Physical vulnerability of critical facilities in Grand Cayman, Cayman Islands

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Abstract

Using the methodology developed by the North Carolina Department of Environment and Natural Resources, USA, we determined the physical vulnerability to the impact of hazards of the main critical facilities at Grand Cayman (*GC*), Cayman Islands. Our results indicate that: 1) About 82% of the emergency response infrastructure, 95% of the government facilities, and 85% of the utilities have physical vulnerabilities in the range from low to moderate; 2) Only 12% of all identified critical facilities at *GC* are exposed to natural and man-made hazards with a high vulnerability; 3) *GC* shows a very good level of protection of its critical facilities to natural hazards; 4) Explosions or leaks of the Airport Texaco Fuel Depot and the fuel pipeline, could impact the George Town Red Cross Building, the Caribbean Utilities and the Owen Roberts International Airport. An explosion of the Home Gas Terminal could damage the John Gray High School, which is also used as shelter in case of emergencies.
Keywords: vulnerability, hazards, physical vulnerability, natural hazards, man-made hazards, critical facilities, Grand Cayman, Cayman Islands.

1 Introduction

Based on the characteristics of the main hazards that may affect the Cayman Islands (*CI*) [1], we identified the level of physical vulnerability for each of the 48 main critical facilities in Grand Cayman (*GC*). The main objectives of the assessment performed in this work are: 1) To prepare maps with critical facilities that might be exposed to or threatened by the natural or man-made hazards identified in *GC*, and 2) To increase the overall awareness of decision makers for disasters prevention and mitigation actions at *CI*.

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It is important to underline that a full vulnerability analysis of the islands should include a complete and quantitative vulnerability assessment of the physical, structural, organizational, historical, socio-economic, and environmental parameters that control the exposure to natural and man-made hazards. To this end, this work constitutes the basis of a future, quantitative vulnerability assessment.

The data for this study were collected via electronic means and from scientific sources in the public domain, including data generated by the Lands and Surveys Department of the *CI*. The Hazard Management Cayman Islands (*HMCI*) provided part of this information. We interpreted and manage the source data with the use of documentary sources such as the list of institutions and facilities reported on the map of Hurricane Ivan Preliminary Damage Assessment [2] and the facilities reported on the Grand Cayman's Public Safety Map.

2 The Cayman Islands

Located in the western Caribbean Sea to the northwest of Jamaica, *CI* is a British overseas territory comprised of three islands: *GC*, Cayman Brac (*CB*), and Little Cayman (*LC*), fig. 1. These three islands occupy around 250 km^2 of land area [3]. *GC* is approximately 35 km long and 13 km at the widest point wide. The highest elevation is about 18 m above sea level and the most striking geographical feature is the North Sound, a shallow reef protected lagoon with an area of about 56 km^2. *CB* lies about 145 km northeast of *GC*. It is about 19 km long and a little over 1.6 km wide. *LC* is 8 km west of *CB* and is 16 km long and 3 km at its widest point, fig. 1. It is the flattest of the three islands with its highest elevation being 12 m. To the west, an 11 km channel separates *CB* from *LC* [3]. The three islands are mostly flat and were formed by large coral heads, covering submerged ice age peaks of western extensions of the Cuban Sierra Maestra range. The highest point is The Bluff, a limestone outcrop 43 m in height on the eastern end of eastern *CB*. The *CI's* lowest elevation is the Caribbean Sea at sea level [3]. Due to the porous nature of the limestone rocks that are present along with the absence of much relief of any kind, all of the Caymans lack rivers or streams [4].

The islands are located above the Cayman Trough (*CT*) which is a depression area on the seafloor of the Caribbean that extends from the Belize margin to northern Jamaica, fig. 1. At its deepest point, the *CT* is over 7500 m deep [5]. This margin consists of a 100-250 km wide seismogenic zone of generally left-lateral, strike-slip deformation which covers over 2000 km along the northern edge of the Caribbean Sea. This left-lateral strike-slip displacement is due to the eastward movement of the Caribbean plate relative to the adjacent North American plate [5]. Geological and geophysical data from the region suggest that the *CT* is underlain by oceanic crust accreted along a short north-south spreading center located between the Oriente and Swan transform faults [6].

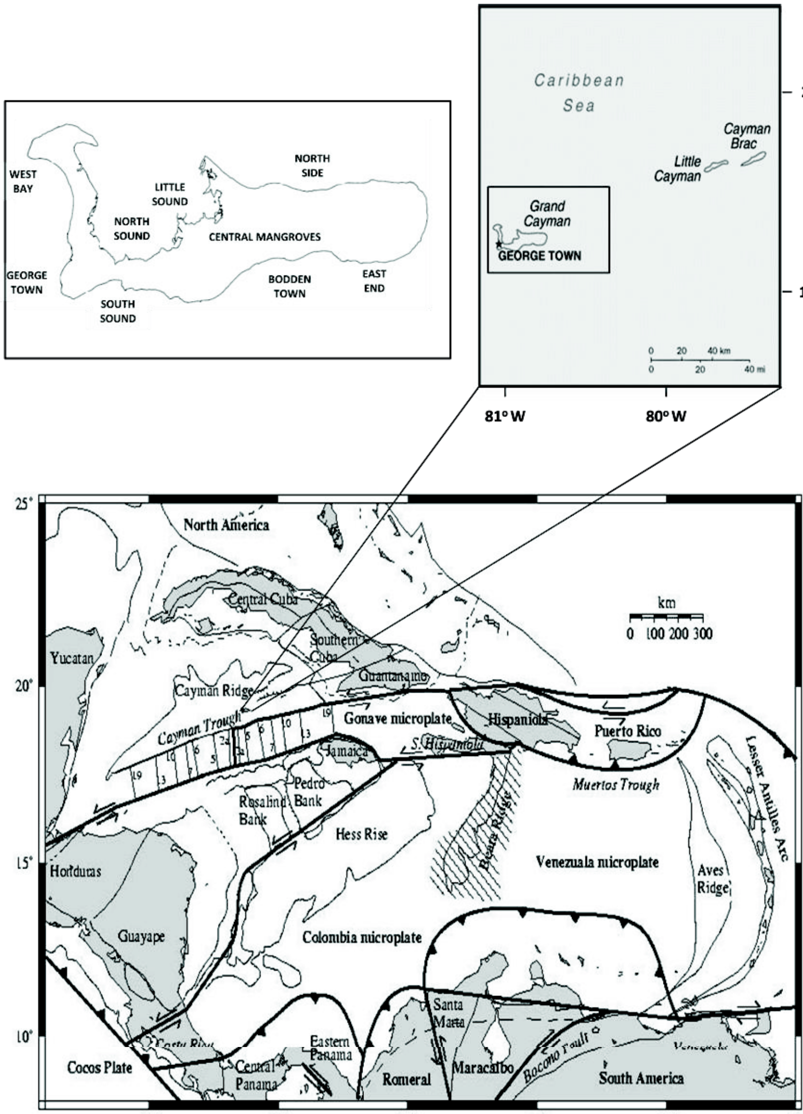

Figure 1: The tectonic boundaries of the Caribbean Plate and the location of the Cayman Islands. The major geologic faults in the northern Caribbean are shown. The Gonave plate is bounded by the Oriente fault to the north, that passes just south of the Cayman Islands, and the Walton fault to the south of it, passing through Jamaica [1].

3 Natural and man-made hazards in the Cayman Islands

Novelo-Casanova and Suárez [1] analyzed the various natural and man-made hazards that may affect *CI* and determined the level of exposure of *GC* to these events. The magnitude, frequency, and probability of occurrence of the natural and man-made hazards that may potentially affect the islands were identified and ranked. The results of Novelo-Casanova and Suárez [1] indicate that the more important natural hazard to which the *CI* is exposed is clearly hurricanes. To a lesser degree, the islands may be occasionally exposed to earthquakes and tsunamis. Explosions or leaks of the Airport Texaco Fuel Depot and the fuel pipeline at *GC* are the most significant man-made hazards.

The results of the hazard evaluation of Novelo-Casanova and Suárez [1] indicate that there are four areas in Grand Cayman with various levels of exposure to natural and man-made hazards: The North Sound, Little Sound and Eastern West Bay (Area 1) show a very high level of exposure; The Central Mangroves, Central Bodden Town, Central George Town and the West Bay (Area 2) have high level of exposure; The Northwestern West Bay, Western Georgetown-Bodden Town, and East End-North Side (Area 3) are under moderate levels of exposure. The remainder of the island shows low exposure (Area 4).

4 Methodology

For our research, we adapted the methodology developed by the North Carolina Department of Environment and Natural Resources and other research partners during the study entitled "New Hanover County/Wilmington Project Impact Partnership" [8]. Briefly, the steps involved in this methodology are as follows:

1. Hazard Identification
2. Hazard Analysis
3. Critical Facility Analysis
4. Societal Analysis
5. Economic Analysis
6. Environmental Analysis
7. Mitigation Opportunity Analysis

Novelo-Casanova and Suárez [1] evaluated the level of exposure to natural and man-made hazards of the *CI,* considering the first two steps. In step 1, hazards are characterized by its probability of occurrence, size of area of impact and the potential damage. For each identified main hazard, a total score is obtained following eqn. (1) by assigning weights to each factor depending on how critical that factor is:

Total Score=(Frequency+Area of Impact) x Potential Damage Magnitude (1)

The frequency, area of impact, and potential damage magnitude values are defined by a scale of numbers ranging from 1 to 6, where: extremely low= 1 and very high= 6. The purpose in this step is to identify the hazards and their

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potential impacts. It is a subjective exercise where the total scores alone do not have absolute statistical significance. The comparison of scores, however, will provide relative rankings that guide the vulnerability assessment process as well as the establishment of hazard mitigation priorities.

In step 2, the exposure areas are determined for each hazard. The objective of this step is to target priority areas for which a hazard evaluation is needed. The purpose is to identify geographically the areas that are most likely to be affected by a given hazard. Once the exposed areas are identified, a prioritization is developed using local data sources. For each identified area a relative level of exposure to the specific hazard being addressed is established.

To determine the level of exposure to natural and man-made hazards of critical facilities at *CI,* we considered the procedures of step 3. In step 3, the vulnerability of key individual facilities or resources within the community is assessed. Because it is not usually feasible to conduct such an analysis for every structure in a community, the work is focused on identifying the categories of structures that are considered "critical facilities" for purposes of conducting individual facility assessments. Next, a critical facilities database is established by collecting some general information. The kind and amount of information collected depends on the intended use of the database. At a minimum, the database should contain information identifying facility types and locations. To help prioritize potential impact on the critical facilities, vulnerability scores for each of the critical facilities are established. Then, the score of each critical facility with the score of the hazard in each area is considered.

Here, using the relative priority scoring system developed by Novelo-Casanova and Suárez [1] for different areas at *GC*, fig. 2, an individual physical assessment for each critical facility at *CI* was conducted. This assessment was performed addressing the location of the facility relative to the potential exposure to the impacts of hazards of the area which the facility is located [1].

5 Inventory of critical facilities

For the purposes of the present work a critical facility is defined as: *"*A facility that is vital for the *CI*'s ability to provide essential services and protect life and property and/or the loss of which would have a severe economic or catastrophic impact*"*. We considered the following three categories of critical facilities: Emergency Response, Government, and Utilities. Within the Emergency Response Facilities we considered Hospitals and Clinics, Police and Fire Stations and the National Emergency Operation Center. This infrastructure is crucial in any disastrous event to attend casualties. Within the Government Facilities we included government buildings, shelters, port and airport. Several schools in *GC* are also used as shelters in case of emergencies. These critical facilities are essential for the procurement of needed food and medical supplies during emergencies. In the Utilities category we considered fuel, water, and power resources that support the economy of the islands.

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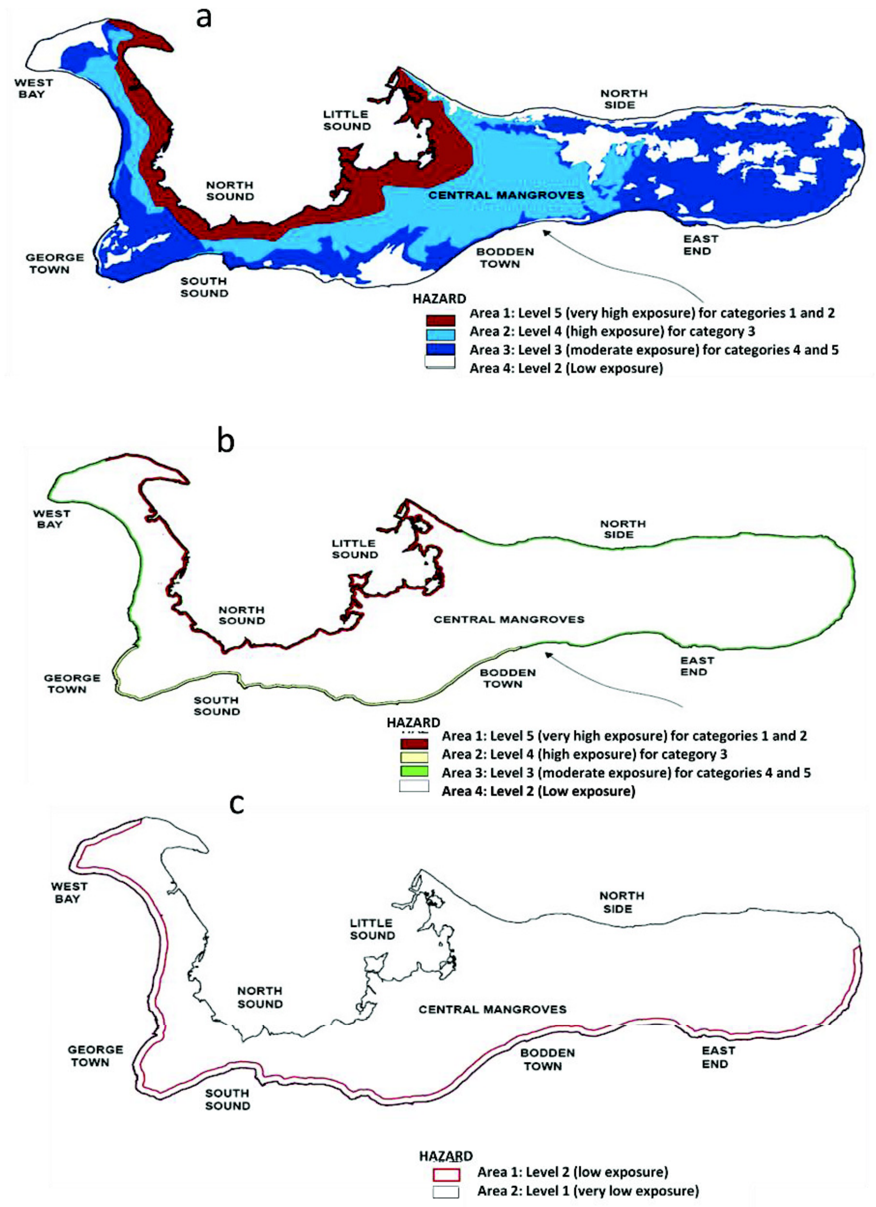

Figure 2: Flood (a) and storm surge areas (b) for different hurricane categories. The arrow indicates the direction of approach of the hurricane; (c) Tsunami hazard areas for tsunamis coming from the Caribbean Sea [1].

A total of 48 critical facilities were identified in our inventory. The George Town Red Cross Building was considered in both, the Emergency Response and Government facilities categories because this facility is also a shelter in case of emergencies.

6 Physical vulnerability of critical facilities

Following the methodology described above, for each critical facility within the three categories considered, we conducted an assessment addressing the location of the facility relative to the four identified hazard areas with different levels of exposure to the impact of hurricanes, earthquakes, tsunamis and man-made hazards, fig. 2 [1]. The physical vulnerability of critical facilities was evaluated using the ArcGIS software. Critical facilities were converted from a simple database of names and locations into a map "layer" of resources. This layer was combined with, or "overlaid" with the map layers of fig 2. This overlay was then used to identify the critical facilities that may be threatened by different hazard events ranked with a specific score, table 1.

Table 1: Level of hazards for different areas at Grand Cayman [1].

Hazard	Hazard Area	Hazard score
Hurricane		
Flooding (Fig 2a) and Storm surge (Fig 2b)		
Category 1 and 2	1	5
Category 3	2	4
Category 4 and 5	3	3
Remainder of Grand Cayman Island	4	2
Earthquake		
Entire Grand Cayman Island	1 to 4	1
Tsunami (Fig. 2c)		
Very Low	near to ocean	1
Remainder of Grand Cayman Island	4	0
Man-made hazard		
Fuel and gas tanks	Adjacent areas	1
Fuel pipeline	Adjacent areas	1
Remainder of Grand Cayman Island		0

Based on the total hazard score of the facility obtained from the sum of the individual score hazard to which the facility is exposed, we established the level of physical vulnerability for each critical facility considering the following thresholds:

- *Low Vulnerability*: total hazard score between 5 and 6. Low exposure to any of the identified main hazards at *CI*.
- *Moderate Vulnerability*: total hazard score between 7 and 8. Moderate exposure to at least floods and storm surges. The facility is located in a zone that is impacted by hurricane categories 4 and 5 that take place approximately every 100 years [1].
- *High Vulnerability*: total hazard score between 9 and 10. High exposure to at least floods and storm surges and to a lesser degree to tsunamis. The facility is located in an area exposed to hurricanes of category 3 (and above) that hit the islands once every 9.06 years [1].
- *Very High Vulnerability*: total hazard score of 11 or greater. Very high exposure to floods and storm surges and to a lesser degree to tsunamis. The facilities located in a zone where coastal flooding and wave action are the highest during hurricanes of categories 1 and 2 (and above). On average these kinds of hurricanes hit the *CI* every 2.23 years [1].

The results of our estimations of physical vulnerability of all identified critical facilities at *GC* indicates that only 12% of all analyzed critical facilities at *GC* are exposed to natural and man-made hazards with a high vulnerability, fig. 3. Explosions or leaks of the Airport Texaco Fuel Depot and the fuel pipeline, could impact the George Town Red Cross Building, the Caribbean Utilities and the Owen Roberts International Airport. An explosion of the Home Gas Terminal could damage the John Gray High School, which is also used as shelter in case of emergencies.

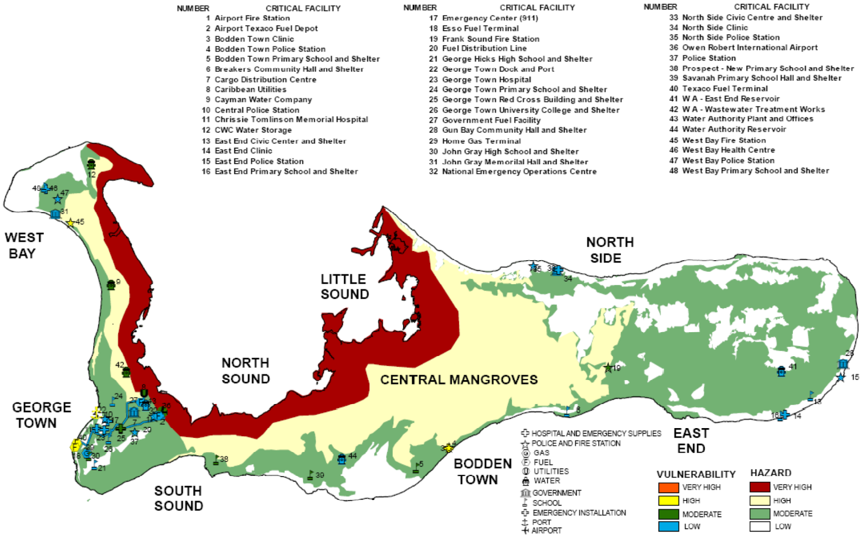

Figure 3: Areas showing the vulnerability and exposure of critical facilities to natural and man-made hazards in Grand Cayman.

In general, *GC* shows a very good level of protection of its critical facilities to natural hazards. The majority of the emergency response (82%) and government facilities (95%) as well as the utilities (85%) have physical vulnerabilities in the range from low to moderate. It is important to point out that none of the main critical facilities were rated with very high vulnerability.

References

[1] Novelo-Casanova, D.A. & Suárez G., Natural and man-made hazards in the Cayman Islands, *Natural Hazards*, **55**, pp. 441-466, 2010.
[2] Lands and Survey Department, Map of Hurricane Ivan Preliminary Damage Assessment, *Cayman Land Info*, Cayman Islands Government, 2005.
[3] Brunt, M.A. & Davies J.E. (Eds.), *The Cayman Islands: natural history and biogeography*, Kluwer Academic Publishers, Boston, MA, pp. 604, 1994.
[4] Folk, R., Roberts, H. & Moore, C., Black phytokarst from hell, Cayman Islands, British West Indies, *Geological Society of America*, **84**, pp. 2351-2360, 1973.
[5] Leroy, S., Mauffret, A., Patriat, P. & De Lepinay, M., An alternative interpretation of the Cayman Trough evolution from a re-identification of magnetic anomalies, *Geophysical Journal International,* **14**, pp. 539-557, 2000.
[6] Rosencrantz, E. & Mann, P., Sea MARC II mapping of transform faults in the Cayman Trough, Caribbean Sea, *Geology*, **19**, pp. 690-693, 1991.
[7] De Mets, C. & Wiggins-Grandison, M., Deformation of Jamaica and motion of the Gonavemicroplate from GPS and seismic data, *Geophysical Journal International*, **168**, pp. 362-378, 2007.
[8] North Carolina Department of Environment and Natural Resources (2001), North Carolina of Crime Control and Public Safety, University of North Carolina at Wilmington, Federal Emergency Management Agency, NOAA Coastal Services Center, Vulnerability Assessment Tutorial, New Hanover County/Wilmington Project Impact Partnership, Online. http://www.csc.noaa.gov/products/nchaz/htm/methov.htm.