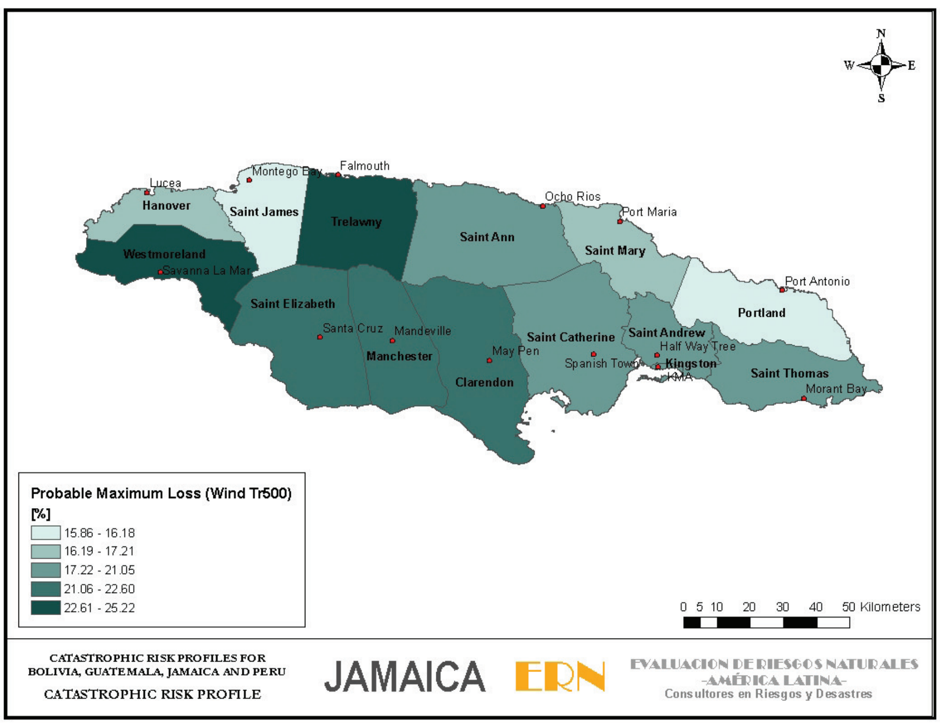


Figure 4.17 Geographical distribution of PML (%) per parish for hurricane winds

4.4.2 Comparison of Losses by Sector

Figure 4.18 shows a comparison between the exposure values by sector at a national scale.

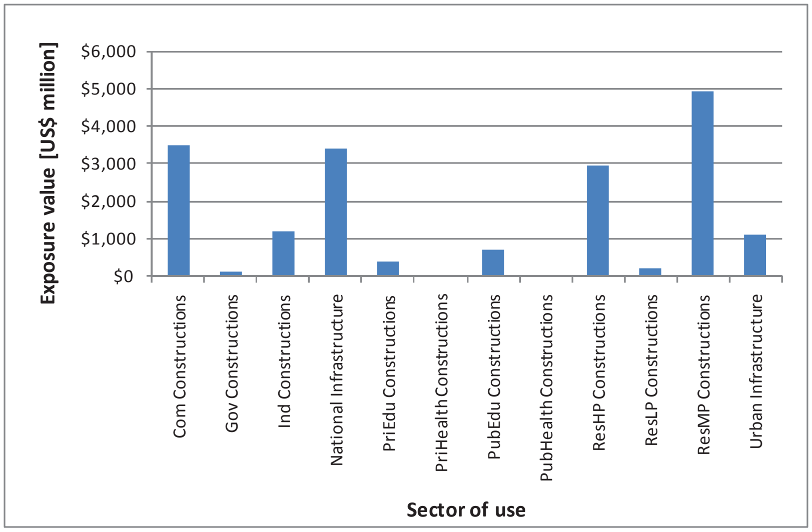


Figure 4.18 Exposure values by sector of use

Figure 4.19 totalizes the average annual losses in value and thousands for each sector of use and for the whole country.

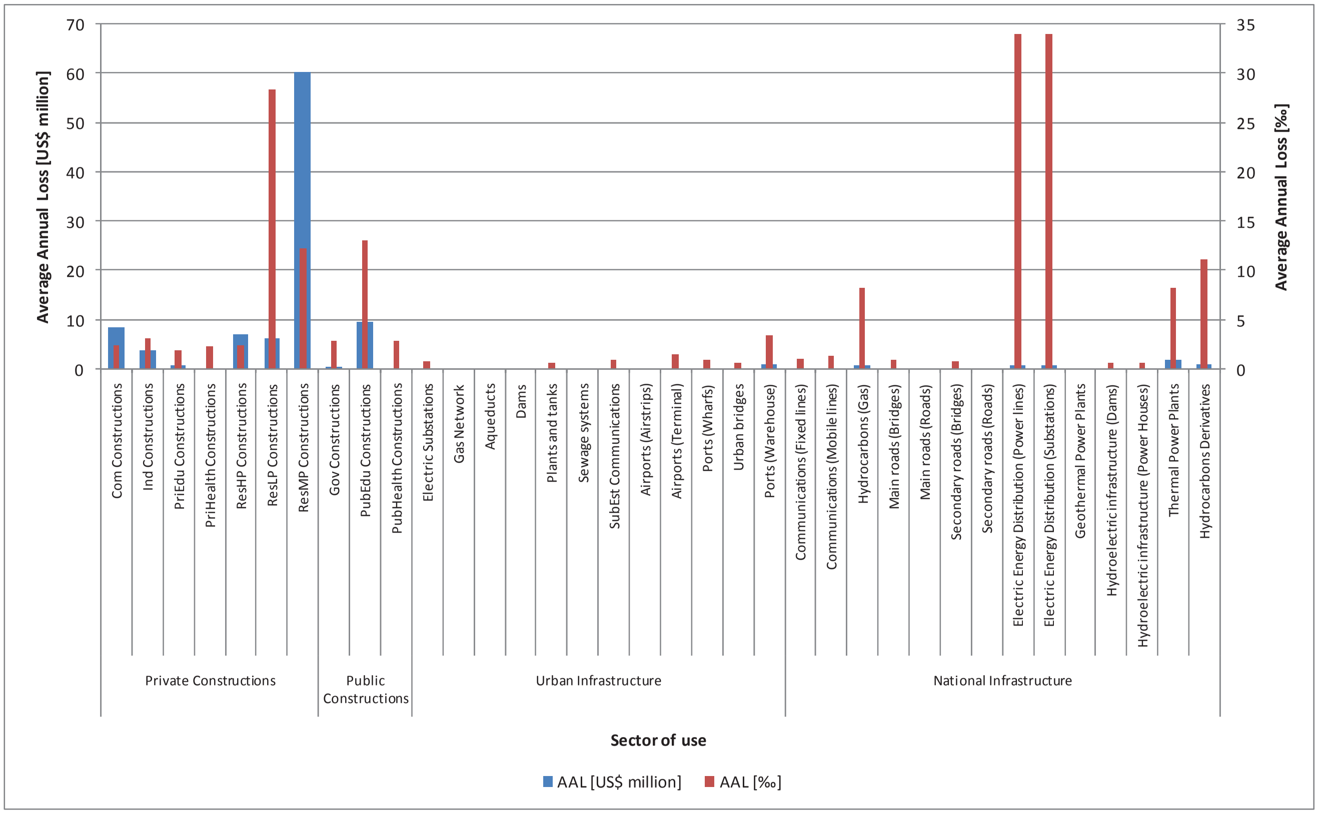


Figure 4.19 Values of AAL per sectors of use for hurricane winds

On the other hand, and summarized, Figure 4.20 totalizes the results for the three main sectors of use corresponding to urban constructions, urban infrastructure and national infrastructure.

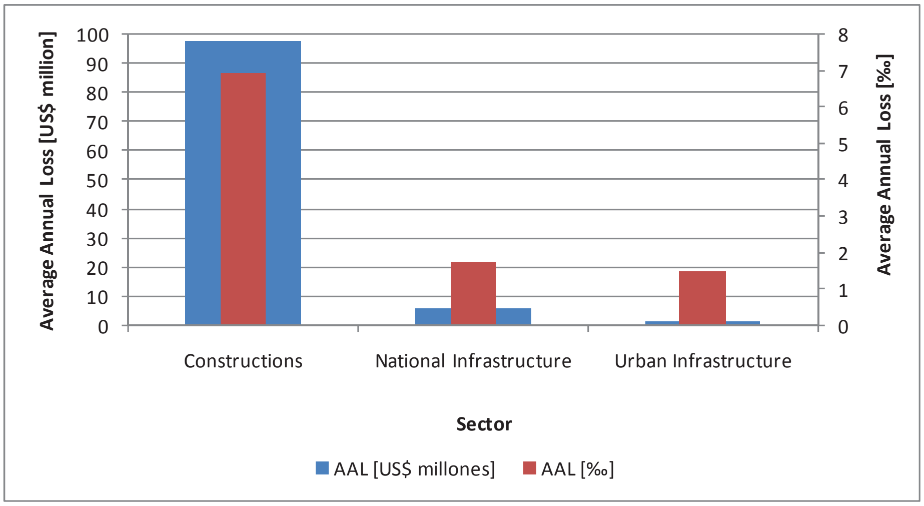


Figure 4.20 Distribution of AAL per sectors of use for hurricane winds summary

4.4.3 Probable Maximum Loss for Public and Private Sectors

To assess probable maximum losses for public and private sectors, it is necessary to conduct analyses for each portfolio due to the results of this type of analysis depending on the relative geographical distribution of the exposed values.

The public sector includes public urban constructions (health, education –when they are property of the State- and government buildings) and the the entire infrastructure. The private sector, on the other hand, includes residential, commercial, industrial constructions and the ones corresponding to the education and health sectors.

Figure 4.21 shows the exposure values for public and private sectors nationally.

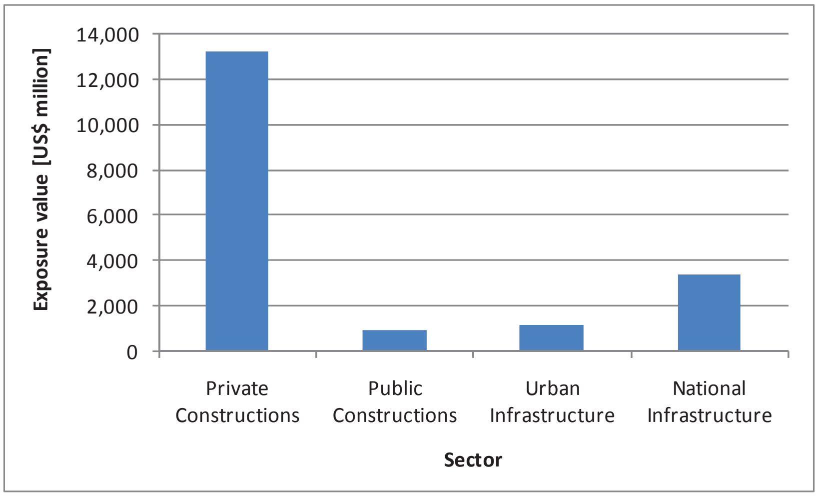
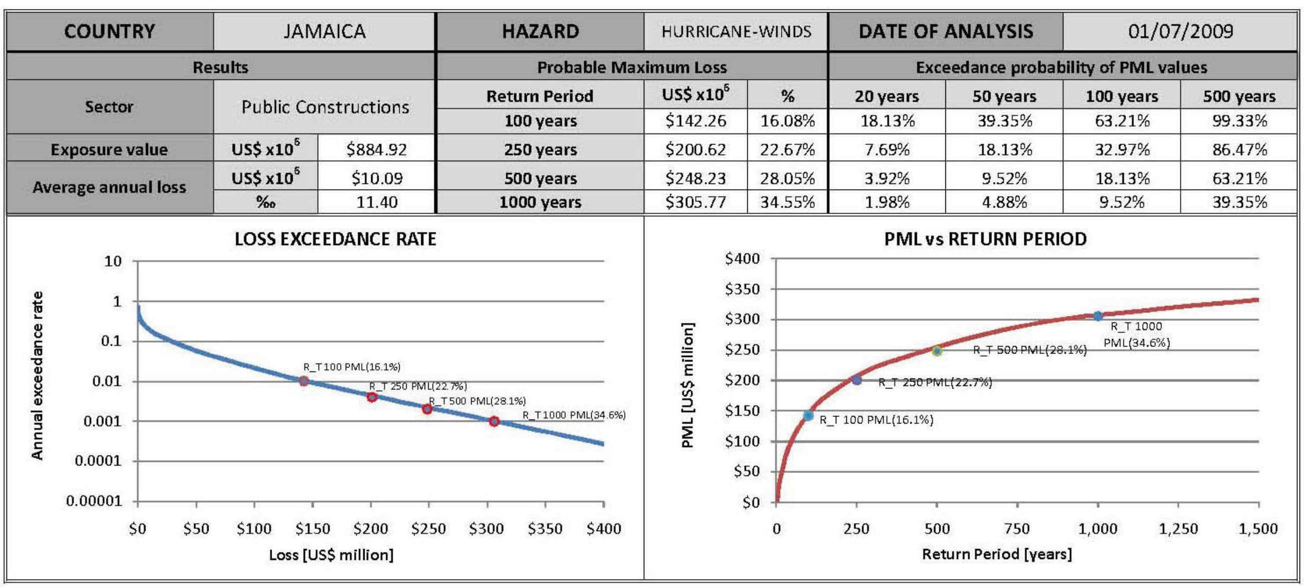


Figure 4.21 Exposure values by sector

Figure 4.22 and Figure 4.23 show the PML curves for each of these sectors.



COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Public Constructions		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$142.26	16.08%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$884.92	250 years	$200.62	22.67%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$10.09	500 years	$248.23	28.05%	3.92%	9.52%	18.13%	63.21%
	‰	11.40	1000 years	$305.77	34.55%	1.98%	4.88%	9.52%	39.35%

Figure 4.22 Loss exceedance curve and PML for public constructions for hurricane winds

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values				
Sector	Private Constructions		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years	
			100 years	$1,338.36	10.13%	18.13%	39.35%	63.21%	99.33%	
Exposure value	US$ x10^6	$13,213.17	250 years	$2,051.79	15.53%	7.69%	18.13%	32.97%	86.47%	
Average annual loss	US$ x10^6	$87.29	500 years	$2,665.70	20.17%	3.92%	9.52%	18.13%	63.21%	
	‰	6.61	1000 years	$3,262.61	24.69%	1.98%	4.88%	9.52%	39.35%	

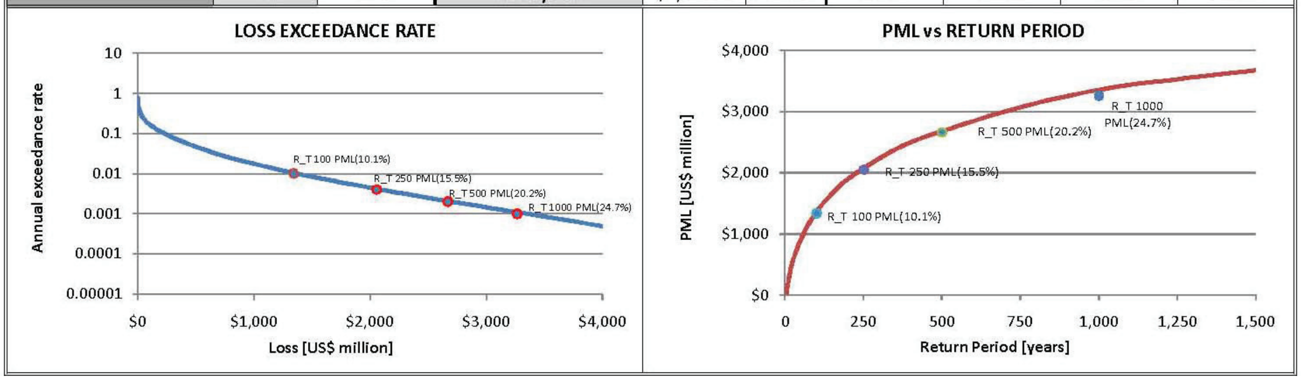


Figure 4.23 Loss exceedance curve and PML for private constructions for hurricane winds

4.4.4 Probable Maximum Loss for the National Infrastructure

A similar analysis is conducted for the national infrastructure sector, taking into account the following analyses:

- Energy generation and distribution
- Communications
- Transportation (road and bridges)
- Hydrocarbons

Results of the PML curves with the return period and global AAL values in value and in thousands are shown for each sector. Figure 4.24 to Figure 4.27 summarize these results.

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Production and distribution (Energy)		Return Period	US$ x10[6]	%	20 years	50 years	100 years	500 years
			100 years	$53.33	12.76%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10[6]	$418.08	250 years	$83.38	19.94%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10[6]	$3.73	500 years	$107.23	25.65%	3.92%	9.52%	18.13%	63.21%
	‰	8.92	1000 years	$129.94	31.08%	1.98%	4.88%	9.52%	39.35%

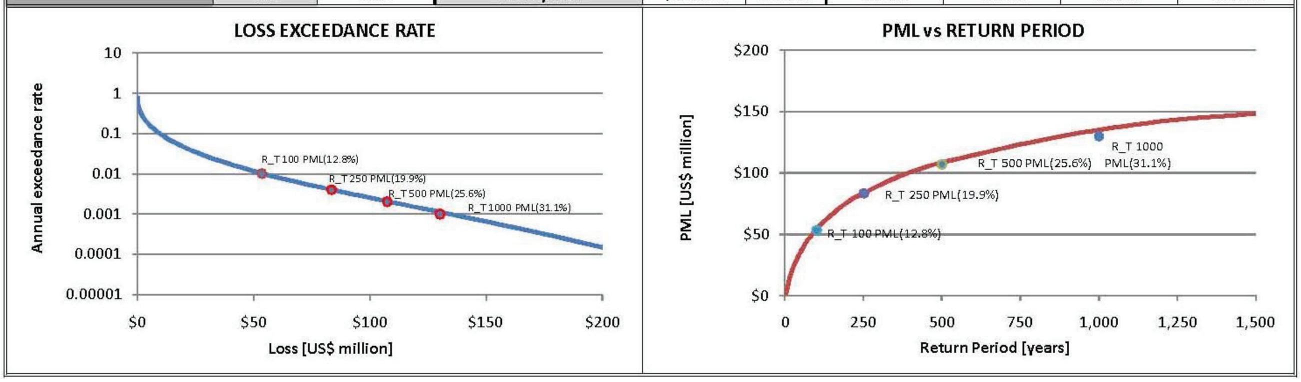


Figure 4.24 Loss exceedance curve and PML for the energy sector for hurricane winds

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Communications		Return Period	US$ x10[6]	%	20 years	50 years	100 years	500 years
			100 years	$0.51	2.59%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10[6]	$19.72	250 years	$0.99	5.02%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10[6]	$0.02	500 years	$1.40	7.08%	3.92%	9.52%	18.13%	63.21%
	‰	1.01	1000 years	$1.83	9.30%	1.98%	4.88%	9.52%	39.35%

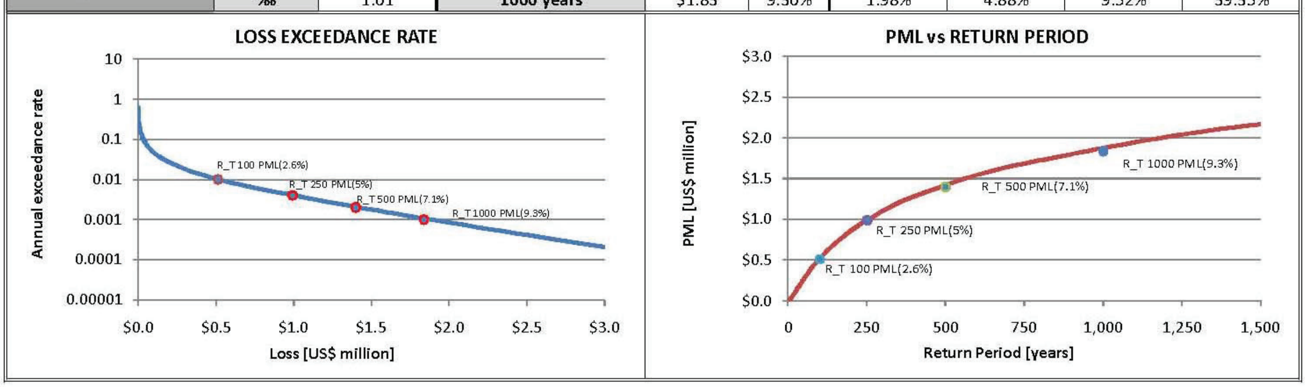


Figure 4.25 Loss exceedance curve and PML for the communication sector for hurricane winds

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	National Roads		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$1.76	0.06%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$2,736.78	250 years	$2.70	0.10%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.13	500 years	$3.55	0.13%	3.92%	9.52%	18.13%	63.21%
	‰	0.05	1000 years	$4.50	0.16%	1.98%	4.88%	9.52%	39.35%

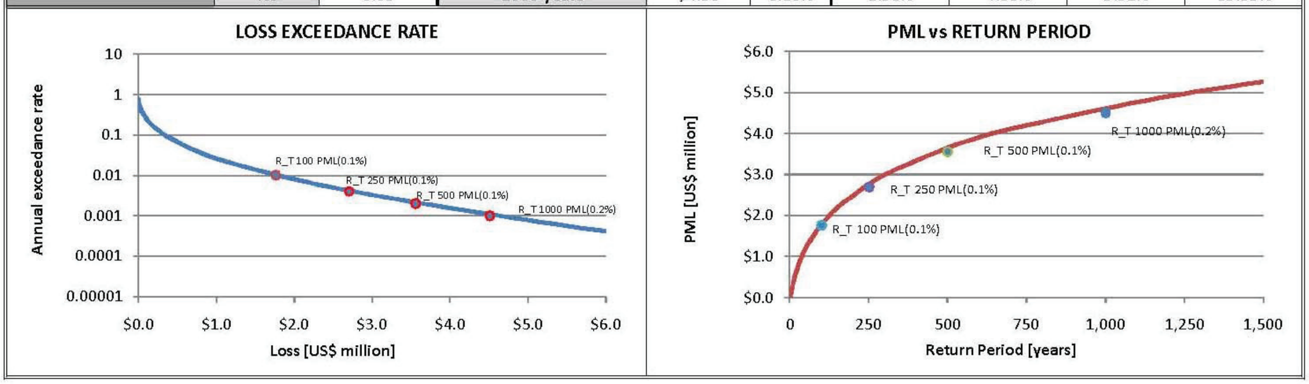


Figure 4.26 Loss exceedance curve and PML for the transportation sector for hurricane winds

COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Hydrocarbons		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$42.49	20.11%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$211.25	250 years	$76.23	36.08%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$2.03	500 years	$103.54	49.01%	3.92%	9.52%	18.13%	63.21%
	‰	9.61	1000 years	$130.30	61.68%	1.98%	4.88%	9.52%	39.35%

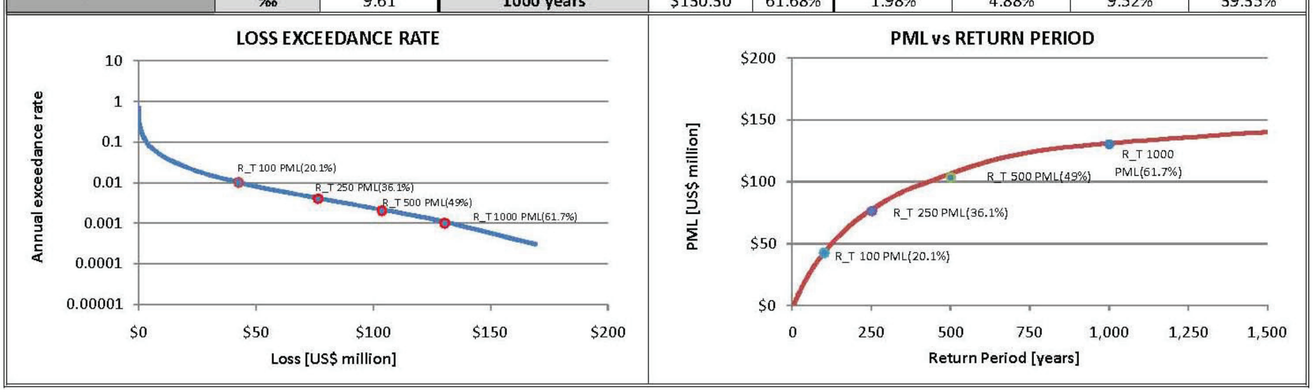


Figure 4.27 Loss exceedance curve and PML for the hydrocarbon sector for hurricane winds

5 COMPARISON OF RISK RESULTS

5.1 EXPECTED ANNUAL LOSS AND PROBABLE MAXIMUM LOSS

Based on the results presented in the previous chapters, Table 5.1 summarizes results at country level for a comparative risk analysis for earthquake and hurricane.

Table 5.1 Comparison of results of AAL and PML for earthquake and hurricane winds

Results					
Hazard		**Earthquake**		**Hurricane - Winds**	
Exposure Value	US$ x10^6	$18,625			
Average Annual Loss	US$ x10^6	$30		$105	
	‰	1.6		5.6	
PML					
Return Period		**Loss**			
years		**US$ x10^6**	**%**	**US$ x10^6**	**%**
50		$381	2.0%	$1,075	5.8%
100		$774	4.2%	$1,574	8.5%
250		$1,455	7.8%	$2,424	13.0%
500		$2,013	10.8%	$3,148	16.9%
1000		$2,583	13.9%	$3,801	20.4%

5.2 EXPECTED ANNUAL LOSS PER PARISH

Figure 5.1 compares the average annual losses for earthquake and hurricane- winds for each parish.

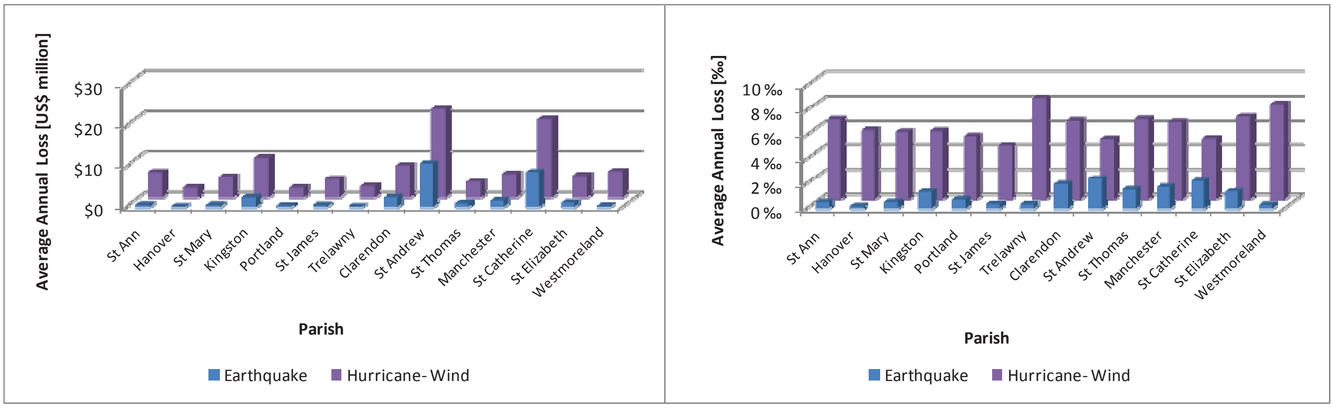


Figure 5.1 Values of AAL for earthquake and hurricane- winds for each parish

5.3 EXPECTED ANNUAL LOSS BY SECTORS

Figure 5.2 shows a comparison of average annual losses for earthquake and hurricane-winds for the different sectors.

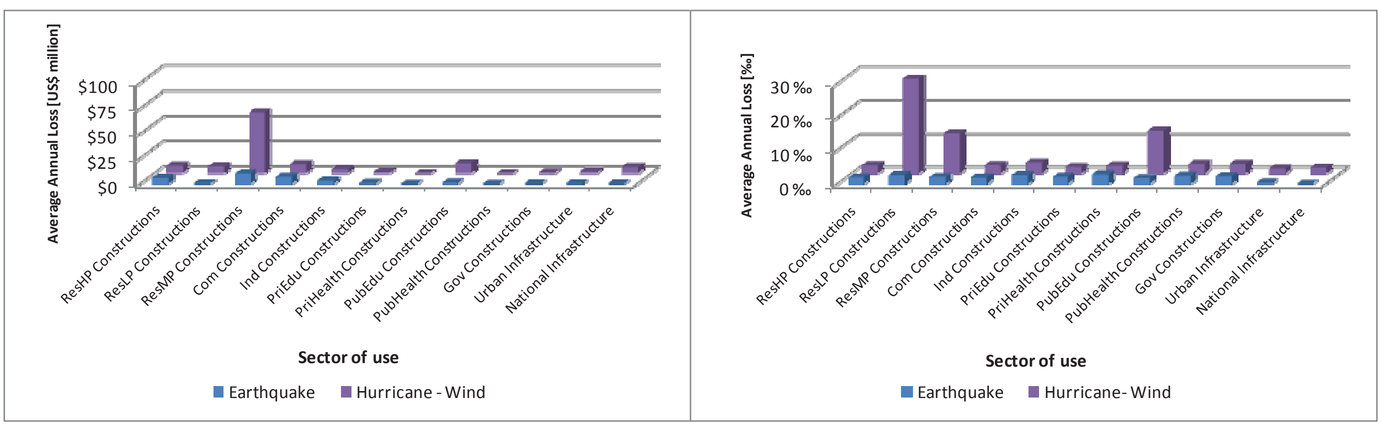


Figure 5.2 Values of AAL for earthquake and hurricane-winds for the different sectors

5.4 EXPECTED ANNUAL LOSS FOR THE PUBLIC AND PRIVATE SECTORS

Figure 5.3 compares average annual losses for earthquake and hurricane-winds for the public and private sectors.

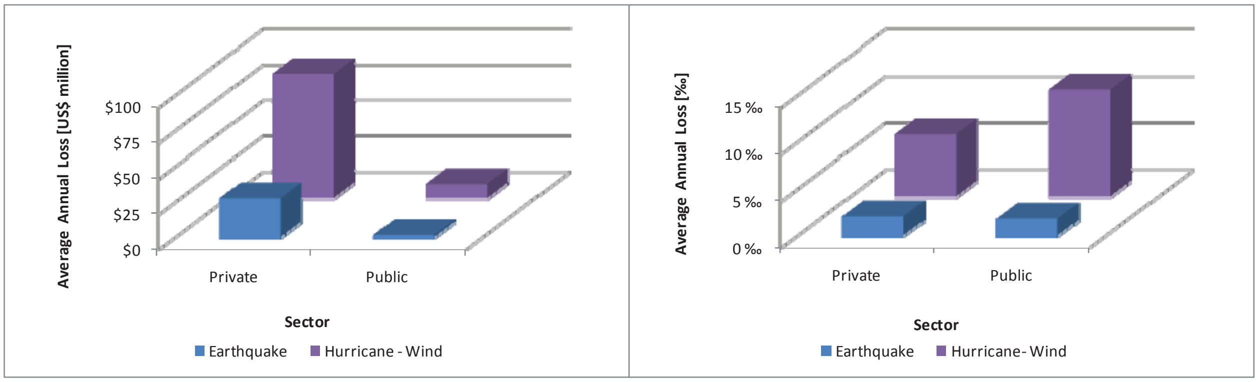


Figure 5.3 Values of AAL for earthquake and hurricane winds for the public and private sectors

5.5 PROBABLE MAXIMUM LOSS PER PARISH

Figure 5.4 compares probable maximum loss for earthquake and hurricane-winds for parishes.

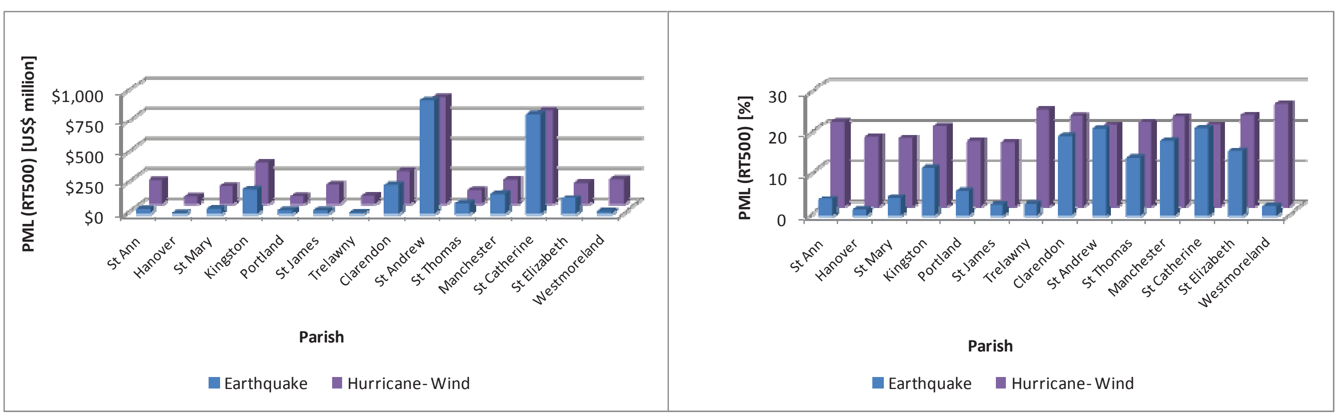


Figure 5.4 Values of PML for earthquake and hurricane-winds per parish

5.6 INFLUENCE OF DEDUCTIBLE

Deductible is the fraction of the total loss retained, which the cedant must pay beforein function of the conditions of the risk transfer negotiation. The effect of deductible is very important for the insurance and/or the reinsurance negotiation, because if the value is high it would reduce the value of the risk premium by a significant amount. On the other hand, deductible must be covered by each one of the insured property owners, except in the cases when the government finances the quantities for the low-income owners, or when the government has a financial strategy to cover those values. For other cases is advisable to cover that part of the loss. In other words, the deductible or priority determines a primary level of risk retention, which is necessary to evaluate in order to consider its implications.

Table 5.2 and Table 5.3 show the values of deductible for the country portfolio, using the following values as a reference: deductibles of 0%, 3%, and 5% (Figure 5.5 and Figure 5.6).

Table 5.2 General results of AAL and PML for earthquake with different deductibles

Results - Earthquake							
Priority	%	0%		3%		5%	
Exposure Value	US$ x10^6	$18,625					
Average Anual Loss	US$ x10^6	$30		$26		$24	
	‰	1.6		1.4		1.3	
PML							
Rerurn Period		Loss					
years		US$ x10^6	%	US$ x10^6	%	US$ x10^6	%
50		$381	2.0%	$328	1.8%	$296	1.6%
100		$774	4.2%	$707	3.8%	$643	3.5%
250		$1,455	7.8%	$1,399	7.5%	$1,306	7.0%
500		$2,013	10.8%	$1,970	10.6%	$1,850	9.9%
1000		$2,583	13.9%	$2,553	13.7%	$2,410	12.9%

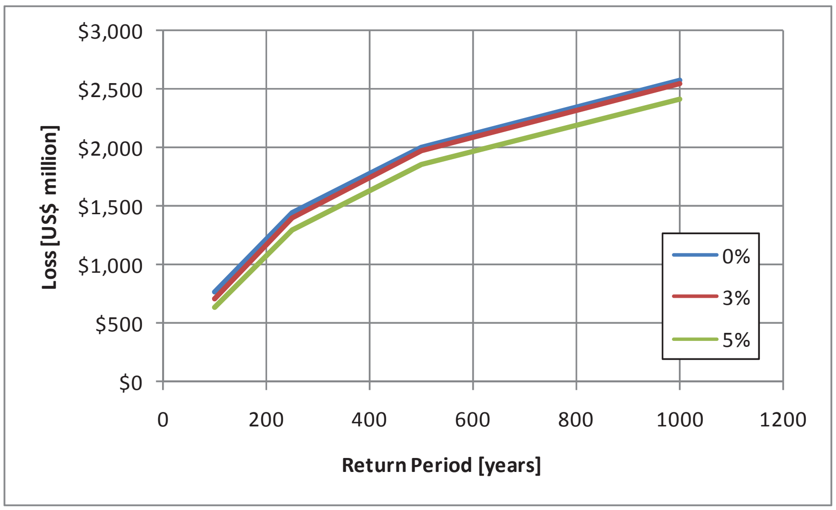


Figure 5.5 PML values for each deductible for earthquake

Table 5.3 General results of AAL and PML for hurricane-winds with different deductibles

Results - Hurricane - Winds							
Priority	%	0%		3%		5%	
Exposure Value	US$ x10^6	$18,625					
Average Anual Loss	US$ x10^6	$105		$96		$91	
	‰	5.6		5.2		4.9	
PML							
Return Period		Loss					
years		US$ x10^6	%	US$ x10^6	%	US$ x10^6	%
50		$1,075	5.8%	$1,010	5.4%	$968	5.2%
100		$1,574	8.5%	$1,509	8.1%	$1,451	7.8%
250		$2,424	13.0%	$2,342	12.6%	$2,271	12.2%
500		$3,148	16.9%	$3,037	16.3%	$2,940	15.8%
1000		$3,801	20.4%	$3,677	19.7%	$3,578	19.2%

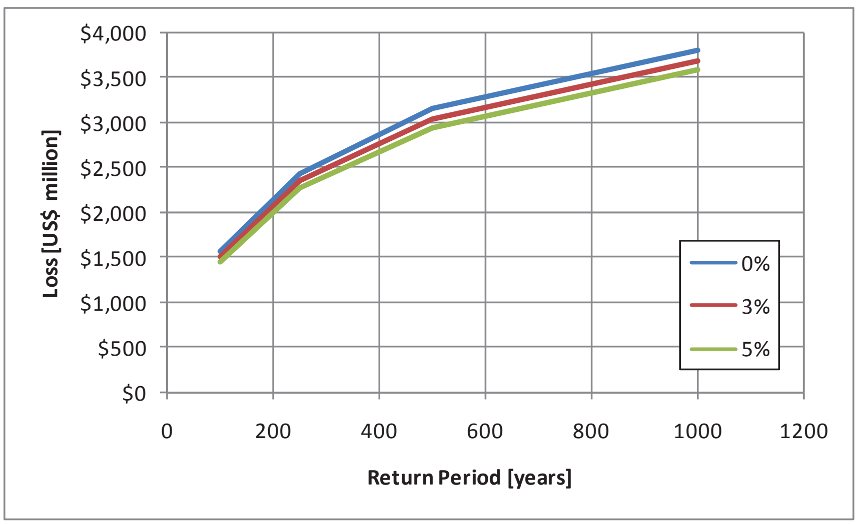


Figure 5.6 PML values for each deductible for hurricane winds

In conclusion, future losses due to hurricanes dominate the catastrophe risk in Jamaica. Notwithstanding, the potential earthquake losses are not negligeable and should be considered in any multi risk coverage to be defined. This study presents figures of particular importance for the design of financial instruments, as described in supplementary report "Alternatives of Financial Instruments for Retention and Transfer of Risk." They could be reserve funds, contingent credits, debt bonds (products related to alternative risk retention) and/or stardard or parametric insurance/reinsurance, catastrophe bonds, risk securitization, and so on (products related to alternative risk transfer).

6 PREMIUMS FOR LOSS LAYERS

In this study, it is made an analysis of the premium costs by layers. These costs are useful to design strategies for financial protection, defining a risk retention and transfer structure to determine the costs of each selected financial instrument for each layer. In the government's case these structures are very important for the fiscal liabilities (infrastructure, government buildings and housing of low income population). Now, when one wants to explore the possibility of compulsory house insurance such as the TCIP or insurance for the coverge of emergencies, such as the CCRIF, it is desirable designing risk retention and transfer structure for all assets, including both the public and private buildings. Both cases are treated here in this section.

6.1 ANALYSIS BY LAYERS OF LOSS FOR THE WHOLE COUNTRY

The main consequence for the risk analysis by layers is that each layer of loss has a premium and therefore there is a premium value for each layer. Usually the analysis by layers is made when the risk tranfer will be partial; i.e. the loss coverage will have limits less than the PML of reference, defined for a specific return period. In this case the risk taker will cover an amount of loss between the priority or the attachment point (from a lower retention layer, if it is defined) and the excess of loss limit defined. This means that the premium paid by the risk cedant will be lower but the amount over the defined limit is uncovered. However, this amount can be another layer to be negotiated, for example, with a reinsurance company or covered, as is usually done in case of catastrophic events, with other capital market alternatives such asa catastrophe bond or other kind of transfer or financial instruments.

Table 6.1 shows the results for the layered coverage of the country due to earthquake.

Table 6.1 Premium variation by layers for the country due to earthquake

Layer	Percentage of Expected Loss	Layer Limit ($ Million)	Upper Layer ($ Million)	Layer Premium ($ Million)	Total premium of layer		Premium Left (upper layer)		Δ Premium (C_i-C_{i-1})	
					(‰)	% of the Total Premium	(‰)	% of the Total Premium	(‰)	% of the Total Premium
1	0.10%	$ 19	$ 18,606	$ 3	0.16	9.5%	1.48	90.5%	0.16	9.53%
2	0.30%	$ 56	$ 18,569	$ 6	0.31	19.1%	1.32	80.9%	0.16	9.56%
3	0.60%	$ 112	$ 18,513	$ 9	0.47	28.8%	1.16	71.2%	0.16	9.74%
4	1.00%	$ 186	$ 18,439	$ 12	0.62	38.2%	1.01	61.8%	0.15	9.41%
5	2.00%	$ 373	$ 18,253	$ 16	0.88	54.2%	0.75	45.8%	0.26	15.91%
6	3.00%	$ 559	$ 18,066	$ 20	1.05	64.6%	0.58	35.4%	0.17	10.46%
7	4.00%	$ 745	$ 17,880	$ 22	1.18	72.2%	0.45	27.8%	0.12	7.54%
8	5.00%	$ 931	$ 17,694	$ 24	1.27	77.8%	0.36	22.2%	0.09	5.60%
9	6.00%	$ 1,118	$ 17,508	$ 25	1.34	82.2%	0.29	17.8%	0.07	4.46%
10	7.00%	$ 1,304	$ 17,321	$ 26	1.40	85.6%	0.23	14.4%	0.06	3.43%
11	8.00%	$ 1,490	$ 17,135	$ 27	1.44	88.4%	0.19	11.6%	0.04	2.74%
12	9.00%	$ 1,676	$ 16,949	$ 27	1.48	90.5%	0.15	9.5%	0.04	2.15%
13	10.00%	$ 1,863	$ 16,763	$ 28	1.51	92.5%	0.12	7.5%	0.03	1.98%
14	11.00%	$ 2,049	$ 16,576	$ 28	1.53	93.7%	0.10	6.3%	0.02	1.20%
15	12.00%	$ 2,235	$ 16,390	$ 29	1.55	94.9%	0.08	5.1%	0.02	1.20%
16	13.00%	$ 2,421	$ 16,204	$ 29	1.57	96.1%	0.06	3.9%	0.02	1.20%
17	14.00%	$ 2,608	$ 16,018	$ 29	1.58	96.7%	0.05	3.3%	0.01	0.57%
18	15.00%	$ 2,794	$ 15,831	$ 30	1.59	97.2%	0.04	2.8%	0.01	0.57%
19	16.00%	$ 2,980	$ 15,645	$ 30	1.59	97.8%	0.04	2.2%	0.01	0.57%
20	17.00%	$ 3,166	$ 15,459	$ 30	1.60	98.4%	0.03	1.6%	0.01	0.57%
21	20.00%	$ 3,725	$ 14,900	$ 30	1.61	99.0%	0.02	1.0%	0.01	0.66%
22	25.00%	$ 4,656	$ 13,969	$ 30	1.63	99.7%	0.00	0.3%	0.01	0.65%
23	30.00%	$ 5,588	$ 13,038	$ 30	1.63	99.9%	0.00	0.1%	0.00	0.24%
24	35.00%	$ 6,519	$ 12,106	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.03%
25	40.00%	$ 7,450	$ 11,175	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.03%
26	45.00%	$ 8,381	$ 10,244	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
27	50.00%	$ 9,313	$ 9,313	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
28	60.00%	$ 11,175	$ 7,450	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
29	70.00%	$ 13,038	$ 5,588	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
30	80.00%	$ 14,900	$ 3,725	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
31	90.00%	$ 16,763	$ 1,863	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%
32	100.00%	$ 18,625	$ -	$ 30	1.63	100.0%	0.00	0.0%	0.00	0.00%

Table 6.2 shows the results for the layered coverage of the country due to hurricane.

Table 6.2 Premium variation by layers for the country due to hurricane

Layer	Percentage of Expected Loss	Layer Limit ($ Million)	Upper Layer ($ Million)	Layer Premium ($ Million)	Total premium of layer (‰)	Total premium of layer % of the Total	Premium Left (upper layer) (‰)	Premium Left (upper layer) % of the Total Premium	Δ Premium (C_i-C_{i-1}) (‰)	Δ Premium (C_i-C_{i-1}) % of the Total
1	0.10%	$ 19	$ 18,606	$ 8	0.45	7.9%	5.26	92.1%	0.45	7.86%
2	0.30%	$ 56	$ 18,569	$ 19	1.02	17.9%	4.69	82.1%	0.58	10.07%
3	0.60%	$ 112	$ 18,513	$ 31	1.64	28.7%	4.07	71.3%	0.62	10.82%
4	1.00%	$ 186	$ 18,439	$ 42	2.24	39.3%	3.47	60.7%	0.60	10.53%
5	2.00%	$ 373	$ 18,253	$ 60	3.23	56.6%	2.48	43.4%	0.99	17.33%
6	3.00%	$ 559	$ 18,066	$ 72	3.85	67.4%	1.86	32.6%	0.62	10.80%
7	4.00%	$ 745	$ 17,880	$ 79	4.27	74.7%	1.44	25.3%	0.42	7.33%
8	5.00%	$ 931	$ 17,694	$ 85	4.56	79.9%	1.15	20.1%	0.29	5.14%
9	6.00%	$ 1,118	$ 17,508	$ 89	4.79	83.9%	0.92	16.1%	0.23	4.01%
10	7.00%	$ 1,304	$ 17,321	$ 92	4.96	86.9%	0.75	13.1%	0.17	2.98%
11	8.00%	$ 1,490	$ 17,135	$ 95	5.09	89.2%	0.62	10.8%	0.13	2.29%
12	9.00%	$ 1,676	$ 16,949	$ 97	5.20	91.0%	0.52	9.0%	0.10	1.82%
13	10.00%	$ 1,863	$ 16,763	$ 99	5.29	92.6%	0.42	7.4%	0.09	1.64%
14	11.00%	$ 2,049	$ 16,576	$ 100	5.35	93.6%	0.36	6.4%	0.06	1.04%
15	12.00%	$ 2,235	$ 16,390	$ 101	5.41	94.7%	0.30	5.3%	0.06	1.04%
16	13.00%	$ 2,421	$ 16,204	$ 102	5.46	95.7%	0.25	4.3%	0.06	0.98%
17	14.00%	$ 2,608	$ 16,018	$ 102	5.49	96.2%	0.22	3.8%	0.03	0.53%
18	15.00%	$ 2,794	$ 15,831	$ 103	5.52	96.7%	0.19	3.3%	0.03	0.53%
19	16.00%	$ 2,980	$ 15,645	$ 103	5.55	97.3%	0.16	2.7%	0.03	0.53%
20	17.00%	$ 3,166	$ 15,459	$ 104	5.59	97.8%	0.13	2.2%	0.03	0.53%
21	20.00%	$ 3,725	$ 14,900	$ 105	5.63	98.5%	0.08	1.5%	0.04	0.73%
22	25.00%	$ 4,656	$ 13,969	$ 106	5.67	99.3%	0.04	0.7%	0.05	0.81%
23	30.00%	$ 5,588	$ 13,038	$ 106	5.70	99.7%	0.01	0.3%	0.02	0.41%
24	35.00%	$ 6,519	$ 12,106	$ 106	5.70	99.9%	0.01	0.1%	0.01	0.11%
25	40.00%	$ 7,450	$ 11,175	$ 106	5.71	100.0%	0.00	0.0%	0.01	0.10%
26	45.00%	$ 8,381	$ 10,244	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.02%
27	50.00%	$ 9,313	$ 9,313	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.02%
28	60.00%	$ 11,175	$ 7,450	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.01%
29	70.00%	$ 13,038	$ 5,588	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.00%
30	80.00%	$ 14,900	$ 3,725	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.00%
31	90.00%	$ 16,763	$ 1,863	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.00%
32	100.00%	$ 18,625	$ -	$ 106	5.71	100.0%	0.00	0.0%	0.00	0.00%

For the cost analysis of different layers, two basic parameters are defined in accordance with the following elements:

y_D : Lower limit of the layer

y_L : Upper limit of the layer

$\bar{y}$: Total premium from value 0 loss to the total insurance value.

$\bar{y}_r$: Premium obtained to protect a layer located between y_D y y_L.

It is defined:

Z_R factor. It is the quotient between the premium of a specific layer, $\overline{y}_r$ (usually placed between the value 0 loss and a value of y_L) and the total premium in percentage (from the total insurable value) in percentage.

$$Z_R = \frac{\overline{y}_r}{\overline{y}}$$

ROL: rate-on-line is the quotient between the premium of the layer, $\overline{y}_r$, and the total value of the layer, y_L-y_D, as follows:

$$ROL = \frac{\overline{y}_r}{y_L - y_D}$$

When y_D=0 and y_L is the exposure value for the country, *ROL* is the total premium expressed as a fraction of the total exposure value for the country.

The following figures show the variations of the Z_R factor and *ROL,* defined above with the upper limit of the loss. This value can be equal to the total exposure value in percentage.

Figure 6.1 and Figure 6.2 show the variations of the Z_R factor and ROL for the country due to earthquake.

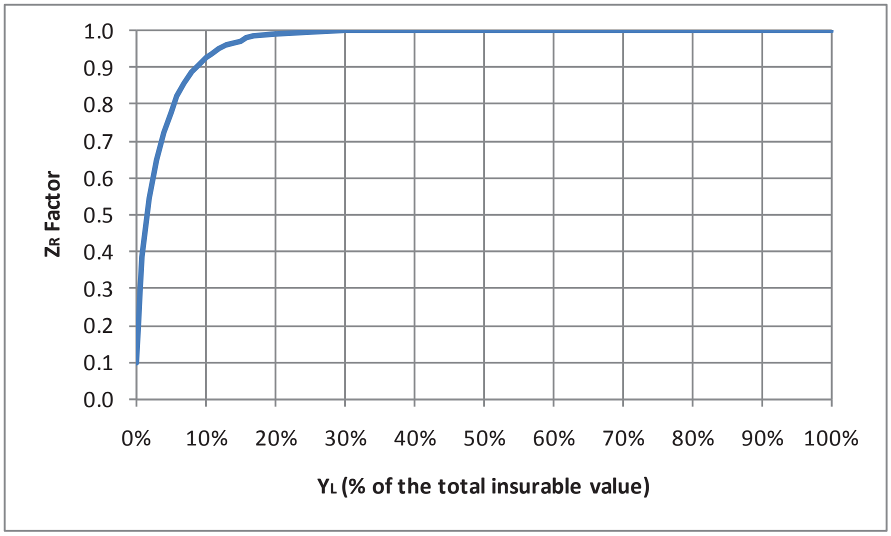


Figure 6.1 Premium variation by layers - Z_R for the country due to earthquake

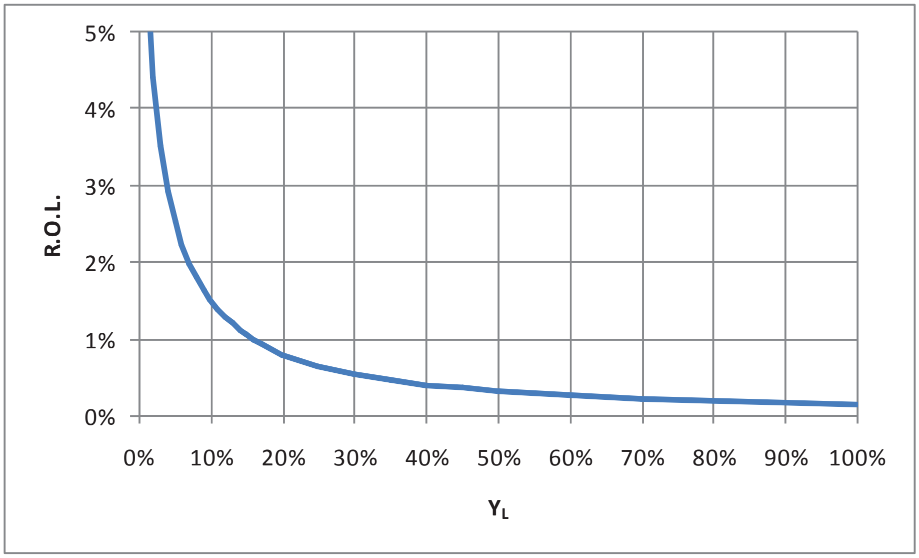


Figure 6.2 Premium variation by layers – ROL for the country due to earthquake

Figure 6.3 and Figure 6.4 show the variations of the Z_R factor and *ROL for the country due to hurricane.*

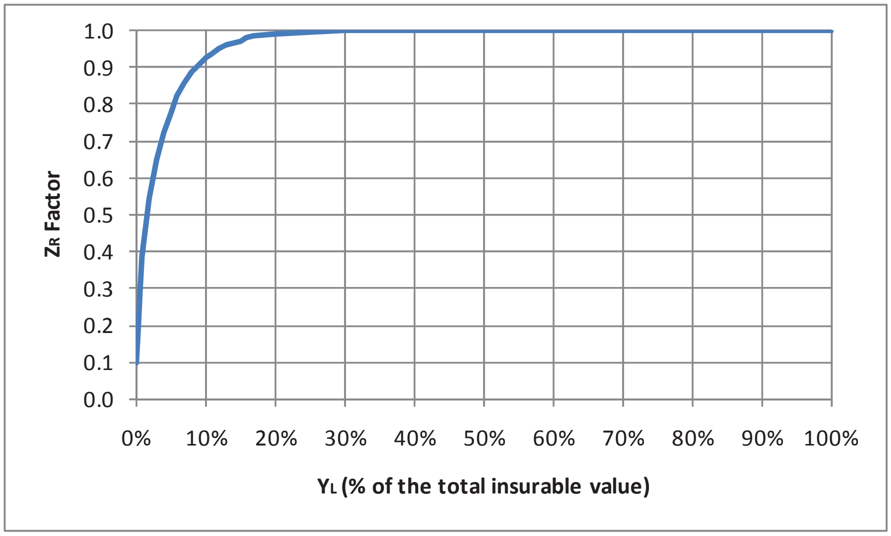


Figure 6.3 Premium variation by layers - Z_R for the country due to hurricane

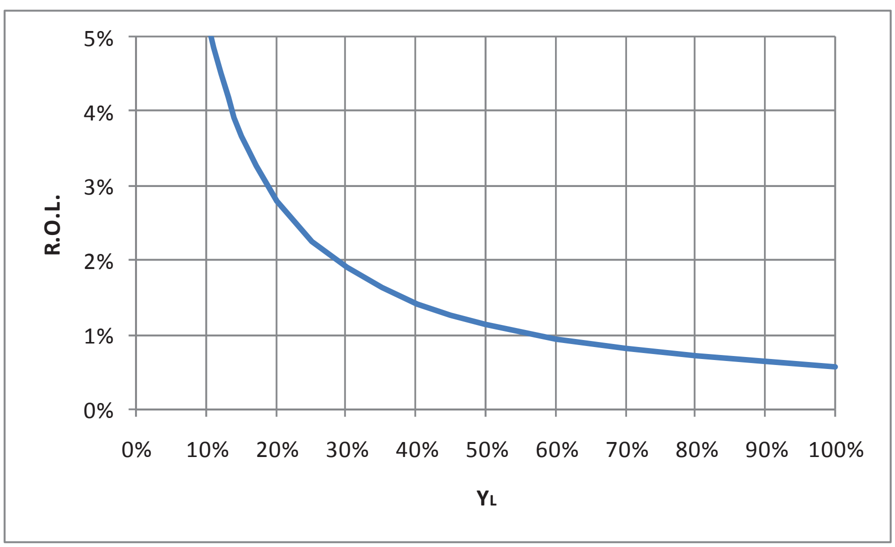


Figure 6.4 Premium variation by layers – ROL for the country due to hurricane

The figures and the tables showed above can be used to estimate the risk premium for any desired layer. Particularly, using Table 6.1 and Table 6.2 is possible to get the risk premium of different intermediate layers.

The way to use those tables is defining the lower limit of the layer (in terms of the loss in percentage according to the insurable value, y_D) and the upper limit of responsability (in percentage of the insurable value, y_L). The value of the premium refered to the layer with losses between y_D and y_L is obtained to substract the premium of the layer 0 to $y_{D,}$ from the premium of the layer 0 to y_L. This table allows the estimation of any layer and the determination of the most efficient or desirable layered structure.

Given that the exposure value of the assets in the country is US$ 18,600 million, the value of the premium for earthquake for a layer with a priority between 3% (equal to US$ 560 million) to 11% (equal to US$ 2,000 million, close to a PML value of 500 years of return period, 10.8%) would be 0.43‰. That means the subtraction between a premium of 1.53‰ (corresponding to 11%) and the premium of 1.05‰ (corresponding to 3%). In economic values that is US$ 20 million substracted from US$28 million: the result is US$ 8 million. Clearly, if the desire is to cover a lower layer to a limit, for example, of US$ 1,400 million (close to a PML value of 250 years of return period) the premium value for this layer from the priority would be 0.39‰ or US$ 7 million.

On the other hand, given that the exposure value of the assets in the country is US$ 18,625 million, the value of the premium for hurricane for a layer with a priority between 3% (equal to US$ 559 million) to 17% (equal to US$ 3,166 million, close to a PMLvalue of 500 years of return period, 16.9%) would be 1.7‰. That means the subtraction between a premium of 5.59‰ (corresponding to 17%) and the premium of 3.85‰ (corresponding to 3%). In economic values that is US$ 72 million substracted from US$ 104 million: the result is US$ 32 million. Clearly, if the desire is to cover a lower layer to a limit, for example, of US$ 2,421 million (close to a PML value of 250 years of return period) the premium value for this layer from the priority would be 1.6‰ or US$ 30 million.

The financial risk arising from possible future disasters due to hurricanes is high for the society in Jamaica. For this reason it is important to explore the possibility of promoting a strategy of financial protection for both the public and private sectors. Currently there are different instruments or products that have been used by different countries, including developing countries. It is convenient for the government that the private sector can cover its losses when damage occurs. This is the reason why some countries have promoted voluntary and mandatory collective insurance, for example of housing, with or without government participation. Similarly, alternatives have been identified for financial protection of public assets and to cover the losses of the lower-income socio-economic strata that at the end will be a fiscal liability due to their economic inability to pay an insurance coverage.

6.2 ANALYSIS BY LAYERS OF LOSS FOR FISCAL LIABILITY

The government in addition of its role of decision-maker and regulator is also an important property owner in all territorial levels. It should manage its risks not only taking into account risk reduction but also considering risk retention and transfer. It is also responsible of risks associated to the damage of private sector, when it is covering the post-event financial recover of low-income owners.

For this reason the fiscal vulnerability reduction natural disasters should include: evaluation the financial risk for the State and its impact in the public finances; construction of a strategy for the financial coverage of risk of the State; and with the use of advanced techniques of loss evaluation to study the risk retention and transfer alternatives.

Table 6.3 shows the results for the layered coverage of the fiscal liability due to earthquake.

Table 6.3 Premium variation by layers for the fiscal liability due to earthquake

Layer	Percentage of Expected Loss	Layer Limit ($ Million)	Upper Layer ($ Million)	Layer Premium ($ Million)	Total premium of layer		Premium Left (upper layer)		Δ Premium (C_i-C_{i-1})	
					(‰)	% of the Total Premium	(‰)	% of the Total Premium	(‰)	% of the Total Premium
1	0.10%	$ 6	$ 5,632	$ 1	0.13	24.6%	0.39	75.4%	0.13	24.61%
2	0.30%	$ 17	$ 5,621	$ 1	0.22	42.0%	0.30	58.0%	0.09	17.43%
3	0.60%	$ 34	$ 5,604	$ 2	0.29	56.9%	0.22	43.1%	0.08	14.86%
4	1.00%	$ 56	$ 5,581	$ 2	0.36	69.1%	0.16	30.9%	0.06	12.17%
5	2.00%	$ 113	$ 5,525	$ 2	0.44	84.9%	0.08	15.1%	0.08	15.83%
6	3.00%	$ 169	$ 5,468	$ 3	0.47	91.6%	0.04	8.4%	0.03	6.72%
7	4.00%	$ 225	$ 5,412	$ 3	0.49	95.2%	0.02	4.8%	0.02	3.60%
8	5.00%	$ 282	$ 5,356	$ 3	0.50	97.2%	0.01	2.8%	0.01	2.02%
9	6.00%	$ 338	$ 5,299	$ 3	0.51	98.4%	0.01	1.6%	0.01	1.20%
10	7.00%	$ 395	$ 5,243	$ 3	0.51	99.0%	0.01	1.0%	0.00	0.54%
11	8.00%	$ 451	$ 5,186	$ 3	0.51	99.5%	0.00	0.5%	0.00	0.48%
12	9.00%	$ 507	$ 5,130	$ 3	0.51	99.6%	0.00	0.4%	0.00	0.16%
13	10.00%	$ 564	$ 5,074	$ 3	0.51	99.8%	0.00	0.2%	0.00	0.15%
14	11.00%	$ 620	$ 5,017	$ 3	0.51	99.9%	0.00	0.1%	0.00	0.10%
15	12.00%	$ 676	$ 4,961	$ 3	0.51	99.9%	0.00	0.1%	0.00	0.03%
16	13.00%	$ 733	$ 4,905	$ 3	0.51	99.9%	0.00	0.1%	0.00	0.03%
17	14.00%	$ 789	$ 4,848	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.03%
18	15.00%	$ 846	$ 4,792	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
19	16.00%	$ 902	$ 4,735	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
20	17.00%	$ 958	$ 4,679	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
21	20.00%	$ 1,127	$ 4,510	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.01%
22	25.00%	$ 1,409	$ 4,228	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
23	30.00%	$ 1,691	$ 3,946	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
24	35.00%	$ 1,973	$ 3,664	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
25	40.00%	$ 2,255	$ 3,382	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
26	45.00%	$ 2,537	$ 3,101	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
27	50.00%	$ 2,819	$ 2,819	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
28	60.00%	$ 3,382	$ 2,255	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
29	70.00%	$ 3,946	$ 1,691	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
30	80.00%	$ 4,510	$ 1,127	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
31	90.00%	$ 5,074	$ 564	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%
32	100.00%	$ 5,637	$ -	$ 3	0.51	100.0%	0.00	0.0%	0.00	0.00%

Table 6.4 shows the results for the layered coverage of the fiscal liability due to hurricane.

Table 6.4 Premium variation by layers for the fiscal liability due to hurricane

Layer	Percentage of Expected Loss	Layer Limit ($ Million)	Upper Layer ($ Million)	Layer Premium ($ Million)	Total premium of layer		Premium Left (upper layer)		Δ Premium (C_i-C_{i-1})	
					(‰)	% of the Total Premium	(‰)	% of the Total Premium	(‰)	% of the Total Premium
1	0.10%	$ 6	$ 5,632	$ 3	0.49	11.2%	3.85	88.8%	0.49	11.19%
2	0.30%	$ 17	$ 5,621	$ 6	1.09	25.2%	3.25	74.8%	0.61	13.96%
3	0.60%	$ 34	$ 5,604	$ 10	1.69	39.1%	2.64	60.9%	0.60	13.92%
4	1.00%	$ 56	$ 5,581	$ 13	2.25	51.8%	2.09	48.2%	0.55	12.71%
5	2.00%	$ 113	$ 5,525	$ 17	3.07	70.7%	1.27	29.3%	0.82	18.95%
6	3.00%	$ 169	$ 5,468	$ 20	3.49	80.4%	0.85	19.6%	0.42	9.70%
7	4.00%	$ 225	$ 5,412	$ 21	3.75	86.4%	0.59	13.6%	0.26	6.01%
8	5.00%	$ 282	$ 5,356	$ 22	3.92	90.4%	0.42	9.6%	0.17	3.93%
9	6.00%	$ 338	$ 5,299	$ 23	4.04	93.1%	0.30	6.9%	0.12	2.76%
10	7.00%	$ 395	$ 5,243	$ 23	4.11	94.7%	0.23	5.3%	0.07	1.62%
11	8.00%	$ 451	$ 5,186	$ 24	4.17	96.3%	0.16	3.7%	0.07	1.52%
12	9.00%	$ 507	$ 5,130	$ 24	4.21	97.0%	0.13	3.0%	0.03	0.77%
13	10.00%	$ 564	$ 5,074	$ 24	4.24	97.8%	0.10	2.2%	0.03	0.75%
14	11.00%	$ 620	$ 5,017	$ 24	4.26	98.4%	0.07	1.6%	0.02	0.58%
15	12.00%	$ 676	$ 4,961	$ 24	4.28	98.7%	0.06	1.3%	0.01	0.32%
16	13.00%	$ 733	$ 4,905	$ 24	4.29	99.0%	0.04	1.0%	0.01	0.32%
17	14.00%	$ 789	$ 4,848	$ 24	4.31	99.3%	0.03	0.7%	0.01	0.32%
18	15.00%	$ 846	$ 4,792	$ 24	4.31	99.4%	0.02	0.6%	0.00	0.11%
19	16.00%	$ 902	$ 4,735	$ 24	4.32	99.5%	0.02	0.5%	0.00	0.11%
20	17.00%	$ 958	$ 4,679	$ 24	4.32	99.7%	0.02	0.3%	0.00	0.11%
21	20.00%	$ 1,127	$ 4,510	$ 24	4.33	99.9%	0.01	0.1%	0.01	0.20%
22	25.00%	$ 1,409	$ 4,228	$ 24	4.33	100.0%	0.00	0.0%	0.01	0.12%
23	30.00%	$ 1,691	$ 3,946	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.02%
24	35.00%	$ 1,973	$ 3,664	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.01%
25	40.00%	$ 2,255	$ 3,382	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
26	45.00%	$ 2,537	$ 3,101	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
27	50.00%	$ 2,819	$ 2,819	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
28	60.00%	$ 3,382	$ 2,255	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
29	70.00%	$ 3,946	$ 1,691	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
30	80.00%	$ 4,510	$ 1,127	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
31	90.00%	$ 5,074	$ 564	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%
32	100.00%	$ 5,637	$ -	$ 24	4.34	100.0%	0.00	0.0%	0.00	0.00%

The following figures show the variations of the Z_R factor and the *ROL,* defined above with the upper limit of the loss. This value can be equal to the total exposure value in percentage.

Figure 6.5 and Figure 6.6 show the variations of the ZR factor and the ROL for fiscal liability due to earthquake.

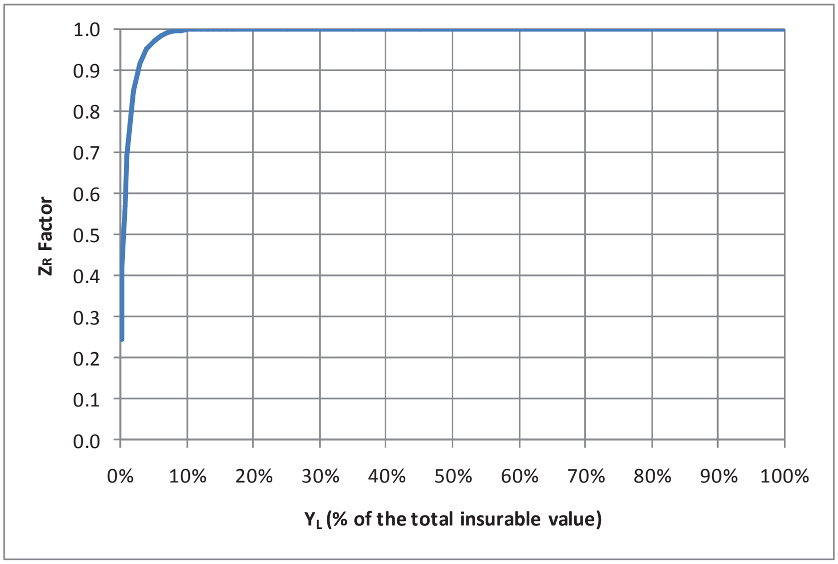


Figure 6.5 Premium variation by layers - Z_R for fiscal liability due to earthquake

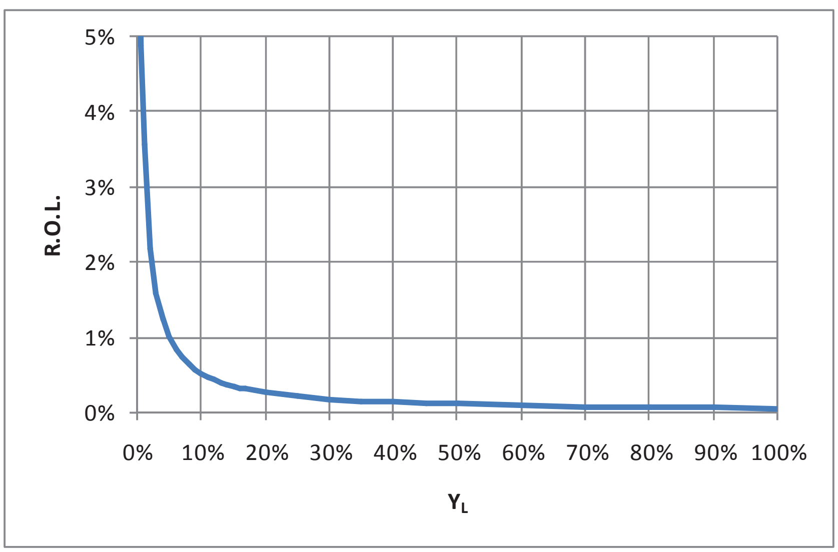


Figure 6.6 Premium variation by layers – ROL for fiscal liability due to earthquake

Figure 6.7 and Figure 6.8 show the variations of the ZR factor and the ROL, for fiscal liability due to hurricane.

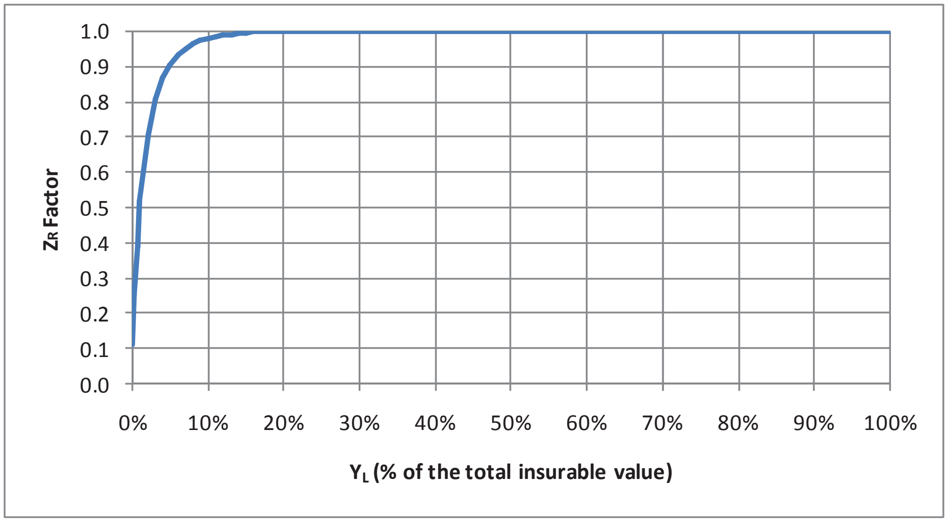


Figure 6.7 Premium variation by layers - Z_R for fiscal liability due to hurricane

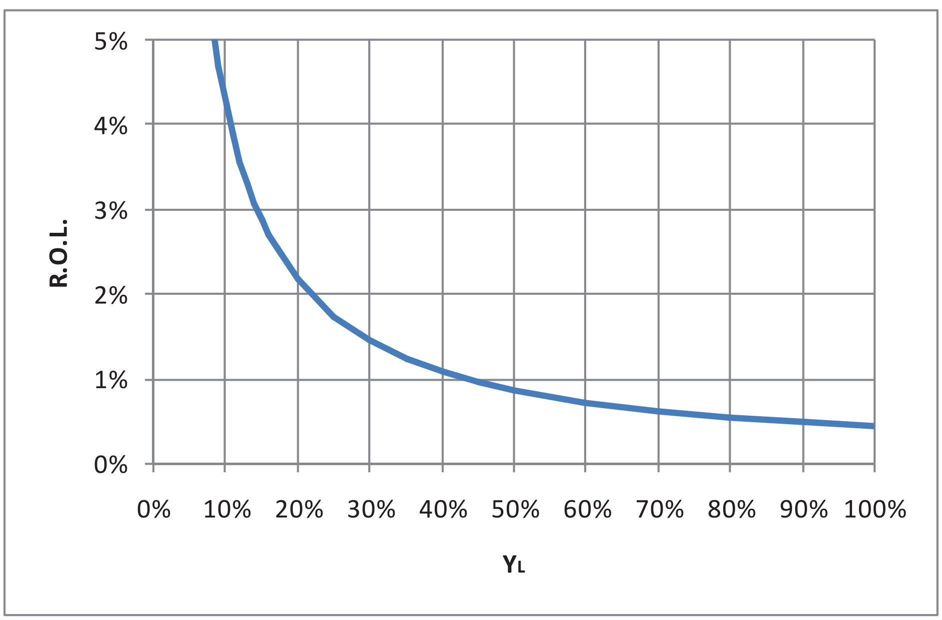


Figure 6.8 Premium variation by layers – ROL for fiscal liability due to hurricane

The figures and the tables showed above can be used to estimate the risk premium for any desired layer. Particularly, using Table 6.3 and the
Table 6.4 is possible to get the risk premium of different intermediate layers.

Given that the exposure value of the public assets and low-income properties in the country is US$5,637 million, the value of the premium for earthquake for a layer of fiscal liability with a priority between 3% (equal to US$169 million) to 11% (equal to US$620 million, close to a PML value of 500 years of return period, 10.8%) would be 0.03‰. That means the subtraction between a premium of 0.51‰ (corresponding to 11%) and the premium of 0.47‰ (corresponding to 3%). In economic values that is US$2.7 million substracted from US$2.9 million: the result is US$0.2 million. Clearly, if the desire is to cover a lower layer to a limit, for example, of US$451 million (close to a PML value of 250 years of return period) the premium value for this layer from the priority would be 0.03‰ or US$0.2 million.

On the other hand, given that the exposure value of the public assets and low-income properties in the country is US$5,637 million, the value of the premium for hurricane for a layer of fiscal liability with a priority between 3% (equal to US$169 million) to 17% (equal to US$958 million, close to a PML value of 500 years of return period, 16.9%) would be 0.83‰. That means the subtraction between a premium of 4.32% (corresponding to 17%) and the premium of 3.49‰ (corresponding to 3%). In economic values that is US$19.7 million substracted from US$24.4 million: the result is US$4.7 million. Clearly, if the desire is to cover a lower layer to a limit, for example, of US$733 million (close to a PML value of 250 years of return period) the premium value for this layer from the priority would be 0.79‰ or US$4.5 million.

In summary, this approach allows building a risk financing structure with different alternatives of risk retention and risk transfer for the country. The premiums of each layer of loss are the base to estimate the financial cost of the layer coverage and it is possible to explore the optimal risk financing structure taking into account, for example, self-insurance, reserves funds, contingent credits, budged reassignment, captives, standard or

parametric insurance/reinsurance, catastrophe bonds, international loans, taxes, etc. Use of one versus the other reverts to the discussion regarding risk governance and risk tolerance levels, and cost/benefit tradeoffs arising from the search for optimum value of the financial protection.

7 DISASTER DEFICIT INDEXES

Disaster risk and vulnerability indicators and performance risk management benchmarks are needed to facilitate decision makers' access to relevant information as well as the identification and proposal of effective policies and actions. The Indicators System of Disaster Risk and Risk Management for the Americas (IDB-IDEA) was proposed to meet this need and to enable the depiction of disaster risk at the national and subnational level, allowing the identification of vulnerability key issues by economic and social category. It also made possible the creation of national risk management benchmarks in order to establish performance targets for improving management effectiveness. Four groups of composite indicators were designed to represent the main elements of vulnerability and show each country's progress in managing risk. One of these indicators related to the macroeconomic potential impact of future disasters, the *Disaster Deficit Index* (DDI), has been useful to give account the fiscal vulnerability of a country regarding the disaster risk. These indicators were developed in 2004 by the Institute of Environmental Studies (IDEA in Spanish) of the National University of Colombia, in Manizales, and have been updated in 2009 for most countries of the region for the IDB by this consortium of consultants (ERN – America Latina), in the framework of its action plan and new policy on disaster risk management. Program reports, technical details and the application results for the countries in the Americas can be consulted at the following web page: http://idea.unalmzl.edu.co

The DDI reflects country risk from a macroeconomic and financial perspective according to possible catastrophic events. It requires the estimation of critical impacts during a given period of exposure, as well as the country's financial ability to cope with the situation. This index measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation. Construction of the DDI requires undertaking a forecast of the potential loss, like the PML

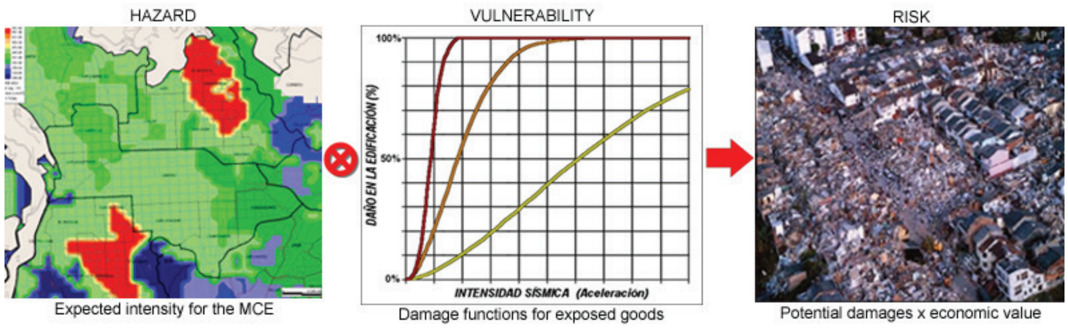
and the AAL calculated in this report, based on historical and scientific evidence. There are two relevant types of DDI for this report.

The first one, the DDI_{MCE} that captures the relationship between the demand for contingent resources to cover the fiscal liability or potential losses for the public sector, caused by the Maximum Considered Event (MCE) –that can be the PML–, and the public sector's economic resilience; i.e. the availability of internal and external funds for restoring affected inventories.

This country's financial ability to cope with the situation takes into account: *Insurance and reinsurance payments* that the country would approximately receive for goods and infrastructure insured by government; *Disaster reserve funds* that the country has available during the evaluation year; public, private, national or international *aid and donations*; *New taxes* that the country could collect in case of disasters; *Budgetary reallocations* which usually corresponds to the margin of discretional expenses available to the government; *External credit* that the country could obtain from multilateral organisms and in the capital market; and *Internal credit* the country may obtain from commercial banks as well as the central bank. IDEA (2005) presents a method for estimating taxes on financial transactions. In addition, it presents a model for calculating the external financial situation of a country and the access to internal credit taking into account the associated uncertainties. It is important to indicate that this estimation is proposed considering restrictions or feasible values and without considering possible associated costs of access to some of these funds and opportunity costs which could be important.

A DDI_{MCE} greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the DDI_{MCE}, the greater the gap between losses and the country's ability to face them. If constrictions for additional debt exist, this situation implies the impossibility to recover.

Figure 7.1 shows a scheme about the calculation of the DDI_{MCE}.



$$DDI = \frac{\text{MCE loss}}{\text{Economic resilience}}$$

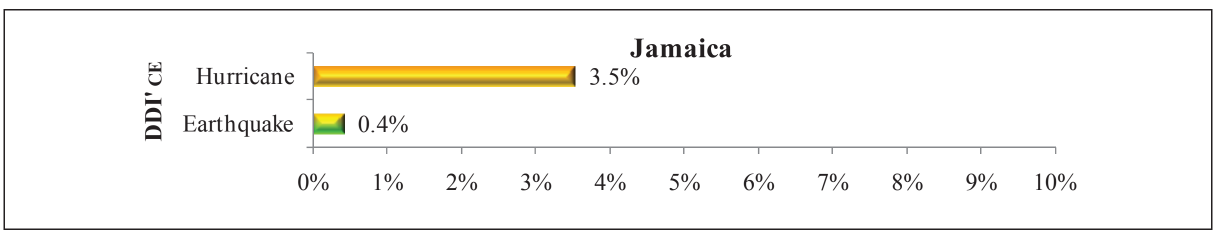
Description	Indicators
Insurance and reinsurance payments	F_1^P
Reserve funds for disasters	F_2^P
Aid and donations	F_3^P
New taxes	F_4^P
Budgetary reallocations	F_5^P
External credit	F_6^P
Internal credit	F_7^P

Figure 7.1 Schematic description of the DDI_{MCE} calculation

The second, the DDI_{CE} that captures the portion of a country's annual Capital Expenditure (CE) that corresponds to the expected annual loss or the pure risk premium; i.e. the AAL. This indicator shows the percentage of the annual investment budget that would be needed to pay for future disasters. In this case the pure premium value is equivalent to the annual average investment or saving that a country would have to approximately cover losses associated with major future disasters. In the case that annual losses represents a significant fraction of the country's annual capital investment it is predicted that over time there will be a deficit due to disasters that inevitably increase the overall debt levels. That is to say, the country does not have sufficient resources to face future disasters. In the case that restrictions to additional indebtedness should exist, this situation would signify that recovery is impossible.

For the evaluation these indexes it is necessary to evaluate the potential economical losses in country due to natural events using a simplified method to dimension the inventory of exposed assets based on proxy values validated by institutions and local consultants in each country. Basically, a set of parameters are estimated using the cost per square meter of different construction classes, the number of constructed square meters in each main cities in relation with the number of inhabitants and the distribution of the constructed areas in public and private portfolios of buildings; inventory of assets that, in case of disaster, would be a fiscal responsibility.

Using the exposure proxy developed for this country specific-risk evaluation that have been made and validated based on random samples, the indexes have been evaluated using the PML and AAL for the fiscal liability for hurricane and earthquake. The Figure 7.2 presents the results of the DDI_{CE} and DDI_{MCE} for different return periods.



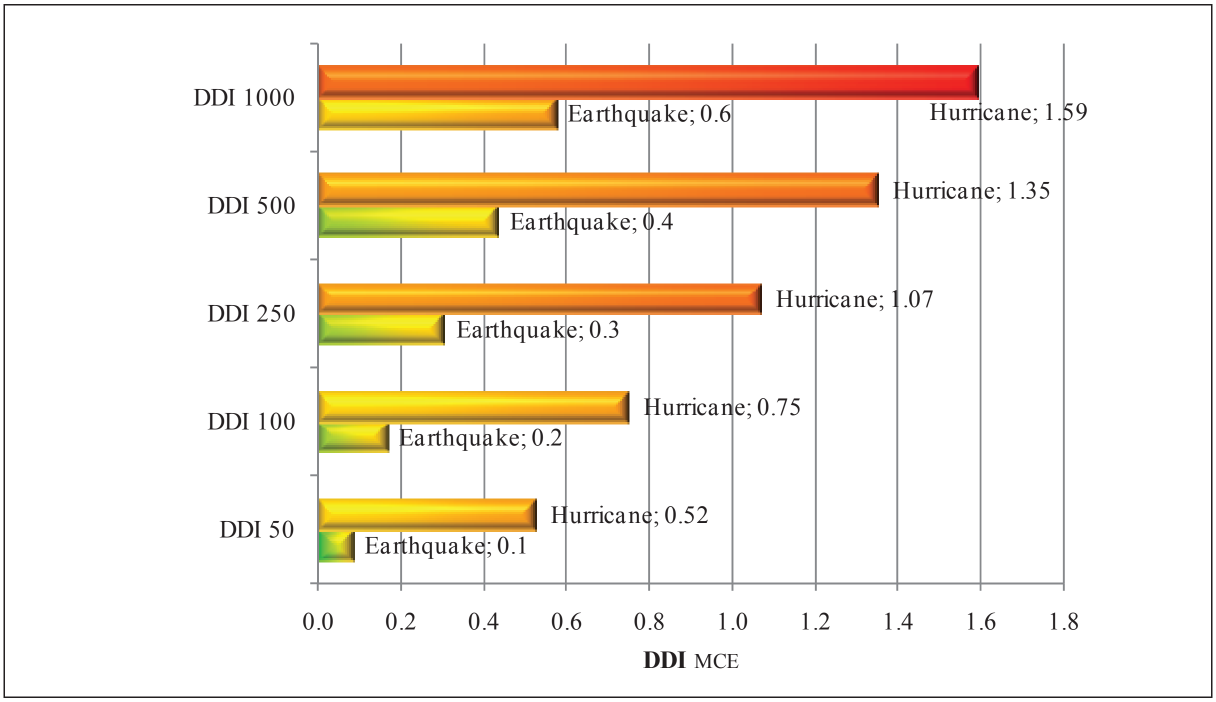


Figure 7.2 Results of the DDI_{CE} and DDI_{MCE} for different return periods.

This is an approximated method as the original, however it is more accurate due to the major details of the exposure proxy and the type of assumptions made to reflect the physical direct effects. These indexes are lower than those calculated by the original method because mainly the latter is more conservative and coarse grain and it has been calibrated to include non-structural damage and indirect economical effects. In any case both approaches allow to government officials using the model with relatively small efforts and without having the necessity of very detailed cadastral data.

In summary, each DDI gives an interested and useful image, for a Ministry of Finance and Economics, related to the potential financial sustainability problem of the country regarding the potential disasters. On the other hand, they together give a compressed picture of the fiscal vulnerability of the country due to disasters.

These indicators provide a simple way of measuring a country's fiscal exposure and potential deficit (or contingent liabilities) in case of extreme disasters. They allow national decision makers to measure the budgetary implications of such an event and highlight the

importance of including this type of information in financial and budgetary processes. These results substantiate the need to identify and propose effective policies and actions such as, for example, using insurance and reinsurance (transfer mechanisms) to protect government resources or establishing reserves based on adequate loss estimation criteria. Other such actions include contracting contingent credits and, in particular, the need to invest in risk reduction based on structural retrofitting and rehabilitation, and nonstructural prevention and mitigation, to reduce potential damage and losses as well as the potential economic impact of disasters.

It is important to point out that the calculation of the IDDs using the results of this study of risk is more refined than that obtained in the framework of the program of risk indicators and risk management for the Americas. Although the methods are conceptually similar, the modeling done in this study is less coarse grain than that done in the framework of indicators program. Differences in the probable maximum loss may be two or three times since the model used in indicators project is more approximate, conservative and generally considers the indirect impact; i.e.consequential and indirect losses. The model applied here is of higher resolution and data that have been included only has been used for determining direct physical damage.

8 REFERENCES

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ANNEX 1. AVAILABLE GEOGRAPHIC INFORMATION

Administrative Division

- JAM0.shp: borders limits at national level.
- JAM1.shp: divisions and names of parishes at national level.

Infrastructure

- JAM_roads.shp: roads and highways according to type and importance at national level.
- JAM_rails.shp: existing train network and condituons for operation.

Geographical Issues

- JAM_water_areas_dcw.shp: lakes and names.
- JAM_water_lines_dcw.shp: rivers ana names.

ANNEX 2. METODOLOGY FOR THE EVALUATION OF EXPOSED ELEMENTS

1 BUILT AREA BY GROUP OF USE

1.1 General Indexes

Table A.2.1, shows the assumed values for the index of built area per capita for each complexity level and type of use.

Table A. 2.1
Index of built area per capita (m²/Hab)

Level of Complexity	Use [V 5]									
	Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov
	m^2/Pop LP	m^2/Pop MP	m^2/Pop HP	m^2/WF	m^2/WF	m^2/beds	m^2/stud.	m^2/beds	m^2/stud.	m^2/PE
High	5	15	25	20	50	10	12	8	10	5
Medium	4	12	22	20	50	8	10	6	8	5
Low	3	11	20	20	50	6	8	4	6	5

Table A.2.2 shows the percentage of public health and education for each level of complexity.

Table A. 2.2
Percentage of education and public health

Level of Complexity	Public Education	Public Heath
	(%)	(%)
High - 1	50%	68%
Medium - 2	80%	92%
Low - 3	100%	100%

1.2 Residential Buildings

Residential buildings are subdivided in three categories: Res PB, which holds the low economic capacity population; Res PM, which holds the average economic capacity population and Res PA, holding the high economic capacity population.

To calculate the residential building area of each parish, an initial assumption is made regarding the average built area that a person needs to live and depending on the level of complexity of each parish and the category being analyzed: Res PB, PM or Res Res PA

(See Table A.2.1) Additionally for each level of complexity it necessary to consider the percentage related to the population PB, which is the population with low economic capacity, the population PM which is the population with medium economic capacity and the population PA which is the population with high economic capacity. With this information and with the population of each parish the constructed area is calculated as follows: For each complexity level, population percentages for each economic capacities considered are calculated (PB for low economic capacity, PM for average economic capacity and PA for high economic capacity):

$$Area\,(m^2) = Pob[Hab] * MP\left[m^2/Hab\right] * PCE\,[\%]$$

where: *Area:* residential building area for an economic capacity
Pob: parish population
MP: average built area index per capita in the residential sector, taking into account the category being analyzed and the parish complexity level.
PCE: percentage of population for an economic capacity. It depends on the parish complexity level.

1.3 Commercial Buildings

Commercial built area is calculated using the occupancy rates indicated in Table A.2.1, and the population employed in commercial services, as follows:

$$Acom(m^2) = CTC * MC\left[m^2/T\right]$$

where: *Acom:* commercial built area
CTC: Total workers in commercial services of each parish
MC: index of average built area per employee in the commercial sector (see Table A.2.1).
T: Worker

1.4 Industrial Buildings

Industrial built area is calculated as follows:

$$Aind(m^2) = CTI * MI\left[m^2/T\right]$$

where: *Aind:* industrial built area
CTI: total industry workers in each parish

MI: index of average built area per industry worker (see Table A.2.1).
T: Worker

1.5 Education Buildings (Private and Public)

For the calculation of building area for education, it is assumed the average built area per student in a school; a value which depends on the level of complexity of each parish and whether the entity is public or private (See Table A.2.2). On the other hand, with the percentage of public education for each level of complexity (see Table A.2.3), it is possible to estimate the area built in the education sector. It is is computed assuming an average built area per student in a school, value which depends on the complexity level of each parish and the public or private character of the institution (see Table A.2.1), and the percentage of public education students for each complexity level (see .Table A.2.2):

$$Aedu(m^2) = CE[Est] * ME\left[m^2/_{Est}\right] * PEP[\%]$$

where:

A*edu:* educational built area
CE: number of students of each parish
ME: index of average built area per student. It depends on the parish complexity level.
PEP: percentage of public education students for each complexity level (see Table A.2.2).

For private education the PEP is replaced for (1-PEP).

1.6 Health Buildings (Private and Public)

Health built area is calculated using an assumption on the occupied area by a hospital bed, value which depends on the complexity level of each parish and the public or private character of the institution (see Table A.2.1). Since the hospital bed quantity and the percentage of public beds is known for each parish, public health bed percentage of each complexity level is calculated (see Table A.2.2). With the foregoing, health built area is calculated as follows:

$$Asal(m^2) = Pob[Hab] * CH[Und / Hab] * MS\left[m^2/_{Und}\right] * PSP[\%]$$

where:

Asal: Health built area
Pob: parish population
CH: number of beds per capita
MS: occupied area by a hospital bed. It depends on the parish complexity level
PSP: Percentage of public health. It depends on the Parish complexity level.

For private health PSP is replaced for (1-PSP).

1.7 Government Buildings

Government built area is calculated using an assumption on the occupancy index for government workers shown in Table A. 2.1. With the amount of government employees for each parish, the government built area is calculated as follows:

$$Agov(m^2) = CEG[EG] * MG\left[m^2 \middle/ EG\right]$$

where: *Agov:* government built area
CEG: number of government employees in each parish.
MG: average built area for a government worker.
EG: government employee.

2 EXPOSED VALUE BY GROUP OF USE

Exposure value is calculated using the country official minimum income in US$, and an assuming that the value of each square meter of Res PB, on a high complexity level is equal to the country official minimum income in US$, 70% of this value for an average complexity level, and 50% for a low complexity level (see Table A. 2.3). Other uses are:

Res MP = 2 * Res LP
Res HP = 3 * Res LP
Com = Res PM
Ind = Res HP
PriHealth = Res HP
PubHealth = 0.8 * PriHealth
PriEdu = Res LP
PubEdu = PriEdu
Gob = Res LP

Table A. 2.3
Exposed value by built area index (USD $ / m²)

Level of Complexity	Use (US$/m2) [V 6]									
	Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov
High	125	250	375	250	375	375	250	300	250	250
Medium	88	175	263	175	263	263	175	210	175	175
Low	63	125	188	125	188	188	125	150	125	125

Exposed value by group of use is then calculated as:

$$Vuso(US\$) = CM[m^2] * IVE\left[US\$ \middle/ m^2\right]$$

where: *Vuso:* Exposed value by group of use
CM: Parish built area for each use

IVE: Exposed value by built area index. Depends on the parish complexity level. (See Table A. 2.4)

3 BUILDING OCCUPANCY

Based on the group of use under analysis, and the parish complexity level, an assumption is made on the number of inhabitants every 100 m^2. Also an occupancy rate for use and scenario (day or night) is assumed. Table A. 2.4 shows this occupancy rates.

Table A. 2.4
Occupancy index by built area for different occupancy scenarios

Level of Complexity	Use (Pop/100m²)									
	Res LP	Res MP	Res HP	Com	Ind	PriHealth	PriEdu	PubHealth	PubEdu	Gov
High	7.0	8.0	7.0	7.0	3.0	20.0	15.0	20.0	15.0	30.0
Medium	5.0	6.0	5.0	6.0	2.0	15.0	10.0	15.0	10.0	25.0
Low	4.0	5.0	4.0	5.0	1.0	10.0	5.0	10.0	5.0	20.0
Day scene	45%	45%	45%	80%	90%	100%	80%	100%	80%	80%
Night scene	100%	100%	100%	30%	50%	100%	0%	100%	0%	0%

The previous occupation indexes are made base on the number of m² previously estimated using the methodology presented and the population assigned to each sector of use. Thus each of the indexes presented in this table has been subject to adjustments to reach the total population. Similarly, the population assigned to each scenario is base don the present work force in the country and the number of students, public and helath employees.

Knowing the parish built area, occupation is calculated as follows:

$$Ouso(Hab) = CM[m^2] * IH\left[{}^{Hab}\!/_{100m^2}\right] * PO[\%]$$

where:

Ouso: number of inhabitants for a given use
CM: Parish built area for each use.
IH: Occupancy index by built area. It depends on the parish complexity level. (See Table A.2.4)
PO: occupancy rate for use and scenario (day or night).

In general, it is important to mention that usually for the representation of the exposure it is not possible to have information element by element (for example building by building) because there are not available catastral data. In most cases a proxy is developed using indirect variables and correlations. The construction of the proxy how it was decribed in this annex depends of the existing information that can be treated by levels. The following figures describe the levels of resolution of de exposure or elements at risk.

ANNEX 3. EXPOSED PROXY VALUES

Indice General

Población	
Urbana	1,400,060 Hab
Rural	1,293,625 Hab
Total	2,693,681 Hab

	Unidad	Valor	Valor per capita	1/PIB per Capita	
Área Construida					
Área construida Urbana	m^2	62,320 x10³	44.5	-	
Densidad Construcción Urbana	m^2/m^2 terreno urbano	0.24	-	-	
Valoración Infraestructura					
Valor construcciones urbanas	USx10^6$	14,098	5,234	1.09	75.69%
Valor construcciones rurales	USx10^6$	-	-	-	-
Infraestructura Urbana	USx10^6$	1,141	815	0.17	6.13%
Infraestructura Nacional	USx10^6$	3,386	1,257	0.26	18.18%
Total Infraestructura país	**USx10^6$**	**18,625**	**6,914**	**1.44**	

VALORES EN EXPOSICION

Indice General

Sector	Unidad	Unidad per capita país	Unidad per capita sector	Valor	Valor per capita país
Construcciones Urbanas	[m^2x10^3]	[m^2 / Hab]		[USx10^6$]	[US$ / Hab]
Residencial PB	2,299	0.9	1.64 [Hab Urb]	225	84
Residencial PM	23,203	8.6	16.57 [Hab Urb]	4,915	1,825
Residencial PA	9,406	3.5	6.72 [Hab Urb]	2,962	1,099
Comercial	17,089	6.3	20 m²/FL	3,476	1,290
Industrial	4,010	1.5	50 m²/FL	1,223	454
Salud Privada	5	0.00	1.8 m²/1000Hab	2	1
Educación Privada	1,800	0.7	3.4 m²/Est	410	152
Salud Pública	16	0.01	6.0 m²/1000Hab	4	1
Educación Pública	3,796	1.4	7.2 m²/Est	739	275
Gobierno	696	0.3	5 m²/EP	142	53
Total	**62,320**	**23.1**		**14,098**	**5,234**

Sector	Ocupación Dia	Ocupación Noche	
Construcciones Urbanas	[Hab]	[Hab]	
Residencial PB	57,822	128,493	
Residencial PM	731,262	1,625,027	
Residencial PA	251,992	559,981	
Comercial	868,186	325,570	1.02
Industrial	84,827	47,126	1.06
Salud Privada	944	944	
Educación Privada	194,727	0	1.01
Salud Pública	2,731	2,731	
Educación Pública	338,454	0	
Gobierno	148,957	0	1.07
Total	**2,679,902**	**2,689,872**	

Sector	Unidad	Unidad per capita Urbano	Valor	Valor per capita Urbano	Valor por Unidad
Infraestructura Urbana			[USx10^6$]	[US$ / Hab]	
SubEst Eléctricas	-	-	84	60	-
SubEst Comunicaciones	-	-	67	48	-
Presas	-	-	0	0	-
Plantas y tanques	-	-	27	19	-
Red Acueducto	-	-	40	29	-
Red Alcantarillado	-	-	45	32	-
Red Gas	-	-	23	16	-
Aeropuertos (Terminal)	103,644 m²	74.0	150	107	1,449 US / m²
Aeropuertos (Pistas)	9 km	0.0	60	43	7 USx10^6 / km
Puertos (Bodegas)	316,672 m²	226.2	303	216	957 US / m²
Puertos (Muelle)	102,832 m²	73.4	289	206	2,807 US / m²
Puentes Urbanos	28 und	0.0	53	38	2 USx10^6 / und
Total	**-**	**-**	**1,141**	**815**	**-**

Sector	Unidad	Valor	Valor per capita Nacional	Valor por Unidad
Infraestructura Nacional	[km]	[USx10^6$]	[US$ / Hab]	[USx10^6$ / km]
Red vial principal (Vias)	905	2,352	873	2.6
Red vial secundaria (Vias)	734	239	89	0.33
Red vial principal (Puentes)	4	72	27	20
Red vial secundaria (Puentes)	5	74	28	15
Hidroelectricas (Presas)	-	85	31	-
Hidroelectricas (Casas de Maquinas)	-	44	17	-
Plantas Térmicas	-	240	89	-
Plantas Geotérmicas	-	0	0	-
Distribución energética (Subestaciones)	-	24	9	-
Distribución energética (Redes)	-	24	9	-
Comunicaciones (Líneas Fijas)	-	12	5	-
Comunicaciones (Líneas Móviles)	-	7	2.8	-
Hidrocarburos Derivados	-	100	37	-
Hidrocarburos (Gas)	-	111	41	-
Total	**-**	**3,386**	**1,257**	**-**

ANNEX 4. SEISMIC HAZARD ASSESSMENT MODEL

1 HAZARD ASSESSMENT METHODOLOGY

Seismic hazard assessment requires technical and scientific treatment, based on analytical and mathematical models. The theoretical bases of the seismic hazard assessment methodology here presented can be consulted on www.ecapra.org. In this study, seismic hazard was obtained using CRISIS2007 (Ordaz et. al. 2007). A flowchat showing the main elements of the seismic hazard model applied is shown in Figure A. 4.1. The main steps of the methodology are:

Definition and characterization of the main seismic sources: the main seismic sources are geometrically defined based on available geological and tectonic information.

Seismicity of the main sources: based on the country seismic catalogue, and previous available studies, sources seismicity parameters are assigned, following a Poisson recurrence model. Generation of a set of stochastic events consistent with the regional distribution of location, depth, frequency and magnitude of earthquakes: from the above information, a set of probable seismic events is generated through a recursive geometry division sampling of the sources, and the allocation of seismicity parameters for each segment weighted by its area contribution on the total area. For each segment a series of scenarios is generated whose magnitude depends of the source specific magnitude recurrence curve.

G*round motion attenuation model:* based on information gathered, previous hazard studies and the state of the art in spectral attenuation functions, an attenuation model is proposed at country level for the appropriate assessment of hazard intensity levels. These results are calibrated to the extent that existing information permits, with those reported in the available previous studies.

Hazard maps of representative events: maps of spatial distribution of intensity in terms of peak and spectral ground acceleration, velocity and displacement, are developed.

Probabilistic seismic hazard integration: through the probabilistic integration of the computed intensities for each of the stochastic events generated, seismic hazard maps for different ground motion intensity parameters are obtained. These are defined for different return periods.

Ground motion parameters: the main ground motion parameters that best illustrate the probable damages in infrastructure and buildings are:

- Peak ground acceleration, velocity and displacement.
- Spectral acceleration, velocity and displacement for different structural periods of vibration.

- Characteristic frequency content of ground motion signals, captured based on the corresponding spectral amplitudes.

These parameters are given for different return periods.

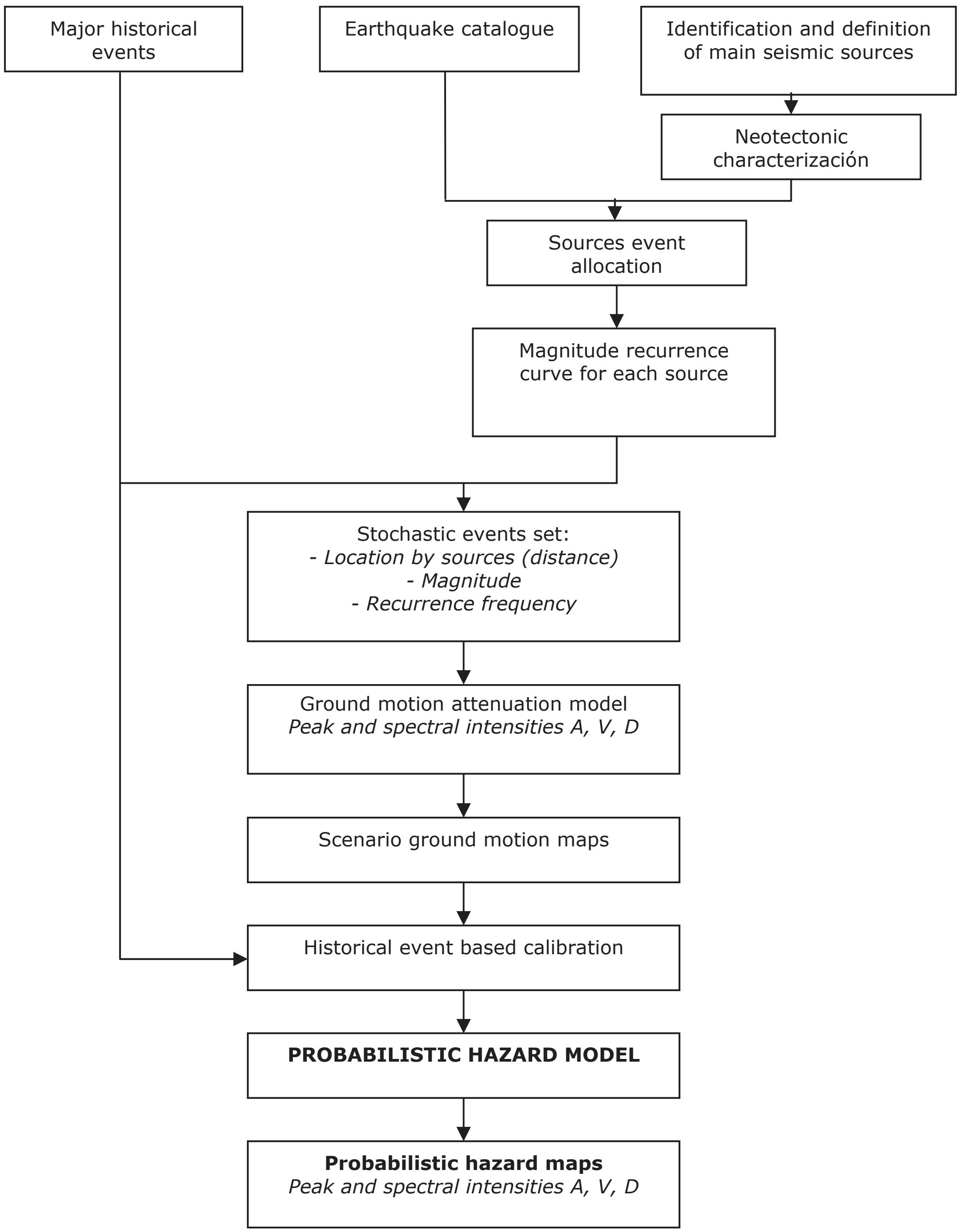

Figure A. 4.1
Flowchart of seismic hazard model

2 SEISMOTECTONICS OF JAMAICA

The Jamaican territory is an elevated portion above the sea level of the underwater volcanic platform of Nicaragua (Nicaragua Bank). Seismicity conditions of the country are associated with the interaction between the North American plate, the Gonave microplate, and the Caribbean plate (on which lies the island). Major regional earthquake generation sources are associated with the movement of Gonave microplate, which is bounded on the north by the Oriente fault zone (OFZ), west by the Cayman Spreading Center (CSC), and south by Walton (WFZ) and Enriquillo (EFZ) fault zones (see Figure A. 4.2).

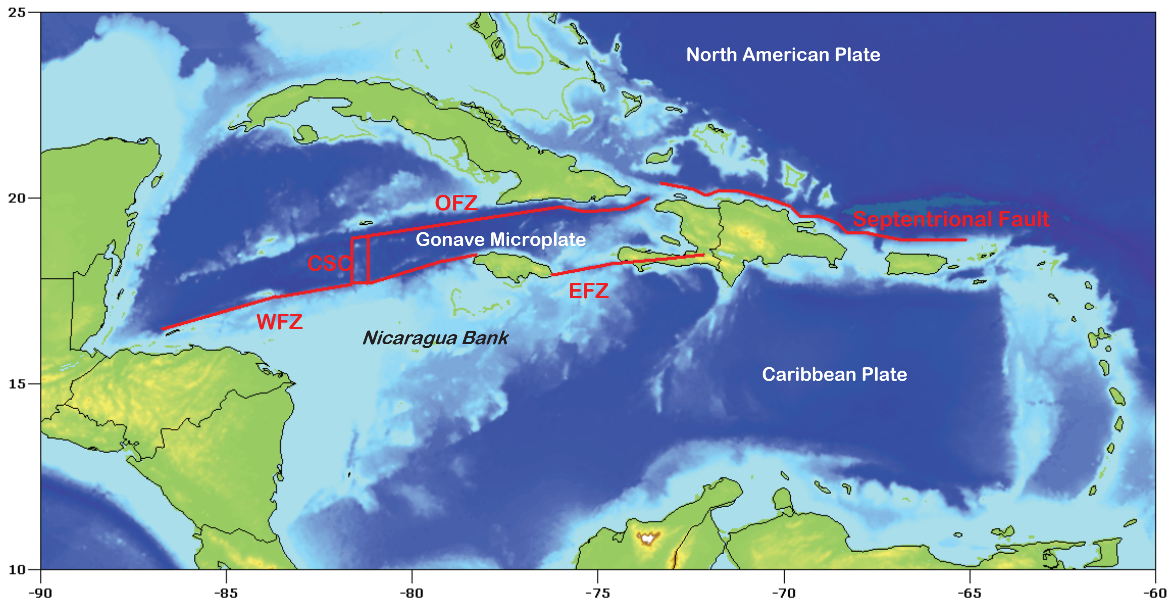

Figure A. 4.2
Seismotectonic environment of Jamaica

In general, the Gonave microplate movement is composed by divergent movement on the CSC (about 12 to 20 mm / year), and convergence movement toward the center of Española island (Haiti and Dominican Republic). The upper limit is given by the OFZ of 950 km in length, linking the northern edge of CSC with the Septentional Fault in Española island. Based on the solution of earthquakes focal mechanism occurred at OFZ, it was determined that the fault movement consists exclusively on lateral displacement southwest of Cuba and oblique convergence along the Santiago deformed belt, southeast of Cuba (Moreno et al. 2002). South of the CSC, movement is taken by the undersea WFZ, which extends to the west of Jamaica, transmitting the deformation to local faulting systems like Spur Tree and Santa Cruz, predominantly oriented SE-NW. To the east of the country, the deformations are absorbed by the River Minho and Plantain Garden systems. The latter continues to the east where connects with the EFZ, south of Española island.

3 SEISMIC PARAMETERS OF SEISMOGENIC SOURCES

The seismicity parameters of the sources are assigned following a Poisson recurrence model (Figure A. 4.3), in which the activity of the ith seismic source is specified in terms of the exceedance rate of magnitudes, $\lambda_i(M)$, generated by this source. Exceedance rate of magnitudes measures how often a source generates earthquakes with magnitude greater than a given. For most of the seismic sources, the function $\lambda_i(M)$ is a modified version of the relation of Gutenberg and Richter. In these cases, seismicity is described as follows:

$$\lambda(M) = \lambda_0 \frac{e^{-\beta M} - e^{-\beta M_u}}{e^{-\beta M_0} - e^{-\beta M_u}} \qquad \textbf{(Ec. 1)}$$

where M_0 is the threshold magnitude. λ_0, β_i, and M_u are parameters that define the rate of exceedance of each of the seismic sources. These parameters, different for each source, are estimated using maximum likelihood statistical procedures, plus expert information, especially about the value of M_u, the maximum magnitud that can be generated in each source. Each of the sources is characterized by a series of seismic parameters which are determined based on seismic information available. The parameters defined are:

Magnitude recurrence: defined by parameter β, represents the average slope of the magnitude recurrence curve (curve of number of events with magnitude greater than *M*, versus seismic magnitude *M*) in the low magnitude zone.

Maximum magnitude M_u: it is estimated based on the maximum probable rupture length of each of the sources and other morphotectonics features.

Recurrence rate of earthquakes with magnitude greater than 3.0 λ_0: corresponds to the average number of earthquakes per year with magnitude greater than 3.0 occurring in a given source.

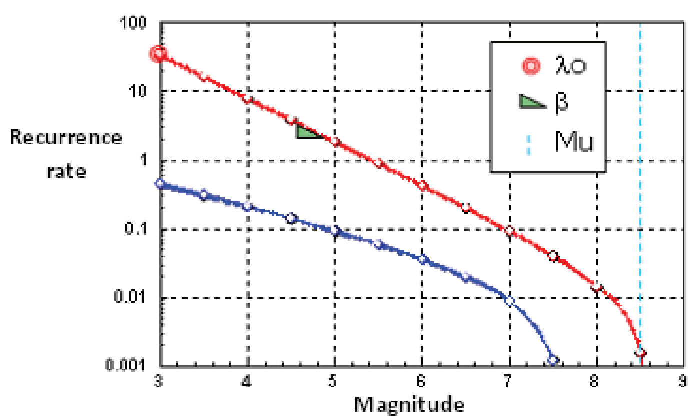

Figure A. 4.3
Sample rates of** exceedance **of magnitudes for the Poisson model.

The calculation model of seismic hazard is carried out based on the regional seismogenic sources identified in this study from existing available information (Shepherd & Aspinall 1980, USAID & OAS 2001, DeMets & Wiggins-Grandison 2007). Figure A. 4-4 presents the national geographical distribution of seismic sources and Table A.4.1 presents the seismicity parameters used in the analysis, for each source.

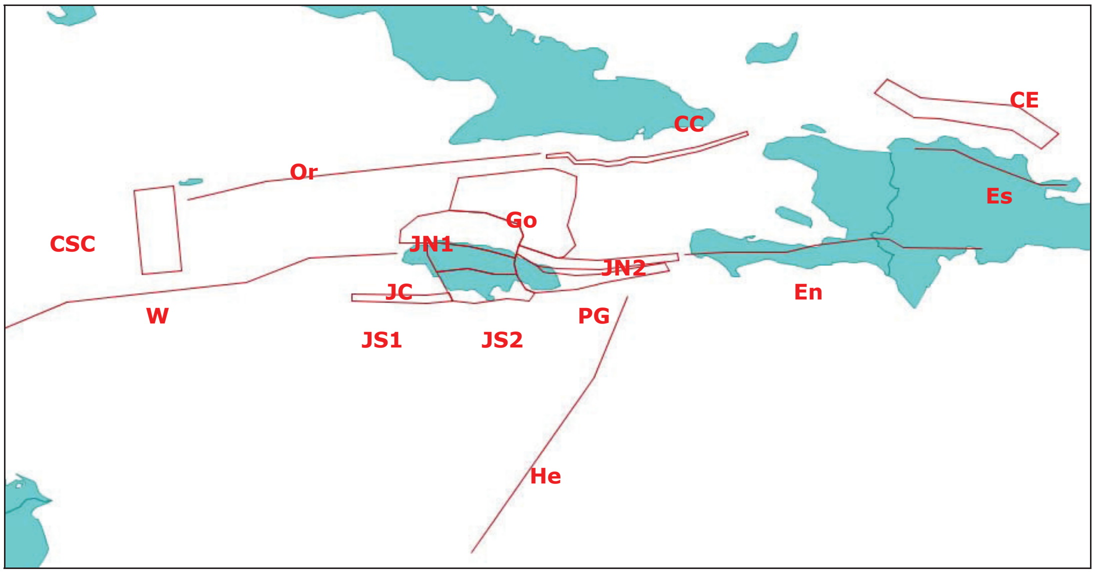

Figure A.4.4
Geographic location of the seismic sources nationwide

Table A.4.1
Seismicity parameters of Jamaican model sources

N°	Source	ID	Average depth [Km]	Mu	λ0	β	Mo
1	Falla Walton	W	17.6	7.0	1.971	0.654	3
2	Cayman Spreading Centre	CSC	21.1	7.0	1.143	0.748	3
3	Falla Oriente	Or	18.1	7.9	2.343	0.843	3
4	Fallas del norte de Jamaica 1	JN1	9.8	6.0	0.229	1.127	3
5	Fallas del norte de Jamaica 2	JN2	12.3	6.0	0.371	1.287	3
6	Sistema fallas Gonave	Go	7.8	6.0	0.686	1.086	3
7	Zona compresión Cuba	CC	18.9	6.0	2.029	0.747	3
8	Sistema de fallas Jamaica centro	JC	13.0	6.0	0.286	1.266	3
9	Sistema de fallas Jamaica sur 1	JS1	12.0	6.0	0.600	1.148	3
10	Sistema de fallas Jamaica sur 2	JS2	12.0	8.0	0.571	1.087	3
11	Falla Plantain Garden	PG	14.1	7.0	1.000	1.148	3
12	Zona escarpe Sur	He	20.6	6.0	0.800	0.819	3
13	Falla Enriquillo	En	32.7	6.5	2.257	0.687	3
14	Falla Española	Es	33.3	6.7	2.286	0.701	3
15	Zona compresión Española	CE	29.9	6.0	0.857	0.824	3

4 ATTENUATION OF SEISMIC WAVES

Once the rate of activity of each one of the seismic sources is determined, it is necessary to evaluate the expected impact in terms of ground motion intensity, on a given site of interest. This requires the prediction of the intensity levels presented on the site in question, at bedrock level, if in the ith source occurs an earthquake with a given magnitude. The expressions that relate magnitude, relative position source-site and seismic intensity are known as *attenuation laws.*

Usually, the relative position source-site is specified by the focal (hypocentral) distance. It is considered that the relevant seismic intensities are the ordinates of the acceleration response spectra ***a***, (for 5% of critical damping), amounts that are approximately proportional to the lateral inertia forces induced in structures during earthquakes. Given the random nature of seismic intensity is assumed as a random variable with lognormal distribution. Spectral attenuation laws are used in order to that accurately include in the model the fact that attenuation is different for waves of different natural frequencies, making it possible to calculate the expected response spectra given a magnitude and a distance.

Jamaica currently does not have an attenuation model based on local intensity measurements. For this reason, the attenuation model proposed by Boore, Joyner and Fumal in 1997, calculated from accelerometer records of the United States, is used. The attenuation law defines the expected spectral accelerations as follows:

$$\ln\left(Sa(T)\right) = B_1 + B_2\left(M-6\right) + B_3\left(M-6\right)^2 + B_4 \cdot \ln\left(\sqrt{R^2+h^2}\right) + B_V \cdot \ln\left(1000/V_a\right) \quad \textbf{(Ec. 2)}$$

Where M is the seismic magnitude, R is hypocentral distance*,* and the other parameters included in the equation depend on the analysis structural period T*,* as shown in Table A. 4.2. The resulting value of *Sa* is given as a fraction of the gravity acceleration *g.*

Table A. 4.2
Attenuation model parameters proposed in Joyner Boore and Fumal 1997

T [seg]	B_1	B_2	B_3	B_4	B_V	V_a	h	σ
0.00	-0.242	0.527	0	-0.778	-0.371	1396	5.57	0.52
0.10	1.059	0.753	-0.226	-0.934	-0.212	1112	6.27	0.479
0.15	1.204	0.702	-0.228	-0.937	-0.238	1820	7.23	0.492
0.20	1.089	0.711	-0.207	-0.924	-0.292	2118	7.02	0.502
0.30	0.7	0.769	-0.161	-0.893	-0.401	2133	5.94	0.522
0.50	-0.025	0.884	-0.09	-0.846	-0.553	1782	4.13	0.556
1.00	-1.08	1.036	-0.032	-0.798	-0.698	1406	2.9	0.613
1.50	-1.55	1.085	-0.044	-0.796	-0.704	1479	3.92	0.649
2.00	-1.743	1.085	-0.085	-0.812	-0.655	1795	5.85	0.672

5 SEISMIC HAZARD

From the seismicity of the sources and seismic waves attenuation patterns, seismic hazard can be calculated considering the sum of the effects of all the seismic sources on a given site. Hazard, expressed in terms of exceedance rates of intensities ***a***, can be calculated using the following expression:

$$\nu(a \mid Ro, p) = \sum_{n=1}^{n=N} \int_{Mo}^{Mu} -\frac{\partial \lambda}{\partial M} \Pr(A > a \mid M, Ro) dM \qquad \textbf{(Ec. 3)}$$

Where the summation covers all the seismic sources *N,* and *Pr (A>* ***a*** *| M, R* $_{i)}$ is the probability that the intensity exceeds a certain value, given the magnitude of the earthquake *M,* and the distance between the ith source and the site $R_{i.}$ Functions λ_i *(M)* are the rates of activity of seismic sources. The integral is performed from M_0 to $M_{u,}$ indicating that takes into account, for each seismic source, the contribution of all possible magnitudes. Since it is assumed that given the magnitude and distance, the intensity has lognormal distribution, the probability Pr *(A> a | M, R* $_{i)}$ is calculated as follows:

$$\Pr(A > a \mid M, Ro) = \phi\left(\frac{1}{\sigma_{Lna}} \ln \frac{E(A \mid M, R_i)}{a}\right) \qquad \textbf{(Ec. 4)}$$

Where $\phi(\cdot)$ the standard normal distribution, *E (A | M, R* $_{i)}$ the expected value of the logarithm of the intensity (given by the corresponding attenuation law) and σ_{lna} its corresponding standard deviation. The seismic hazard is expressed, then, in terms of the exceedance rate of given values ofseismic intensity. As mentioned, in this case the seismic intensity, ***a,*** is measured by the ordinates of the response spectra of pseudo-accelerations for 5% of critical damping and natural period of vibration of the structure of interest, *T.*

6 REFERENCES

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ANNEX 5. HURRICANE WIND HAZARD ASSESSMENT MODEL

1 HAZARD ASSESSMENT METHODOLOGY

In order to accurately consider the future losses associated with hurricane phenomena, the model is based on the trajectory of strong winds and pressure changes associated with the movement of the hurricane. This methodology allows consideration of all potential losses associated with the pass of a given hurricane over the region. The theoretical bases of the wind hazard assessment methodology can be consulted in detail on www.ecapra.org. Wind hazard calculation is performed using ERN-Huracán (ERN 2009).

A flowchat showing the main elements of the hurricane wind hazard model applied is shown in Figure A. 5.1. The main steps of the methodology are:

Generation of a set of stochastic events based on historical information. The event set consists of thousands of hurricane trajectories, with defined parameters such as intensity, size and shape described at regular intervals along the same trajectory. It identifies the average trajectory and the translational speed of the storm as well as the distribution around these expected values. Each event has its own frequency of occurrence.

Stochastic are generated using a "random-walk" simulation technique which involves a sampling of historical distributions in the location of generation of the storm, in order to calculate a forward speed which allows the storm to move forward and sampling the distribution at the new location for the next time interval and so on. The simulation includes an inertia correction in order to generate relatively smooth trajectories. This methodology allows generating several thousands of trajectories. Each simulated trajectory is different from every other simulated or historical trajectory, but the set of events simulated preserves the same statistical properties as the set of historical events.

Once the trajectory is defined, central storm pressure is assigned using a random generation routine. Each simulation is guided by the historical distribution of intensity variations with conditional sampling of the current intensity of the storm and other parameters dependent on the trajectory. The intensity values are limited by the theoretical maximum local values. Frequency of storms is calibrated against historical data and available information. To complete each simulated event description, wind field and shape intensity is added to the trajectory information, using statistical relations that depend on the central pressure and latitude.

Wind hazard is considered by selecting all the hurricane trajectories that can derive on significant impact on the country. This subset of events is verified to confirm that the trajectories and their parameters are consistent with the global relations for frequency-severity on the south-western Caribbean.

Wind hazard maps are calculated and generated, in terms of top wind velocity. For each grid point the expected peak speed is calculated. Maps are generated for at least about 5 return periods. The model is calibrated and set to the parameters of Jamaica. The information of the trajectory is translated into continental wind speeds following a three steps process:

Compute the gradient wind field (wind at a sufficient height above the ground, not reflecting the effects of the surface, usually about 1 km). The wind gradient at any point of interest is a function of distance from the center of the storm, the direction to the analysis site relative to the trajectory, central pressure and forward speed of the storm, peak wind relation and wind field shape parameters.

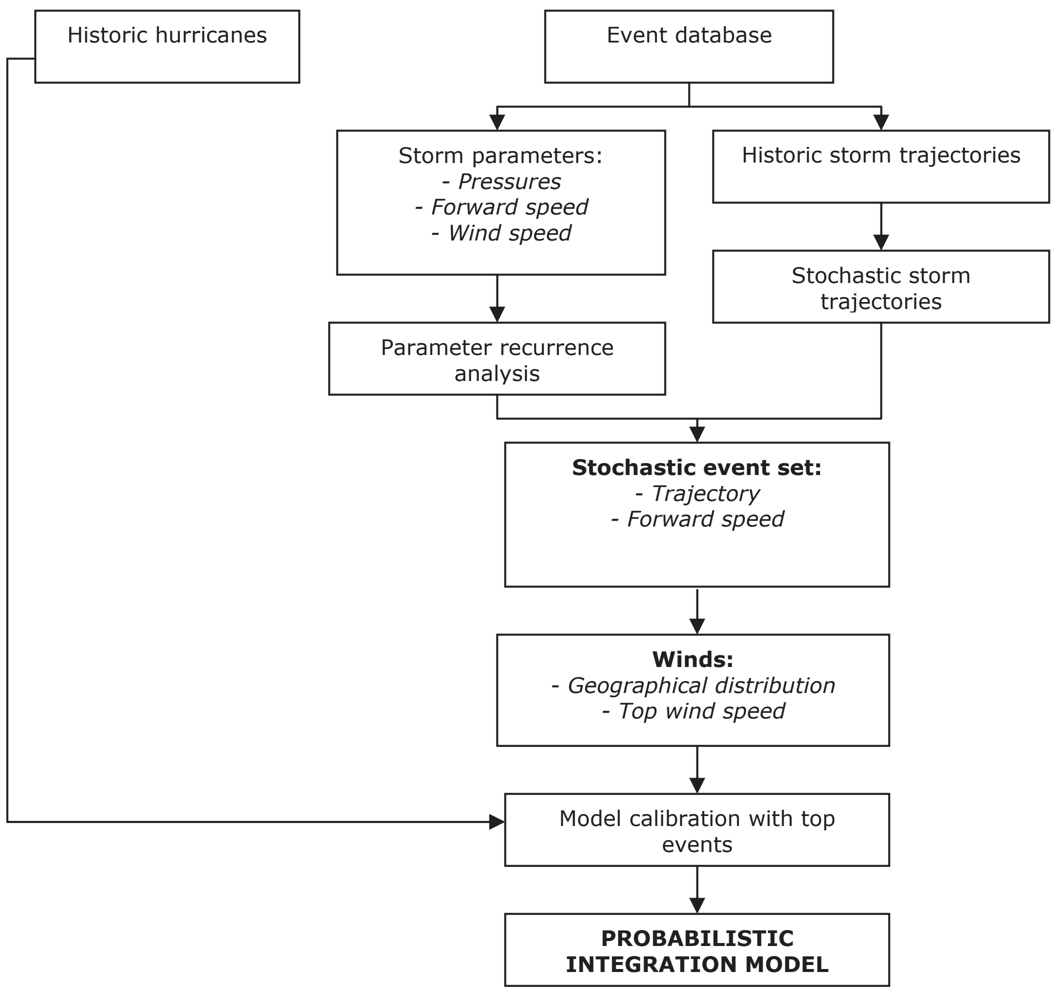

Figure A. 5.1
Flowchart of hurricane wind hazard model

Compute the velocity from the wind gradient at sea level, assuming a uniform water surface.

Compute the specific wind velocity from surface roughness and topography.

The above process is repeated for each time interval along the trajectory, retaining the maximum wind for each location, over the life of the storm.

Calibration is performed in order to ensure consistency of the results with the statistical characteristics of different parameters on the south-western Caribbean. Return periods of specific wind speeds generated by the model are verified.

2 INFORMATION FOR THE MODEL

The hurricane wind hazard assessment model requires specific information that may be available only on a coarse detail level. The quality of the results depends on the detail of the information collected. The following information is required:

- Topography.
- Urban areas and land use.
- Records of wind speed.
- Catalogue of hurricanes

3 TOPOGRAPHY

Wind velocity field is modified by the existing orography obstacles. The model's capacity to detect small variations of wind speed depends heavily on the quality of the available topographic information. The digital elevation model for the Jamaican territory was obtained from the *Shuttle Radar Topography Mission (SRTM)* and has a resolution of 0.0008333 degrees (about one pixel every 92 meters), which is an acceptable resolution to perform national and subnational analysis. Figure A. 5.2 shows the digital elevation model used in this study.

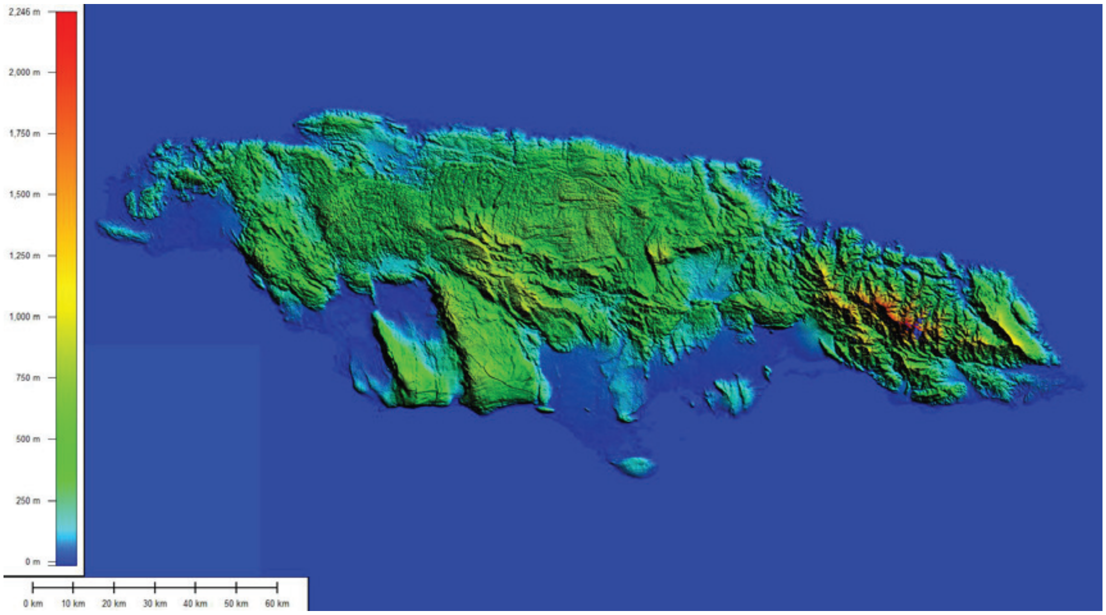

Figure A. 5.2
Digital elevation model used

4 URBAN AREAS AND LAND USE

The rate of growing of the top wind velocity with height is a function of the terrain roughness. The velocity gradient must be based on geographical information for land use, which can be used to set the specific roughness conditions. The urban areas and land use polygons of Jamaica were obtained from the "Global Geographic Information Systems" Database of the USGS. Figure A. 5.3 presents the urban areas and land use polygons.

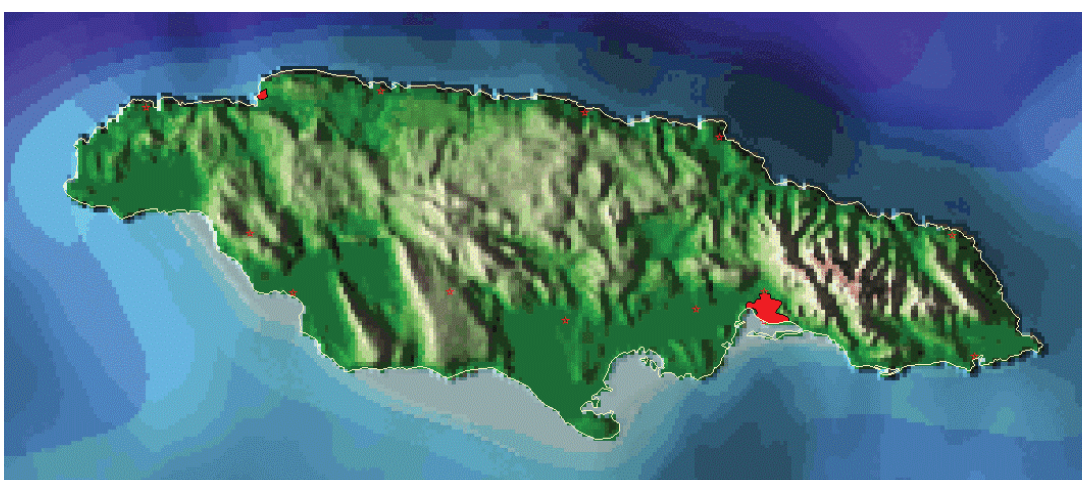

Figure A. 5.3
Polygons of urban areas and land use in Jamaica

5 LOCAL RECORDS OF WIND SPEED

Local records of historical intensities are highly useful for model calibration. In this case, no historical records were found with such information, therefore no special considerations were included in the modeling of the phenomenon.

6 HURRICANES CATALOGUE

Historical events trajectory information, as well as intensity parameters, were obtained from the *HURDAT* database, of the *National Hurricane Center,* of the U.S. agency *NOAA*. This database has the following information:

- Date (hour, day, month and year)
- Cyclone central pressure (in millibars)
- Geographical location (latitude, longitude)
- Maximum sustained wind speed averaged at 1 min

For the Atlantic Ocean, the *HURDAT* database has 1394 tropical cyclones between the years 1851 and 2008. Figure A. 5.3 shows the trajectories of tropical cyclones for the Atlantic Ocean contained in the *HURDAT* database until 2008.

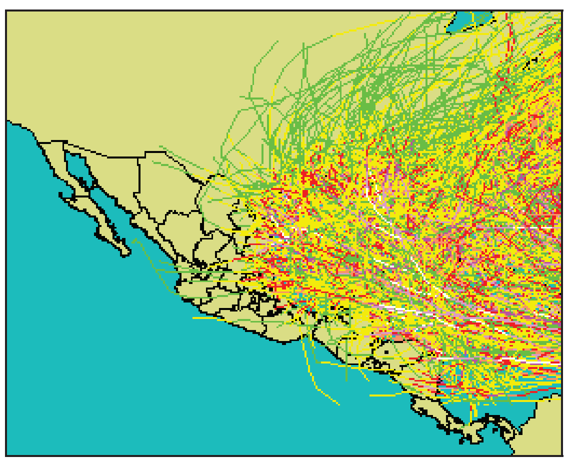

Figure A. 5.3
Trajectory of tropical cyclones for the Atlantic Ocean to the year 2008 according to information from the database HURDAT of the NOAA.

7 REFINEMENT OF HURRICANE CATALOG

From the HURDAT database of the NOAA, the hurricane catalogue was debugged in order to keep under consideration only those tropical cyclones that have affected the Jamaican territory. The criteria used were the following:

- Events classified as H1 (119 km / h) or more on the Saffir-Simpson scale (SS).

- Events with trajectories passing within 200 km of the Jamaican coast.

The above criteria applied to the tropical cyclones database for the Atlantic Ocean, allowed the identification of 121 hurricanes classified as H1 or more. En la Tabla A.5.1 presents the main parameters (wind speed, category, name and date) of each of the 121 hurricane events considered for this study.

Table A. 5.1
Main parameters (wind speed, category, name and date) of tropical cyclones considered.

#	Name	Date	Top Speed [Km/h]	Top SS Category
1	NOT NAMED	23/09/1857	166.53	H2
2	NOT NAMED	01/10/1859	203.54	H3
3	NOT NAMED	25/08/1864	129.52	H1
4	NOT NAMED	05/09/1865	166.53	H2
5	NOT NAMED	12/08/1866	166.53	H2
6	NOT NAMED	26/10/1867	203.54	H3
7	NOT NAMED	04/10/1868	166.53	H2
8	NOT NAMED	04/10/1870	185.04	H3
9	NOT NAMED	25/09/1873	185.04	H3
10	NOT NAMED	30/10/1874	166.53	H2
11	NOT NAMED	07/09/1875	185.04	H3
12	NOT NAMED	11/09/1876	185.04	H3
13	NOT NAMED	11/10/1876	185.04	H3
14	NOT NAMED	07/08/1878	129.52	H1
15	NOT NAMED	31/08/1878	166.53	H2
16	NOT NAMED	17/10/1878	166.53	H2
17	NOT NAMED	03/08/1880	240.55	H4
18	NOT NAMED	14/08/1880	148.03	H1
19	NOT NAMED	06/10/1884	166.53	H2
20	NOT NAMED	27/06/1886	157.28	H2
21	NOT NAMED	12/08/1886	249.80	H4
22	NOT NAMED	14/08/1886	194.29	H3
23	NOT NAMED	11/09/1887	157.28	H2
24	NOT NAMED	09/10/1887	138.78	H1
25	NOT NAMED	11/09/1889	175.78	H2
26	NOT NAMED	17/09/1894	194.29	H3
27	NOT NAMED	21/08/1895	175.78	H2
28	NOT NAMED	22/09/1896	203.54	H3
29	NOT NAMED	25/10/1899	175.78	H2
30	NOT NAMED	26/08/1900	231.29	H4
31	NOT NAMED	09/09/1901	129.52	H1
32	NOT NAMED	06/08/1903	194.29	H3
33	NOT NAMED	10/06/1904	129.52	H1
34	NOT NAMED	12/10/1904	129.52	H1

35	NOT NAMED	01/10/1905	194.29	H3
36	NOT NAMED	21/09/1908	175.78	H2
37	NOT NAMED	13/07/1909	185.04	H3
38	NOT NAMED	20/08/1909	194.29	H3
39	NOT NAMED	13/09/1909	194.29	H3
40	NOT NAMED	06/10/1909	194.29	H3
41	NOT NAMED	08/11/1909	166.53	H2
42	NOT NAMED	05/09/1910	175.78	H2
43	NOT NAMED	11/10/1912	157.28	H2
44	NOT NAMED	11/11/1912	240.55	H4
45	NOT NAMED	05/08/1915	222.04	H4
46	NOT NAMED	31/08/1915	157.28	H2
47	NOT NAMED	22/09/1915	212.79	H4
48	NOT NAMED	12/08/1916	203.54	H3
49	NOT NAMED	21/08/1916	157.28	H2
50	NOT NAMED	27/08/1916	157.28	H2
51	NOT NAMED	12/10/1916	194.29	H3
52	NOT NAMED	20/09/1917	194.29	H3
53	NOT NAMED	31/07/1918	166.53	H2
54	NOT NAMED	05/11/1924	157.28	H2
55	NOT NAMED	07/08/1928	129.52	H1
56	NOT NAMED	30/08/1930	240.55	H4
57	NOT NAMED	05/09/1931	203.54	H3
58	NOT NAMED	08/09/1931	157.28	H2
59	NOT NAMED	25/09/1932	194.29	H3
60	NOT NAMED	30/10/1932	212.79	H4
61	NOT NAMED	26/06/1933	166.53	H2
62	NOT NAMED	16/09/1933	175.78	H2
63	NOT NAMED	01/10/1933	240.55	H4
64	NOT NAMED	25/10/1933	157.28	H2
65	NOT NAMED	23/09/1935	194.29	H3
66	NOT NAMED	18/10/1935	138.78	H1
67	NOT NAMED	09/08/1938	157.28	H2
68	NOT NAMED	23/08/1938	157.28	H2
69	NOT NAMED	29/10/1939	148.03	H1
70	NOT NAMED	21/08/1942	185.04	H3
71	NOT NAMED	16/08/1944	194.29	H3
72	NOT NAMED	12/10/1944	194.29	H3
73	NOT NAMED	10/10/1945	157.28	H2
74	NOT NAMED	09/08/1947	175.78	H2
75	NOT NAMED	18/09/1948	194.29	H3
76	NOT NAMED	12/10/1949	166.53	H2
77	KING	13/10/1950	194.29	H3
78	CHARLIE	12/08/1951	212.79	H4
79	DOG	27/08/1951	185.04	H3
80	FLORENCE	23/09/1953	203.54	H3
81	HAZEL	05/10/1954	222.04	H4

82	HILDA	10/09/1955	203.54	H3
83	JANET	21/09/1955	277.55	H5
84	GRETA	30/10/1956	222.04	H4
85	ELLA	30/08/1958	185.04	H3
86	FLORA	26/09/1963	231.29	H4
87	CLEO	20/08/1964	249.80	H4
88	INEZ	21/09/1966	240.55	H4
89	BEULAH	05/09/1967	259.05	H5
90	FRANCELIA	28/08/1969	185.04	H3
91	ALMA	17/05/1970	129.52	H1
92	CARMEN	29/08/1974	240.55	H4
93	FIFI	14/09/1974	175.78	H2
94	CAROLINE	24/08/1975	185.04	H3
95	ELOISE	13/09/1975	203.54	H3
96	FREDERIC	29/08/1979	212.79	H4
97	ALLEN	31/07/1980	305.31	H5
98	DENNIS	07/08/1981	129.52	H1
99	KATRINA	02/11/1981	138.78	H1
100	DANNY	11/08/1985	148.03	H1
101	GILBERT	08/09/1988	296.06	H5
102	GORDON	08/11/1994	138.78	H1
103	DOLLY	19/08/1996	129.52	H1
104	MARCO	13/11/1996	120.27	H1
105	GEORGES	15/09/1998	249.80	H4
106	MITCH	21/10/1998	286.80	H5
107	LENNY	13/11/1999	249.80	H4
108	DEBBY	19/08/2000	138.78	H1
109	IRIS	04/10/2001	231.29	H4
110	ISIDORE	14/09/2002	203.54	H3
111	LILI	21/09/2002	231.29	H4
112	CLAUDETTE	06/07/2003	138.78	H1
113	CHARLEY	09/08/2004	231.29	H4
114	IVAN	02/09/2004	268.30	H5
115	DENNIS	04/07/2005	240.76	H4
116	EMILY	10/07/2005	250.02	H5
117	WILMA	15/10/2005	277.80	H5
118	ERNESTO	24/08/2006	120.38	H1
119	DEAN	13/08/2007	268.54	H5
120	GUSTAV	25/08/2008	240.76	H4
121	PALOMA	05/11/2008	231.50	H4

Table A. 5.3 shows the distribution by category in the Saffir-Simpson scale of the 121 hurricane scenarios selected.

Table A. 5.3
Distribution by category in the Saffir-Simpson scale of tropical cyclones considered.

Category	Number of storms
H1	20
H2	32
H3	35
H4	25
H5	9

8 TOPOGRAPHIC WIND EXPOSURE FACTORS

Hurricane wind speed field is usually modified by the effect of local topography. In order to consider this effect in the hazard model, topography factors are defined so the increase or decrease in wind speed can be calculated for different types of terrain, for example at the top of ridges, slopes, islands or closed valleys. In this study, wind speed on flat ground is multiplied by an amplification factor to consider the surface roughness effects above explained. These topography factors are assigned based on the definition of wind exposure areas (Avelar, 2006). Wind exposure areas are calculated following a procedure that allows generating, from Digital Elevation Models (DEM), digital maps of topographic exposure factors. The definition and characteristics of the topographic exposure factors used in this study are shown in Table A.5.4. Figure A.5.4 shows the spatial distribution of the topographic exposure factors used.

Table A. 5.4
Wind topographic exposure factors for Jamaica

Site	Topography	F_T
Protected	Closed valleys	0.8
Flat	Flat land, open field, no significant topographic changes, slopes lower than 5%	1.0
Exposed	Tops of ridges, hills or mountains, areas with slopes greater than 5%	1.2

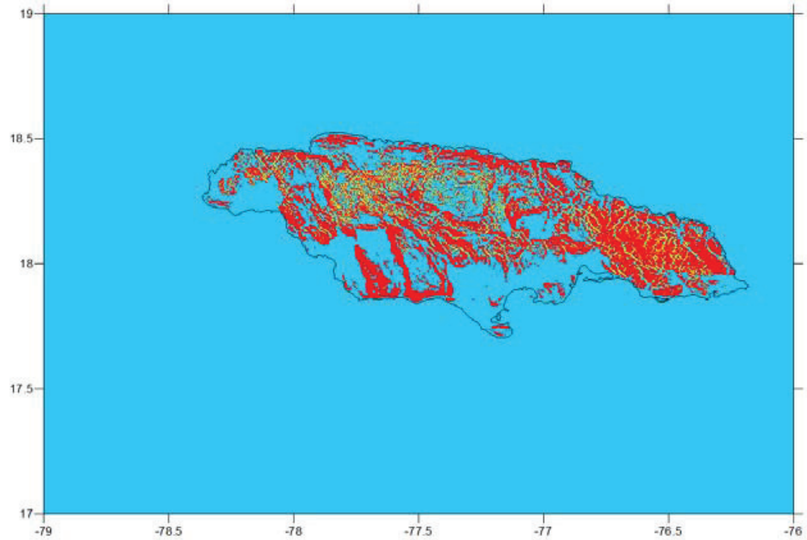

Figure A.5.4
Wind topographic exposure factors geographical distribution. Yellow regions represent protected sites, blue represent flat sites, and red represent exposed sites.

9 WIND SPEED VARIATIONS WITH HEIGHT

Air masses movement is restricted near the surface as an effect of the terrain roughness, causing a nearly null speed at surface contact, and the consequent growth in speed magnitude with height until reaching the undisturbed flow velocity, called *gradient velocity*. For very smooth terrain, wind speed remains high even near the ground surface, while at the center of large cities with tall buildings, speed decreases rapidly from a height of several tens of meters to the ground surface. The expression than allows estimating the change in wind speed with height, for different types of terrain, is:

$$Frz = 1.56\left(\frac{Z}{\delta}\right)^{\alpha} \quad si \quad 10 < Z < \delta$$

$$Frz = 1.56\left(\frac{10}{\delta}\right)^{\alpha} \quad si \quad Z \leq 10 \quad m$$

$$Frz = 1.56 \quad si \quad Z \geq \delta$$

(Ec. 5)

Where: Z is the analysis height in meters. Parameters α and δ are presented in Table A. 5.5 for different types of terrain.

Table A. 5.5
Parameters α and δ for different types of terrain

Type	Description	α	δ(m)
1	**Open field** (open field, almost flat and unobstructed, as flat coastal strips, wetland areas, airfields, grassland and farmland)	0,099	245
2	**Trees or dispersed constructions** (fields or farms with few obstructions such as fences, trees and dispersed constructions)	0,128	315
3	**Woods, residential neighborhood** (ground covered by numerous closely spaced obstructions, such as urban and suburban areas and forest; obstructions size corresponds to housing)	0,156	390
4	**Very rugged, city center** (terrain with numerous large obstructions, closely spaced, as a city center and well developed industrial complexes)	0,170	455

Figure A.5.5 shows the variation with height of *Frz* factor above the ground surface. Note that for a height of 10m above the ground surface, the biggest *Frz* value is 1,137, which occurs in terrain type 1 (open field, almost flat and unobstructed). The smallest value *Frz* for the same height corresponds to 0.815, which occurs in terrain type 4 (terrain with numerous obstructions).

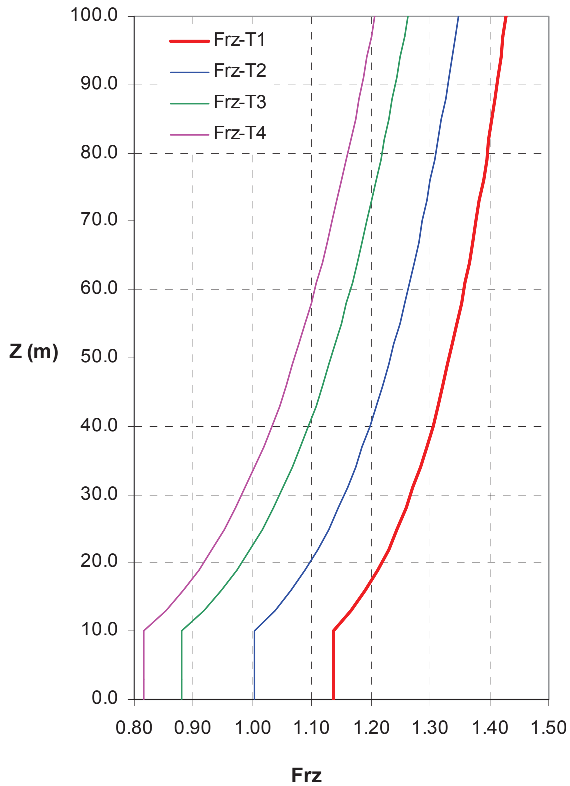

Figure A. 5.5
Variation of wind speed with height for different types of terrain.

10 REFERENCES

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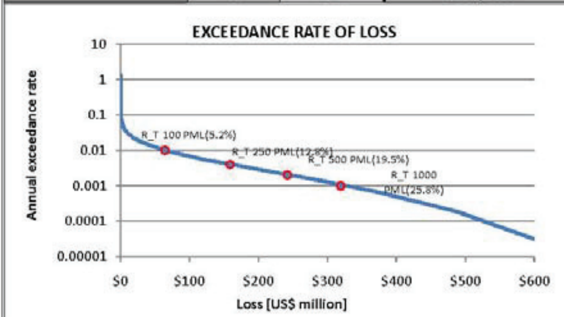
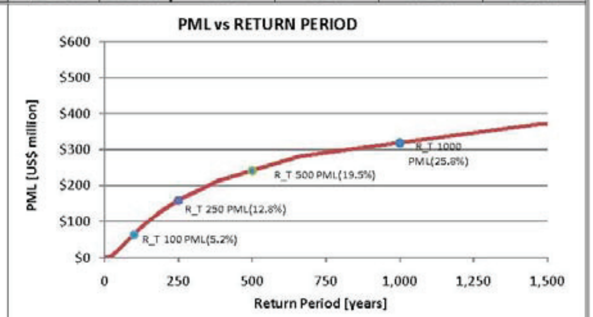
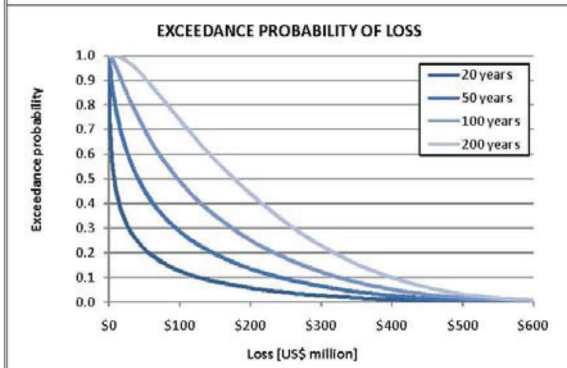
◊ USGS. Global Geographic Information Systems. http://webgis.wr.usgs.gov/globalgis/

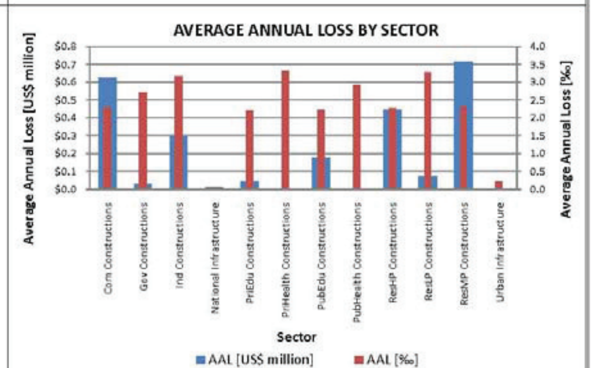
ANNEX 6. INDIVIDUAL RESULTS PER PARISH

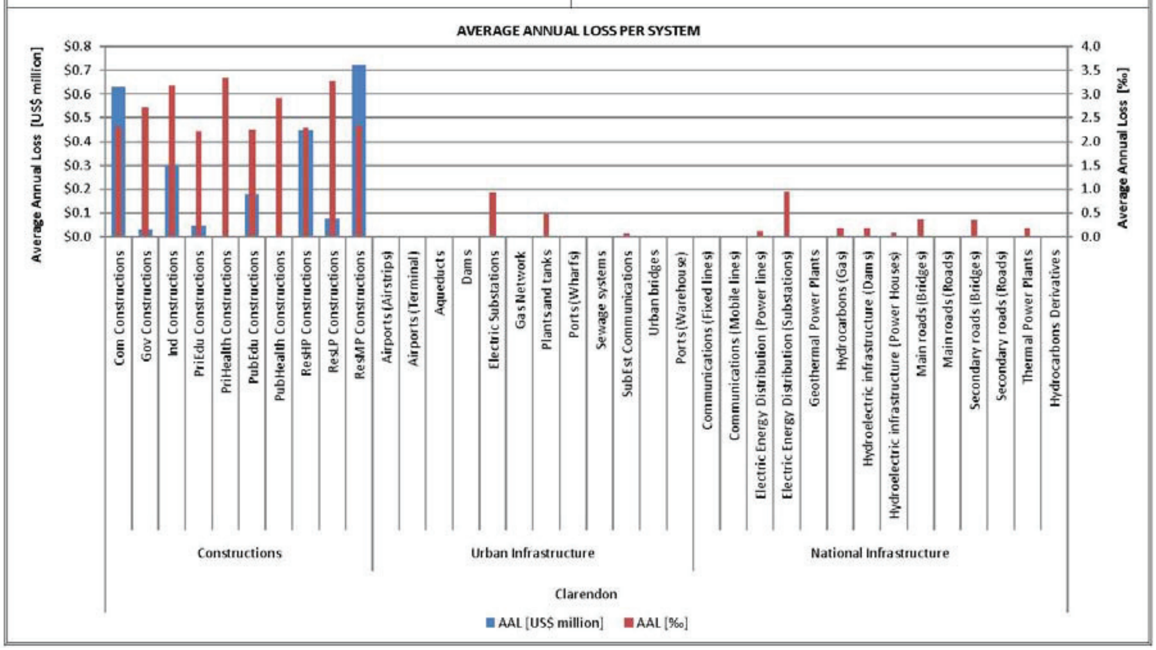
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Clarendon		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$63.63	5.15%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$1,234.61	250 years	$158.23	12.82%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$2.43	500 years	$241.26	19.54%	3.92%	9.52%	18.13%	63.21%
	‰	1.97	1000 years	$318.60	25.81%	1.98%	4.88%	9.52%	39.35%



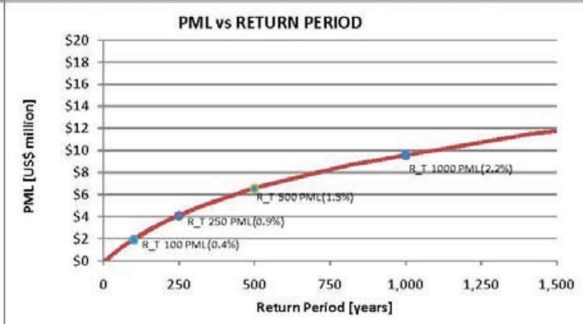


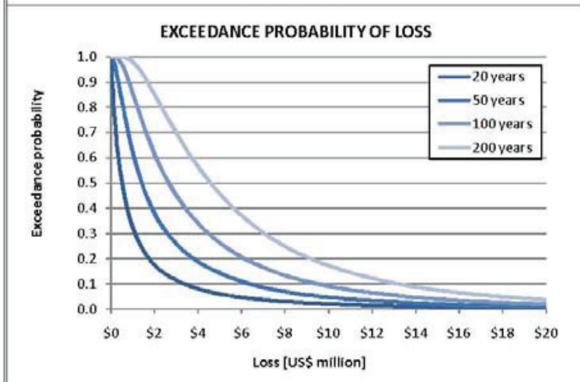


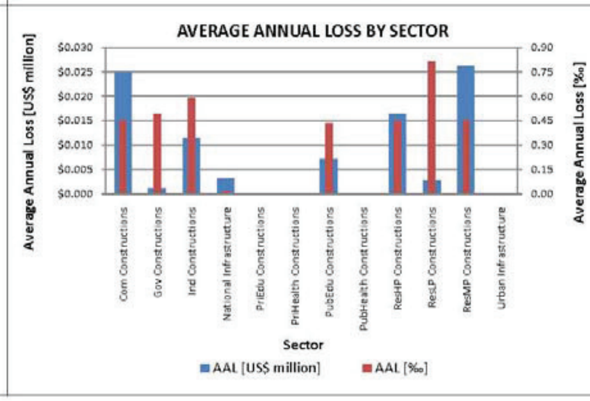


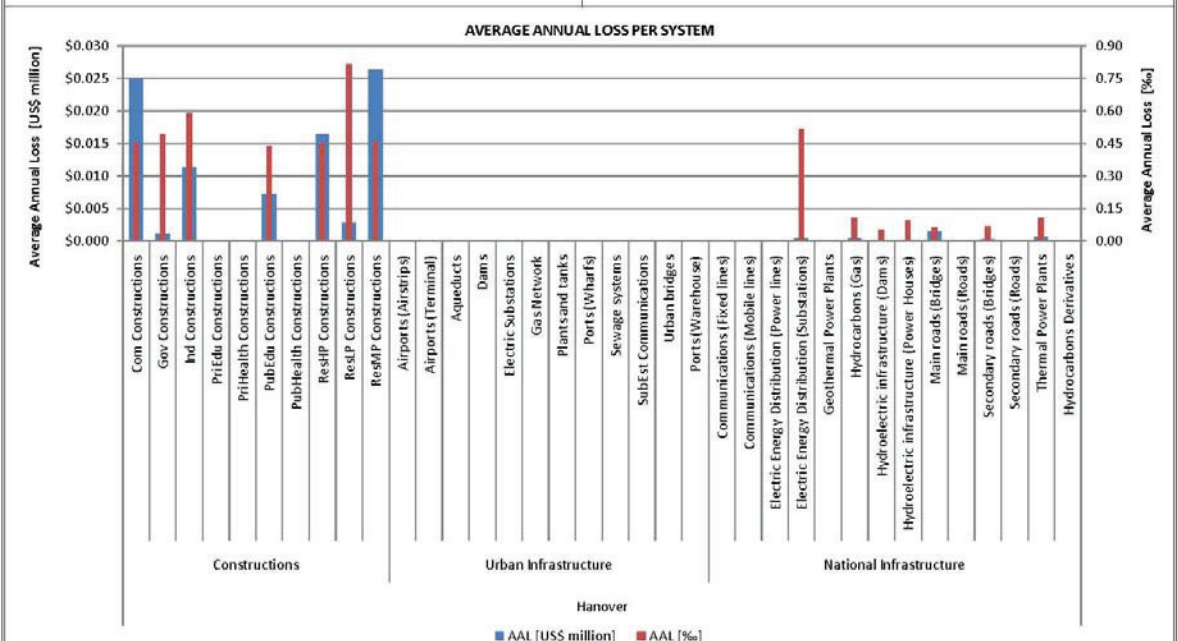


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Hanover		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$1.90	0.43%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$436.82	250 years	$4.08	0.93%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.09	500 years	$6.56	1.50%	3.92%	9.52%	18.13%	63.21%
	‰	0.21	1000 years	$9.56	2.19%	1.98%	4.88%	9.52%	39.35%

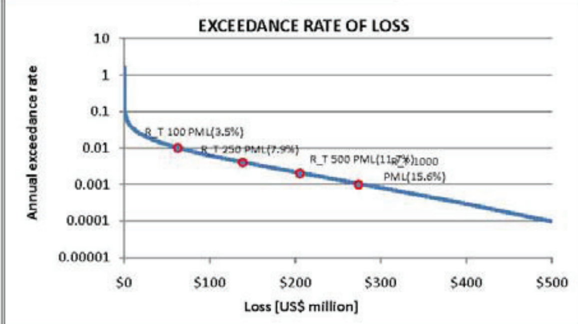


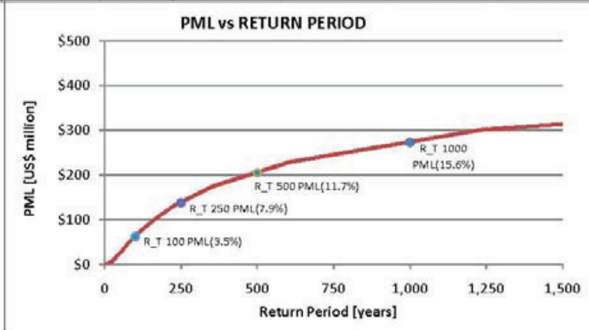


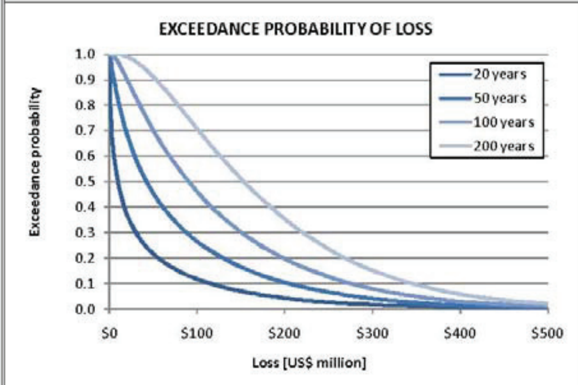


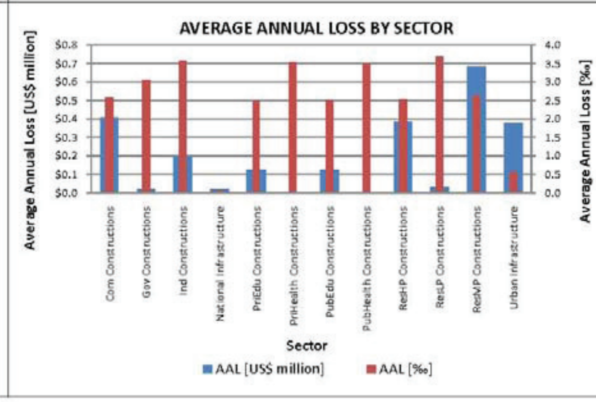


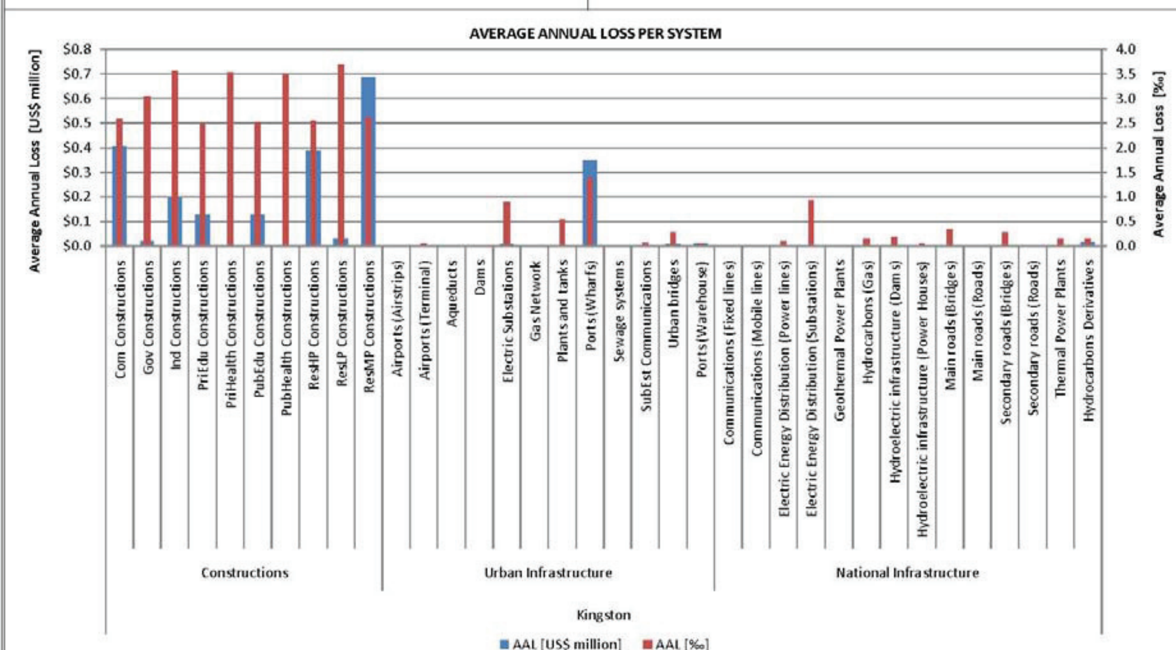
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Kingston		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$62.02	3.53%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$1,756.02	250 years	$138.06	7.86%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$2.38	500 years	$205.03	11.68%	3.92%	9.52%	18.13%	63.21%
	‰	1.36	1000 years	$273.31	15.56%	1.98%	4.88%	9.52%	39.35%



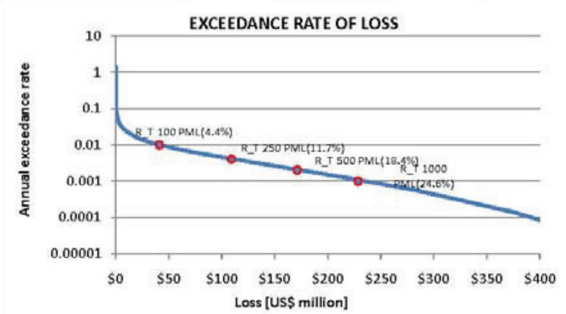


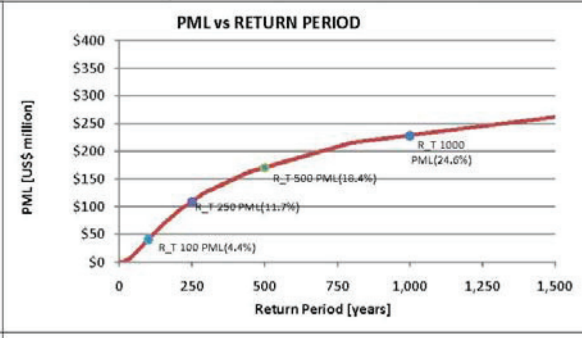


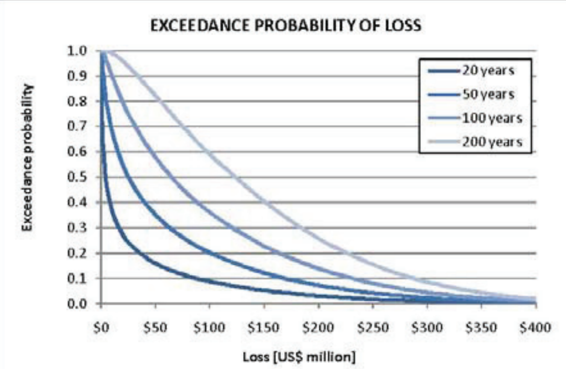


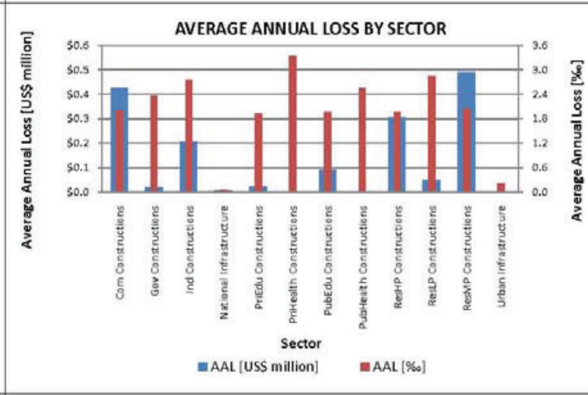


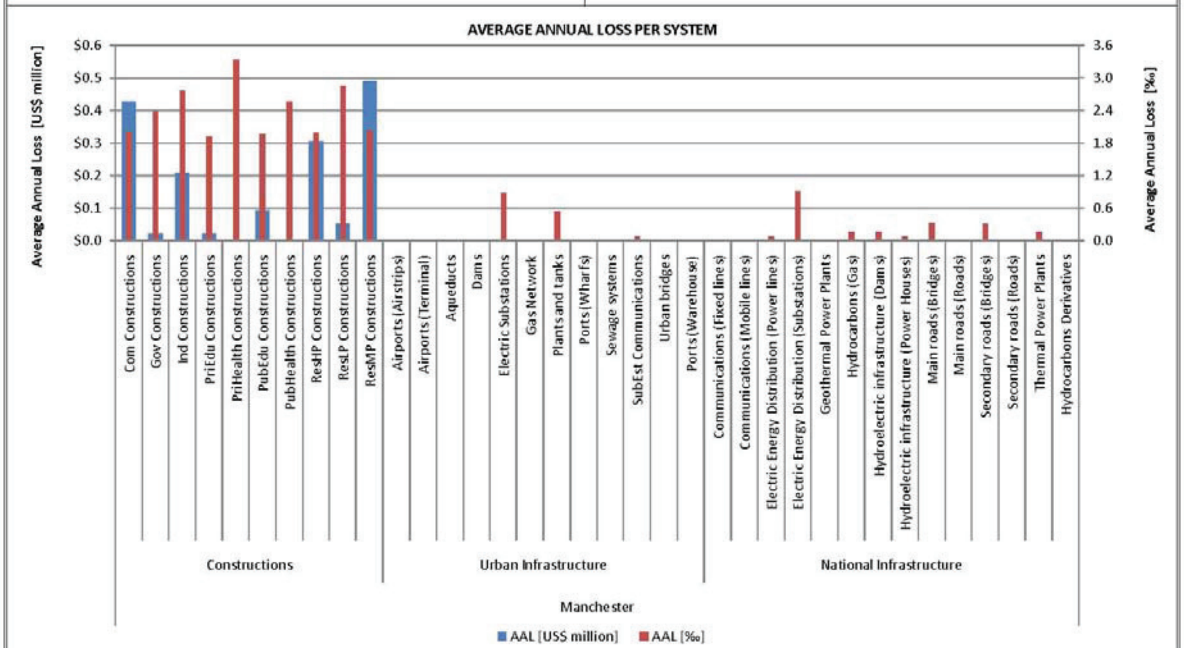
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Manchester		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$40.70	4.38%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$928.39	250 years	$108.59	11.70%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$1.63	500 years	$170.63	18.38%	3.92%	9.52%	18.13%	63.21%
	‰	1.76	1000 years	$228.21	24.58%	1.98%	4.88%	9.52%	39.35%



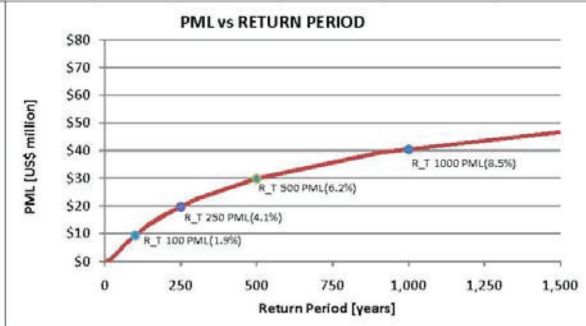


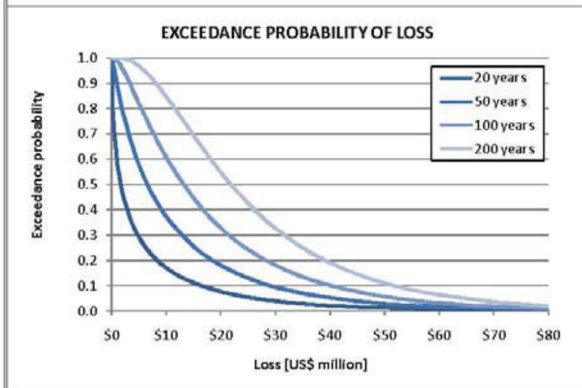


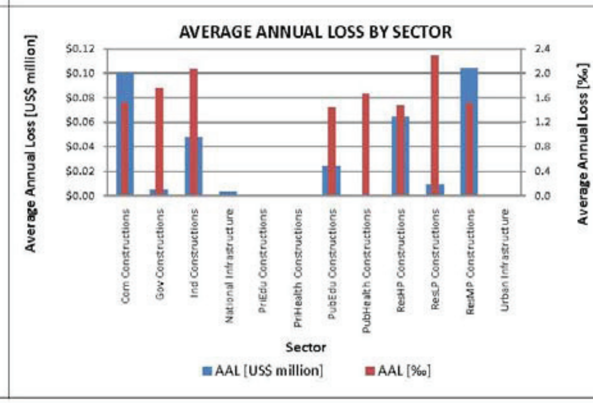


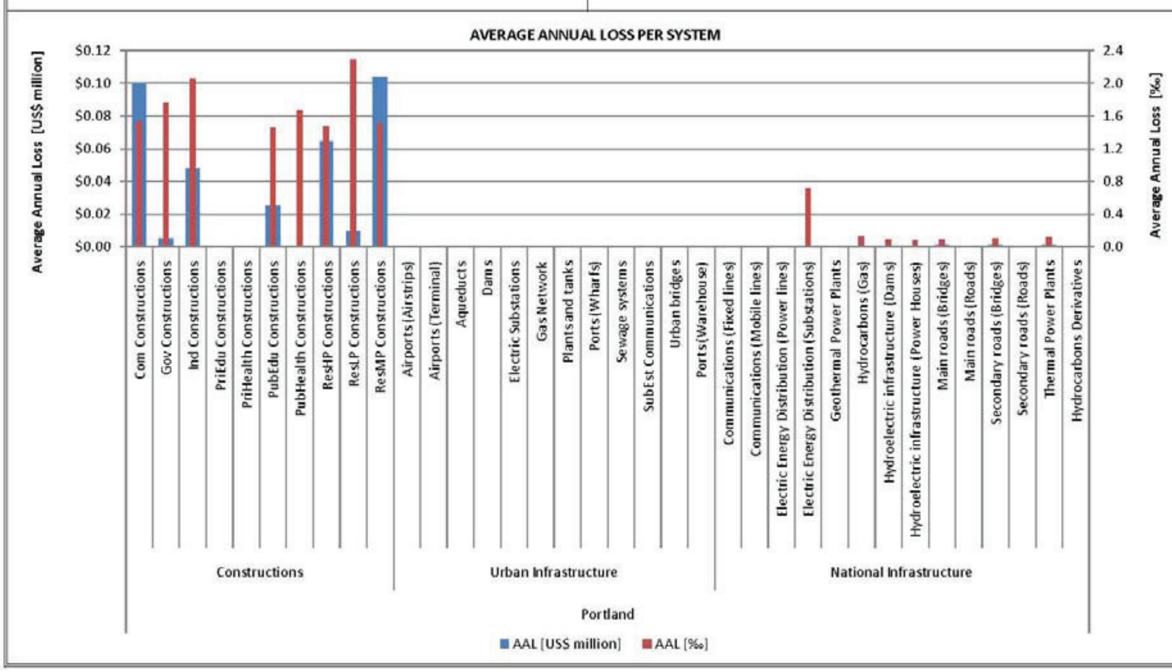


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Portland		Return Period	US$ $x10^6$	%	20 years	50 years	100 years	500 years
			100 years	$9.27	1.94%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ $x10^6$	$477.47	250 years	$19.63	4.11%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ $x10^6$	$0.36	500 years	$29.80	6.24%	3.92%	9.52%	18.13%	63.21%
	‰	0.75	1000 years	$40.42	8.47%	1.98%	4.88%	9.52%	39.35%

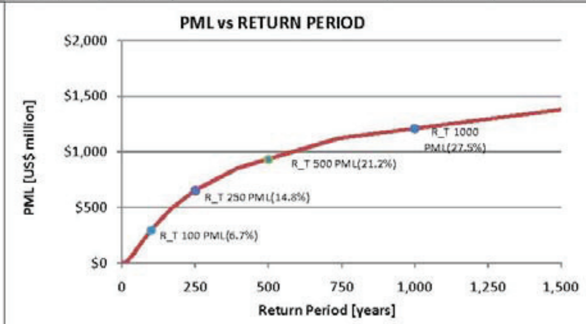


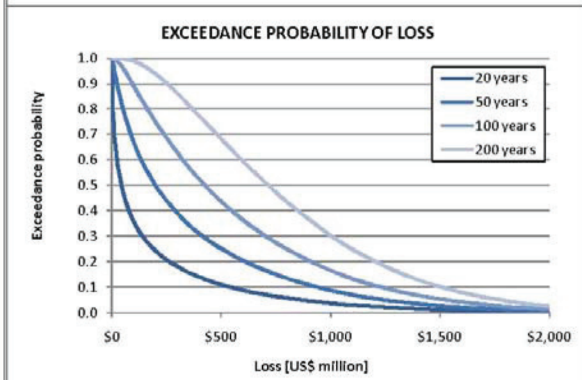


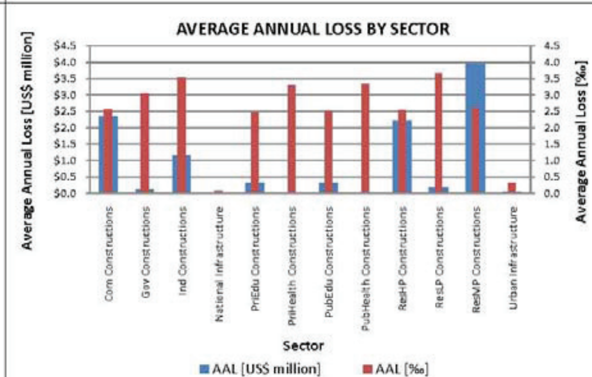


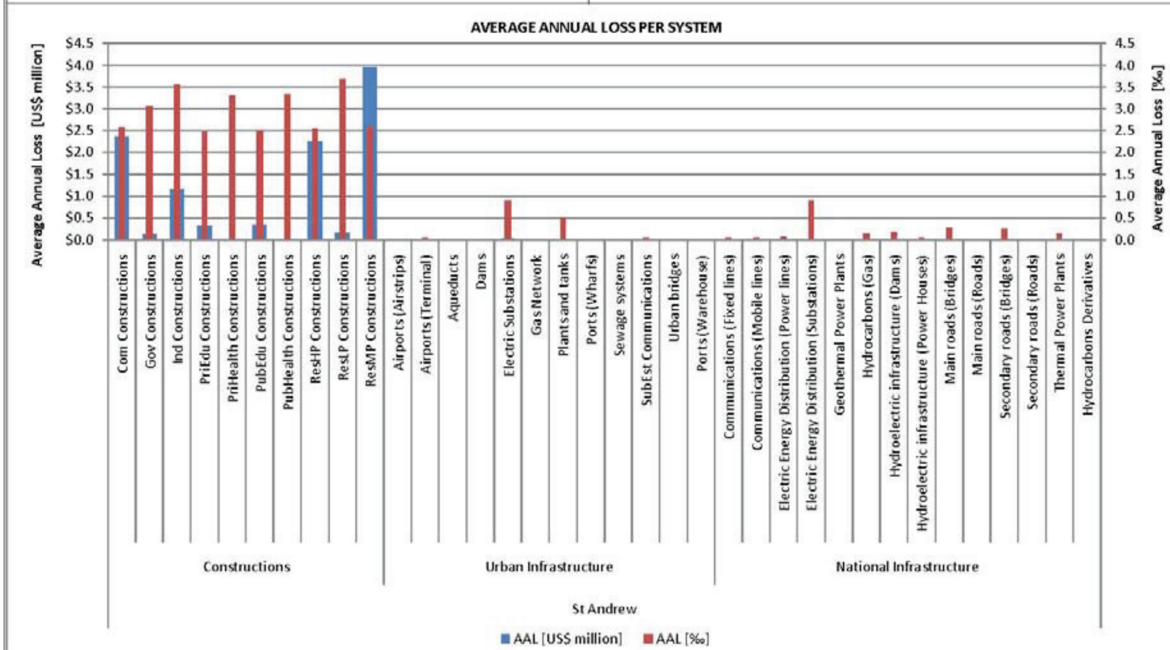


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Andrew		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$292.87	6.66%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$4,396.69	250 years	$649.29	14.77%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$10.69	500 years	$932.55	21.21%	3.92%	9.52%	18.13%	63.21%
	‰	2.43	1000 years	$1,208.23	27.48%	1.98%	4.88%	9.52%	39.35%

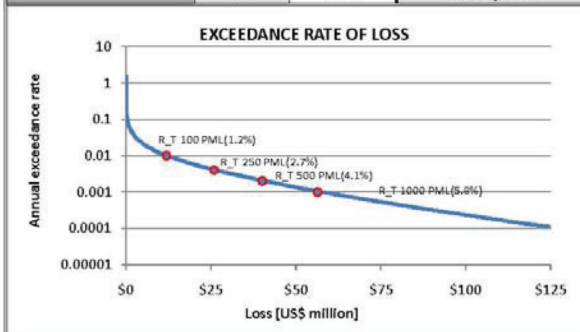


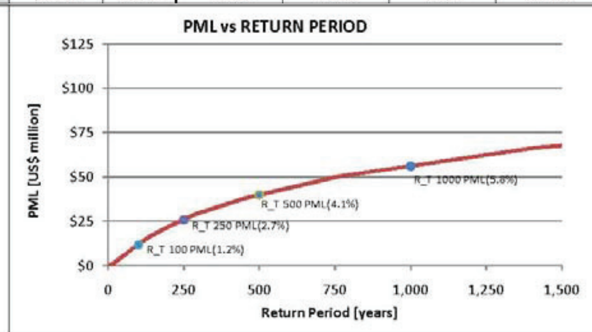


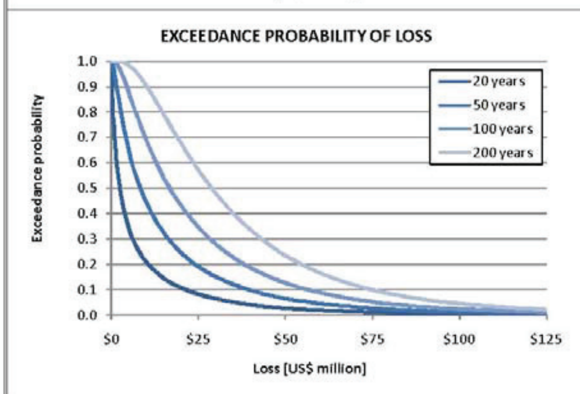


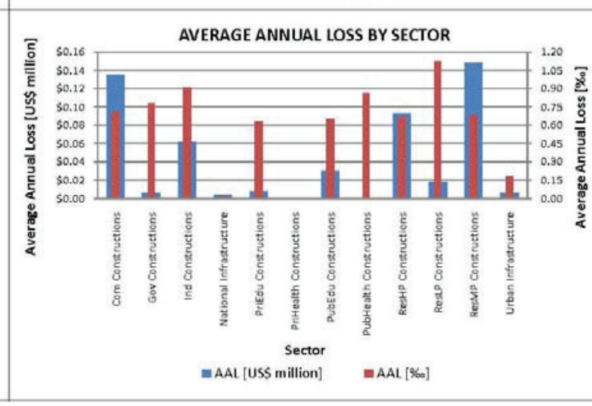


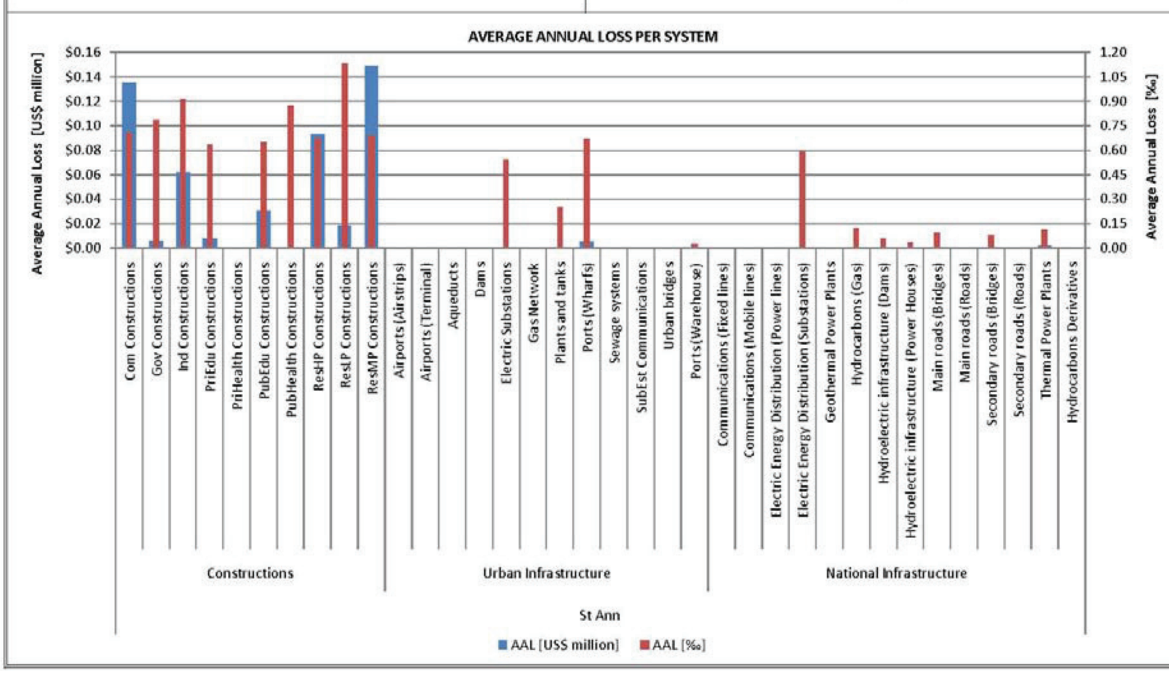
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Ann		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$11.76	1.22%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$966.98	250 years	$25.80	2.67%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.51	500 years	$39.96	4.13%	3.92%	9.52%	18.13%	63.21%
	‰	0.53	1000 years	$56.19	5.81%	1.98%	4.88%	9.52%	39.35%



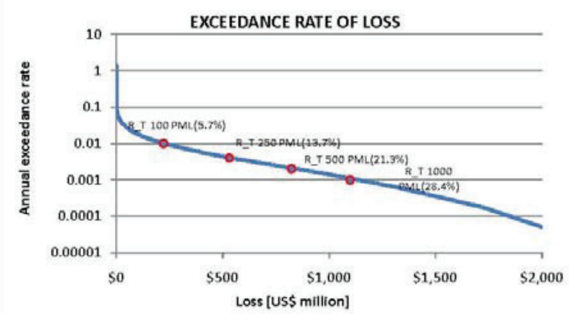


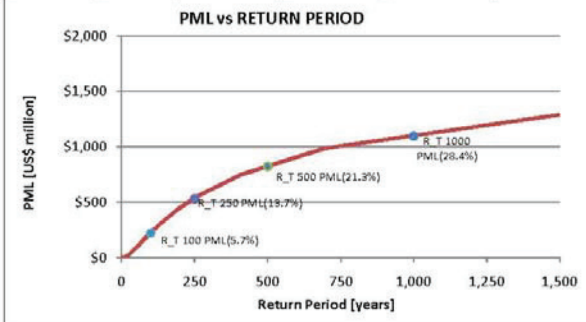


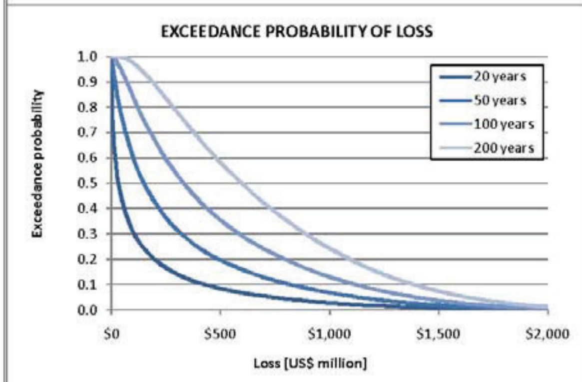


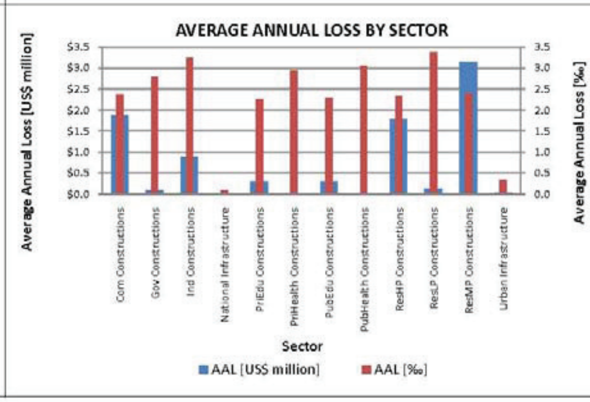


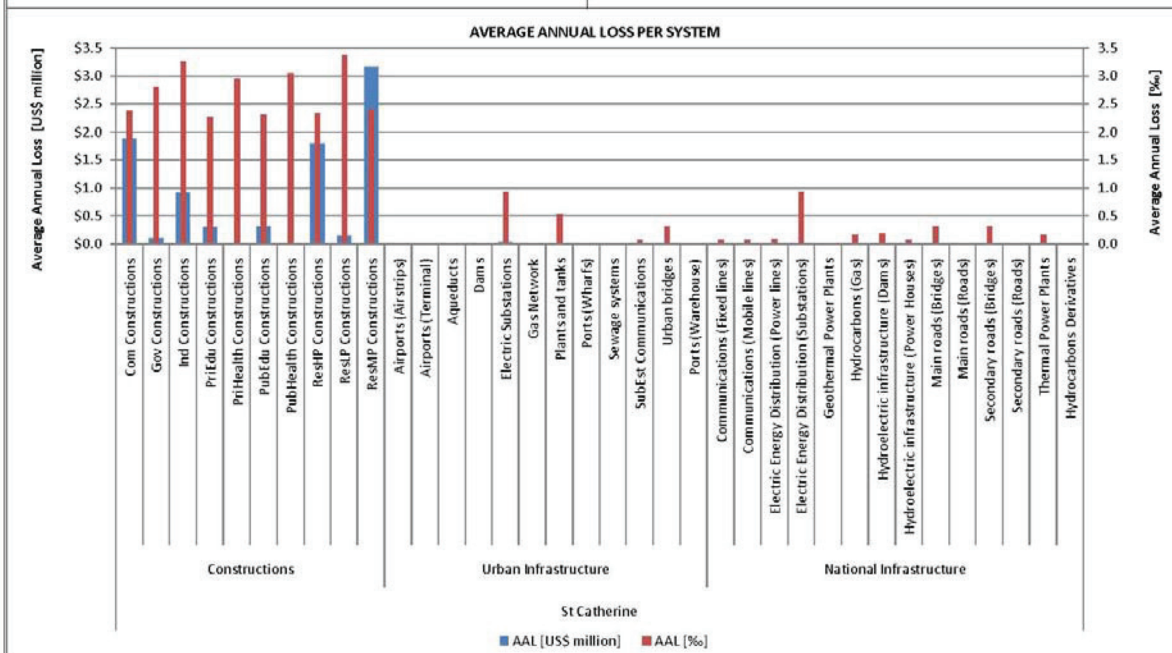
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Catherine		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$221.71	5.74%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$3,863.77	250 years	$530.55	13.73%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$8.62	500 years	$822.08	21.28%	3.92%	9.52%	18.13%	63.21%
	‰	2.23	1000 years	$1,097.88	28.41%	1.98%	4.88%	9.52%	39.35%



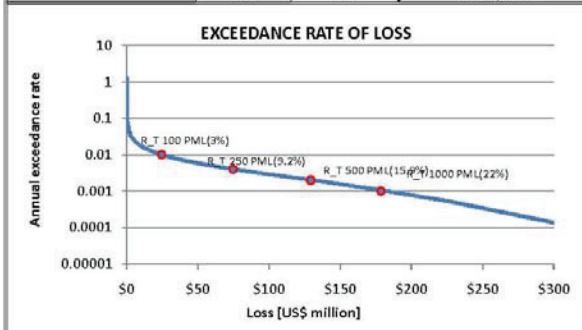


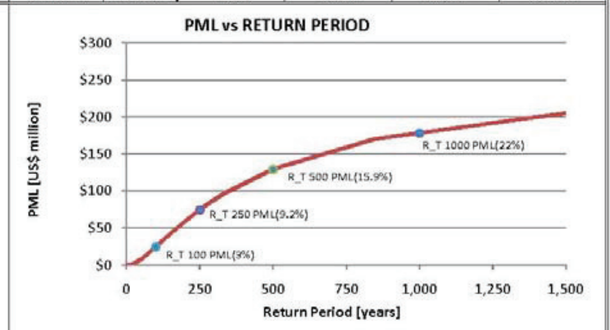


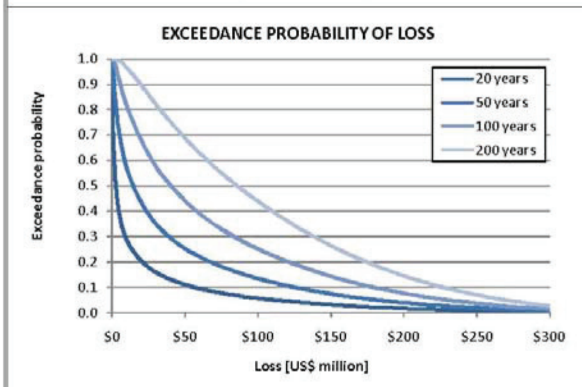


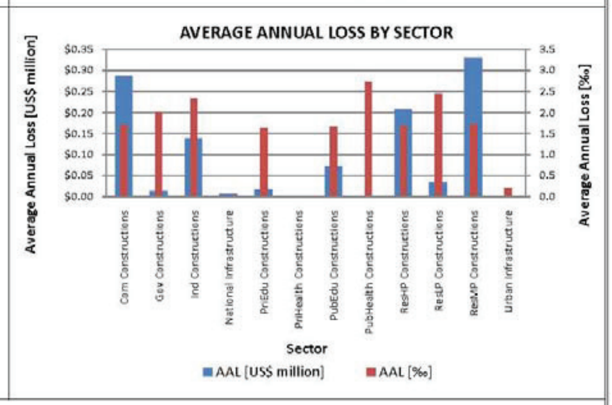


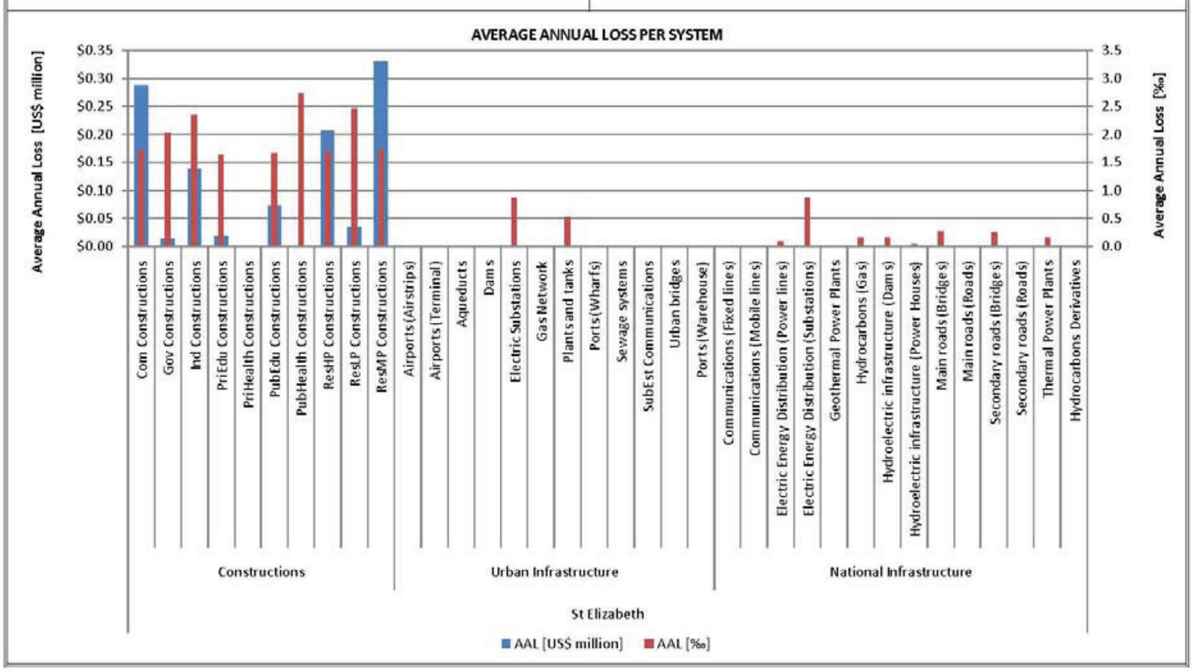
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Elizabeth		Return Period	US\$ $x10^6$	%	20 years	50 years	100 years	500 years
			100 years	\$24.12	2.98%	18.13%	39.35%	63.21%	99.33%
Exposure value	US\$ $x10^6$	\$808.85	250 years	\$74.43	9.20%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US\$ $x10^6$	\$1.11	500 years	\$129.00	15.95%	3.92%	9.52%	18.13%	63.21%
	‰	1.37	1000 years	\$178.18	22.03%	1.98%	4.88%	9.52%	39.35%



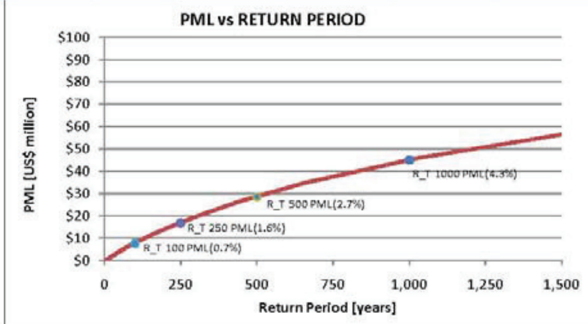


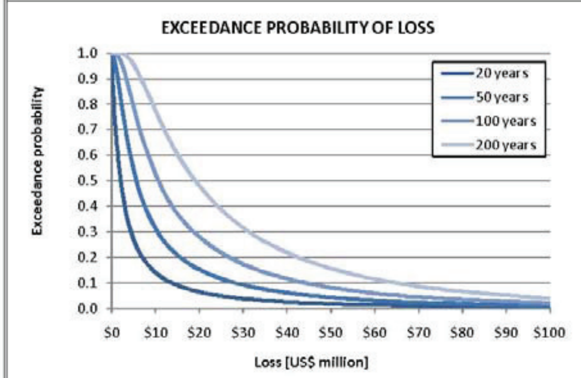


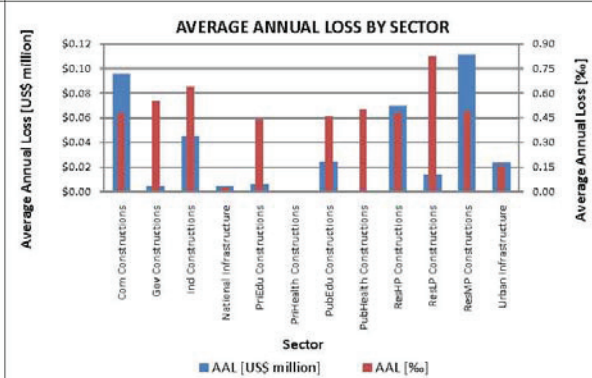


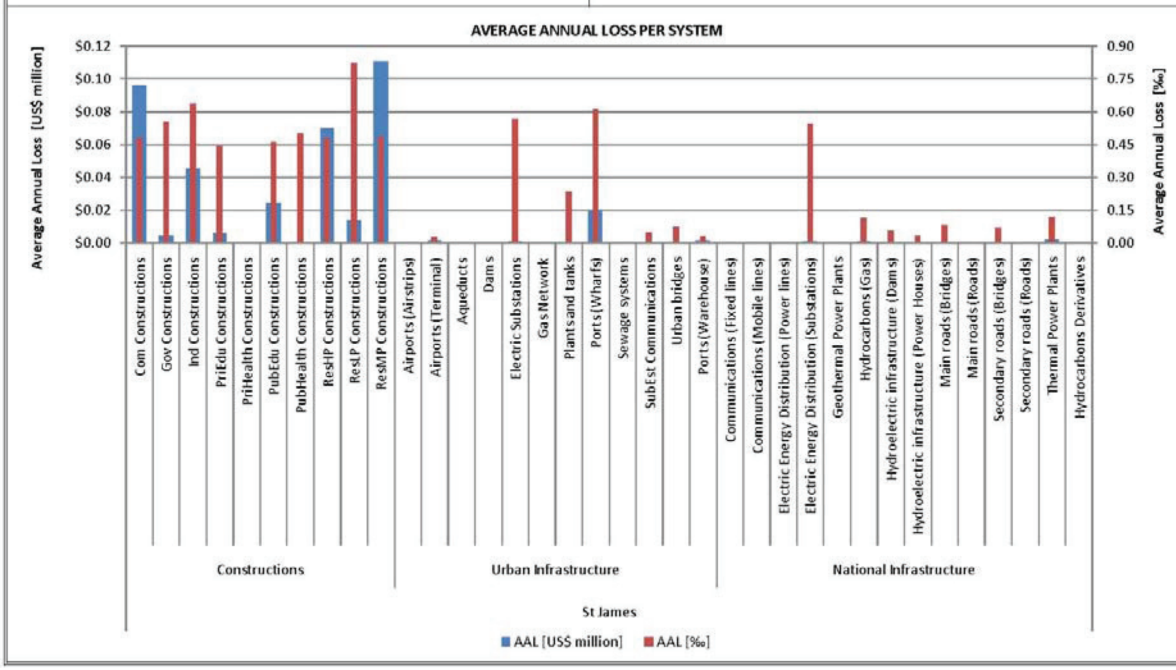


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St James		Return Period	US$ x10[6]	%	20 years	50 years	100 years	500 years
			100 years	$7.60	0.72%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10[6]	$1,058.13	250 years	$16.82	1.59%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10[6]	$0.40	500 years	$28.54	2.70%	3.92%	9.52%	18.13%	63.21%
	‰	0.38	1000 years	$45.09	4.26%	1.98%	4.88%	9.52%	39.35%

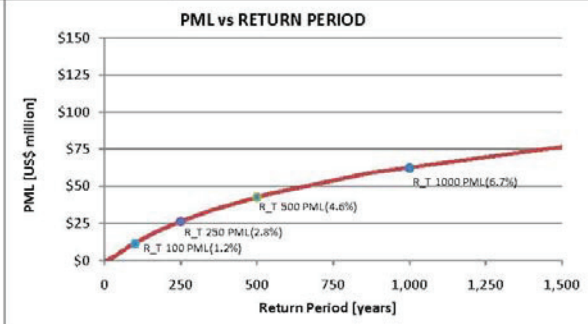


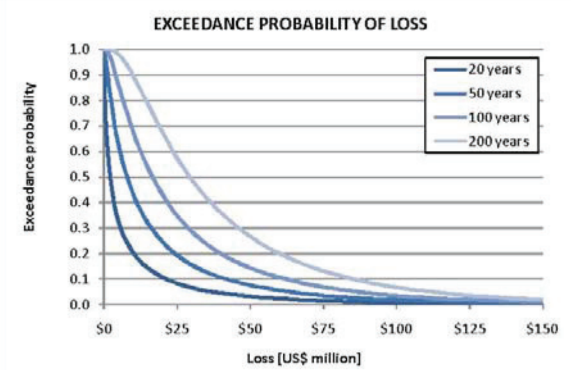


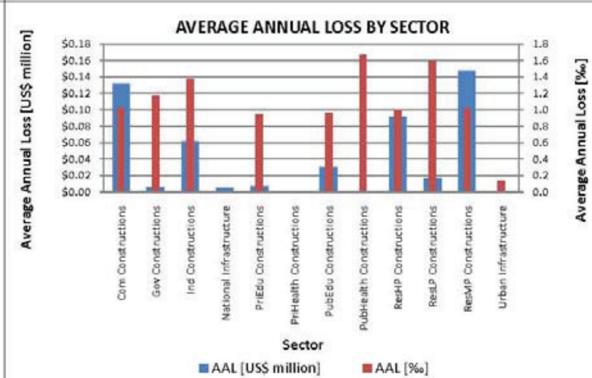


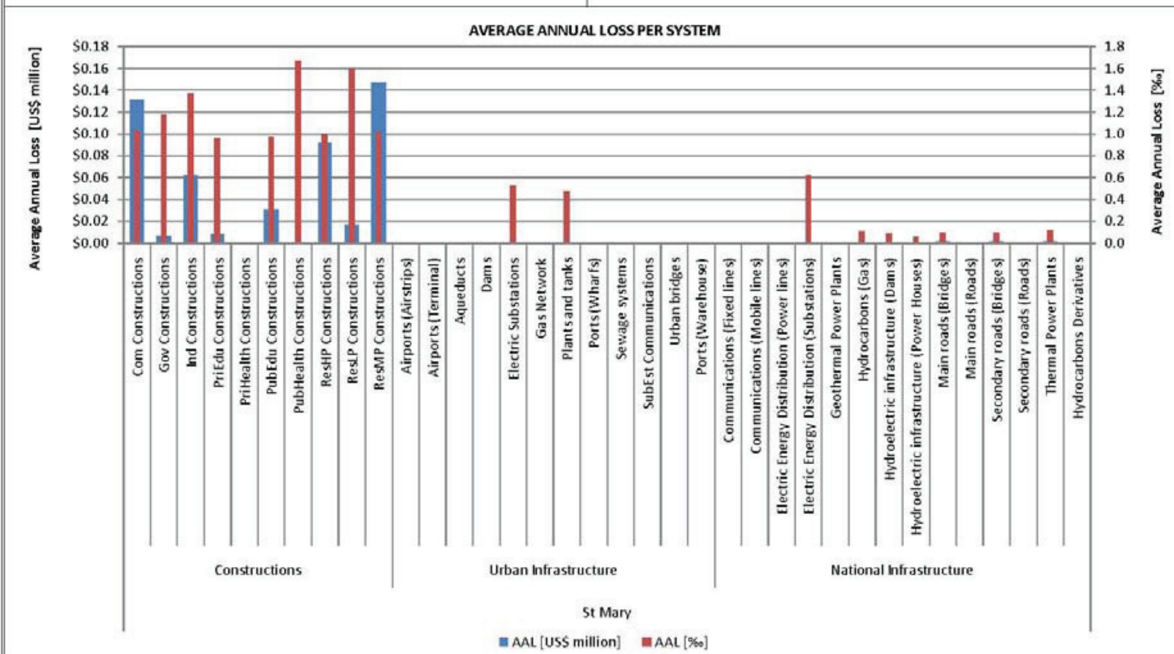


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			**Probable Maximum Loss**			**Exceedance probability of PML values**			
Parish	St Mary		**Return Period**	**US$ x10⁶**	**%**	**20 years**	**50 years**	**100 years**	**500 years**
			100 years	$11.33	1.22%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$931.78	**250 years**	$26.27	2.82%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.50	**500 years**	$42.56	4.57%	3.92%	9.52%	18.13%	63.21%
	‰	0.54	**1000 years**	$62.47	6.70%	1.98%	4.88%	9.52%	39.35%

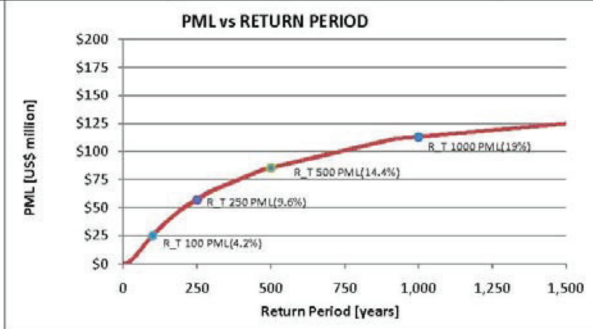


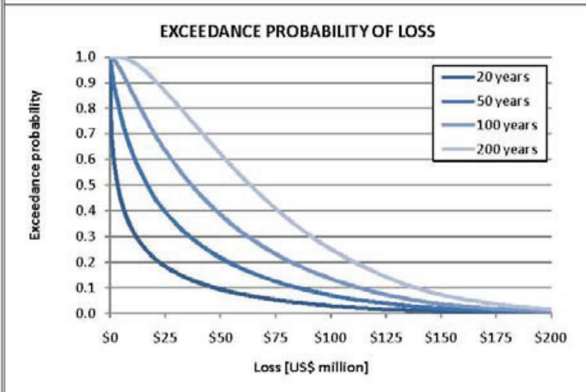


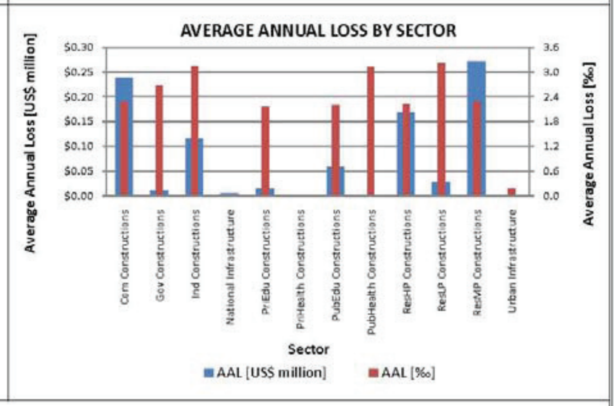


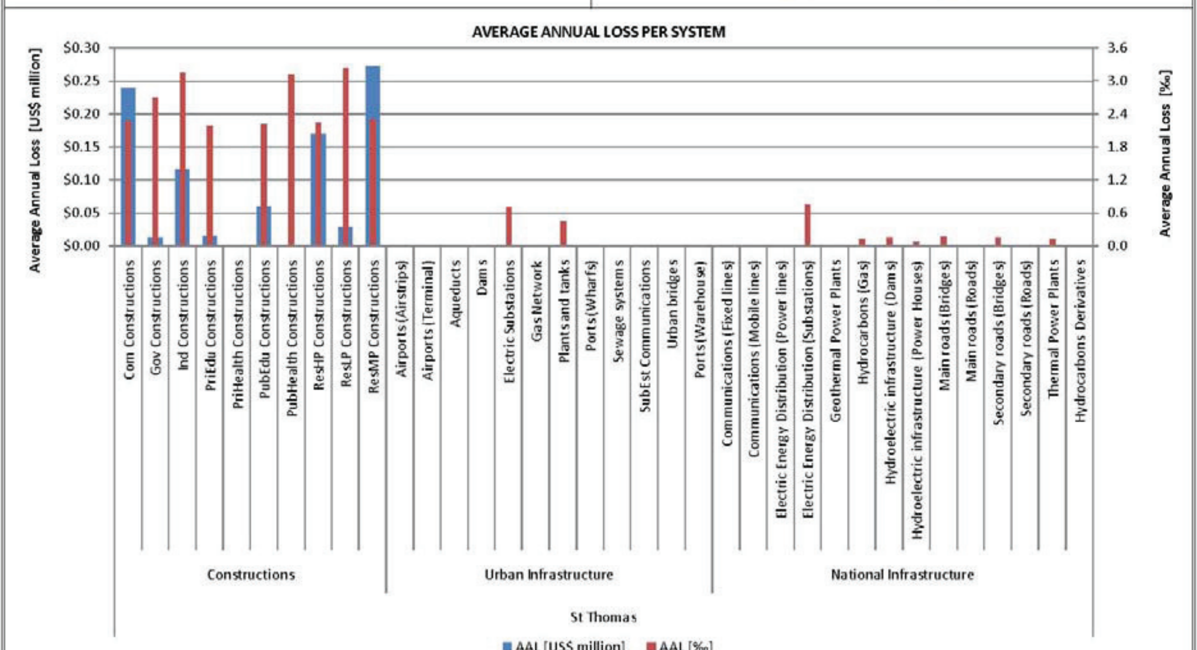


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Thomas		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$24.95	4.21%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$593.08	250 years	$56.90	9.59%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.92	500 years	$85.49	14.42%	3.92%	9.52%	18.13%	63.21%
	‰	1.55	1000 years	$112.94	19.04%	1.98%	4.88%	9.52%	39.35%

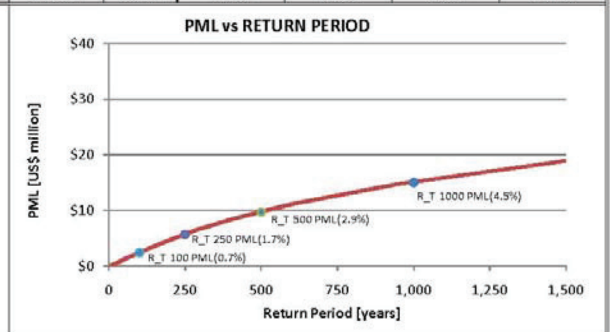


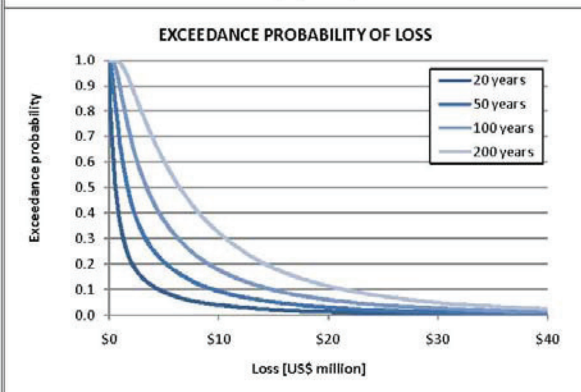


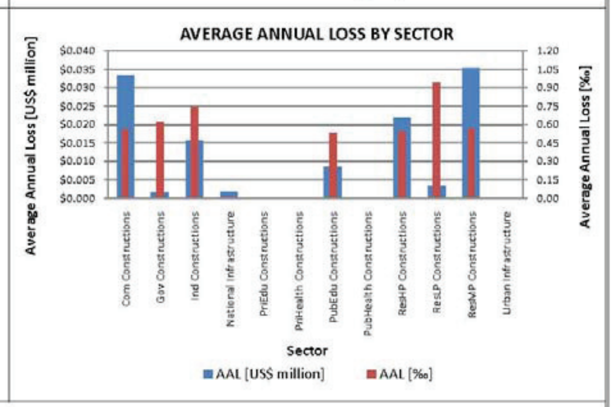


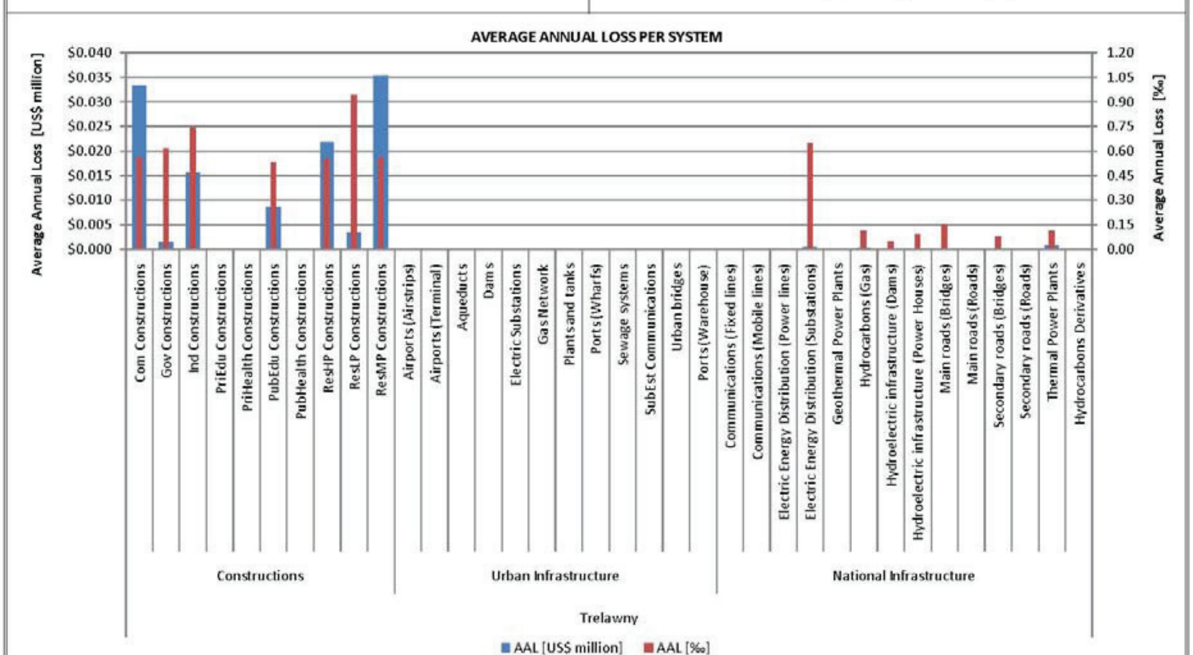


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Trelawny		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$2.34	0.69%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$337.66	250 years	$5.65	1.67%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.12	500 years	$9.68	2.87%	3.92%	9.52%	18.13%	63.21%
	‰	0.36	1000 years	$15.03	4.45%	1.98%	4.88%	9.52%	39.35%

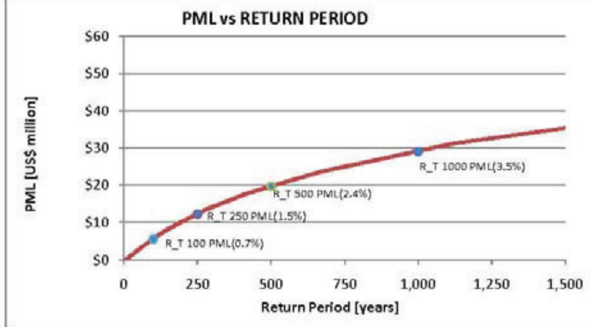


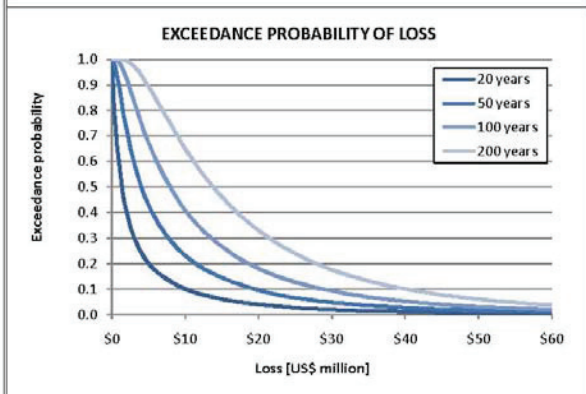


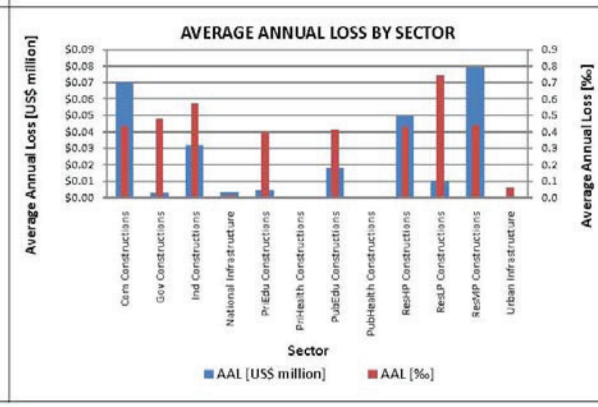


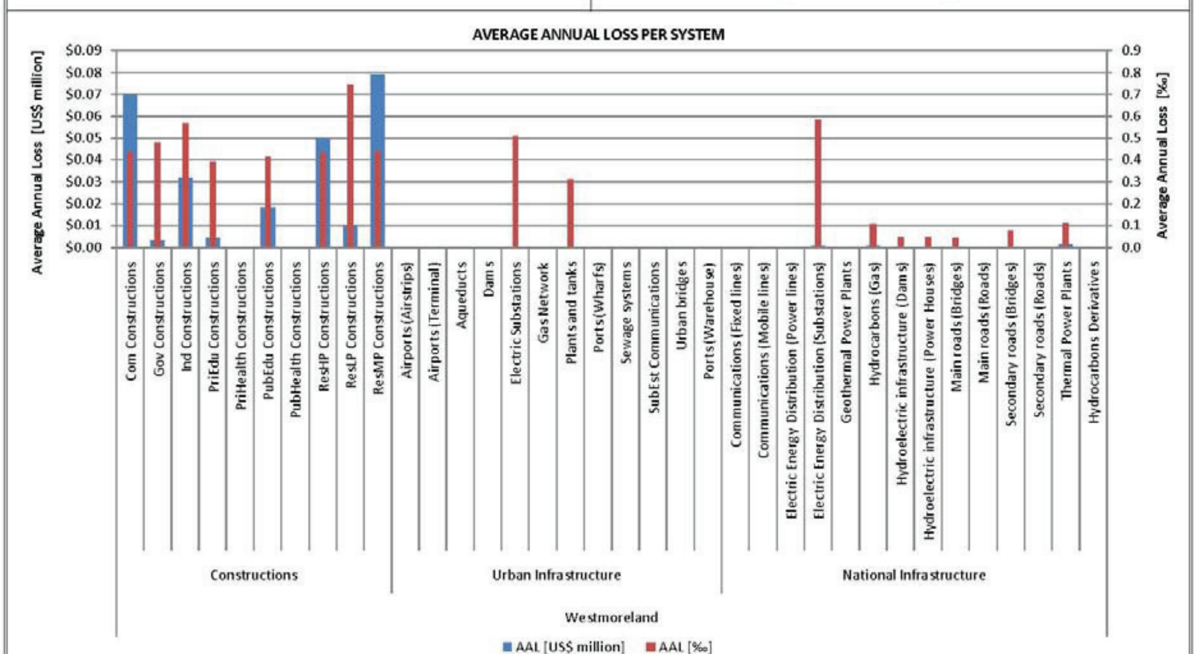


COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Westmoreland		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$5.55	0.66%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$834.89	250 years	$12.29	1.47%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.27	500 years	$19.68	2.36%	3.92%	9.52%	18.13%	63.21%
	‰	0.32	1000 years	$29.12	3.49%	1.98%	4.88%	9.52%	39.35%

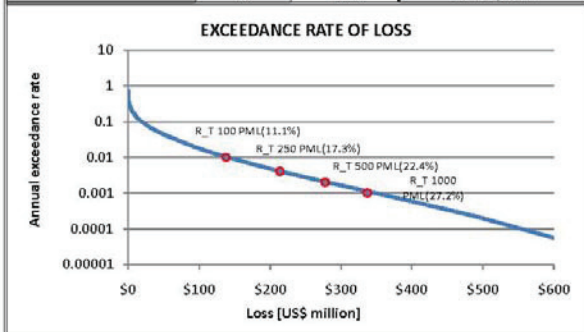


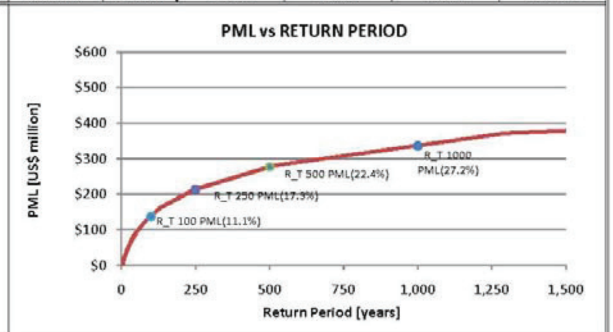


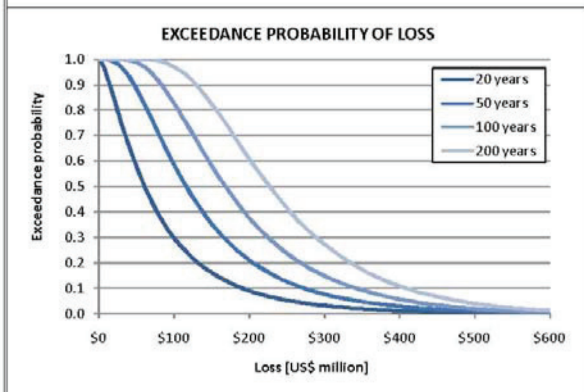


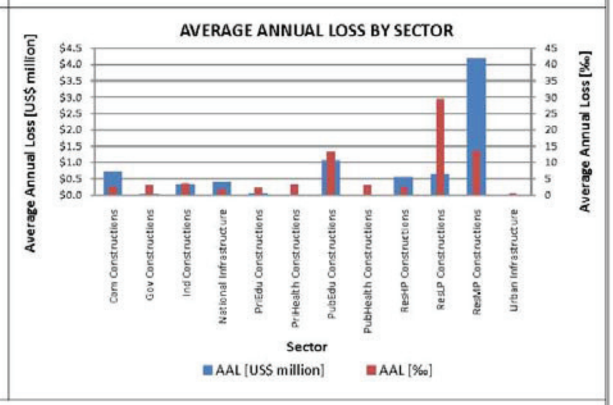


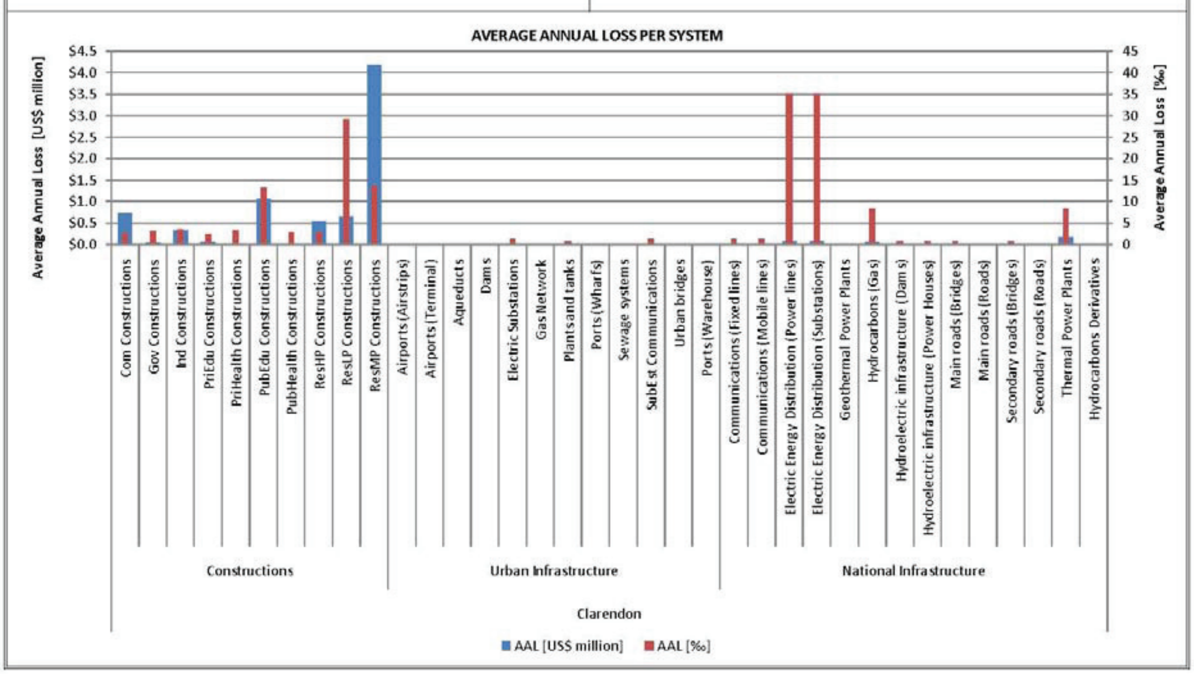
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			**Probable Maximum Loss**			**Exceedance probability of PML values**			
Parish	Clarendon		**Return Period**	**US$ x10⁶**	**%**	**20 years**	**50 years**	**100 years**	**500 years**
			100 years	$137.39	11.13%	18.13%	39.35%	63.21%	99.33%
Exposure Value	**US$ x10⁶**	$1,234.61	**250 years**	$213.25	17.27%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	**US$ x10⁶**	$7.97	**500 years**	$276.74	22.42%	3.92%	9.52%	18.13%	63.21%
	‰	6.46	**1000 years**	$336.27	27.24%	1.98%	4.88%	9.52%	39.35%



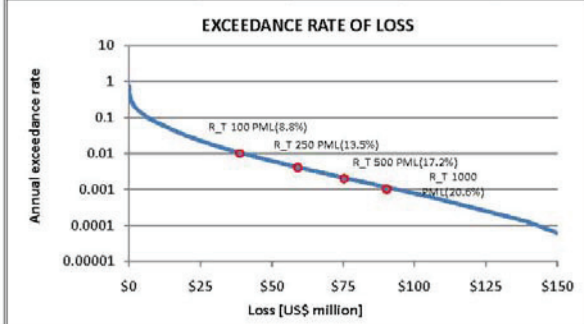


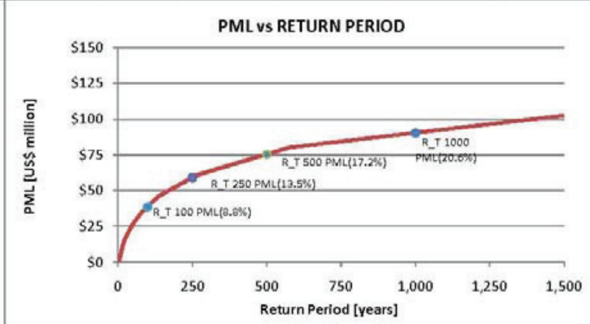


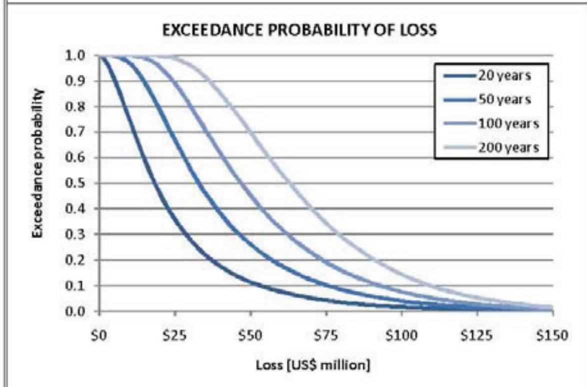


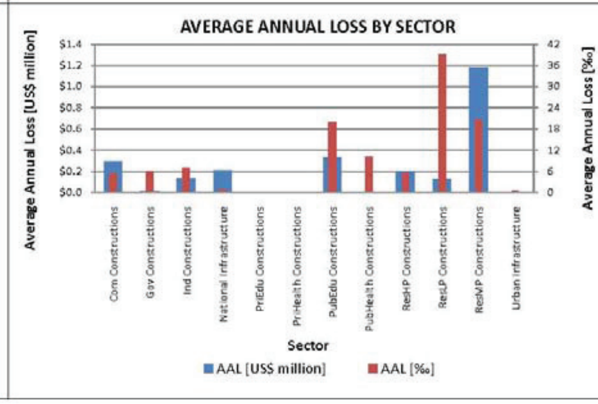


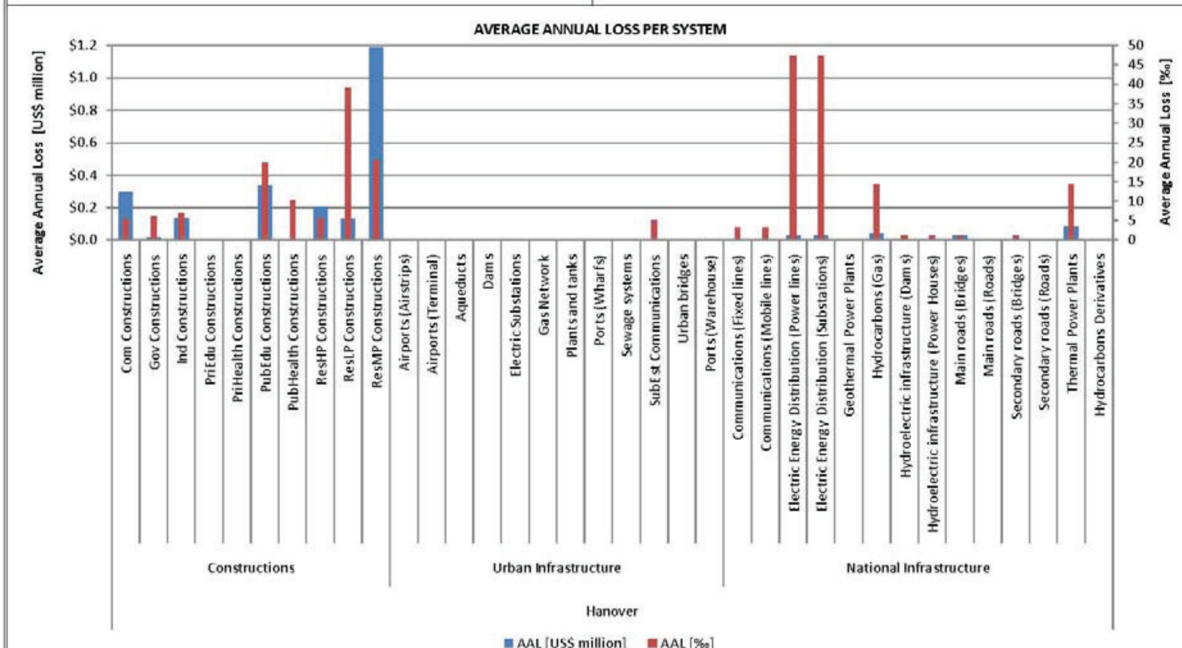
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Hanover		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$38.61	8.84%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$436.82	250 years	$58.96	13.50%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$2.50	500 years	$75.17	17.21%	3.92%	9.52%	18.13%	63.21%
	‰	5.72	1000 years	$90.15	20.64%	1.98%	4.88%	9.52%	39.35%



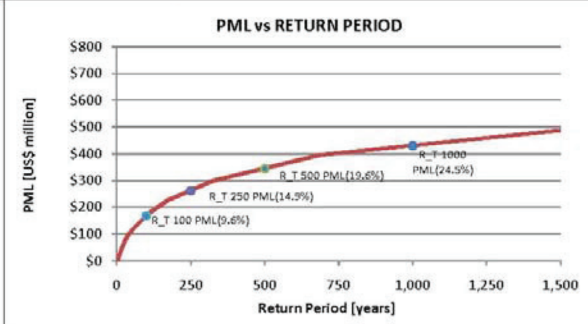


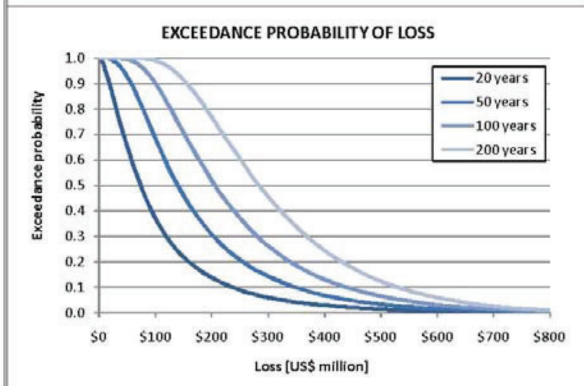


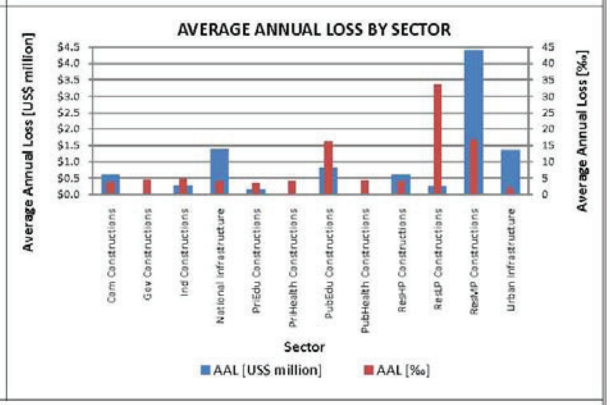


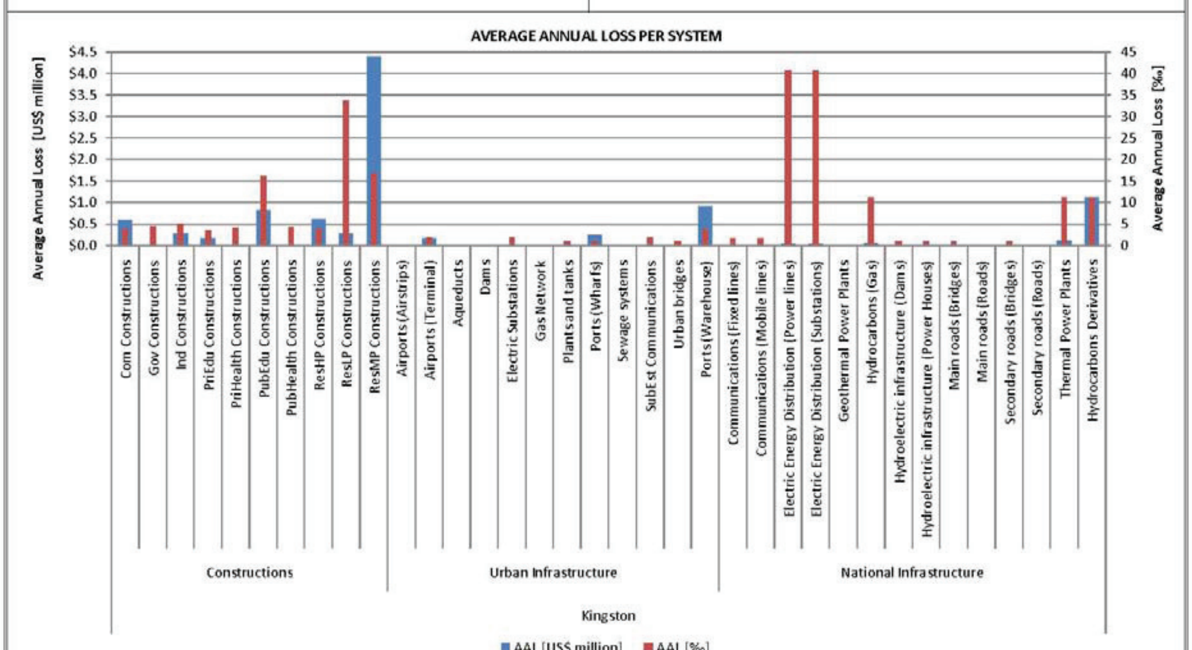


COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Kingston		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$168.00	9.57%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10⁶	$1,756.02	250 years	$261.76	14.91%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10⁶	$9.90	500 years	$344.67	19.63%	3.92%	9.52%	18.13%	63.21%
	‰	5.64	1000 years	$430.26	24.50%	1.98%	4.88%	9.52%	39.35%





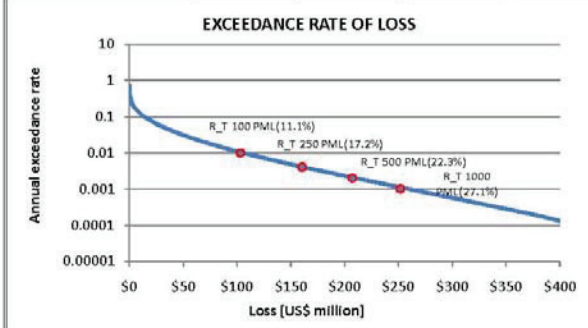


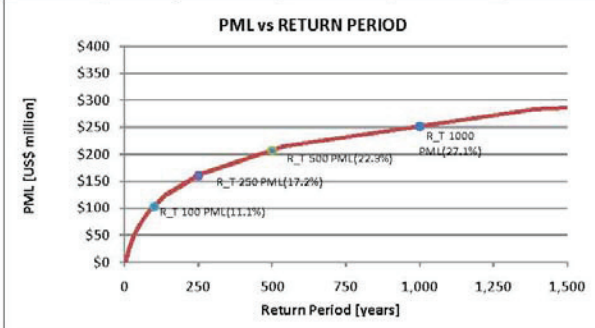


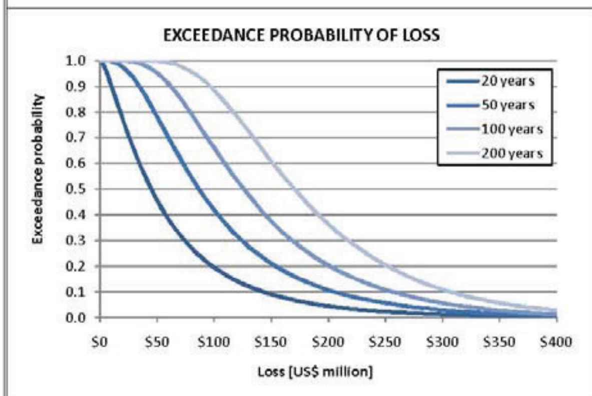
COUNTRY	JAMAICA	HAZARD	HURRICANE-WINDS	DATE OF ANALYSIS	01/07/2009

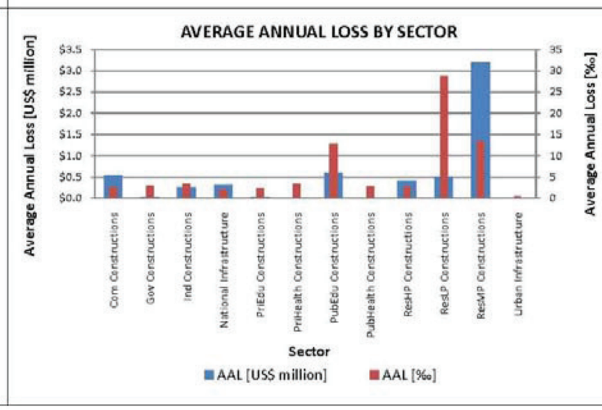
Results		
Parish	Manchester	
Exposure Value	US$ $x10^6$	$928.39
Average Annual Loss	US$ $x10^6$	$5.89
	‰	6.34

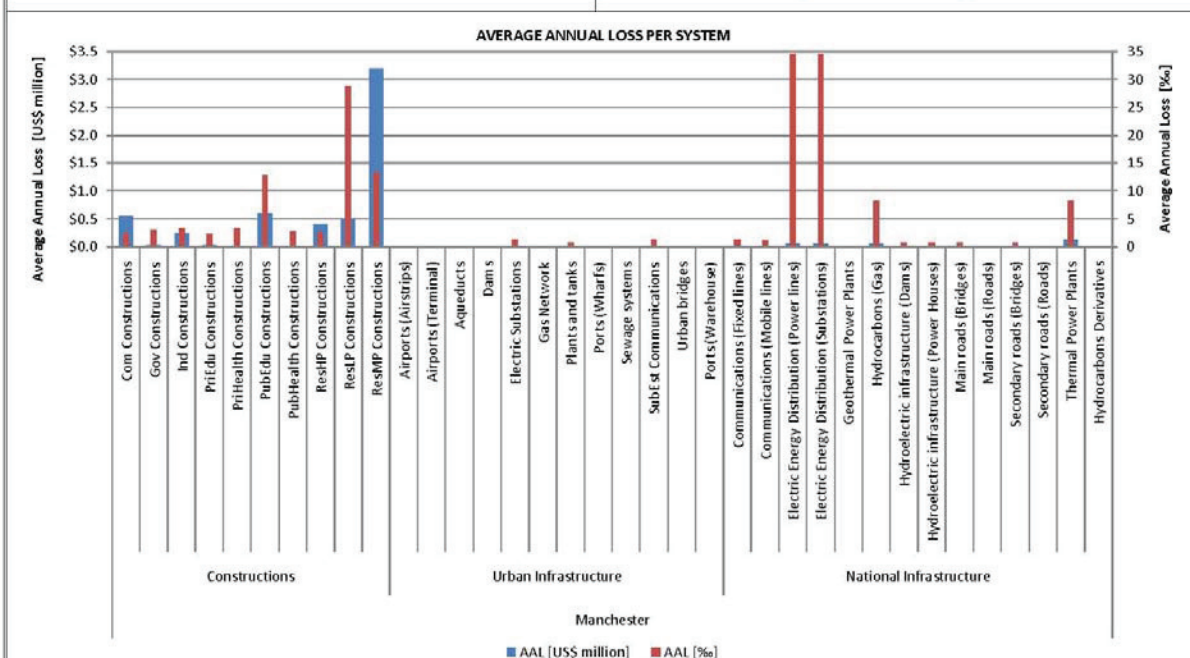
Probable Maximum Loss			Exceedance probability of PML values			
Return Period	US$ $x10^6$	%	20 years	50 years	100 years	500 years
100 years	$102.87	11.08%	18.13%	39.35%	63.21%	99.33%
250 years	$159.89	17.22%	7.69%	18.13%	32.97%	86.47%
500 years	$206.58	22.25%	3.92%	9.52%	18.13%	63.21%
1000 years	$251.29	27.07%	1.98%	4.88%	9.52%	39.35%







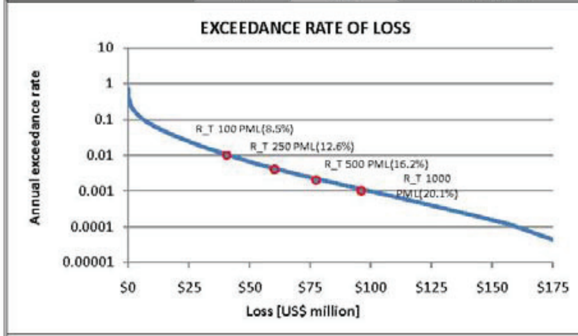


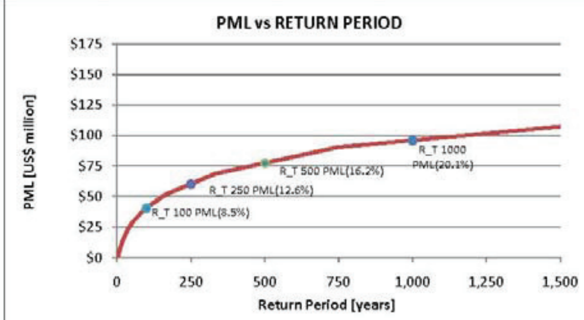


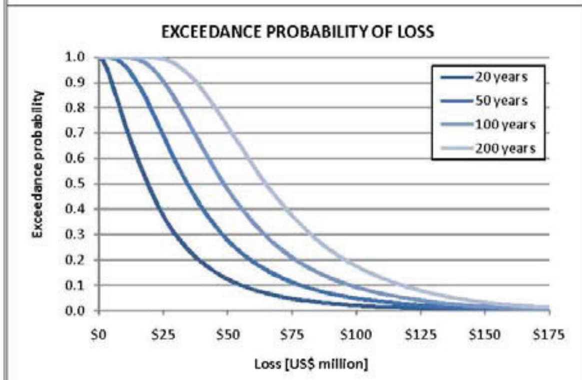
COUNTRY	JAMAICA	HAZARD	HURRICANE-WINDS	DATE OF ANALYSIS	01/07/2009

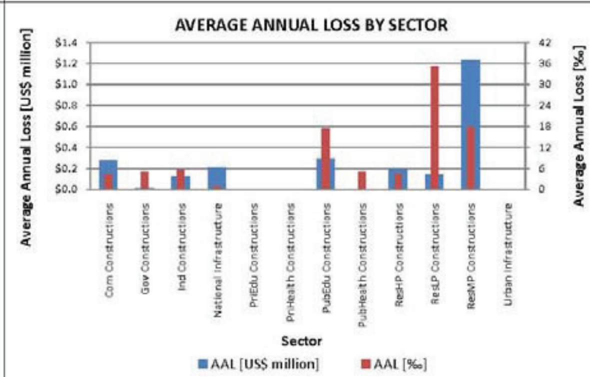
Results		
Parish	Portland	
Exposure Value	US$ x10^6	$477.47
Average Annual Loss	US$ x10^6	$2.49
	‰	5.21

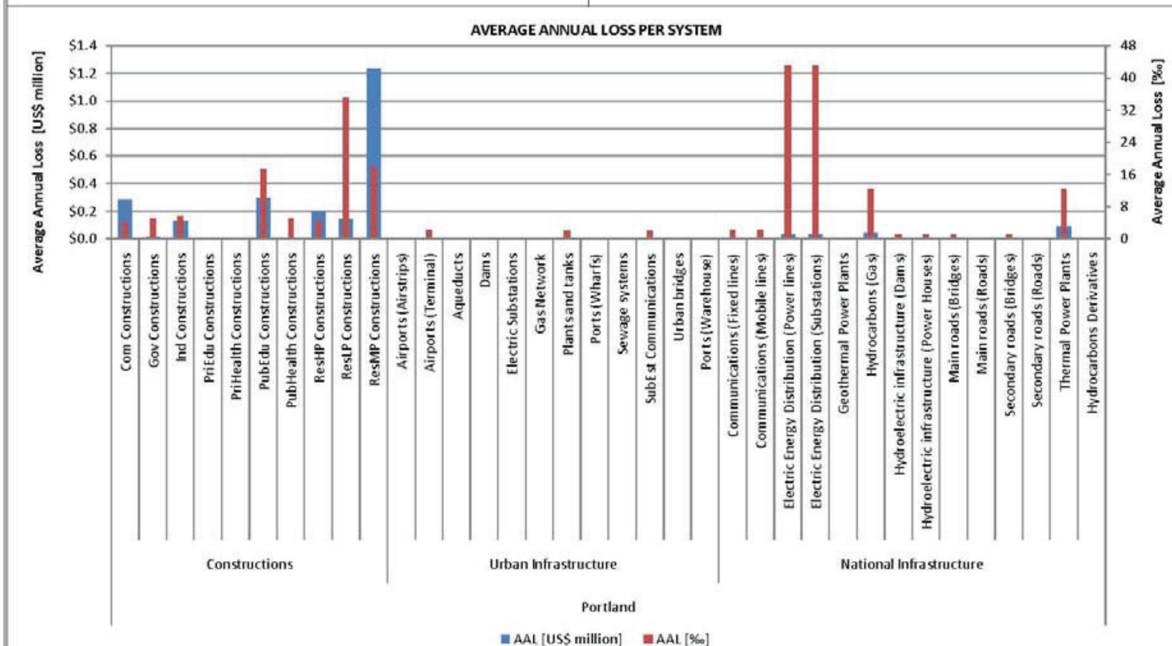
Probable Maximum Loss			Exceedance probability of PML values			
Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
100 years	$40.45	8.47%	18.13%	39.35%	63.21%	99.33%
250 years	$60.11	12.59%	7.69%	18.13%	32.97%	86.47%
500 years	$77.23	16.18%	3.92%	9.52%	18.13%	63.21%
1000 years	$95.86	20.08%	1.98%	4.88%	9.52%	39.35%



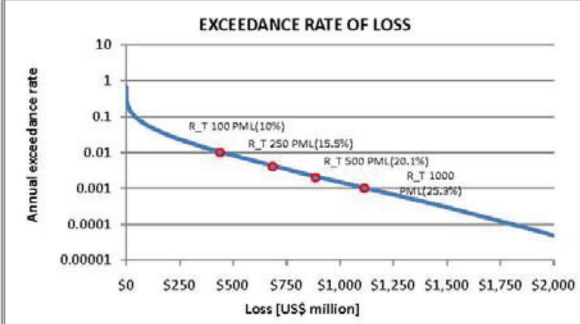


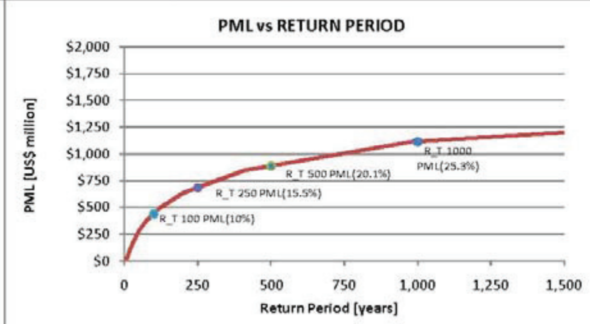


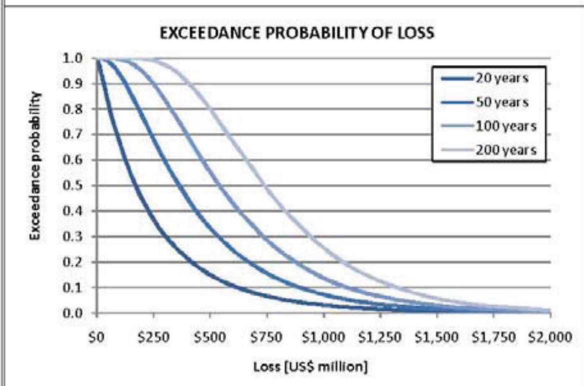


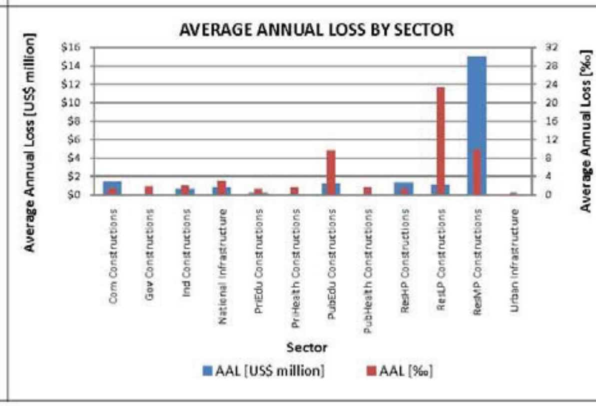


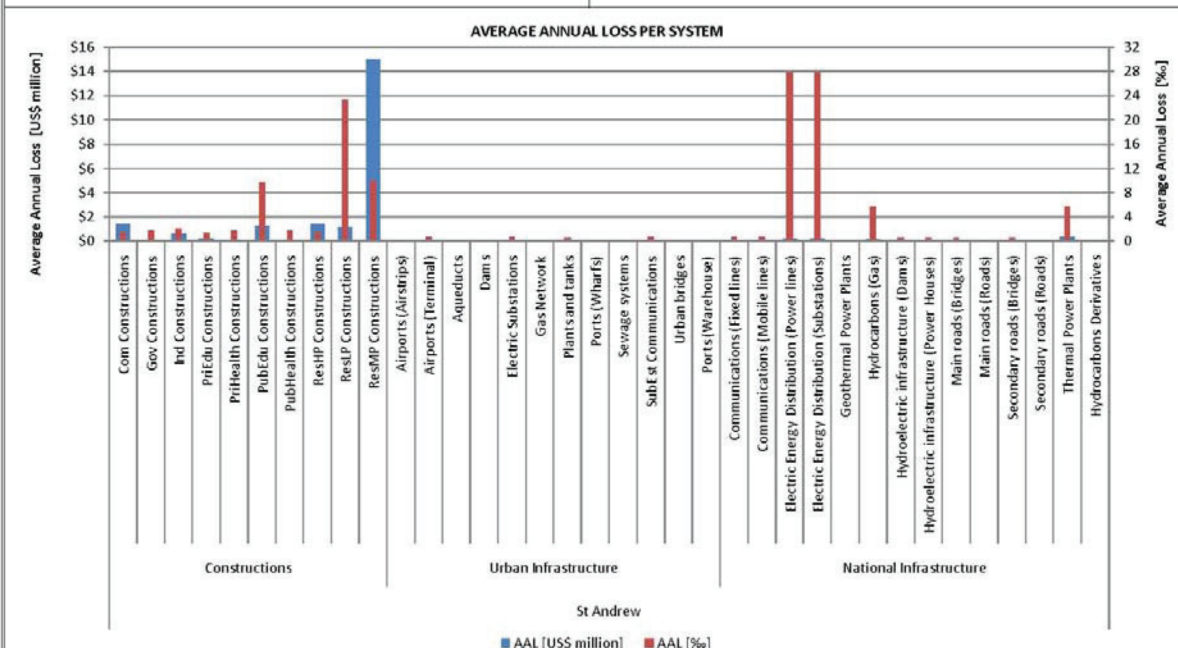
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Andrew		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$437.70	9.96%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$4,396.69	250 years	$683.58	15.55%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$21.93	500 years	$885.01	20.13%	3.92%	9.52%	18.13%	63.21%
	‰	4.99	1000 years	$1,113.26	25.32%	1.98%	4.88%	9.52%	39.35%



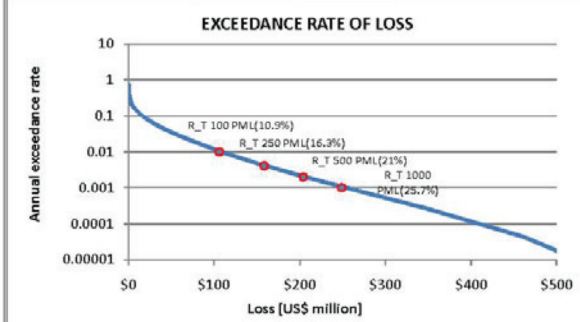


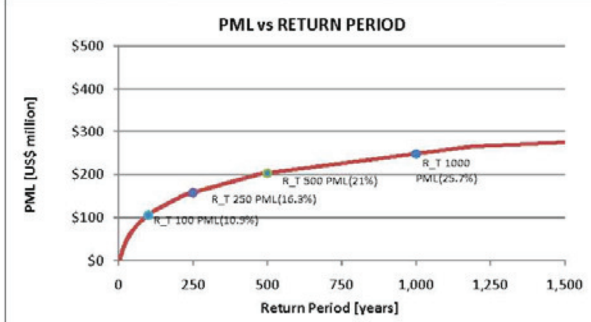


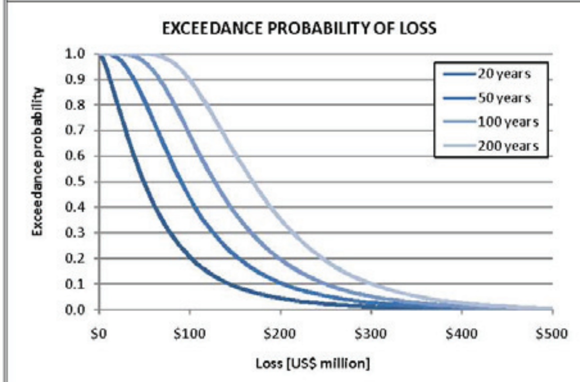


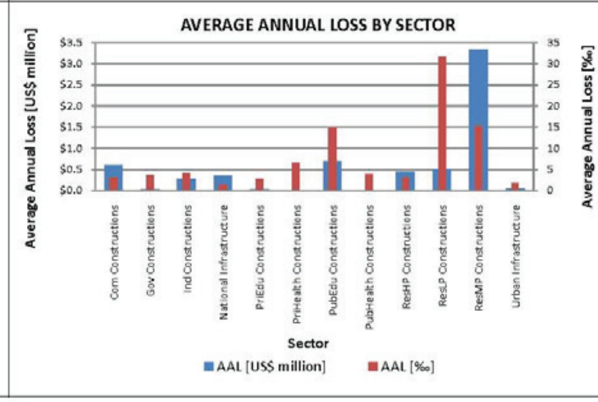


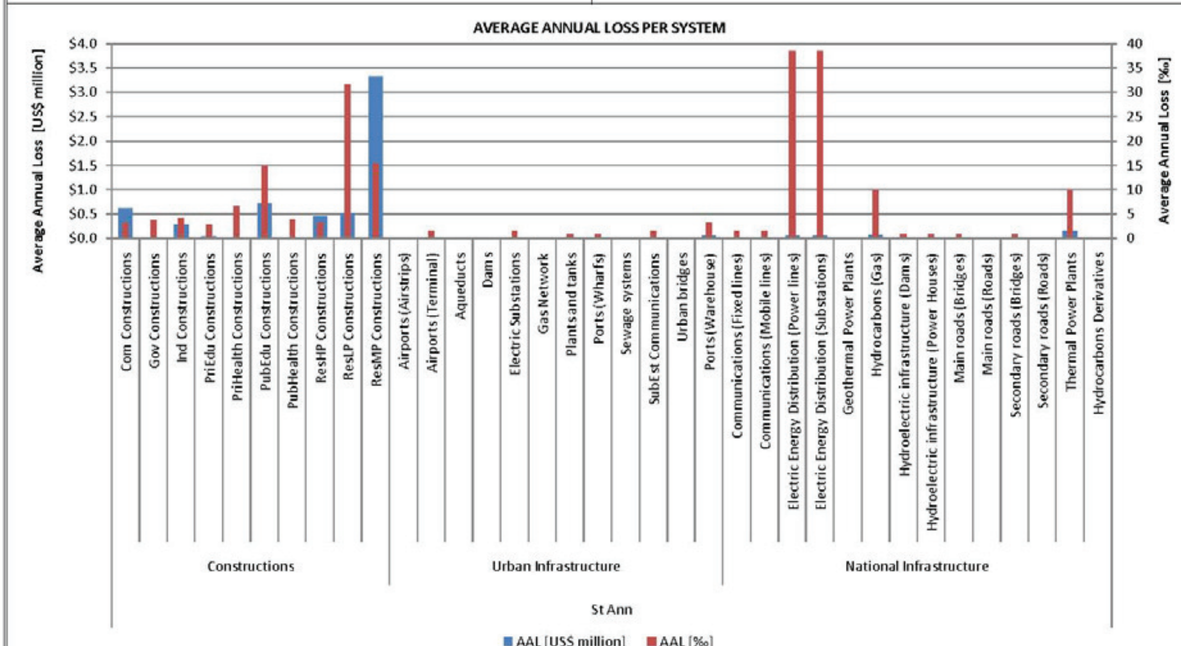
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Ann		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$105.39	10.90%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$966.98	250 years	$157.71	16.31%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$6.34	500 years	$203.52	21.05%	3.92%	9.52%	18.13%	63.21%
	‰	6.56	1000 years	$248.13	25.66%	1.98%	4.88%	9.52%	39.35%



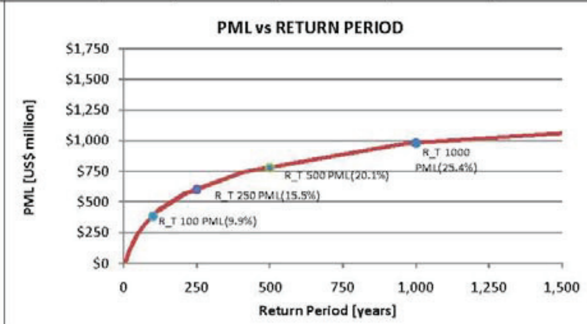


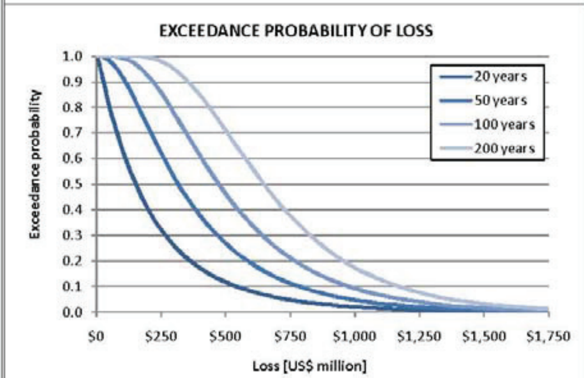


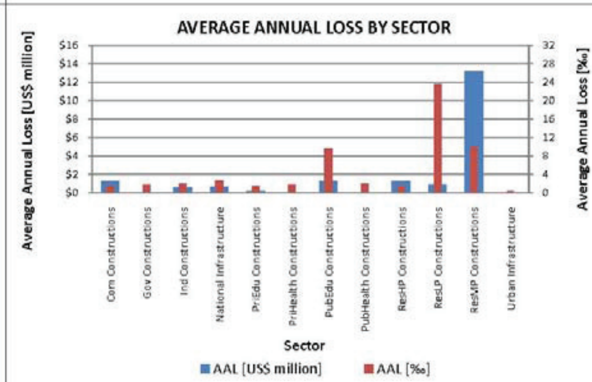


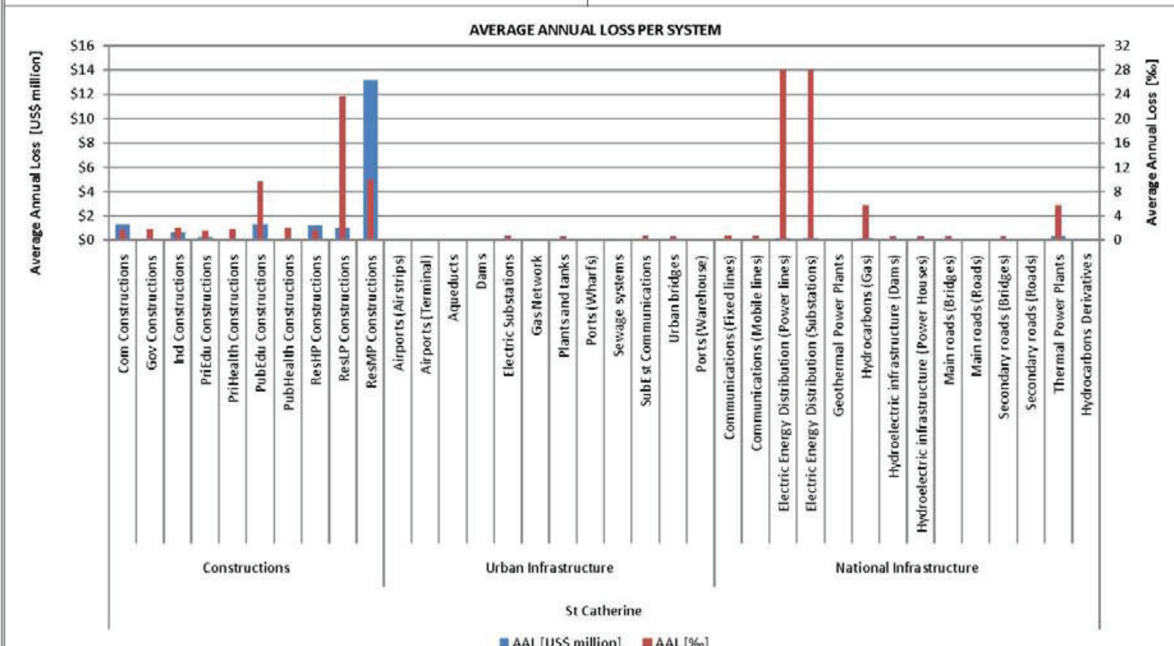


COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Catherine		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$382.90	9.91%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10⁶	$3,863.77	250 years	$599.83	15.52%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10⁶	$19.42	500 years	$778.52	20.15%	3.92%	9.52%	18.13%	63.21%
	‰	5.03	1000 years	$980.52	25.38%	1.98%	4.88%	9.52%	39.35%

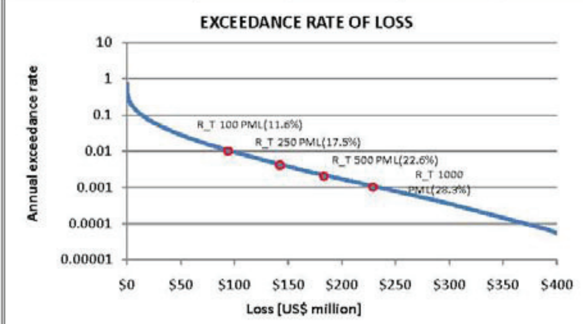


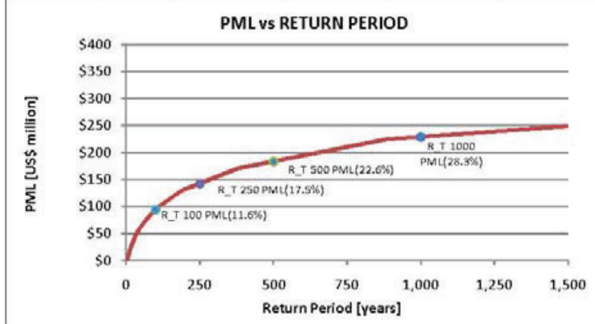


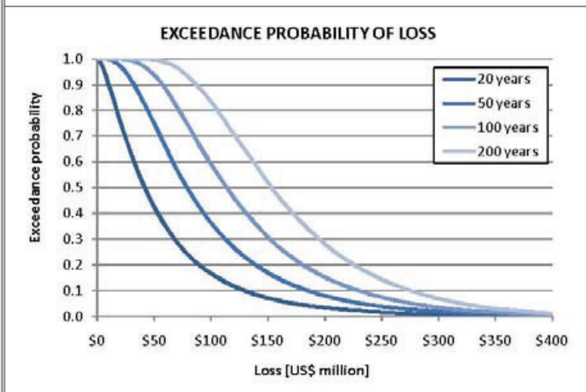


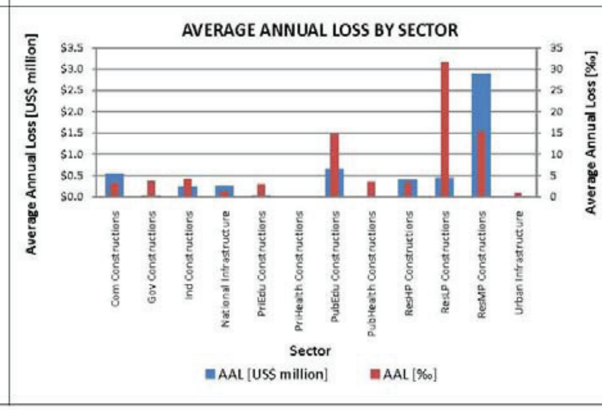


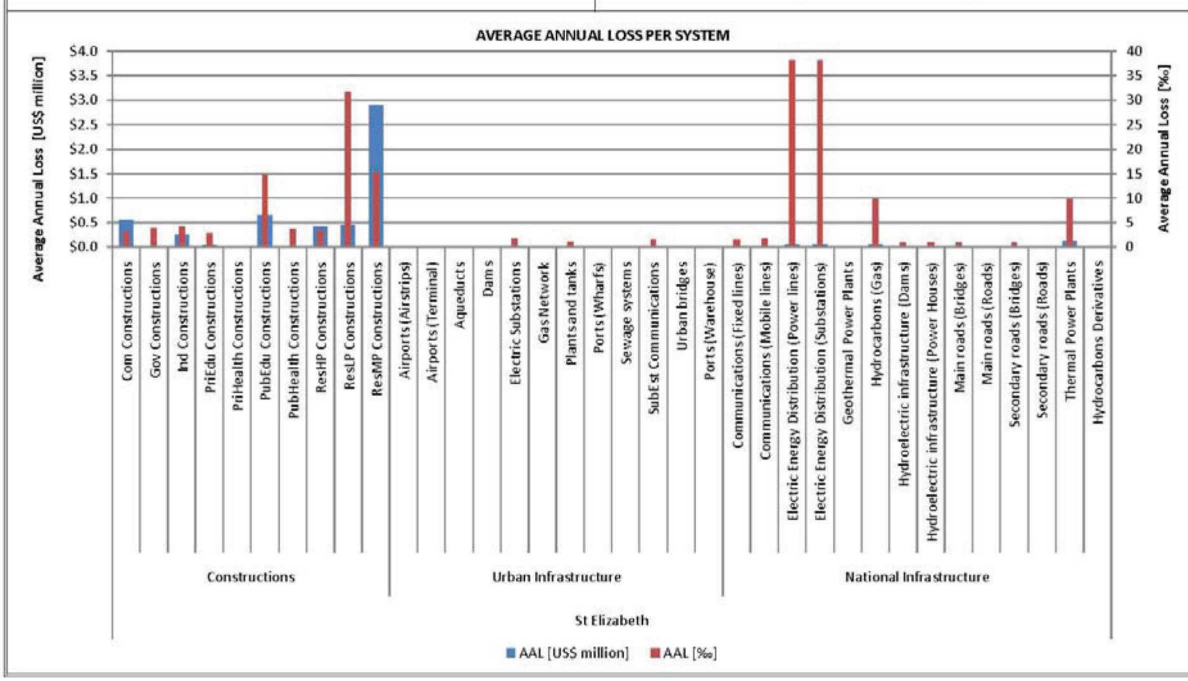
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Elizabeth		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$93.89	11.61%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$808.85	250 years	$141.81	17.53%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$5.49	500 years	$182.81	22.60%	3.92%	9.52%	18.13%	63.21%
	‰	6.79	1000 years	$228.50	28.25%	1.98%	4.88%	9.52%	39.35%



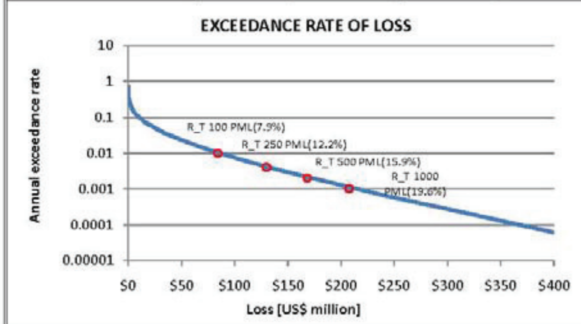


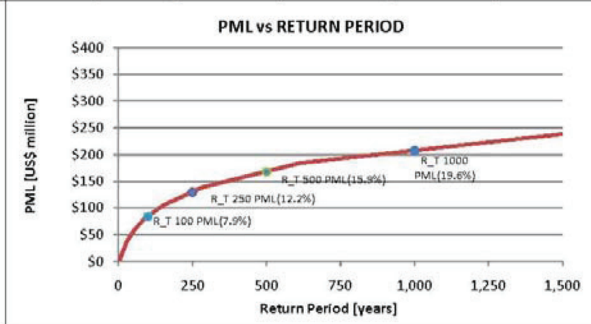


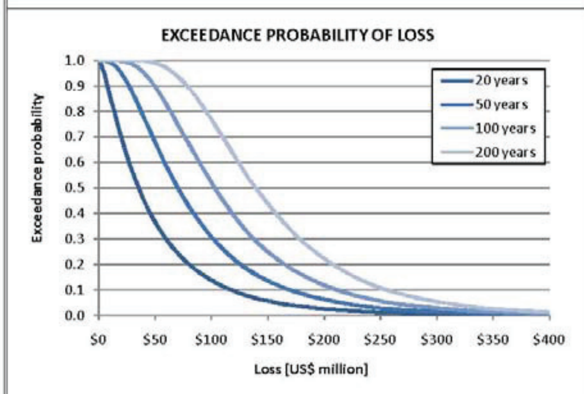


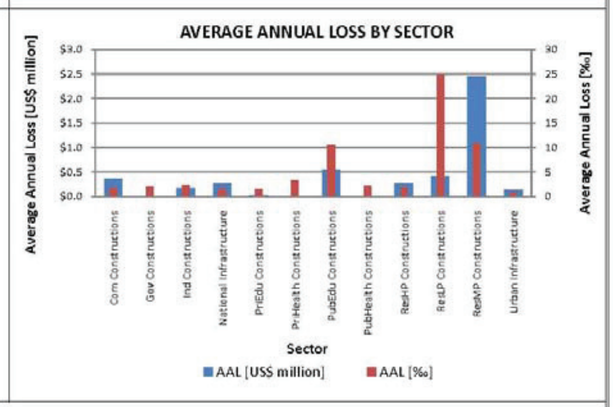


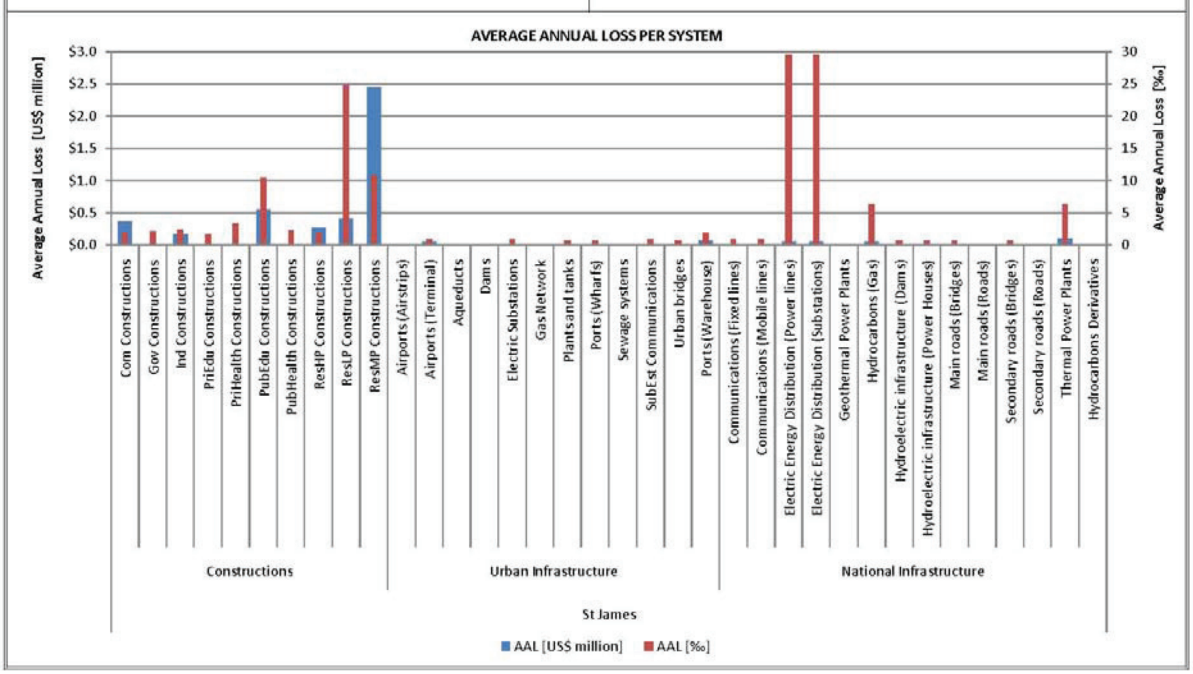
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St James		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$83.82	7.92%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$1,058.13	250 years	$129.38	12.23%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$4.64	500 years	$167.80	15.86%	3.92%	9.52%	18.13%	63.21%
	‰	4.39	1000 years	$207.06	19.57%	1.98%	4.88%	9.52%	39.35%



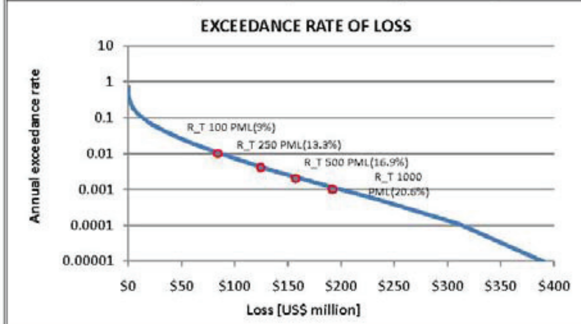


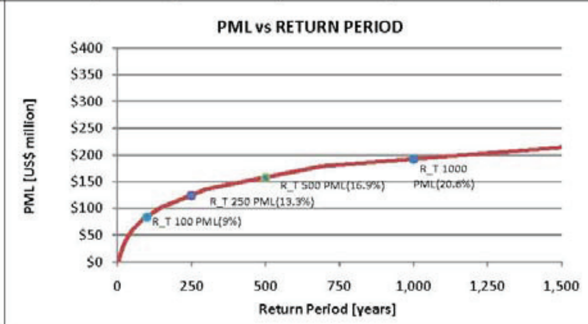


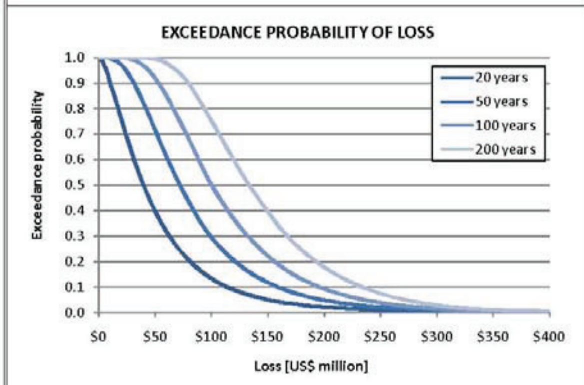


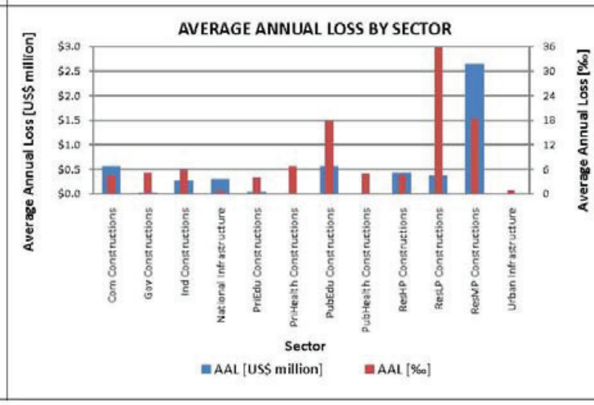


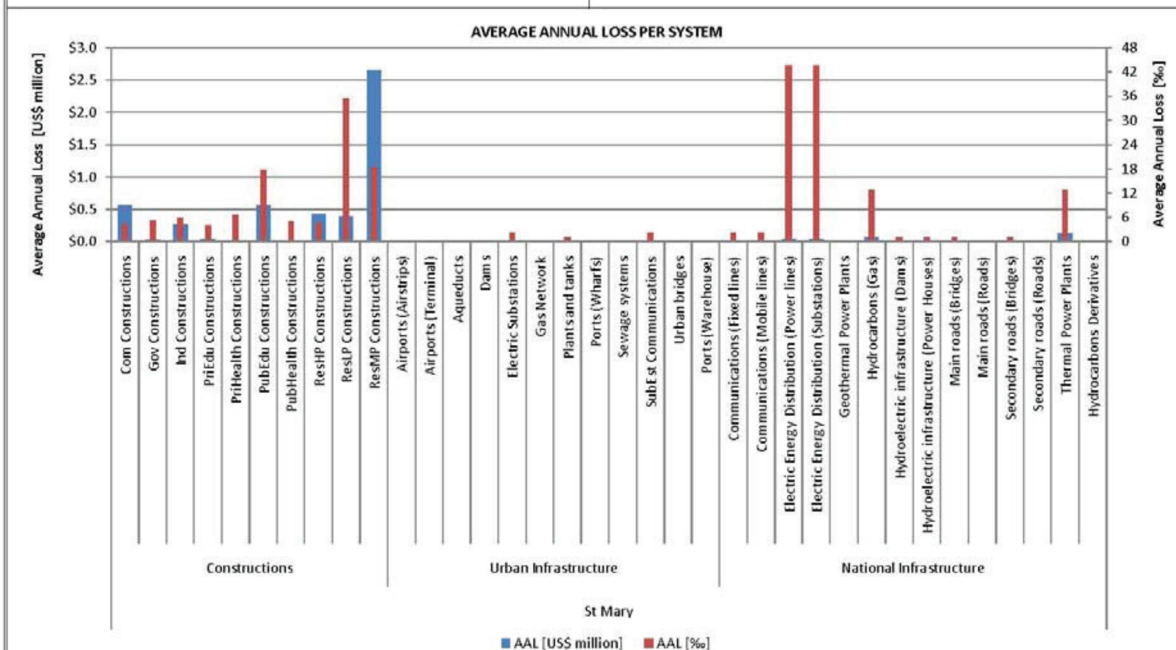
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Mary		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$83.63	8.98%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$931.78	250 years	$124.09	13.32%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$5.19	500 years	$157.10	16.86%	3.92%	9.52%	18.13%	63.21%
	‰	5.57	1000 years	$191.54	20.56%	1.98%	4.88%	9.52%	39.35%



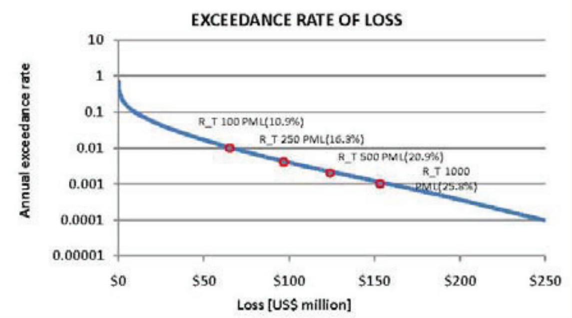


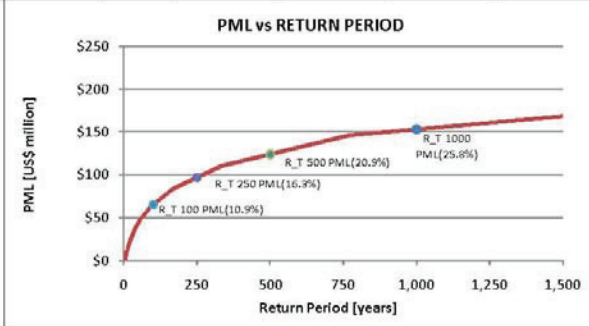


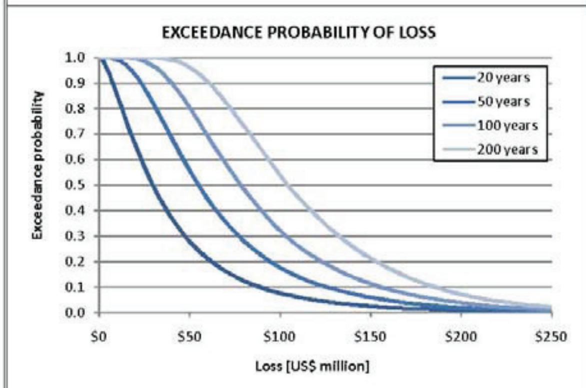


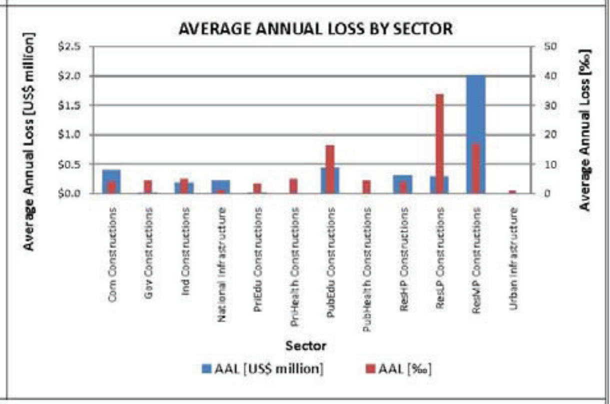


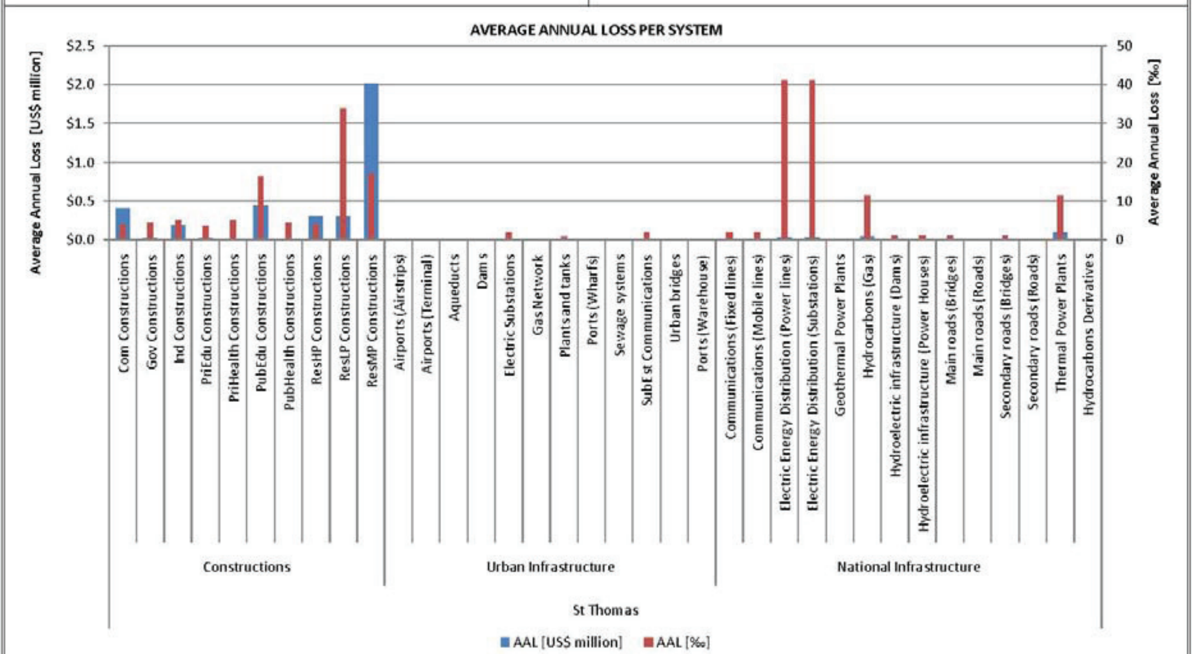
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	St Thomas		Return Period	US$ x10[6]	%	20 years	50 years	100 years	500 years
			100 years	$64.94	10.95%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10[6]	$593.08	250 years	$96.55	16.28%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10[6]	$3.90	500 years	$123.71	20.86%	3.92%	9.52%	18.13%	63.21%
	‰	6.58	1000 years	$153.06	25.81%	1.98%	4.88%	9.52%	39.35%



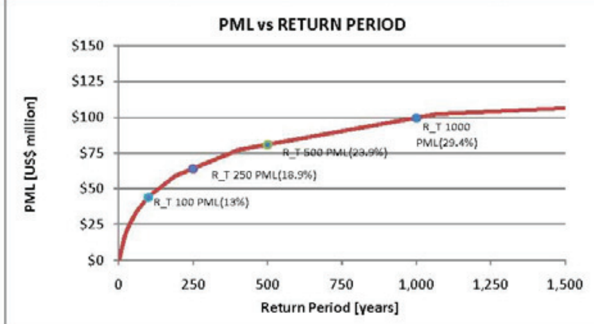


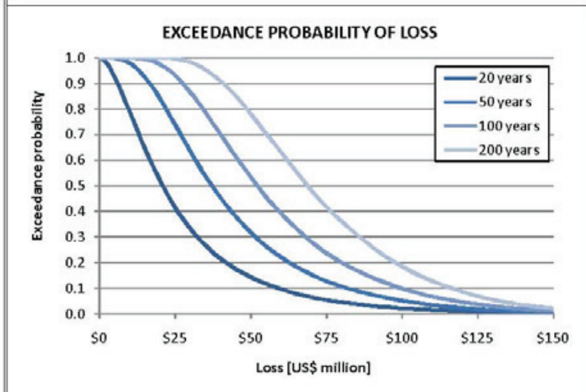


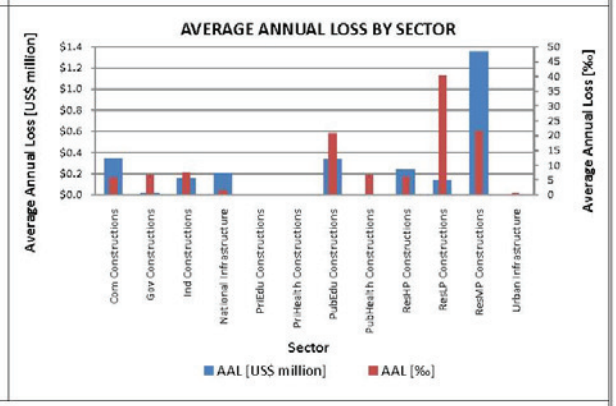


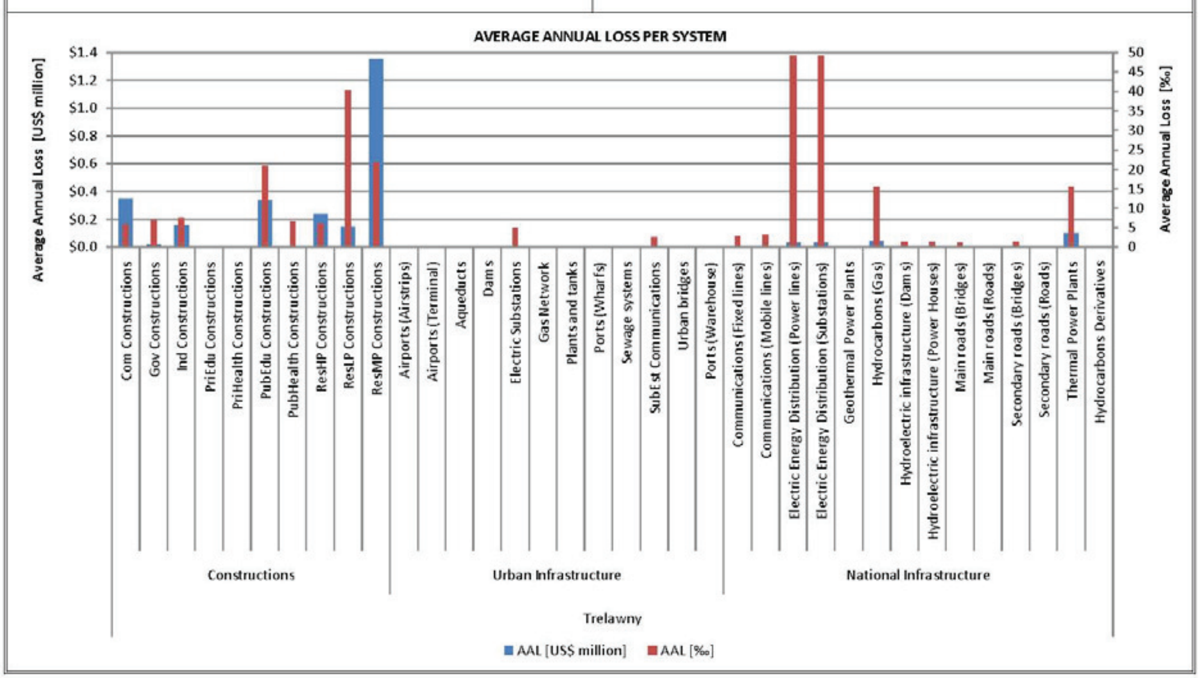


COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Trelawny		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$43.78	12.96%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$337.66	250 years	$63.73	18.87%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$2.81	500 years	$80.72	23.91%	3.92%	9.52%	18.13%	63.21%
	‰	8.32	1000 years	$99.44	29.45%	1.98%	4.88%	9.52%	39.35%

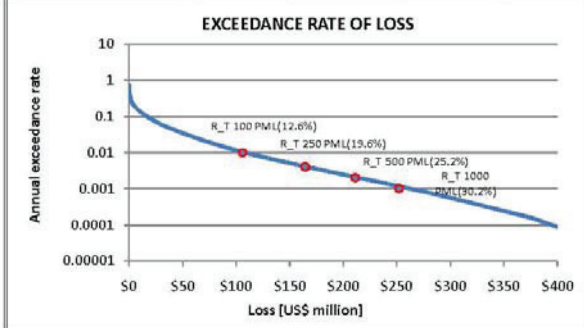


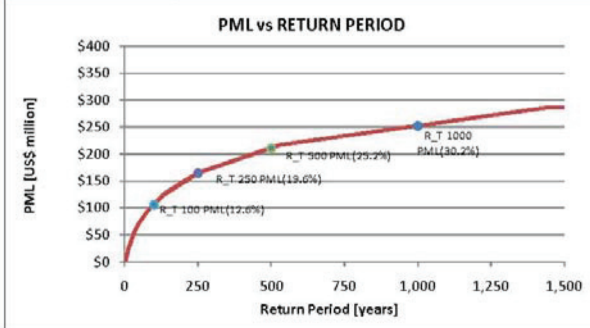


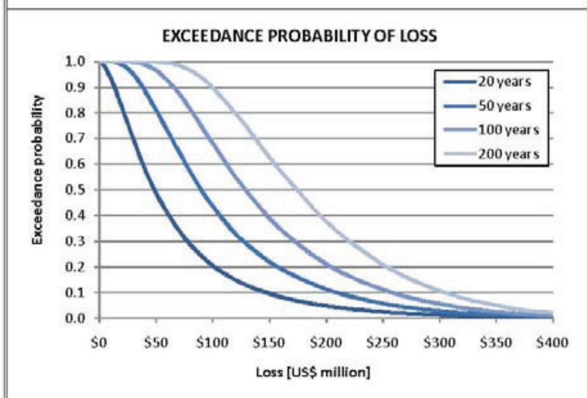


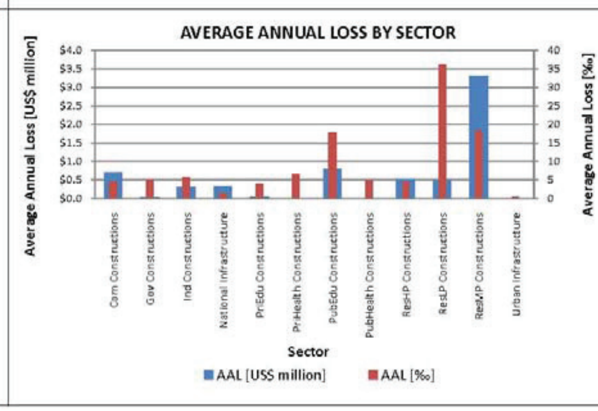


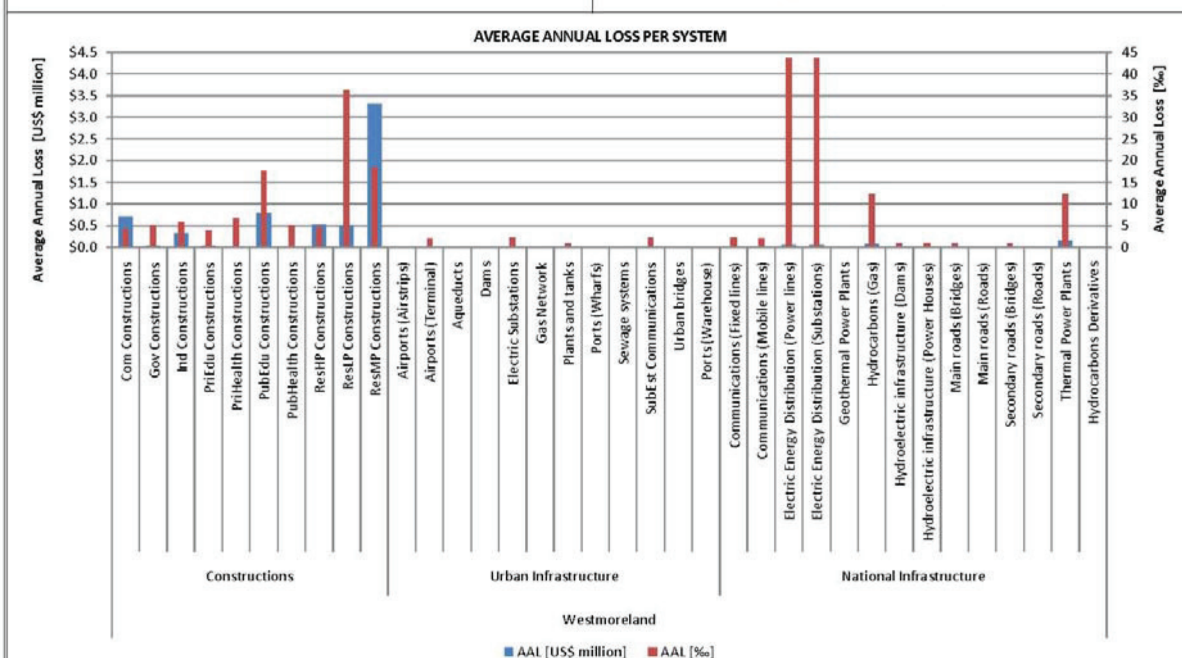
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Parish	Westmoreland		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$105.49	12.64%	18.13%	39.35%	63.21%	99.33%
Exposure Value	US$ x10^6	$834.89	250 years	$164.00	19.64%	7.69%	18.13%	32.97%	86.47%
Average Annual Loss	US$ x10^6	$6.54	500 years	$210.58	25.22%	3.92%	9.52%	18.13%	63.21%
	‰	7.83	1000 years	$251.96	30.18%	1.98%	4.88%	9.52%	39.35%





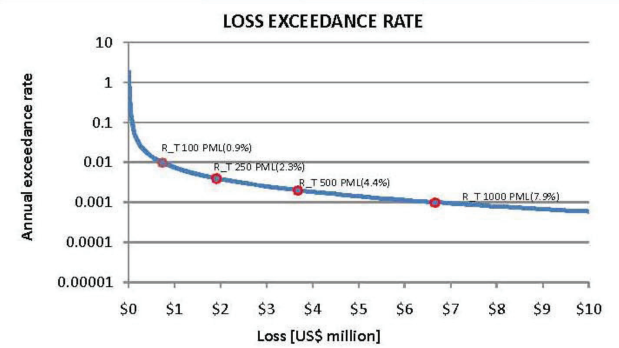


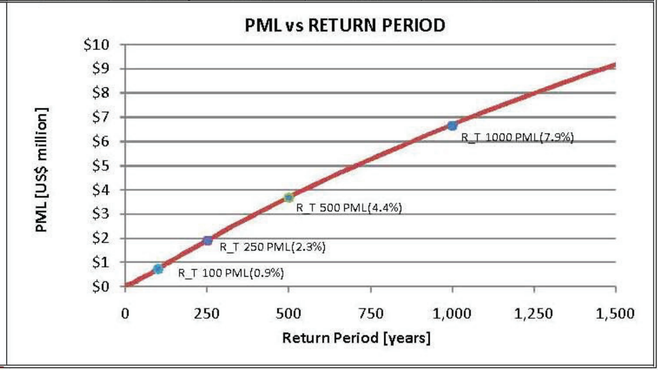




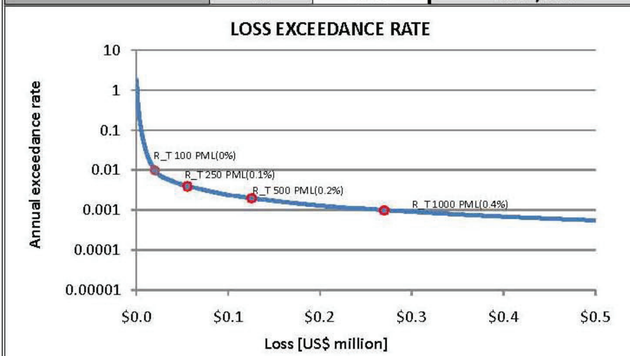
ANNEX 7. INDIVIDUAL RESULTS BY SECTOR

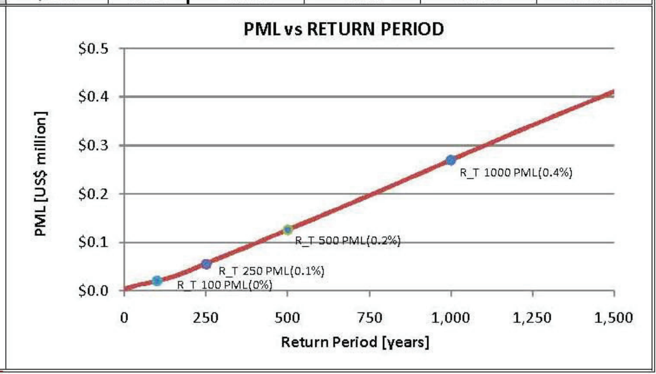
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Electric Substations		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.72	0.86%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$84.09	250 years	$1.90	2.26%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.07	500 years	$3.67	4.37%	3.92%	9.52%	18.13%	63.21%
	‰	0.83	1000 years	$6.65	7.91%	1.98%	4.88%	9.52%	39.35%



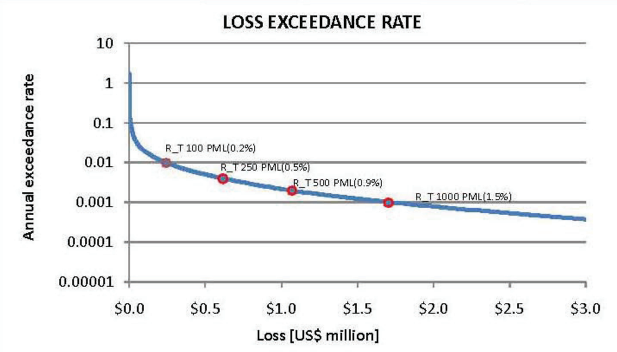


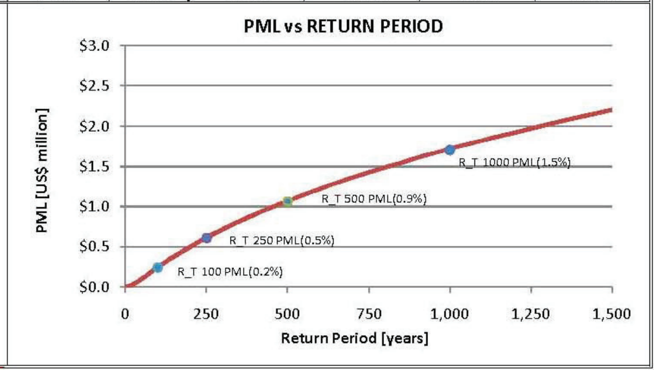
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	SubEst Communications		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.02	0.03%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$67.07	250 years	$0.06	0.08%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.00	500 years	$0.13	0.19%	3.92%	9.52%	18.13%	63.21%
	‰	0.00	1000 years	$0.27	0.40%	1.98%	4.88%	9.52%	39.35%



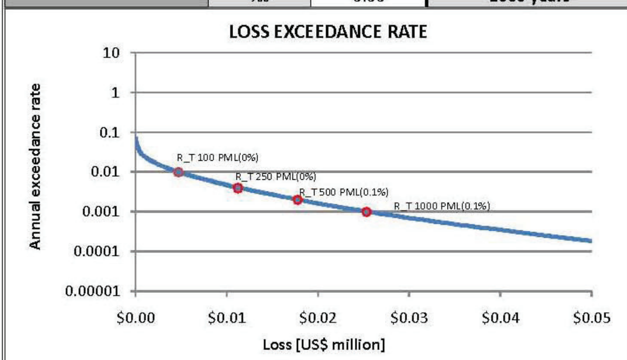


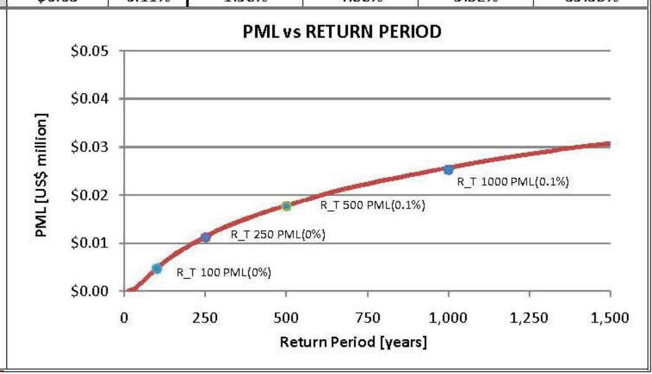
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Production and distribution (Water)		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.24	0.21%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$112.57	250 years	$0.61	0.54%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.01	500 years	$1.07	0.95%	3.92%	9.52%	18.13%	63.21%
	‰	0.09	1000 years	$1.70	1.51%	1.98%	4.88%	9.52%	39.35%



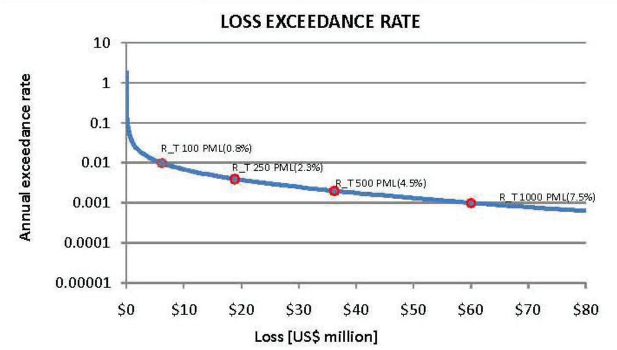


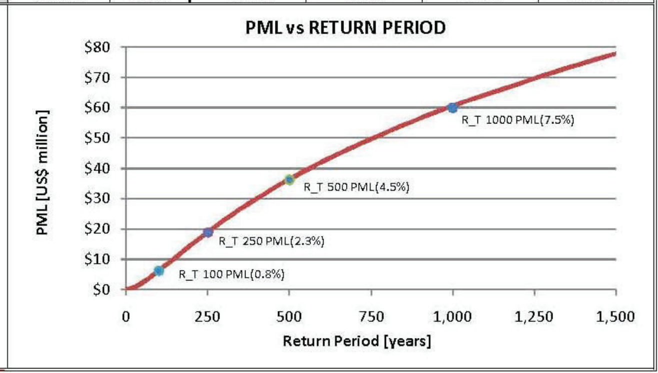
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Gas Network		Return Period	US$ x10⁶	%	20 years	50 years	100 years	500 years
			100 years	$0.00	0.02%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10⁶	$22.64	250 years	$0.01	0.05%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10⁶	$0.00	500 years	$0.02	0.08%	3.92%	9.52%	18.13%	63.21%
	‰	0.00	1000 years	$0.03	0.11%	1.98%	4.88%	9.52%	39.35%



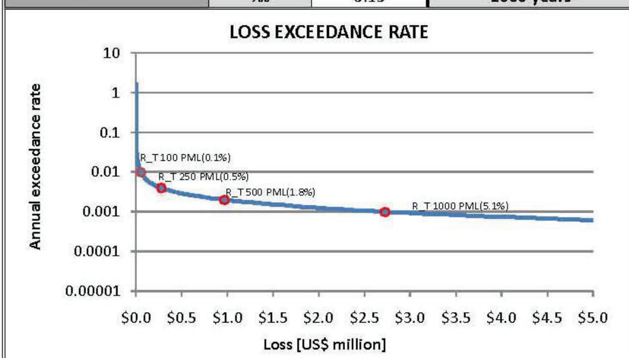


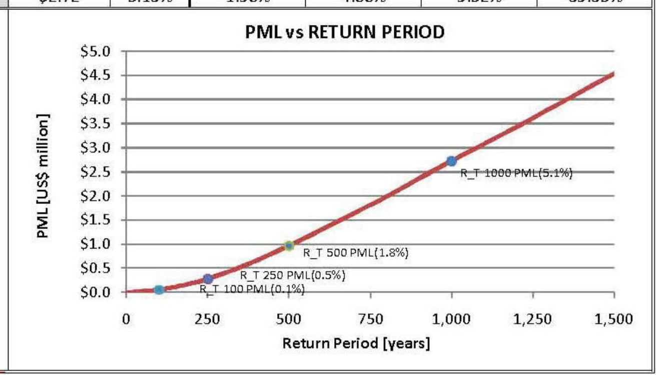
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Transportation terminals		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$6.14	0.77%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$801.87	250 years	$18.81	2.35%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.39	500 years	$36.17	4.51%	3.92%	9.52%	18.13%	63.21%
	‰	0.49	1000 years	$60.00	7.48%	1.98%	4.88%	9.52%	39.35%



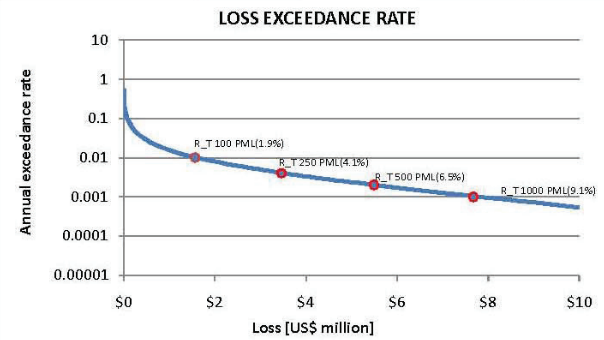


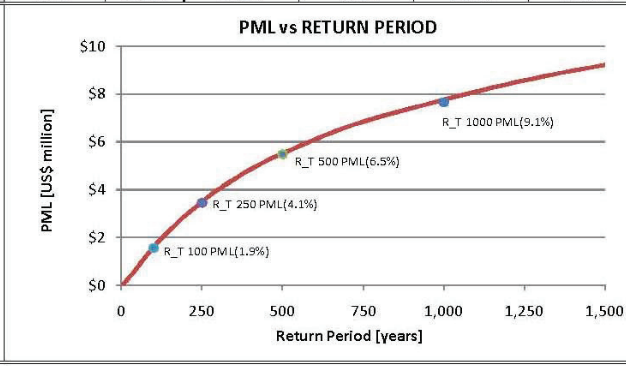
COUNTRY	JAMAICA		HAZARD	EARTHQUAKE		DATE OF ANALYSIS	01/07/2009		
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Urban bridges		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$0.05	0.09%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$52.98	250 years	$0.27	0.51%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.01	500 years	$0.96	1.82%	3.92%	9.52%	18.13%	63.21%
	‰	0.19	1000 years	$2.72	5.13%	1.98%	4.88%	9.52%	39.35%



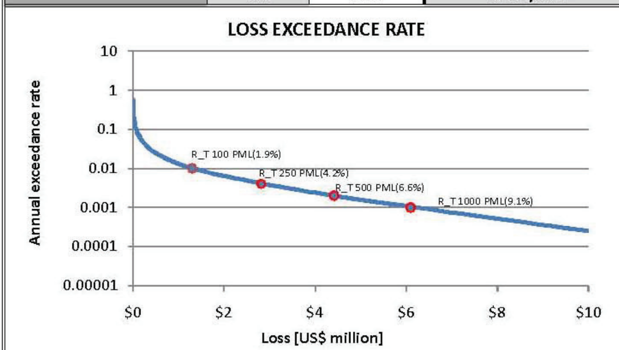


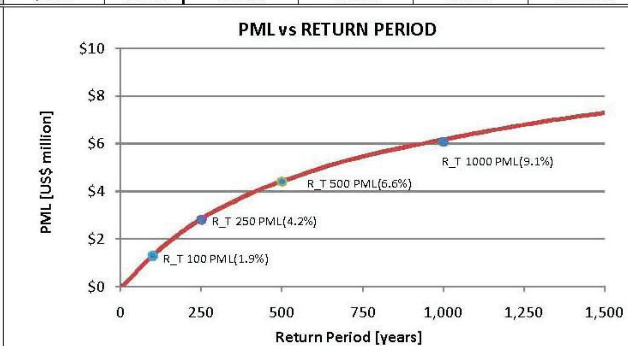
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Electric Substations		Return Period	US$ $x10^6$	%	20 years	50 years	100 years	500 years
			100 years	$1.56	1.85%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ $x10^6$	$84.09	250 years	$3.45	4.11%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ $x10^6$	$0.07	500 years	$5.48	6.52%	3.92%	9.52%	18.13%	63.21%
	‰	0.83	1000 years	$7.67	9.12%	1.98%	4.88%	9.52%	39.35%



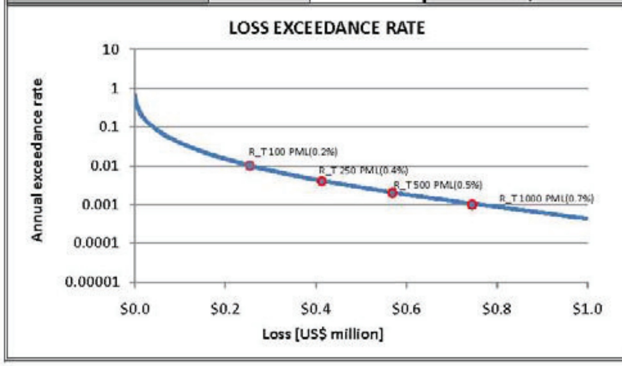


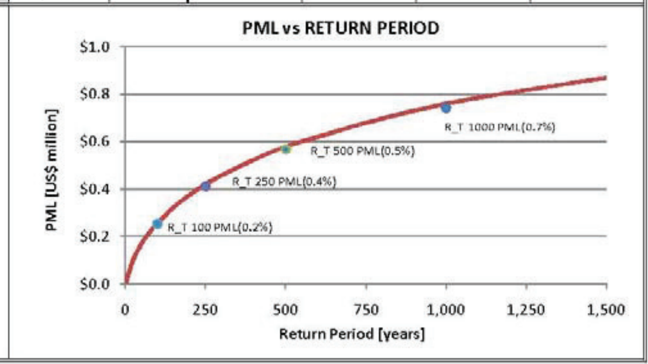
COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	SubEst Communications		Return Period	US$ $x10^6$	%	20 years	50 years	100 years	500 years
			100 years	$1.29	1.92%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ $x10^6$	$67.07	250 years	$2.81	4.18%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ $x10^6$	$0.06	500 years	$4.41	6.57%	3.92%	9.52%	18.13%	63.21%
	‰	0.89	1000 years	$6.09	9.07%	1.98%	4.88%	9.52%	39.35%



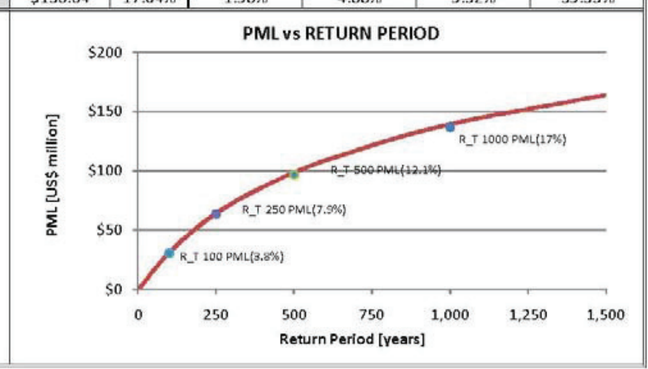


COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Production and distribution (Water)		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$0.25	0.22%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$112.57	250 years	$0.41	0.37%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.02	500 years	$0.57	0.50%	3.92%	9.52%	18.13%	63.21%
	‰	0.18	1000 years	$0.74	0.66%	1.98%	4.88%	9.52%	39.35%





COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Transportation terminals		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$30.28	3.78%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$801.87	250 years	$63.26	7.89%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$1.51	500 years	$96.76	12.07%	3.92%	9.52%	18.13%	63.21%
	‰	1.88	1000 years	$136.64	17.04%	1.98%	4.88%	9.52%	39.35%



COUNTRY	JAMAICA		HAZARD	HURRICANE-WINDS		DATE OF ANALYSIS		01/07/2009	
Results			Probable Maximum Loss			Exceedance probability of PML values			
Sector	Urban bridges		Return Period	US$ x10^6	%	20 years	50 years	100 years	500 years
			100 years	$0.62	1.17%	18.13%	39.35%	63.21%	99.33%
Exposure value	US$ x10^6	$52.98	250 years	$1.04	1.97%	7.69%	18.13%	32.97%	86.47%
Average annual loss	US$ x10^6	$0.04	500 years	$1.47	2.78%	3.92%	9.52%	18.13%	63.21%
	‰	0.76	1000 years	$1.98	3.74%	1.98%	4.88%	9.52%	39.35%