

# AVAILABILITY OF BATHYMETRY, INUNDATION AND EVACUATION MAPS FOR THE CARIBBEAN BASIN

*REPORT OF THE WORKING GROUP 2 (WG2) OF THE ICG/CARIBE-EWS.*

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## 1. OBJECTIVE

To gauge the existence and availability of coastal bathymetry and/or tsunami evacuation maps within member states of the ICG/CARIBE-EWS.

## 2. JUSTIFICATION

Although tsunamis in the Caribbean are infrequent, historical accounts from early colonizers have shown that the Caribbean region has not been exempt from these natural events. The fact that the Caribbean region is already densely populated and that it is a popular tourist destination makes the region particularly vulnerable to tsunamis. As opposed to hurricanes, tsunamis are not frequent enough for the permanent population to be aware of the risk; therefore the best tool to minimize their effects is by engaging the permanent and floating population in preventive and permanent education.

### 2.1. TSUNAMI EVACUATION MAPS (TEMS)

Tsunami evacuation maps are among the most useful tools used in tsunami preparedness because of the critical information they provide: evacuation area, evacuation routes, distances and location of assembly points, vertical evacuation structures among others (Figure 1). The information is useful particularly for people not familiar with the place or the phenomena. TEMs might be available as printed or digital maps and usually include information on what to do in case of tsunami.

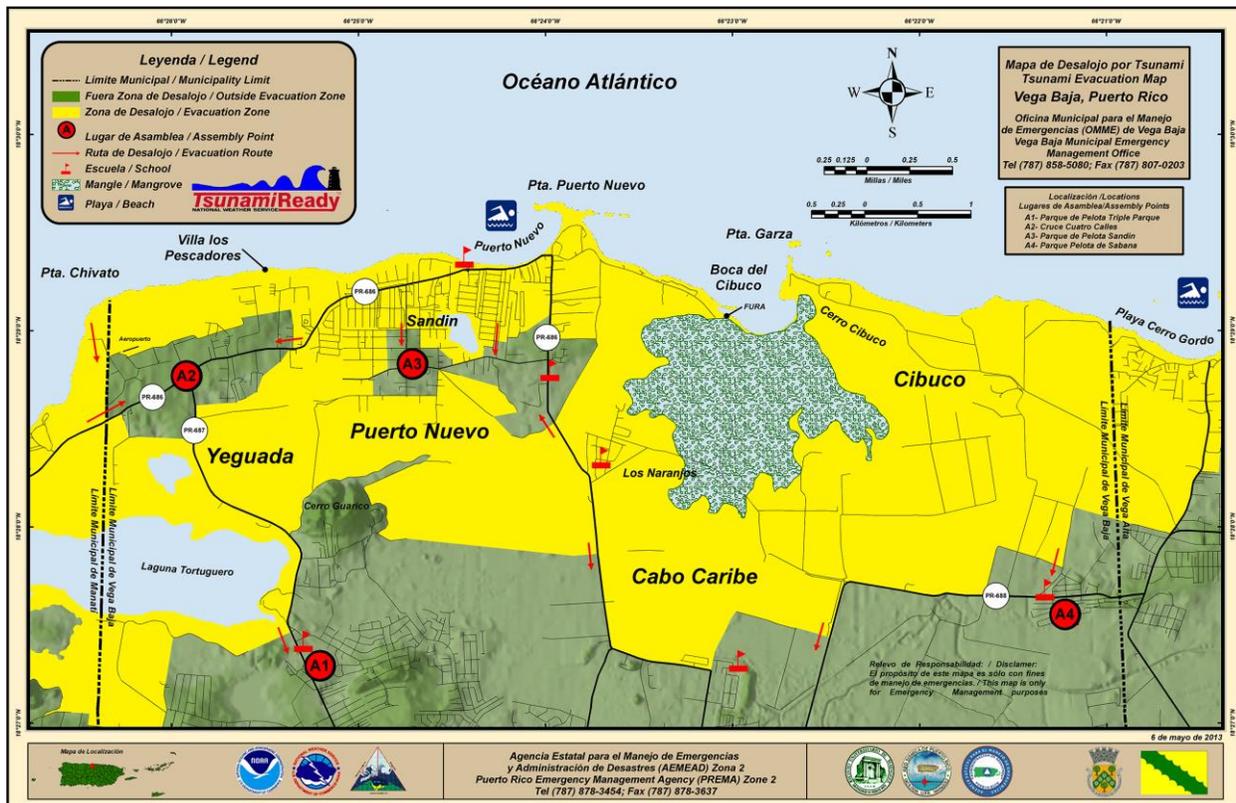


Figure 1. Example of a TEM from Puerto Rico. The evacuation region is shown in yellow.

To elaborate TEMs it is necessary to define the evacuation region: the region a tsunami may affect under specific conditions; for instance a worst case scenario or maximum of maximums. This can be done in two different ways: one is from tsunami inundation maps (TIMs) and the other is to use a fixed-height level based on an estimation of maximum tsunami height.

In order to help Caribbean nations develop TEMs, the first step is to perform a survey and enquire about the existence of these maps and related data, so that strengths and weaknesses within the region can be identified. WG2 has moved towards the creation of a database that would categorize the current assets in the region.

## 2.2. TSUNAMI INUNDATION MAPS (TIMS)

TIMs indicate the area flooded by a tsunami based on results of tsunami numerical modeling (Figure 2). Developing TIMs require a large amount of input data and qualified personal to perform the modeling. Often times TIMs are elaborated based on several scenarios considered, either consisting on historical tsunamis or assessment of tsunami potential, or both (GONZÁLEZ-RIACHO et al., 2013). Then, usually the evacuation region is defined after the superposition of the maximum flooded region for all the scenarios. As the process to elaborate TIMs is time consuming, it is recommended to begin with TEMs elaborated from fixed-height level before moving to maps developed through simulations (UNESCO, 2015).

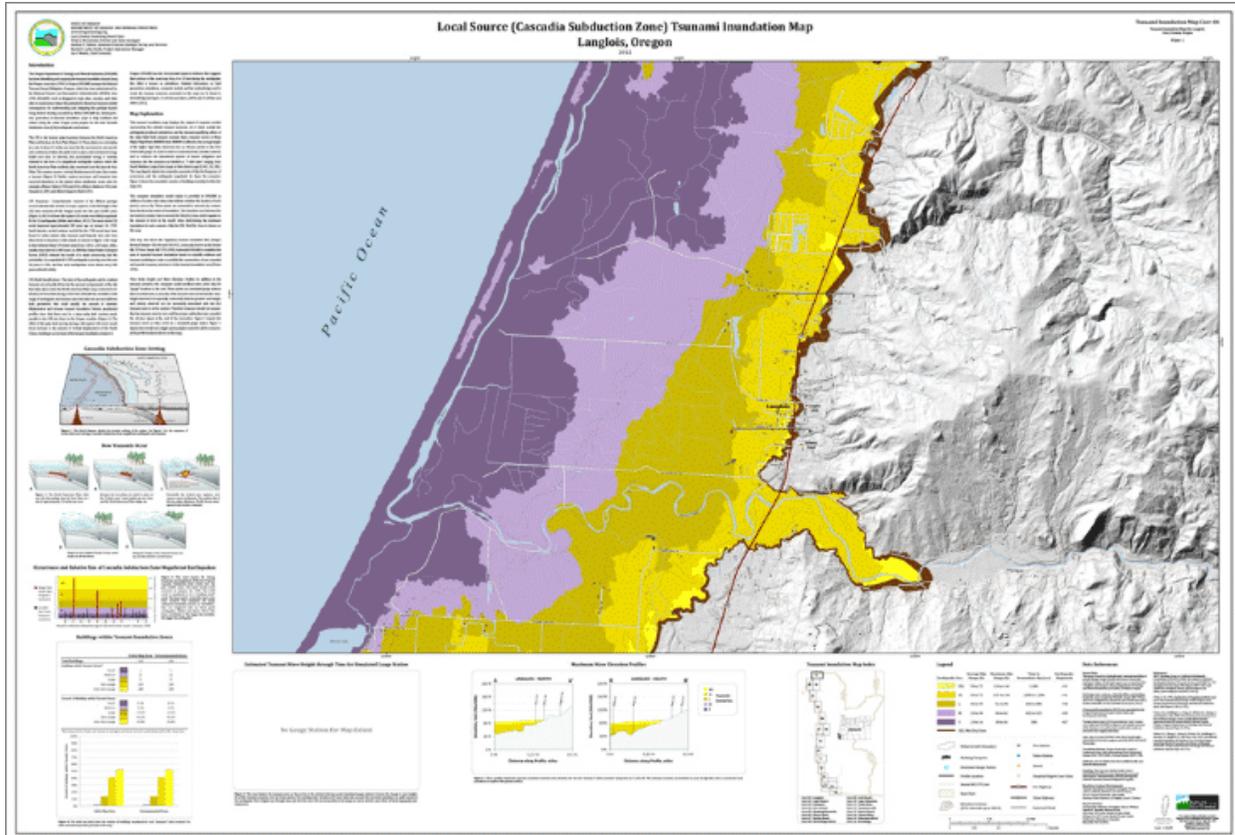


Figure 2. Example of TIM from Oregon, US.

As part of the interest of the ICG/CARIBE-EWS to develop awareness of tsunami effects in the Caribbean region, the WG2 has been tasked to run simulations and quantify the effects of potential tsunamis across Caribbean coasts. These results can in turn be used to elaborate TEMs, an effort WG2 has been interested to provide through capacity building.

### 2.3. BATHYMETRIC DATA

To perform tsunami numerical modeling and obtain TIMs it is necessary to have adequate topographic and bathymetric data, being the later the most difficult to access.

Therefore, it is important to know which ICG/CARIBE-EWS member states have good quality bathymetric data obtained from bathymetry surveys and which states rely only on data extracted from nautical charts. In some cases, nautical charts are elaborated from data obtained long time ago and its accuracy might not be optimal.

Based on the expert's recommendations (UNESCO, 2015), data obtained from nautical charts may be used to perform tsunami numerical modeling when optimal data is not available. However, "Precise forecasting of the extent of coastal inundation depends upon the availability of high-resolution bathymetric/topographic data. The higher the resolution available is, the higher the confidence in estimating the effects of a given scenario is." (UNESCO, 2015). In some cases the small scale nautical charts necessary to model tsunami inundation are only available for harbors and not for other coastal communities that might have larger population and/or tourism traffic.

### 3. METHODOLOGY

To assess the availability of bathymetric data and tsunami evacuation maps of Caribbean member states, a simple survey was sent through email to each member state's TNC and TWFP. The survey consisted of the following two questions:

1. As representative of your member state, specify whether your country have developed tsunami inundation and/or tsunami evacuation maps? If so, please specify a list of those communities?
2. Does your country have bathymetric data? Please observe that this is not to request the data itself, but to populate an inventory of regions within the Caribbean that already possess the data. Have in mind that the development of the inventory will help assess your country's capabilities on tsunami preparedness. If the country you are representing has bathymetric data please indicate the resolution and extent.

It is worth noting that Saint Vincent and the Grenadines, who currently are not members of the ICG/CARIBE-EWS, were included in the survey for completion purposes, although at the end they did not answer the survey. Since Cuba currently lacks a TNC and TWFP, the email was sent to Leonardo Álvarez, who works at the National Center of Seismological Research (CENAIIS).

The first email was sent on February 2015 and several reminders were sent on March and April. In some cases due to the lack of answers from the TNC/TWFP the inquiry was sent to other people having attended to IOC/UNESCO trainings.

### 4. RESULTS

Of the 37 states across the Caribbean region (both member and non-member states), 33 completed the inquiry by replying to the message. To date, the remaining 4 member states have not supplied the requested information. Among the reasons that have hampered a 100% response rate is that the TNC or TWFP is outdated or official information does not exist.

From the states that replied, only five of them have TEMs for all the communities and six of them have TEMs for some communities (see Appendix A). While some states are small islands facilitating the complete coverage of evacuation maps, other states are large islands or continental countries, hence having very long coastlines have hindered the task. The countries having coasts at both Caribbean and Pacific sides, had given priority on elaboration of TEMs and TIMs to the Pacific shores due to higher tsunami incidence on that basin.

One state reported that they are currently elaborating TEMs (see Appendix A). However, the great majority (20 states for a 54%) reported that no TEMs exist at all (Figure 3a). The proportion is similar for TIMs: three states reported having TIMs for all the coastal communities and eight states reported having partial coverage TIMs. Two states reported elaborating TIMs at the moment and 18 states reported not having TIMs at all for a 49% (Figure 3b).

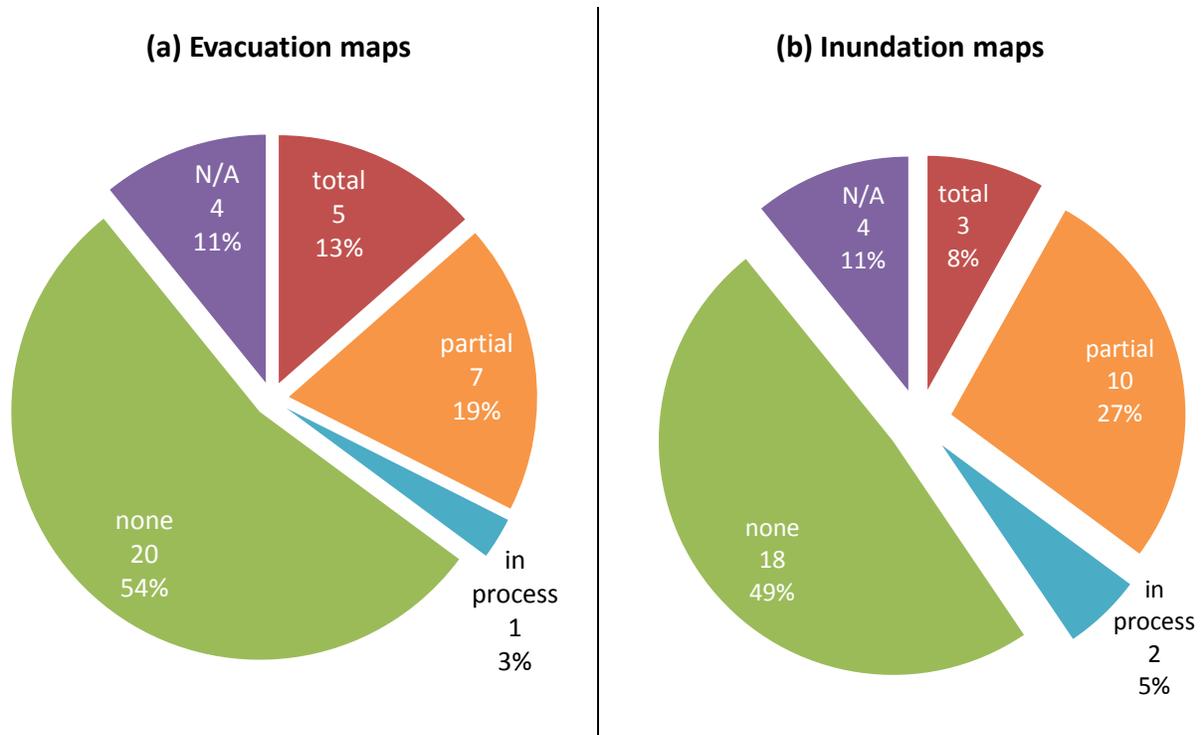


Figure 3. Existence of (a) TEMs and (b) TIMs within Caribbean nations.

Of the 20 states not having TEMs only three of them have TIMs and one more is elaborating them, meaning 16 states do not have TIMs either (

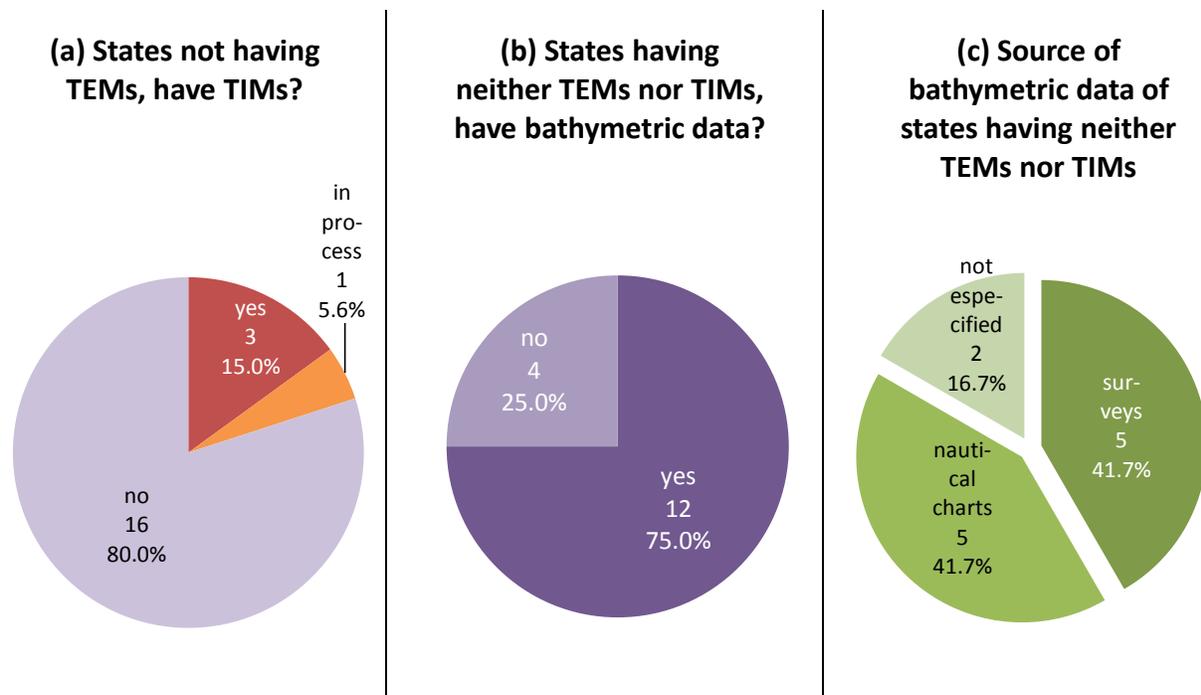


Figure 4a). Those 16 states might build a first version of TEMs based on a fixed height and then perform numerical modeling to obtain a more accurate inundation region if they have the proper

bathymetric data. Of those 16 states having neither TEMs nor TIMs, only four of them do not have bathymetric data at all (

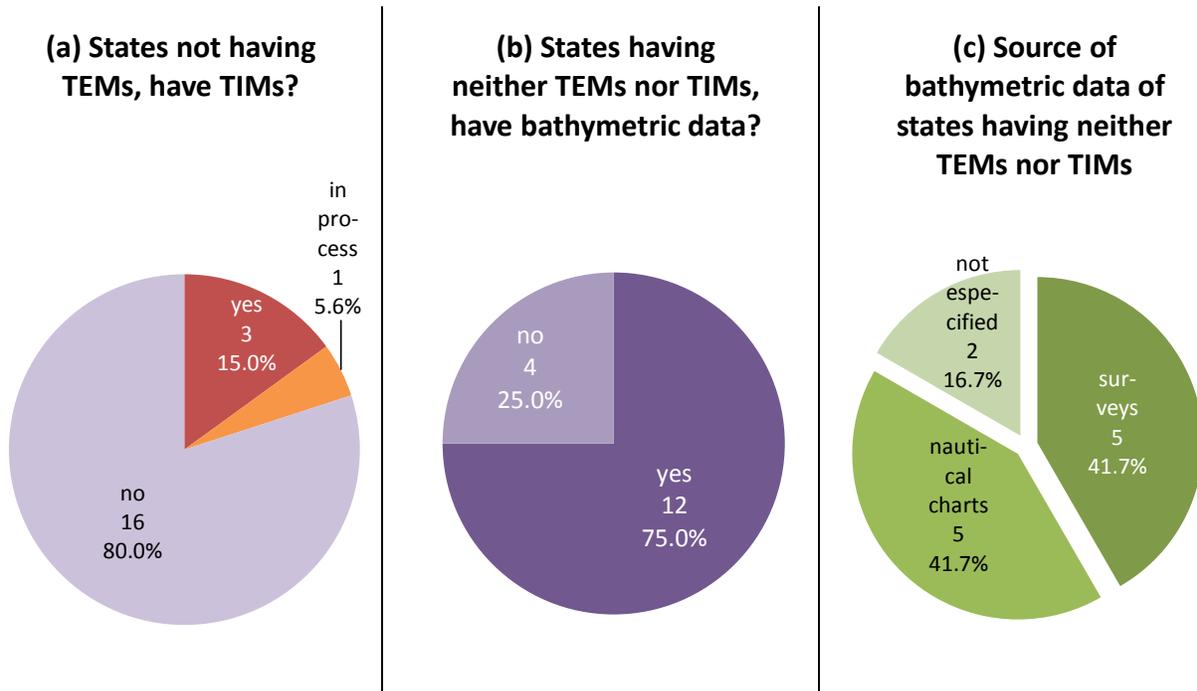


Figure 4b). The other 12 states have bathymetric data from surveys, nautical charts and not specified sources (

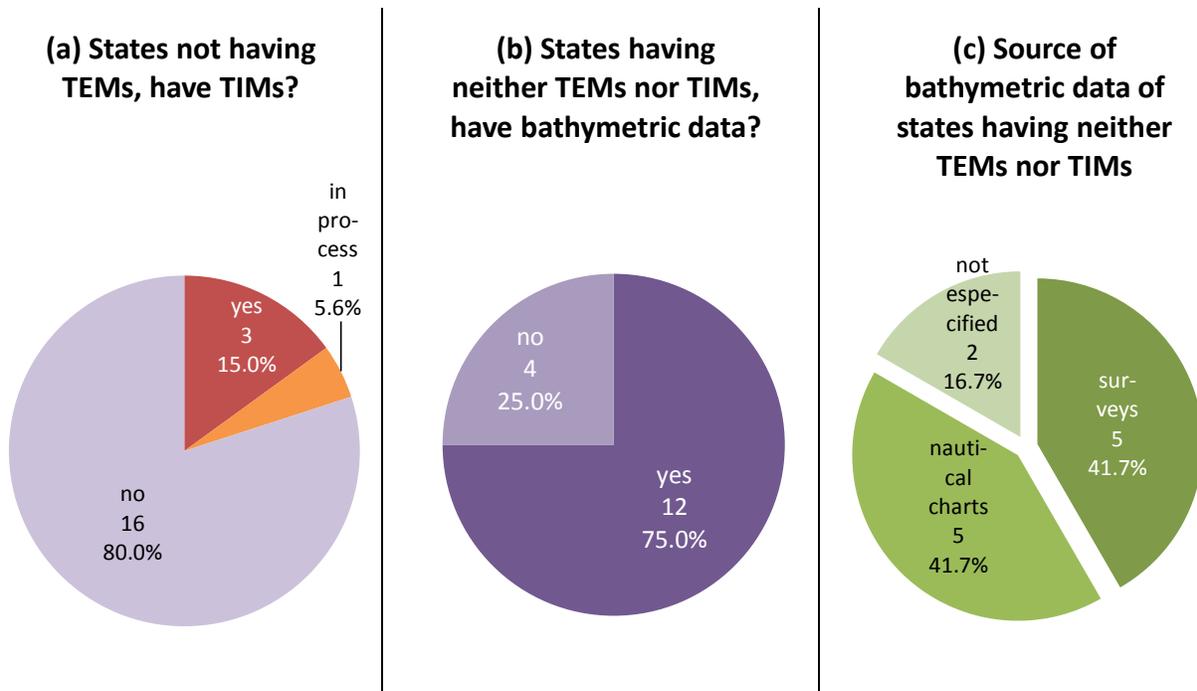
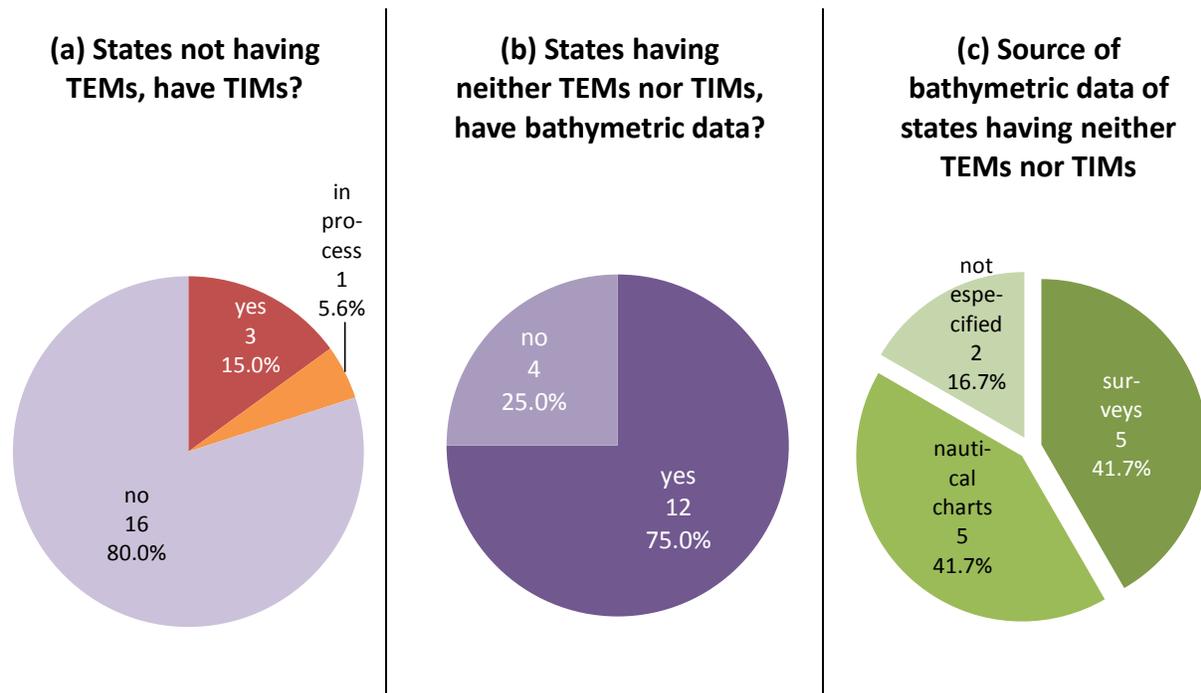


Figure 4c, Appendix C). Whether those 12 states have the scientific expertise and enough bathymetric data of the required quality to elaborate TIMs would be the matter of a more

specialized inquiry, together with the availability of funds and other data necessary to build TEMs (like topography, roads, population density, touristic visitation, etc.).



**Figure 4. (a) Availability of TIMs in states not having Evacuation Maps. (b) Availability of bathymetric data in states having neither Evacuation nor Inundation Maps. (c) Source of the bathymetric data available in (b).**

With regards to bathymetric data, within all the states, 26 reported having partial coverage (Figure 5). However, it is worth noting that the extension of these data was not reported in most of the cases. The quality of the bathymetric data is varied, as the sources range from surveys to nautical charts. In some cases the surveys are recent or are being performed at the moment ensuring first quality data (i.e. Barbados, Dominica, Sint Maarten, Bermuda, UK Virgin Islands, Puerto Rico, etc.), but in some cases the nautical charts employed to obtain the bathymetric data were elaborated almost a hundred years ago (i.e. Costa Rica). In some states, bathymetric data belongs to private companies and therefore its use is strictly for government agencies, in which case their use to create inundation maps might not be straightforward as authorizations may result in a lengthy process.

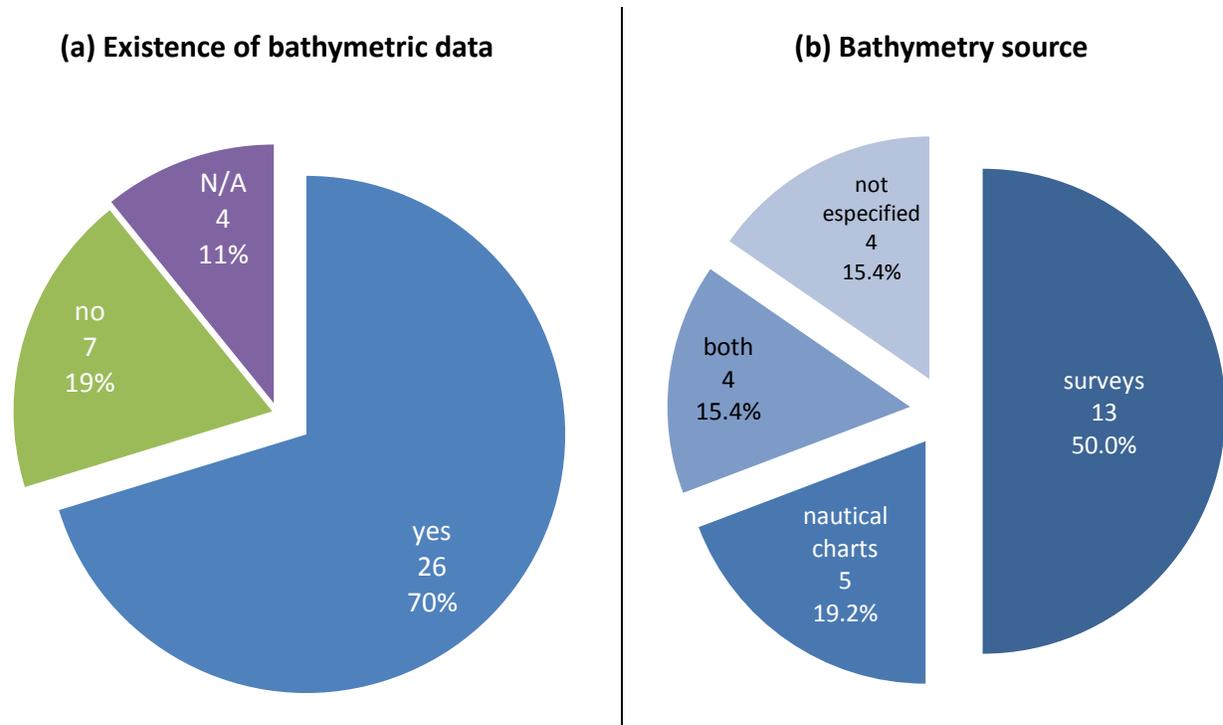


Figure 5. (a) Existence of some kind of bathymetric data. (b) Source of the bathymetric data when exists.

## 5. CONCLUSIONS AND RECOMMENDATIONS

If the availability of TEMs along all the Caribbean states is desired, it would be necessary to perform a deeper diagnosis of the capabilities of the 20 states not having TEMs to elaborate them. Preliminary TEMs can be elaborated based on a fixed-height level for the 16 states not having TIMs. Then, for 12 of those states which do have bathymetric data it is recommended to inquire about their capabilities to elaborate TIM for a definitive version of TEM. For the four three states having not TEM, TIM and bathymetric data it would be necessary to explore possibilities to collect the proper bathymetric data that will allow for the eventual development of TIMs and then of TEMs.

In case TIMs are available, a definitive version of TEMs can be performed, assuming TIMs cover the range of scenarios needed, over the required coastal communities. TIMs are available on three of the 20 states not having TEMs and in process for one more.

Two more states reported having TEMs but no TIMs, these states might need to perform an update of their TEMs based on TIMs. Both states reported not having governmental bathymetric data, however, one of them indicated the data might be available from private agencies. Whether these private agencies are able and willing to provide the bathymetry needs to be further explored and reported to the WG2.

International joint research projects might make possible that scientists within the region perform the numerical modeling to obtain TIMs for those countries not having the scientific expertise. Alternatively, a group of experts might be able to visit the country to perform a pilot project and build the required capacity for local researchers/technicians continue the study. However, it is

imperative that funds for these studies be identified. Similarly, states lacking bathymetric data would require additional funding for collecting all the required data and for the elaboration of TEMs. Additionally, the disclosure of the bathymetric data for research purposes must be prompt and guaranteed.

As the group of experts from the Tsunami Mitigation and Modeling Workshop (UNESCO, 2015) recommended, Caribbean countries capable of performing bathymetric surveys could help other countries that are unable to do them by themselves in a way that would foster international collaborations.

## 6. REFERENCES

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UNESCO. 2015. *Workshop on Tsunami Modelling and Mitigation. ICG/CARIBE-EWS Working Group 2: Tsunami Hazard Assessment*. Cartagena de Indias, Colombia.

## APPENDIX A: STATES HAVING OR CURRENTLY ELABORATING TEMS

| <b>State</b>   | <b>Partial or total coverage of Tsunami Evacuation Maps</b> |
|--|---|
| Antigua & Barbuda  | Partial   |
| Barbados   | In process  |
| Dominican Republic   | Partial   |
| France (French Guyana, Guadeloupe, Martinique, St. Martin) | Partial   |
| Haiti  | Partial   |
| Jamaica  | Partial   |
| UK Anguilla  | Total   |
| UK Bermuda   | Total   |
| UK British Virgin Islands                                  | Total   |
| UK Turks and Caicos  | Partial   |
| US Puerto Rico   | Total   |
| US Virgin Islands  | Total   |
| Bolivarian Republic of Venezuela                           | Partial   |

## APPENDIX B: STATES NOT HAVING TEMS BUT HAVING TIMS

| <b>State</b> | <b>Partial or Total Coverage of TIMs</b> |
|--------------|--|
| Aruba        | In process                               |
| Colombia     | Partial                                  |
| Curacao      | Partial with a very simplistic model     |
| Sint Maarten | Partial                                  |

## APPENDIX C: STATES HAVING NEITHER TEMS NOR TIMS, BUT HAVING BATHYMETRIC DATA

| <b>State</b>        | <b>Bathymetric data coverage</b> | <b>Bathymetric data source</b>              |
|---------------------|----------------------------------|---|
| Belize              | Partial                          | N/A   |
| Canada              | Partial                          | Surveys                                     |
| Costa Rica          | Partial                          | Nautical charts                             |
| Cuba                | Partial                          | N/A   |
| Dominica            | Partial                          | Surveys, currently performing LAIDA surveys |
| Guyana              | Total                            | Nautical charts                             |
| Honduras            | Partial                          | Surveys                                     |
| Mexico              | Total                            | Nautical charts                             |
| Nicaragua           | Total                            | Nautical charts                             |
| Panama              | Total                            | Nautical charts                             |
| Trinidad and Tobago | Partial                          | Surveys                                     |
| UK Cayman Islands   | Total                            | Surveys                                     |

## APPENDIX D: STATES NOT HAVING TEMS, TIMS OR BATHYMETRIC DATA

|  |
|--|
| Grenada                                    |
| Guatemala                                  |
| Netherlands (Bonaire, Saba, St. Eustatius) |
| Saint Kitts and Nevis                      |

## APPENDIX E: STATES HAVING TEMS BUT NO TIMS

| <b>State</b> | <b>Having bathymetric data?</b> |
|--------------|---------------------------------|
| UK Anguilla  | No                              |

|                     |  |
|---------------------|--|
| UK Turks and Caicos | Yes but on private agencies, obtained from surveys on some locations |
|---------------------|--|

## APPENDIX F: STATES THAT DID NOT REPLIED TO THE INQUIRY FOR THE SURVEY

|                            |
|----------------------------|
| Bahamas                    |
| Saint Lucia                |
| Saint Vincent & Grenadines |
| Suriname                   |