Terms of Reference
GIS Review of the Earthquake and Tropical Cyclone Loss Assessment Model (SPHERA) for Central America and the Caribbean

1. Background

In 2007, the Caribbean Catastrophe Risk Insurance Facility (CCRIF) was formed as the first multi-country risk pool in the world, and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It was initially designed as a regional catastrophe fund for Caribbean governments to limit the financial impact of devastating hurricanes and earthquakes by quickly providing financial liquidity when a policy is triggered. CCRIF was developed under the technical leadership of the World Bank and with a grant from the Government of Japan. It was capitalized through contributions to a multi-donor Trust Fund by the Government of Canada, the European Union, the World Bank, the governments of the United Kingdom and France, the Caribbean Development Bank and the governments of Ireland and Bermuda, as well as through membership fees paid by participating governments.

In 2014, the facility was restructured into a segregated portfolio company (SPC) to facilitate expansion into new geographic areas and the development of new products and is now named CCRIF SPC. The new structure, in which products are offered through a number of segregated portfolios, allows for total segregation of risk. In April 2015, CCRIF SPC signed an MOU with COSEFIN - the Council of Ministers of Finance of Central America, Panama and the Dominican Republic - to enable Central American countries to formally join the facility. The expansion into Central America and the Caribbean is supported through the World Bank administered Central America and Caribbean Catastrophe Risk Insurance Program Multi-Donor Trust Fund (MDTF) established for that purpose. The MDTF channels resources from various donors, including: Canada, through the Department of Foreign Affairs, Trade and Development, the United States, through the Department of the Treasury; the European Union, through the European Commission, and Germany through the Federal Ministry for Economic Cooperation and Development.

Funding under the Program has been allocated to: (i) expand the services and membership of CCRIF SPC through a recipient-executed Project implemented by CCRIF SPC. The Central America and Caribbean Catastrophe Risk Insurance Project (P149670) was approved by the Regional Vice President for Latin America and the Caribbean on June 30, 2015**.** The Project is implemented by CCRIF SPC. The Project development objective is to improve affordability of high quality sovereign catastrophe risk transfer associated with earthquakes and climate-related events for CCRIF participating countries. The expansion of membership into Central America has the potential to diversify the risk portfolio, improve access to reinsurance markets hence reduce the cost of risk transfer, allowing these benefits to be passed on to s members. The peer review of the actuarial soundness of CCRIF SPC's loss assessment models for Central America and the Caribbean will be financed with grant funding from the Central America and Caribbean Catastrophe Risk Insurance Project (P149670).

CCRIF SPC is registered in the Cayman Islands with a board of directors which is responsible for governance and the strategic direction of the company and a chief executive officer with responsibility for managing the company on a day-today basis. It operates as a virtual organization, supported by a network of service providers covering the areas of risk management, risk modelling, captive management, reinsurance, reinsurance brokerage, asset management, technical assistance, corporate communications and information technology. CCRIF SPC offers earthquake, tropical cyclone and excess rainfall policies to Caribbean and Central American governments. CCRIF SPC helps to mitigate the short-term cash flow problems small developing economies suffer after major natural disasters. CCRIF SPC's parametric insurance mechanism allows it to provide rapid payouts to help members finance their initial disaster response and maintain basic government functions after a catastrophic event.

Sixteen Caribbean governments are currently members of the facility: Anguilla, Antigua & Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts & Nevis, Saint Lucia, St. Vincent & the Grenadines, Trinidad & Tobago and Turks & Caicos Islands. Nicaragua is the first Central American government to become a CCRIF SPC member.

CCRIF SPC's sustainability relies on certain key factors:

- Continuing operations with the capacity to fund payouts, within the agreed timeframe, while maintaining adequate capital and reserves
- Ability to attract members by offering relevant products with competitive pricing while at all times reinforcing the objectives and limitations of parametric insurance coverage
- Supporting the membership with technical assistance and ensuring a close working relationship with members that value the need for parametric insurance coverage in light of more frequent and severe natural disasters.

On an ongoing basis, membership tend to measure affordability and quality of CCRIF's products based on the perception of whether the insurance payout generally matched the actual loss to the extent of the policy parameters selected, with an anticipated level of over or underestimation. This requires careful design of the policy terms and conditions as well as precise and robust models. CCRIF has recently implemented a new Excess Rainfall Loss model (XSR 2.0) which computes the country aggregated losses due to excess rainfall on a daily basis and, when the excess rainfall exceeds a threshold level on a sufficiently large portion of a country, it computes the losses and the insurance payout according to pre-defined policy parameters.

CCRIF SPC seeks to replace the current Tropical Cyclone (TC) and Earthquake (EQ) loss assessment models that are collectively known by the name of Multi-hazard Parallel Risk Evaluation System (MPRES). MPRES currently underpins the TC and EQ insurance products purchased by several Caribbean and Central American countries. The objective of CCRIF SPC is to use the new TC and EQ Loss Assessment Models, called hereafter System for Probabilistic Hazard Evaluation and Risk Assessment (SPHERA), to design the TC and EQ policy conditions for Caribbean and Central American Countries starting with the June 2018/19 policy cycle. To underpin such products, CCRIF SPC needs TC and EQ loss assessment models that are state-of-the-art and utilize the most up to date datasets and techniques.

CCRIF will procure the services of four Consultants qualified on the subject to perform the peer review of different aspects of the model and the technical documentation.

This TOR supports the tender for a Consultant who will perform the review of the Exposure Data Base (EDB) loss assessment model and related documents ("Peer Reviewer"). This peer review does not concern the hazard, vulnerability and financial modules of the SPHERA model.

Appendix 1 contains an overview of the model.

2. Objectives

As a risk management strategy, an independent peer review of the model in its entirety and the technical documentation is being commissioned to obtain independent and comprehensive understanding of the model and of each underlying component. This model will be developed for CCRIF by a company referred to herein as "the Developer" and CCRIF intends to have all modules of the model, documentation and other deliverables from the Developer separately peer reviewed by technical experts. This TOR refers specifically to the peer review of the Exposure Data Base.

3. Scope of the Assignment

The peer review is a technical review of

a) The deliverables of the Exposure Database (DB) of the EQ and TC SPHERA model, which consist of a geo-referenced exposure database that includes both buildings and major infrastructure in the Group 1, Group 2 and Group 3 countries listed in the Appendix. The buildings part of the DB comprises

- Residential buildings
- Commercial buildings (except hotels)
- Industrial buildings
- Hotels
- Public buildings (except educational and healthcare assets)
- Educational buildings
- Healthcare buildings
- Agricultural buildings

The infrastructure part of the DB instead contains:

- Airports
- Ports
- Power generation facilities
- Roads

Each asset is characterized by a location and by characteristics of the asset relevant to the assessment of TC- and EQ-induced losses (e.g., in the case of buildings: asset type, material, height, age, replacement cost). The location of buildings and infrastructure will be aggregated in the DB at the same level of granularity used in the computation of the effects of TCs and EQs (e.g., 1km or 250m).

The DB evaluation would also include, construction material, height and age. This would also extend to method and appropriateness of total replacement value modeled.

Review the exposure database to assess whether: (i) the linkages between exposure and vulnerability are appropriate; and (ii) the level of detail of the geo-referenced exposure database is appropriate.

b) A technical document explaining the assumptions and methodology followed to develop and assemble the buildings and infrastructure exposure DB.

4. Services

The expected services from a successful Peer Reviewer are the following:

(i) Read the A technical document explaining the assumptions and methodology followed to develop and assemble the building and exposure DB(3b) and evaluate the related deliverables of the Exposure Data Base of the EQ and TC SPHERA model ***as indicated in section (3a)***. CCRIF will provide the Peer Reviewer information necessary/requested for the peer review. The documentation may consist of, but is not limited to, the following items:

a. A description of the assumptions and methodology utilized for assembling the building and infrastructure DB.
b. A presentation and underlying technical documentation by the authors about the module to be reviewed
c. Maps or other exhibits with findings
d. Digital files with deliverables, as necessary

Before receiving any such material, the Peer Reviewer will be required to sign a Non-Disclosure Agreement with the Model Developer and CCRIF.

(ii) ***Interaction with the model Developer.*** The Peer Review would be conducted remotely and the peer reviewer would be conducted remotely and the peer reviewer r is expected to interact with the Developer via electronic mail, webex and other means for clarifications. If the interactions occur via electronic mail, the Peer Reviewer will carbon copy a designated person at CCRIF. If the interactions occur via phone, the designated CCRIF person will be notified so that he/she can participate in the call, if needed. CCRIF will provide the Peer Reviewer with the point of contact of the Developer to address any such request.

(iii) ***Interaction with CCRIF.*** The Peer Reviewer is expected to interact with the designated person at CCRIF regarding the Peer Review. Although the Peer Reviewer will not have direct access to the Developer's catastrophe model, he/she may ask the CCRIF designated

person to carry out specific analyses with the Developer's model and to report back the model output, if appropriate. The CCRIF designated person may also provide the Peer Reviewer with comments about the peer review findings.

(i) Interaction with other consultants. The Peer reviewer is expected to coordinate and participate in at least two (2) meetings/conference calls/video-conferences with the peer reviewers of the other three modules of the model to:

- ***a.*** ensure proper coordination and alignment in the review of the individual modules; and
- ***b.*** contribute to the preparation of the combined final letter report.

(iv) ***Reporting.*** The Peer Reviewer is expected to deliver the following reports:

a. Interim Reports after the review of the material specified in 3(a) and 3(b)

b. A concise letter report of five or fewer pages with an executive summary of the findings. This concise report will be used by CCRIF to interact with insurance regulators, primary insurance companies and customers. Therefore, this letter report will include the primary findings of the review highlighting on the positive aspects of the model and recommendations for future improvements.

c. A Final Report for internal use of CCRIF, if possible, where all the findings are reported at the level of detail necessary for the implementation of ameliorating actions in the successive releases of the catastrophe risk model by the developer. This report will not be shared by CCRIF with any third party with the exception of the Developer.
In close coordination with the other peer reviews, the report should include an analysis to determine (i) the quality, robustness and level of calibration of the hazard, vulnerability and exposure components of the SPHERA model (ii) the quality of the loss metrics and (iii) the implications for basis risk.
Contribute to the preparation of a combined letter report, summarizing the findings of all of the individual review and presenting overall conclusions and recommendations for the model.

5. Requirements

- A degree in Engineering, Computer Science or an equivalent and suitable qualification;
- Experience in geographic information systems (GIS) relating to natural. catastrophe risk management and hazard and risk modelling or an equivalent and suitable qualification;
- At least 3 years of proven experience as a reviewer of catastrophe risk estimation models;
- Excellent analytical skills, and ability to prepare professional narrative reports summarizing observations and conclusions;
- Good oral and written communication abilities in English are required and
- Experience and knowledge of the Central America and the Caribbean context.

6. Time Schedule and proposed Fees

The assignment is expected to commence in November 2017 upon execution of the contract and the expected level of effort (LOE) is no more than 8 days over a two-month period. The specific dates for deliverables will be agreed by contract. Delays are justified if caused by the proven tardiness in receiving the requested information or the results of the model runs by either the Developer or CCRIF.

Appendix 1 - Overview of SPHERA

CCRIF SPC seeks to replace the current Tropical Cyclone (TC) and Earthquake (EQ) loss assessment models that are collectively known by the name of Multi-hazard Parallel Risk Evaluation System (MPRES). MPRES currently underpins the TC and EQ insurance products purchased by several Caribbean and Central American countries. The objective of CCRIF SPC is to use the new TC and EQ Loss Assessment Models, called hereafter SPHERA, to design the TC and EQ policy conditions for Caribbean and Central American Countries starting with the June 2018/19 policy cycle. To underpin such products, CCRIF SPC needs TC and EQ loss assessment models that are state-of-the-art and utilize the most up to date datasets and techniques.
The Caribbean and Central American Countries target of the TC and EQ loss assessment models to be developed are the following (see also Figure 1):

- Group 1 (Caribbean countries currently members of CCRIF): Anguilla, Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad and Tobago, Turks and Caicos Islands.
- Group 2 (Central American countries and the Dominican Republic): Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and the Dominican Republic
- Group 3 (Caribbean countries not currently members of CCRIF): Aruba, Curaçao, Guadeloupe, Guyana, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Suriname.

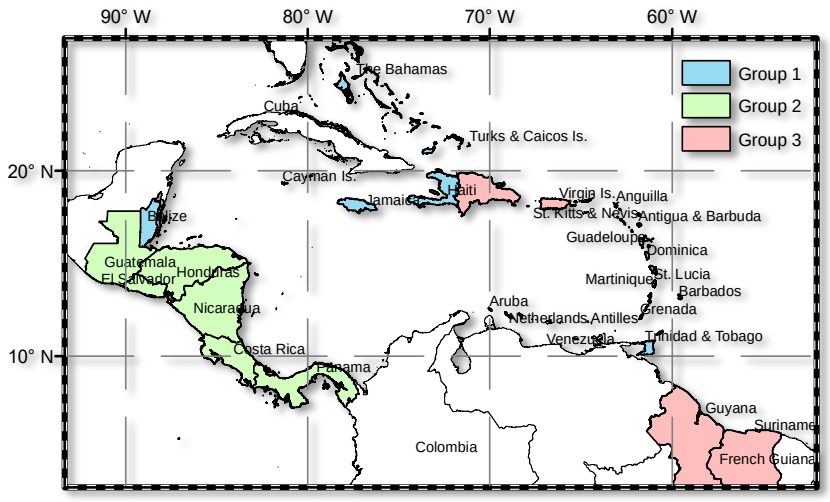

Figure 1 – Location of the three groups of countries (with the exception of Bermuda) to be covered by the TC and EQ loss assessment models

Objectives of the SPHERA loss model development

The list below itemizes the main objectives of the probabilistic SPHERA loss model to be developed. This model needs to:

1. Be suitable for the development of a parametric model for TC and EQ loss assessment for the listed countries in the Central America and Caribbean regions.
2. Be based on a geo-referenced database of buildings and infrastructure in the listed countries of the Central American and Caribbean regions exposed to TC-induced damage caused by wind and storm surge and to EQ-induced damage caused by earthquake ground motion excluding effects of ground liquefaction and lateral spreading. Earthquake-induced tsunamis, landslides, fires need not be included in this model.
3. Include a TC loss estimation module that would
    - be able to statistically estimate frequency of future events of different “strength”, including hurricanes (i.e., tropical cyclones), tropical storms, and tropical depressions, as defined in the Saffir-Simpson scale, in the Central American and Caribbean regions. Tropical storms both in the Atlantic and in the Pacific basins are to be included. The statistical analysis should make use of all available historical TC events even if occurred prior to the period when the records are considered complete. The model is expected to be able to estimate the likelihood of rare future TCs that may occur in the region of interest but have not occurred in the short time window for which historical records are available
    - consider wind and storm surge as sub-perils (TC-induced rainfall is already included in the XSR 2.0 Model and needs not be part of this TC model)
    - be able for each storm at any given location to estimate the maximum wind speed and storm surge depth based on the characteristics of the storm (e.g., central pressure, radius of maximum wind, and forward speed) the geomorphology (e.g., ground elevation and sea bathymetry) of the area affected
    - be able to include the effects of land cover/land use on wind speed estimates
    - be able to estimate damage and losses caused by wind and storm surge to the different types of assets included in the building and infrastructure exposure database via vulnerability functions that provide wind loss as a function of maximum wind speed and storm surge loss as a function of maximum water depth. Explicit modeling of storm-induced contents damage and business interruption is not required. The vulnerability functions are expected to be different for different classes of assets defined as a function of, at least, construction material, height and age.
4. Include an EQ loss module that would
    - be able to statistically estimate frequency of future earthquakes of different magnitude equal to or above M5, in the Central American and Caribbean regions. The statistical analysis should make use of all historical earthquakes even if occurred prior to the periods when the records are considered complete. The model is expected to be able to estimate the likelihood of rare EQs that may occur in the future but have not occurred in the short time window for which historical records are available.
    - consider ground motion as the only effect of earthquakes.
    - be able, for each earthquake, to estimate several intensity measures of ground motion (e.g., Peak Ground Acceleration and spectral accelerations at different vibration periods) that are good predictors of structural and non-structural damage to the different building and infrastructure assets included in the exposure database. Explicit modeling of damage to buildings and infrastructure due to soil failures of any kind (e.g., lateral spread, landslides and liquefaction) is not expected.
    - be able to include the effects of local soil conditions on the ground motion estimates at the surface.
    - be able to estimate damage and losses caused by ground motion to the different types of assets included in the building and infrastructure exposure database via vulnerability functions that provide structural and non-structural damage as a function of appropriate measures of ground motion intensity. Explicit modeling of earthquake-induced contents damage and business interruption is not required. The vulnerability functions are expected to be different for different classes of assets defined as a function of, at least, construction material, height and age.
5. Utilize a parametric structure for the insurance products to be implemented in a software system. The parametric structure is expected to utilize the TC and EQ modeled losses computed based on the built asset exposure database, the TC and EQ hazard module, and the vulnerability functions discussed above, to devise country-specific triggers and consequent payout structure.

6. Be suitable for the design of parametric TC and EQ insurance policies for the listed countries in the Central American and Caribbean regions.

Characteristics of the model

The expected characteristics of the model are listed below.

- Country-specific modeled losses will be considered as the trigger for TC- and EQ-induced loss payouts. The event characteristics of the TCs and EQs to be used for the computation of modeled losses will be provided by reputable third parties (e.g., NOAA for TCs and USGS for EQs).
- The calculation of the maximum wind speeds, the maximum storm surge, and the maximum ground motion intensities generated in the affected region by any future event must be done without ambiguity. The procedure that starts from the extraction of the characteristics of the events, through the computation of their effects, to the computation of modeled losses should be transparent so that it also can be checked and carried out by third parties.
- The maximum wind speed, storm surge height, and ground motion intensities will be computed distributed on a grid of appropriate resolution covering the listed Caribbean and Central American countries.
- The TC hazard module in the TC loss assessment model should be statistically consistent with the hazard model of the CCRIF's XSR 2.0 and Drought models.
- The exposure assets will comprise buildings and major infrastructure whose replacement value will be provided to the loss module by the exposure database to enable loss calculations. The exposed systems should be represented through GIS formats by a shapefile/raster based on databases from national/international agencies, if available, and on satellite imagery.
- The exposure database underpinning the SPHERA model should be consistent with the exposure database used by the CCRIF's XSR 2.0 model.
- The vulnerability functions used in the TC and EQ models will provide distribution of losses for each level of the intensity measure experienced by the asset. The selected intensity measures should be good predictors of the direct losses to structural and non-structural elements caused by wind, storm surge, and earthquake ground motion. The vulnerability functions should reflect the characteristics of different classes of assets to the effects of these natural events. These functions may be different for assets located in different countries.
- The losses predicted by the SPHERA model should be validated, to the extent possible, against historical TC- and EQ-induced losses appropriately trended for population growth, inflation and other macroeconomic parameters, as appropriate.
- The SPHERA should be able to support parametric insurance policies that are offered on a per event rather than a per annum basis.
- The parametric insurance policies supported by SPHERA are expected to be sophisticated enough to capture reasonably well the losses caused by TCs and EQs but simple and understandable by clients and stakeholders.
- The country-specific modeled-loss-based values of the attachment and exhaustion points along with their associated return periods, as well as the coverage limit, will be a matter of design. The product design is expected to be carried out in accordance with CCRIF's higher management and with input from the reinsurer, as appropriate.