Philippines Catastrophe Risk Assessment and Modeling: Component 4 – Prototype Risk Transfer Solutions

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Contact Information

If you have any questions regarding this document, contact:

AIR Worldwide Corporation
388 Market Street, Suite 750
San Francisco, CA 94111
USA
Tel: (415) 912-3111
Fax: (415) 912-3112

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1 Introduction

The Philippines is exposed to a multitude of natural hazards such as earthquakes, typhoons (tropical cyclones[1]), and flooding that result in significant property damage and socio-economic impacts. The Philippines is also widely acknowledged as one of the most disaster[2]-prone countries in the world (Delica, 1994).

According to Benson (1997), roughly 20 tropical disturbances enter the Philippines Area of Responsibility (PAR) on average per year, of which about 11 are classified as typhoons. According to Brown et al. (1991), it is highly likely that at least four typhoons will make landfall in any given year, while an average of eight to nine tropical cyclones would actually reach land and a further two offshore tropical cyclones would result in damage every year. While different studies may differ in their estimates of the frequency and severity of tropical cyclones, the general consensus is that the country is severely impacted by tropical cyclones. The eastern part of the country, particularly the north east, is considered most vulnerable to typhoons.

Severe flooding is normally associated with the heavy rains accompanying typhoons. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) has estimated that some 47% of the average annual rainfall is due to typhoons, 14% to monsoons, and 39% to other weather systems. In December 2011, flash floods caused by typhoon Washi killed over 1,000 people and left hundreds of thousands homeless on the island of Mindanao. In September 2009, typhoon Ondoy impacted Metro Manila. Less than a week later typhoon Pepeng carved a trail of destruction in Northern Luzon for almost two weeks. Consequences of the two typhoons included casualties due to flooding and landslides brought about by continuous rain.

In addition, the Philippines is located between two major tectonic plates, the Pacific and Eurasian plates, and within the Philippine Sea plate (USGS, 2011). The Pacific plate is pushing the Philippine Sea plate beneath the eastern side of the country at a rate of about 7 cm per year (NDCC, 1990), generating regular seismic and volcanic activity. According to the Philippines Institute of Volcanology

[1] The term "tropical cyclone" is used as a generic version of the term "typhoon". Both terms are used interchangeably in the report.

[2] In this report, the term "disaster" is used interchangeably with the term "catastrophe."

and Seismology (PHIVOLCS), the country experiences an average of five sizeable earthquakes per day, in turn resulting in ground shaking, and potentially ground rupture, liquefaction, lateral spreading, landslides, and tsunamis.

In terms of their broader economic impacts, natural hazards experienced in the Philippines can be divided into two distinct categories depending on their frequency of occurrence. Tropical cyclones and floods are the principal hazards falling into the category of more frequently occurring hazards. Both occur annually, although the rate of incidence and severity varies between years. Tropical cyclones alone have been estimated to cause damage equivalent to 0.6% of the gross national product (GNP) every year (ADB, 1994), which significantly impacts the Philippines' economic recovery. The second category comprises more severe disasters with considerably longer return periods, such as major earthquakes, volcanic eruptions, or droughts (Benson, 1997).

The Government of the Philippines (GoP) has begun taking a proactive approach to disaster risk management by approving the Disaster Risk Reduction and Management (DRRM) Act in May 2010 (Republic Act No. 10121). One of the priority areas identified by the DRRM Act is the establishment of appropriate risk finance policies and instruments that will help reduce the fiscal burden of the GoP to natural disaster impacts. Furthering the work on risk finance, the GoP is implementing a technical assistance program that would lead to the formulation of a risk finance strategy. Alongside, the GoP has requested a catastrophe risk assessment study that would provide the quantitative underpinnings for the design of an ensuing catastrophe liquidity facility, especially addressing the higher layers of risk.

The World Bank, which is assisting the GoP with its disaster risk management objectives, has retained AIR Worldwide Corporation (AIR) in partnership with the Asian Disaster Preparedness Center (ADPC) for conducting the catastrophe risk modeling and assessment study.

According to the project's Terms of Reference (ToR), the natural hazards to be considered in this study are earthquake ground shaking, typhoon wind and typhoon-induced precipitation, and flooding due to non-typhoon induced precipitation (i.e., monsoonal precipitation induced flooding). The study is built over five distinct but interconnected components, which are as follows:

- **Component 1:** Hazard Data and Loss Data Collection and Management
- **Component 2:** Exposure Data Collection and Vulnerability Function Development
- **Component 3:** Catastrophe Risk Assessment at the National and Local Levels
- **Component 4:** Design of Parametric Indices for Financial Transactions
- **Component 5:** Support for Placement of Parametric Risk Transfer Products (study can be extended to include this optional component depending on the GoP's decision regarding the use of the parametric risk transfer products towards the disaster risk financing strategy)

This report serves as a summary of the prototype risk transfers solutions developed by AIR/ADPC as part of Component 4's objective to provide realistic examples of potential risk transfer transactions for the Government of the Philippines. Based on communication with the World Bank, two primary types of risk transfer structures were designed: a modeled loss structure and a 1st generation parametric structure (also known as a "cat-in-the-box" structure, where cat is short for catastrophe). The proposed modeled loss structure presents a solution for losses due to earthquakes (ground shaking only) and tropical cyclone (wind and precipitation only) combined[3]. The 1st generation parametric risk transfer solutions presented here propose structures for both earthquake (shake only) and tropical cyclone (wind and precipitation) as separate perils, as well as combined. All prototype transactions proposed in this report are based on emergency losses[4] (as defined in the loss results from Component 3). The following sections provide brief overviews on the fundamental aspects of each type of the risk transfer structure, and then present the salient aspects of each prototype solution developed for this study.

1.1 Limitations

The study, a part of which is summarized in this report is intended for use by the Government of the Philippines and the World Bank to assist them with quantifying the catastrophe risk associated with the population and built environment in the Philippines, and with the process of development and implementation of disaster risk finance strategies. Proper application of this study requires explicit recognition and understanding of the limitations of both the scope and methodology of the entire study.

The physical loss estimates that have been presented for the assets are neither facts nor confirmed predictions of loss that may occur either collectively or to any particular asset as a result of future events or any specific event; as such, the actual damage for a particular event may be materially different from that presented in this study. Furthermore, the assumptions adopted in determining the loss estimates do not constitute the exclusive set of reasonable assumptions, and the use of a different set of assumptions or methodology may produce materially different results. The results presented in

[3] While the risk of non-tropical cyclone (NTC) precipitation has also been assessed in Component 3, it was decided to focus on earthquake and tropical cyclone as the primary hazards for development of the prototype solutions because these perils have greater market acceptability. An NTC solution may be considered in the future, if desired.

[4] Emergency losses are expenditures the government may sustain as a result of providing necessary relief and undertaking recovery efforts. Such efforts include debris removal, setting up shelters for those made homeless, or supplying medicine and food.

this study simply represent our best assessment of the potential for physical losses, based on information and data available to us at the time of this study and that collected during the study.

The scope of services performed during this assessment may not adequately address the needs of other users, and any re-use of (or failure to use) this report or the findings, conclusions, or recommendations presented herein are at the sole risk of the user. Our conclusions with respect to the loss and hazard estimates are based on our professional opinion, engineering experience and judgment, analyses conducted in the course of the study, information and data available in the literature and that provided by the World Bank and various local agencies, and are derived in accordance with current standards of professional practice.

The prototype risk transfer options presented in this report are **not market-ready solutions**. In particular, further optimization of the parametric solutions may be required before a final transaction can be placed. There also may be additional details of each structure that may need to be tailored to meet the needs of the Government of the Philippines. Developing market-ready risk transfer solutions is contemplated within Component 5 of this study, which has not yet been initiated. Information contained in this report is strictly for education purposes using the developed prototypes as examples.

1.2 Glossary of Terms

Aggregate Loss: The sum of losses from qualifying events in a risk period..

Attachment Point: Monetary value that a qualifying event's losses must exceed in order for the risk transfer contract to experience at least a single dollar of loss.. Attachment points can be defined on an aggregate or occurrence loss basis.

Attachment Probability: The annual probability that the risk transfer contract will experience a loss (that the attachment point will be exceeded).

Average Annual Loss (AAL): The monetary amount the risk transfer contract can expect to lose on average over one year.

Basis Risk: The risk that the recovery from an event may be higher or lower than anticipated due to differences between modeled loss and actual loss or from different types of risk transfer contracts, such as a risk transfer based on modeled losses as compared to a risk transfer based on parameters of qualifying events. Positive basis risk is when the recovery amount is higher than expected. Negative basis risk is when the recovery amount is lower than expected.

Ceded Percentage: Percentage of losses above the attachment point and below the exhaustion point that is ceded to the insurer. If the ceded percentage is less than 100%, then a portion of the layer loss is retained by the insured.

Exhaustion Point: Monetary value that a qualifying event's losses must exceed in order for the layer to experience a total loss. Exhaustion points can be set on an aggregate or occurrence loss basis.

Exhaustion Probability: The annual probability that the risk transfer contract will experience a total loss (that the layer limit will be reached). Note that for risk transfer contracts based on aggregate losses, the exhaustion probability is the same as the exceedance probability of the exhaustion point, but the same cannot be said for occurrence treaties.

Layer Limit: The maximum monetary loss amount that a risk transfer contract can experience in a risk period.

Loss on Line: The AAL divided by the layer size. In other words, the average annual loss stated as a percentage of the layer limit.

Occurrence Loss: The loss associated with a single event.

Occurrence Exceedance Probability: The probability that an occurrence loss within a year will exceed a certain amount.

Parametric Structure: A risk transfer contract that is set up to pay out when qualifying events meet certain defined event parameter criteria.

Parametric Trigger: A set of event characteristics that define the events that would generate a payout in a parametric structure.

Qualifying Event: Events that are eligible for coverage under a risk transfer contract. For Component 4, Philippine earthquake and tropical cyclone events were considered qualifying events.

Risk Period: The period of time that coverage is in effect for a layer, usually one year.

Triggering Event: A qualifying event that satisfies the criteria described by the parametric trigger.

Trigger Probability: The probability that a triggering event will occur in a given year.

2 Prototype Modeled Loss Solutions

A risk transfer based on modeled loss will provide protection for the insured based on estimated losses generated from a catastrophe model when a **qualifying event** occurs. A **qualifying event** in a modeled loss risk transfer is defined by the peril and geographical domain of the catastrophe model being used. For example, earthquakes and tropical cyclones that occur in the Philippines.

In addition to a catastrophe model, a modeled loss risk transfer requires a credible source for reporting on the recorded observations of a qualifying event and a database of exposures that are being financially protected for the insured.

When a **qualifying event** occurs, directly observed parameters of the event (such as the epicenter and magnitude of an earthquake) will be input into the catastrophe model along with the database of exposures to produce a **loss estimate**. The **loss estimate** will be a single number representing total losses to the insured from the **qualifying event**.

The **recovery amount** is the amount of money that the insured will receive when a **qualifying event** occurs. The **recovery amount** is purely a function of the **loss estimate**. It is important to note that the **recovery amount** will be based only on the **loss estimate**. Actual losses will not be a factor in determining the **recovery amount**, regardless of how much it differs from the **loss estimate**.

How the **recovery amount** is calculated from the **loss estimate** can involve several features. These features include being based on an **occurrence basis** or an **aggregate basis**, **attachment point**, **exhaustion point**, **franchise deductible**, and **participation percentage**.

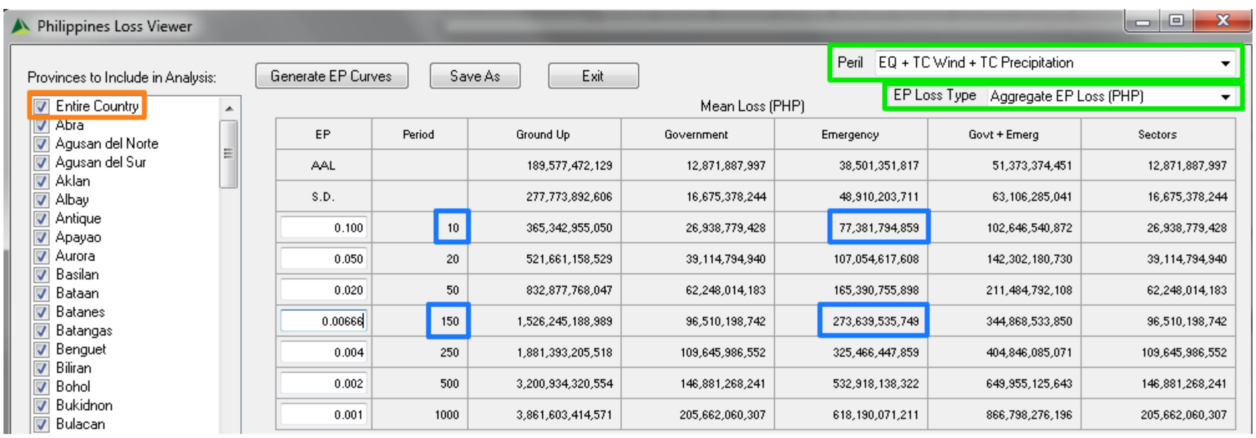
2.1 Example of a Modeled Loss Prototype for the Philippines

For Component 4 of the World Bank Philippines project, the features for the modeled loss risk transfer prototypes included the following:

1. **Qualifying events** are earthquakes and tropical cyclones in the Philippines.
2. The exposure is a combination of the database of government assets and private property assets produced in earlier Components.
3. The **loss estimate** was selected to be the estimated emergency losses calculated using AIR's earthquake or tropical cyclone model for the Philippines.

4. The **recovery amount** calculation is based on annual aggregate losses for both perils combined with an **attachment point** at the 10% **exceedance probability**, an **exhaustion point** at the 0.67% **exceedance probability**, and no **franchise deductible**.

The attachment point and exhaustion point were selected by the World Bank and based on the losses that were modeled by AIR/ADPC in Component 3. As part of the deliverables of Component 4, a software tool – the Philippines Loss Viewer – was developed, which allows users to view the modeled loss associated with different exceedance probabilities from this study, for the selected peril(s) and provinces. This tool is designed to help stakeholders select different terms, such as attachment points and exhaustion points, based on their risk tolerance. For instance, Figure 1 illustrates how the tool can be used to determine the loss associated with 10% exceedance probability as the attachment level, and the loss associated with the 0.67% exceedance probability as the exhaustion (detachment) level, for an aggregate modeled loss structure that covers both perils for the entire county. For more detail on the Philippines Loss Viewer, please refer to the report entitled "Philippines Catastrophe Risk Assessment and Modeling: Component 4 – Loss Viewer User Guide" dated May 5, 2014.



EP	Period	Ground Up	Government	Emergency	Govt + Emerg	Sectors
AAL		189,577,472,129	12,871,887,997	38,501,351,817	51,373,374,451	12,871,887,997
S.D.		277,773,892,606	16,675,378,244	48,910,203,711	63,106,285,041	16,675,378,244
0.100	10	365,342,955,050	26,938,779,428	77,381,794,859	102,646,540,872	26,938,779,428
0.050	20	521,661,158,529	39,114,794,940	107,054,617,608	142,302,180,730	39,114,794,940
0.020	50	832,877,768,047	62,248,014,183	165,390,755,898	211,484,792,108	62,248,014,183
0.00666	150	1,526,245,188,989	96,510,198,742	273,639,535,749	344,868,533,850	96,510,198,742
0.004	250	1,881,393,205,518	109,645,986,552	325,466,447,859	404,846,085,071	109,645,986,552
0.002	500	3,200,934,320,554	146,881,268,241	532,918,138,322	649,955,125,643	146,881,268,241
0.001	1000	3,861,603,414,571	205,662,060,307	618,190,071,211	866,798,276,196	205,662,060,307

Figure 1: Using the "Philippines Loss Viewer" to select terms based on structure, peril, region and loss type

Using the 10,000 simulated years in AIR's catastrophe models for earthquake and tropical cyclone, AIR can then compute the estimated losses under these simulations to produce simulated recovery amounts for the structure described above. These calculations are summarized through the use of a **risk profile**.

The **risk profile** for the modeled loss risk transfer is composed of 3 statistics – the **probability of attachment**, **annual expected loss**, and the **probability of exhaustion**. The **probability of attachment** is the probability that the risk transfer will produce at least a single dollar of recovery. The **annual expected loss** is on average, the percentage of principal an investor can expect to lose in a year. The **probability of exhaustion** is the probability that the risk transfer will pay the full recovery available under the risk transfer. Table 1 provides the estimated annual loss to the modeled loss structure (Expected Loss), with the corresponding probability of having a non-zero loss (Attachment), and having a full principal payout amount (Exhaustion).

Table 1: Modeled Loss Risk Profile

Metric	PHP Terms (in Millions)	Risk Profile (Probability)
Attachment	77,382	9.99%
Expected Loss	5,151	2.62%
Exhaustion	273,640	0.64%
Layer size	196,258	N / A

AIR also produced supplemental information to the **risk profile** to provide additional insight into the nature of the risk transfer. These include segmenting the **expected loss** into various categories such as earthquake versus tropical cyclone recoveries, recoveries by moment magnitude, recoveries by Saffir-Simpson category, and recoveries by various geographies.

Table 2 provides a breakdown of the modeled losses by peril in the covered area arising in the 10,000 annual scenarios of potential tropical cyclone and earthquake activity that were simulated. Table 3 provides a breakdown of the modeled expected loss by magnitude for all earthquakes causing loss to the structure for the 10,000 annual scenarios of potential earthquake activity that was simulated. Table 4 provides a breakdown of the modeled expected loss by Saffir-Simpson category for all tropical cyclones causing loss to the structure for the 10,000 annual scenarios of potential tropical cyclone activity that was simulated. The Saffir-Simpson category for a given tropical cyclone shown in the table is based on the minimum central pressure throughout the event's track.

Table 2: Modeled Loss Contribution by Peril

	Tropical cyclone	Earthquake
Loss Contribution (%)	49.8%	50.2%

Table 3: Contribution to expected loss for modeled loss structure by earthquake magnitude

Magnitude (Mw)	% Contribution to Loss
Less than 6.0	1.4%
6.0 – 6.4	1.8%
6.5 – 6.9	7.5%
7.0 – 7.4	22.2%
7.5 – 7.9	23.6%
8.0 and Greater	43.6%

Table 4: Contribution to expected loss for modeled loss structure by Saffir-Simpson category (based on minimum central pressure throughout track)

S. S. Category (Central Pressure)	% Contribution to Loss
1 (Greater than 980 mb)	3.5%
2 (979 – 965 mb)	9.6%
3 (964 – 945 mb)	24.6%
4 (944 – 920 mb)	27.8%
5 (Less than 920 mb)	34.4%

3 Prototype 1st Generation Parametric Solutions

A risk transfer based directly on parameters of the qualifying event is called a parametric risk transfer solution. Much like a modeled loss risk transfer, a parametric risk transfer requires a credible source for reporting on the recorded observations of a **qualifying event**. However, unlike a modeled loss transaction, a parametric risk transfer does not require exposure information or the running of catastrophe models when a qualifying event occurs.

There are two broad classifications of parametric risk transfers: 1st generation and 2nd generation parametric risk transfers. A 1st generation parametric structure is also sometimes called a "cat in a box" structure (Figure 2). Under this structure, the recovery amount is simply a function of whether or not a **qualifying event** (i.e., the "cat" event) occurred within a certain geographical boundary (i.e., the "box"). The geographical boundary may be not constrained to a single area. Multiple areas can be combined under a single parametric risk transfer.

The recovery also depends on additional parameters of the **qualifying event**, such as being above a certain moment magnitude for earthquakes or reaching a certain Saffir-Simpson category for tropical cyclones. The **qualifying event** would have to satisfy both the geographical boundary constraint and the moment magnitude or Saffir-Simpson constraint to trigger a recovery. A qualifying event that meets these criteria is termed a **triggering event**.

A major difference between a 1st generation parametric risk transfer and a modeled loss risk transfer is that the 1st generation parametric risk transfer does not utilize **attachment points**, **exhaustion points**, or **franchise deductibles**. A **qualifying event** either triggers a recovery or it does not. For this reason, the recoveries under a 1st generation parametric do not vary across **triggering events**.

Since recoveries do not vary in a 1st generation parametric, the **risk profile** has the same **attachment probability**, **expected loss**, and **exhaustion probability**. Since they are all the same, we usually refer to this amount as the **triggering probability**.

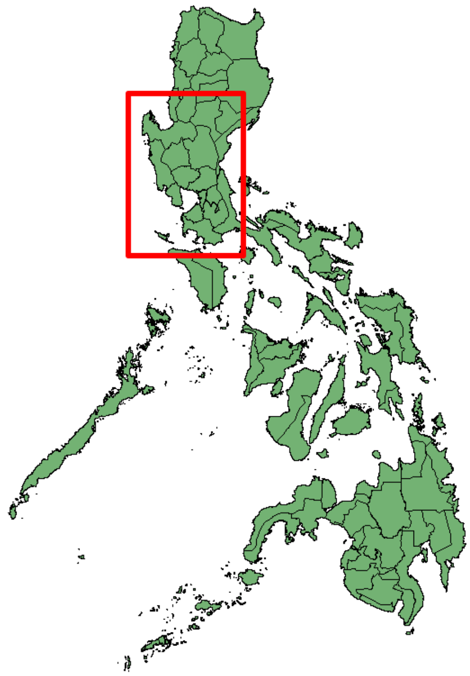


Figure 2: Example of geographical boundary (i.e., the "box" as shown in red) in a 1st generation parametric structure

3.1 Example 1st Generation Parametric Loss Prototype for the Philippines

For the World Bank Philippines risk transfer prototype, a 1st generation parametric risk transfer prototype was developed. AIR's 10,000 year stochastic catalogs of simulated natural catastrophe events[5] were used to help determine the triggering parameters. For example, to determine the parameters of the earthquake structure, the earthquake catalog was filtered by event magnitude, latitude, longitude, and recovery amount for qualifying events that attached to the modeled loss structure described in Section 2.1 (see Figure 3). The blue highlighted areas show that a significant portion of the recoveries are centered on well clustered latitude and longitude bands. Using this information, AIR was able to construct a geographic boundary for the parametric structure. The top right corner of Figure 3 also shows that many of these events had a moment magnitude of 7 or greater. These aspects combine to form the basis of the example 1st generation parametric structure for earthquake under Component 4. The same can be done for the tropical cyclone structure. Figure 4

5 The stochastic catalogs were developed and used to model the hazard in Component 3 of this study. Please refer to the report entitled "Philippines Catastrophe Risk Assessment and Modeling: Component 3 – Country Catastrophe Risk Profiles" for more information.

shows the resulting boundaries for the two tropical cyclone structures (Box 1, Box 2) and the earthquake structure (Box 3), while Table 5 provides the latitude and longitude coordinates of these boxes (in degrees).

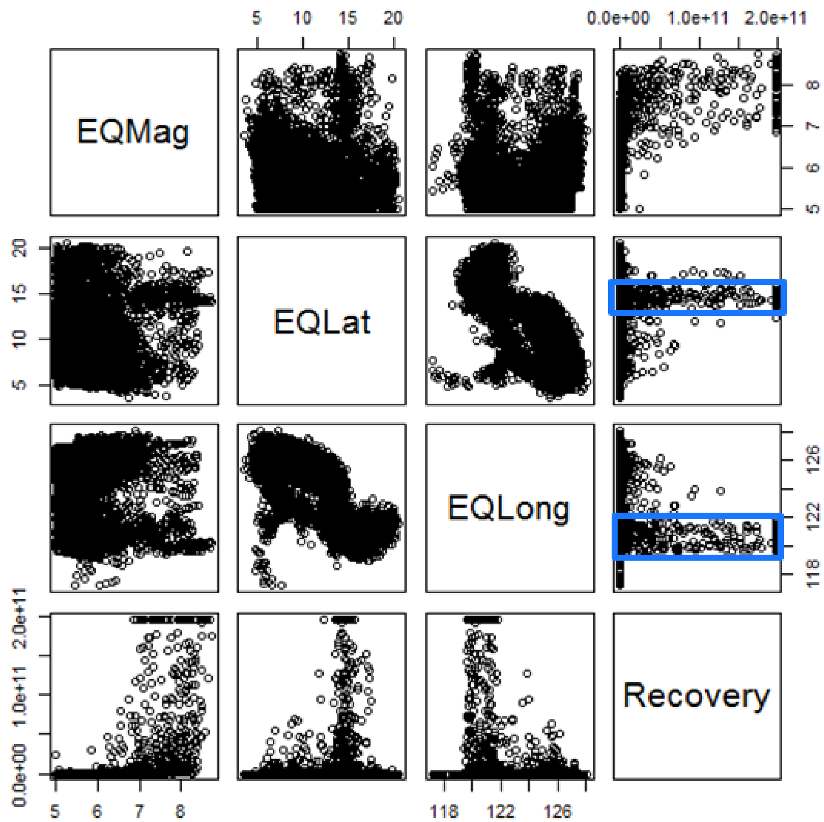


Figure 3: Example of how modeled loss information can be helpful in determining the latitude and longitude boundaries for a first generation parametric structure

In addition to the determining the boundaries, the types of information shown in Figure 3 can also be used to determine other aspects of the structure such as the event parameter thresholds (i.e. the earthquake magnitude and tropical cyclone central pressure). Based on this type of analysis, the following thresholds were determined for each peril for the example application:

- For a tropical cyclone event to be considered a triggering event, it must have a central pressure of 944 mb or less within Box 1, **or** a central pressure of 964 mb or less within Box 2.
- For an earthquake event to be considered a triggering event, it must have an epicenter within Box 3, and have a magnitude of 7.0 or greater.

Table 6 provides the probability that the resulting parametric structure would meet the trigger event conditions in any stochastic year for each peril and both perils combined. All metrics are on an annual basis.

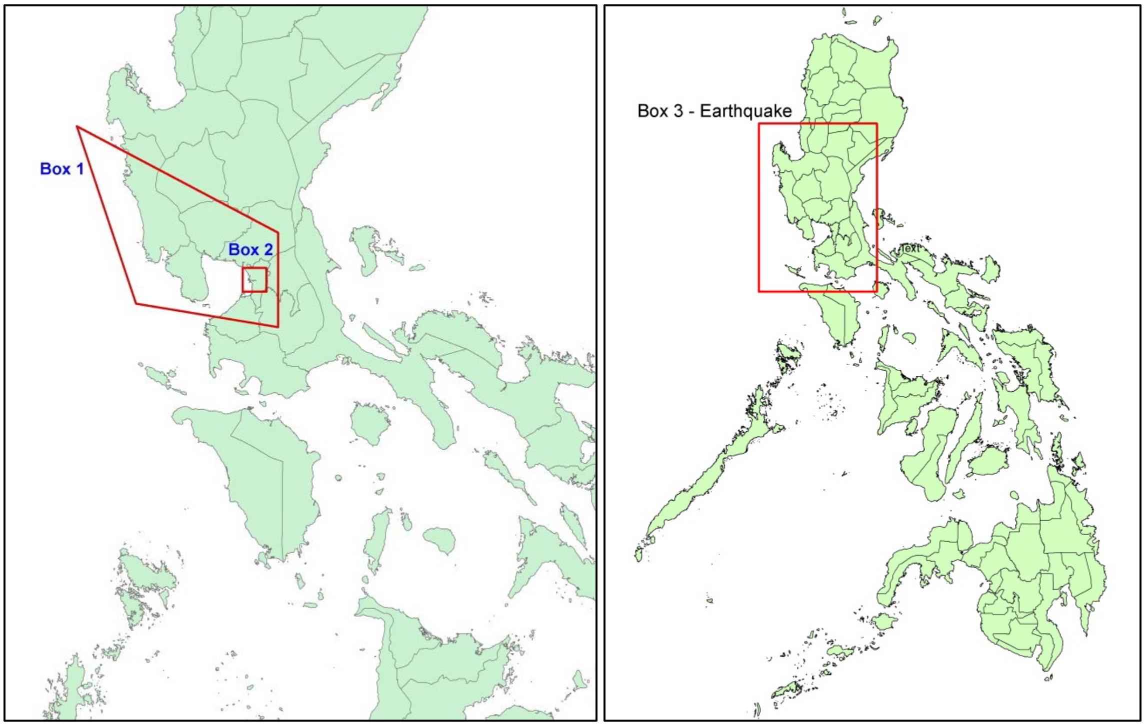


Figure 4: Maps of Parametric Structure Boxes for Tropical Cyclone (left) and Earthquake (right)

Table 5: Parametric Structure Coordinates (Latitude, Longitude)

	Box 1(1)	Box 2(2)	Box 3(3)
Top Left	15.9,119.5	14.7,121.1	16.80,119.48
Top Right	15.0,121.2	14.7,120.9	16.80,121.90
Bottom Left	14.4,120.0	14.5,120.9	13.35,119.48
Bottom Right	14.2,121.2	14.5,121.1	13.35,121.90

(1) The Box 1 parametric structure is deemed to have triggered if a tropical cyclone passes through the structure with a minimum central pressure of less than or equal to 944mb.
(2) The Box 2 parametric structure is enclosed within Box 1. The Box 2 parametric structure is deemed to have triggered if a tropical cyclone passes through the structure with a minimum central pressure of less than or equal to 964mb.

(3) The Box 3 parametric structure is deemed to have triggered if an earthquake with magnitude 7.0 or greater has an epicenter within the box.

Table 6: Parametric Structure Trigger Probability

	Earthquake	Tropical Cyclone	Both Perils(1)
Trigger Probability	4.5%	4.7%	8.9%

(1) The Trigger Probability for both perils can be lower than the sum of trigger probabilities for individual perils due to the potential for overlap. A particular year might trigger both the Earthquake and Tropical cyclone individually, however under the combined structure it would count as a single triggering simulation.

The stochastic catalogs can also be used to gain further insight on what types of events will likely trigger the parametric structure. For instance, Table 7 provides a breakdown of earthquakes by magnitude for catalog years that have triggered the parametric structure for the 10,000 annual scenarios of potential earthquake activity. This shows that over half of the triggering events in the catalog will be earthquakes with magnitudes between 7.0 and 7.4. There are no earthquakes with magnitudes below 7.0 because they are below the threshold of the structure. Similarly, Table 8 provides a breakdown of tropical cyclones by Saffir-Simpson category for catalog years that have triggered the parametric structure for the 10,000 annual scenarios of potential tropical cyclone activity. In this case, the majority of the triggering events have reached Saffir-Simpson category of 4 (central pressure between 944 – 920 mb) while the storm is within the specified boundaries.

Table 7: Contribution to expected loss for parametric structure by earthquake magnitude

Magnitude	% Contribution to Loss(1)
Less than 6.0	0.0%
6.0 – 6.4	0.0%
6.5 – 6.9	0.0%
7.0 – 7.4	52.3%
7.5 – 7.9	30.0%
8.0 and Greater	17.7%

(1) The parametric structure only triggers if an earthquake of magnitude 7.0 of greater has an epicenter within the box. Any event below that threshold does not cause loss to the parametric structure.

Table 8: Contribution to expected loss for parametric structure by Saffir-Simpson category

S. S. Category (Central Pressure)	% Contribution to Loss(1)
1 (Greater than 980 mb)	0.0%
2 (979 – 965 mb)	0.0%
3 (964 – 945 mb)	32.3%
4 (944 – 920 mb)	54.6%
5 (Less than 920 mb)	13.1%

(1) The parametric structure only triggers if a tropical cyclone of severity 3 of higher passes through Box 1, or if a tropical cyclone of severity 4 of higher passes through Box 2. Any event below that threshold does not cause loss to the parametric structure.

It is also informative to look at specific examples to help understand what types of events will trigger this structure. Figure 5 and Table 9 below illustrate three sample stochastic earthquake events that would trigger the parametric structure since they have an epicenter within the box (Box 3), and meet the triggering conditions. Table 9 provides more detailed information about those three stochastic events, their respective losses in the modeled loss structure, as well as their effect on the parametric structure.

Similarly, Figure 6 illustrates all stochastic tropical cyclone events with modeled emergency loss for the entire country greater than PHP 50 billion, PHP 120 billion, and PHP 200 billion, respectively. Box 1 and Box 2 have been superimposed on the event tracks (please note that the triggering condition for the parametric structure is the central pressure of the tropical cyclone while the storm is in the box).

It can also be useful to understand the difference between what events trigger a payout and what events do not for this prototype. Table 10 provides additional information on three specific stochastic tropical cyclone events, their respective losses in the modeled loss structure, as well as their effect on the parametric structure. In this table, Event 1 does not trigger the parametric structure because its path does not fall into either Box 1 or Box 2. Event 2 is a tropical cyclone that triggers a payout because it passes through Box 1 and meets the threshold central pressures. Event 3 is an example of a triggering event that passes through both Box 1 and Box 2.

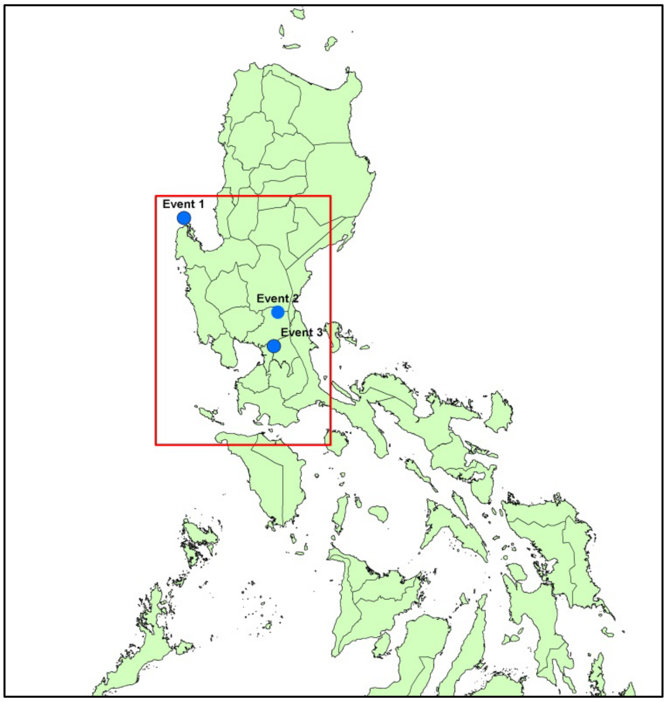


Figure 5: Illustrative stochastic earthquake events

Table 9: Illustrative stochastic events information

Name	Magnitude	Centroid Latitude	Centroid Longitude	Modeled Loss (PHP millions)	Modeled Loss Recovery (PHP millions)	Triggers Parametric
Event 1	8.2	16.496	119.869	52,223	0	Yes
Event 2	8.2	15.191	121.171	209,000	139,068	Yes
Event 3	7.1	14.719	121.114	674,008	196,258	Yes

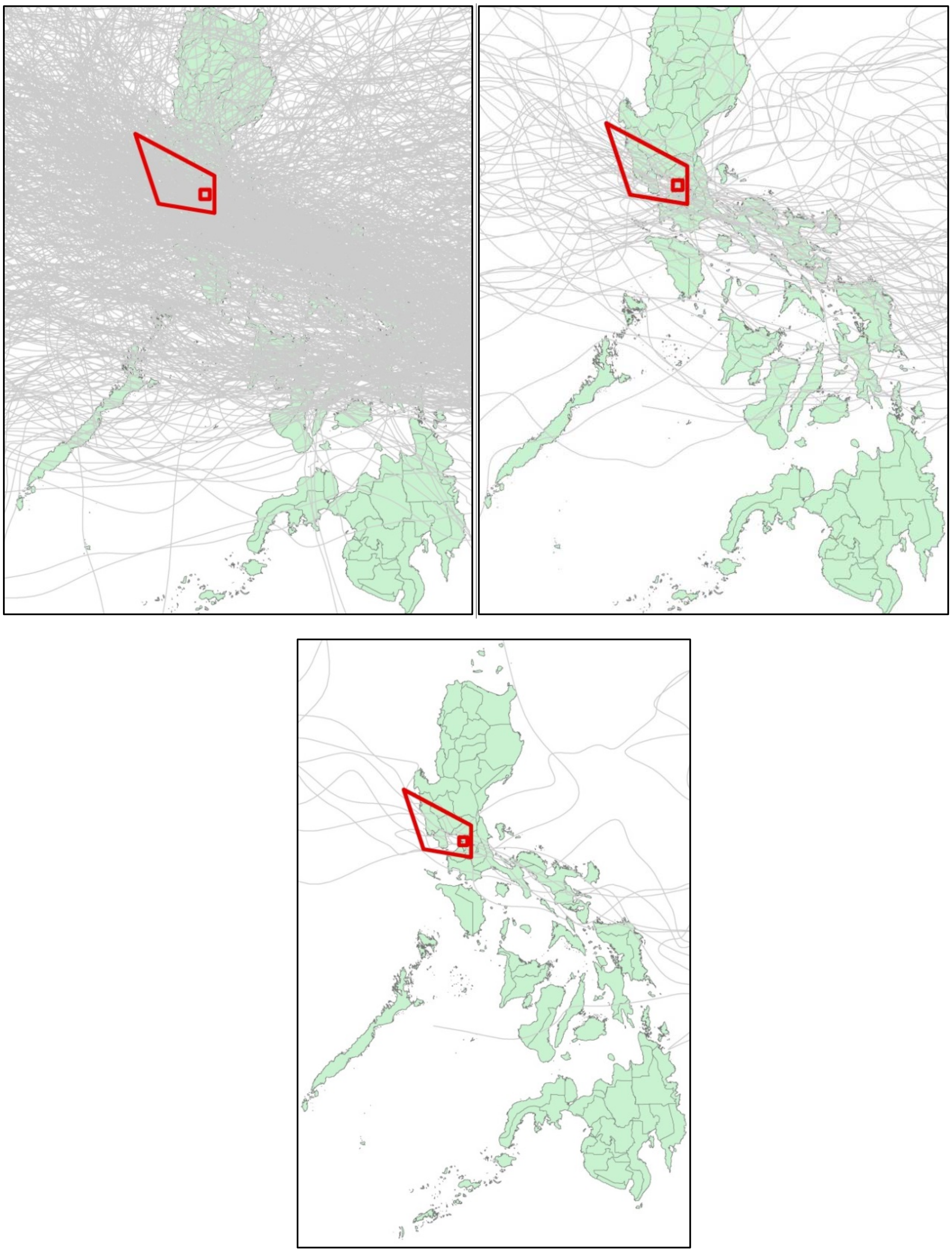


Figure 6: Illustrative stochastic tropical cyclone events above various emergency loss thresholds

Table 10: Illustrative tropical cyclone stochastic events information

Name	Central Pressure	Latitude	Longitude	Modeled Loss (PHP millions)	Modeled Loss Recovery (PHP millions)	Trigger Parametric
Event 1	962.5	15.89	119.52	45,650	0	No
Event 2	927.2	14.30	120.62	124,976	57,011	Box 1 Trigger
Event 3	939.4	14.24	121.20	310,411	196,258	Box 1 + Box 2 Trigger

3.2 Discussion of Basis Risk

It is important to understand that in a 1st generation parametric structure, recoveries depend solely on the parameters of qualifying events, and not on the actual losses sustained from qualifying events. There is a greater potential for the loss computed using the qualifying event's parameters to differ from actual sustained losses, especially without the use of AIR's catastrophe models to produce estimated losses. AIR uses the term **basis risk** to denote the amount of difference there can be between a parametric risk transfer and actual losses. Since an extensive, reliable historical record of actual losses due to natural catastrophes rarely exists, modeled losses are often used in lieu of actual losses to estimate the **basis risk** of a parametric solution.

The example events in Table 9 and Table 10 can be used to illustrate the concept of **basis risk** by comparing the payouts under the modeled loss prototype with the parametric structure prototype. In both tables, the column titled "Modeled Loss Recovery" indicates the payout for the modeled loss structure while the column titled "Trigger Parametric" indicates whether the parametric structure triggers a payout.

In Table 9, the first event results in no recovery under the modeled loss structure; however the event does trigger the parametric structure and results in a payout. This is an example of **basis risk** because the parametric structure was triggered (event within the box exceeding magnitude threshold) even though the modeled loss (52 B PHP) did not exceed the target **attachment point,** which is the loss associated with the 10% exceedance probability (77 B PHP). The opposite situation, i.e. there is a recovery under the modeled loss structure but the parametric structure does not trigger a payout, is also an example of **basis risk**. The parametric structure should aim to minimize instances such as these. Event 2 in Table 9 results in a recovery under the modeled loss structure and also triggers the parametric structure resulting in a payout. In Table 10, the first event causes no recovery to the modeled loss structure, and does not trigger a payout under the parametric structure. Both events are examples of when no **basis risk** occurs and the two structures are consistent. These are the types of instances that are to be maximized when optimizing a parametric solution.

AIR quantifies **basis risk** of a parametric risk transfer by comparing it to a similar modeled loss structure using a 10,000 year stochastic catalog of simulated events and losses. Table 11 compares the parametric structure prototype described in Section 3.1 with the modeled loss structure in Section 2.1. The first row in the table compares the years that contain triggering events in catalog against the years that either attach or do not attach under a similar modeled loss structure. That is, the first row quantifies the percentage of years in the catalog that would trigger the parametric structure as well as attach the modeled loss structure (Yes/Yes), and the years that would trigger the parametric structure but not cause the modeled loss structure to recover (Yes/No). The second row shows the percentage of years that would not trigger the parametric structure but would cause a modeled loss recovery (No/Yes), and the years that would neither trigger the parametric structure nor attach the modeled loss structure (No/No).

When constructing a parametric risk transfer, great consideration is paid to minimizing **basis risk**. Ideally if there were no **basis risk**, the Yes/Yes and the No/No values would add up to 100% while the Yes/No and No/Yes values would equal zero. Thus, optimizing a parametric structure involves maximizing the Yes/Yes and No/No values and minimizing the Yes/No and the No/Yes values. This can be achieved by varying the boundaries of the boxes and the event parameter threshold values.

Table 11: Parametric Structure Basis Risk

		% of Years in Catalog Yielding a Modeled Loss Recovery		
		YES	NO	TOTAL
% of Years in Catalog Triggering a Parametric Payout	YES	4.01%	4.91%	8.92%
	NO	5.98%	85.10%	91.08%
	TOTAL	9.99%	90.01%	100.00%

Appendix A: Additional Prototype Structures

Finding a risk transfer structure that fits the specific needs of the insured can often be a challenging and iterative process. At the request of the World Bank, AIR developed additional modeled loss and 1st generation prototype structures to help better identify disaster risk financing solutions that best serve the Government of the Philippines. The prototypes presented in the following sections aim to yield and expected loss of approximately 2%.

A.1 Example of a Modeled Loss Prototype for the Philippines

The modeled loss risk transfer prototype presented in this section features the following:

1. **Qualifying events** are earthquakes and tropical cyclones in the Philippines.
2. The exposure is a combination of the database of government assets and private property assets produced in earlier Components of this project.
3. The **loss estimate** was selected to be the estimated emergency loss calculated using AIR's earthquake or tropical cyclone model for the Philippines.
4. The **recovery amount** calculation is based on annual occurrence losses for both perils combined with layer terms as stated in Table 12, and no **franchise deductible**.

The attachment point and exhaustion point were selected by the World Bank and based on the losses that were modeled by AIR/ADPC in Component 3. Using the 10,000 simulated years in AIR's catastrophe models for earthquake and tropical cyclone, AIR can compute the estimated losses under these simulations to produce simulated recovery amounts for the structure. These calculations are summarized through the use of a **risk profile**.

The **risk profile** for the modeled loss risk transfer is composed of 3 statistics – the **probability of attachment**, **annual expected loss**, and the **probability of exhaustion**. The **probability of attachment** is the probability that the risk transfer will produce at least a single dollar of recovery. The **annual expected loss** is on average, the percentage of principal an investor can expect to lose in a year. The **probability of exhaustion** is the probability that the risk transfer will pay the full recovery available under the risk transfer. Table 12 provides the estimated annual loss to the modeled loss structure

(Expected Loss), with the corresponding probability of having a non-zero loss (Attachment), and having a full principal payout amount (Exhaustion).

Table 12: Modeled Loss Risk Profile

Metric	PHP Terms (in Millions)	Risk Profile (Probability)
Attachment	110,174	2.34%
Expected Loss	437	2.03%
Exhaustion	131,674	1.77%
Layer size	21,500	N / A

AIR also produced supplemental information to the **risk profile** to provide additional insight into the nature of the risk transfer. These include segmenting the **expected loss** into various categories such as earthquake versus tropical cyclone recoveries, recoveries by moment magnitude, and recoveries by Saffir-Simpson category. Table 13 provides a breakdown of the modeled losses by peril in the covered area arising in the 10,000 annual scenarios of potential tropical cyclone and earthquake activity that were simulated. Table 14 provides a breakdown of the modeled expected loss by magnitude for all earthquakes causing loss to the structure for the 10,000 annual scenarios of potential earthquake activity that was simulated. Table 15 provides a breakdown of the modeled expected loss by Saffir-Simpson category for all tropical cyclones causing loss to the structure for the 10,000 annual scenarios of potential tropical cyclone activity that was simulated. The Saffir-Simpson category for a given tropical cyclone shown in the table is based on the minimum central pressure throughout the event's track.

Table 13: Modeled Loss Contribution by Peril

	Tropical cyclone	Earthquake
Loss Contribution (%)	30.9%	69.1%

Table 14: Contribution to Expected Loss for Modeled Loss Structure by Earthquake Magnitude

Magnitude (Mw)	% Contribution to Loss
Less than 6.0	0.3%
6.0 – 6.4	1.4%
6.5 – 6.9	7.5%
7.0 – 7.4	22.9%
7.5 – 7.9	24.1%
8.0 and Greater	43.8%

Table 15: Contribution to Expected Loss for Modeled Loss Structure by Saffir-Simpson (S.S.) Category (based on minimum central pressure throughout track)

S. S. Category (Central Pressure)	% Contribution to Loss
1 (Greater than 980 mb)	0.0%
2 (979 – 965 mb)	1.7%
3 (964 – 945 mb)	14.2%
4 (944 – 920 mb)	32.4%
5 (Less than 920 mb)	51.8%

A.2 Example 1st Generation Parametric Loss Prototype for the Philippines

The following section presents a 1st generation parametric prototype based on an expected loss of approximately 2%. AIR's 10,000 year stochastic catalogs of simulated natural catastrophe events[6] were used to help determine the triggering parameters. Table 16 and Table 17 below illustrate the latitude

[6] The stochastic catalogs were developed and used to model the hazard in Component 3 of this study. Please refer to the report entitled "Philippines Catastrophe Risk Assessment and Modeling: Component 3 – Country Catastrophe Risk Profiles" for more information.

and longitude coordinates of the boxes for each peril, as well as the magnitude/central pressure threshold required to trigger a payout for the parametric structure. Figure 7 shows the boundaries for the four tropical cyclone gateways, as well as the boundaries for the ten earthquake boxes.

Table 16: Tropical Cyclone Parametric Structure Saffir-Simpson (S.S.) Category Threshold and Coordinates (Latitude, Longitude)

Gateway	S.S. Category (Central Pressure) Threshold	North End	South End
A	5 (920 mb)	122.7, 14.3	122.8, 13.0
B	5 (920 mb)	125.0, 11.0	125.1, 10.0
C[1]	4 (944 mb)	124.0, 13.3	124.1, 12.7
D[1]	3 (964 mb)	121.0, 14.7	121.1, 14.0

(1) Gateway C and D requires that a single tropical cyclone passes through gateway C and gateway D while at category 4 and category 3 or higher strength respectively.

Table 17: Earthquake Parametric Structure Magnitude Threshold and Coordinates (Latitude, Longitude)

Box	Magnitude Threshold	NW Corner	SE Corner
A	8.0	17.5,120.0	16.8, 120.4
B	8.0	16.1, 120.8	15.7, 121.1
C	7.9	15.7, 119.5	13.5, 121.7
D	7.8	12.1, 123.4	11.7, 124.1
E	7.7	10.0, 122.5	9.0, 123.0
F	7.5	15.5, 119.8	14.6, 120.5
G	7.1	15.5, 120.5	13.5, 121.2
H	6.8	14.8, 121.2	14.4, 121.7
I	6.5	14.8, 120.7	14.4, 121.2
J	7.8	14.6, 119.5	13.6, 120.5

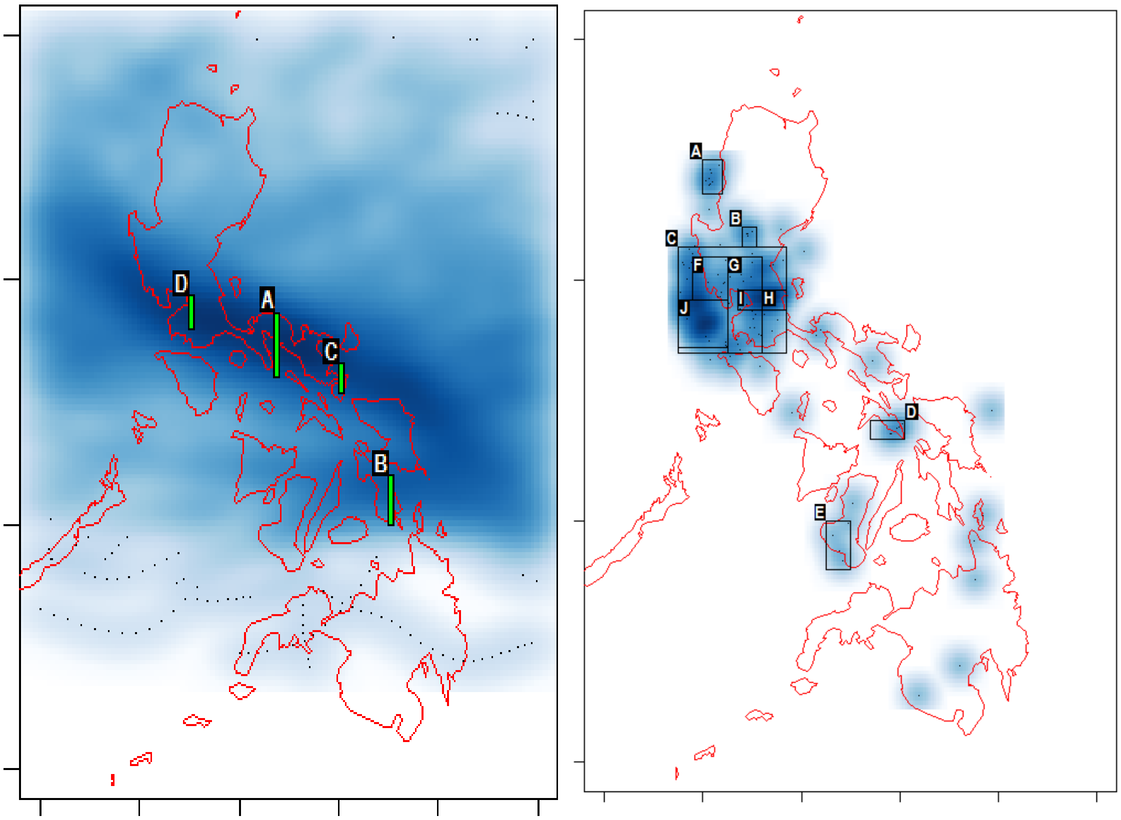


Figure 7: Maps of Parametric Structure Gateways/Boxes for Tropical Cyclone (left) and Earthquake (right)

Table 18 provides the probability that the resulting parametric structure would meet the trigger event conditions in any stochastic year for each peril individually, and for both perils combined. All metrics are on an annual basis.

Table 18: Parametric Structure Trigger Probability

	Earthquake	Tropical Cyclone	Both Perils(1)
Trigger Probability	1.93%	1.77%	3.68%

(1) The Trigger Probability for both perils can be lower than the sum of trigger probabilities for individual perils due to the potential for overlap. A particular year might trigger both the Earthquake and Tropical cyclone individually, however under the combined structure it would count as a single triggering simulation.

The stochastic catalogs can also be used to gain further insight on what types of events will likely trigger the parametric structure. For instance, Table 19 provides a breakdown of earthquakes by magnitude for catalog years that have triggered the parametric structure for the 10,000 annual scenarios of potential earthquake activity. This shows that over half of the triggering events in the catalog will be earthquakes with magnitudes greater than 8.0. There are no earthquakes with magnitudes below 6.5 because they are below the minimum threshold of the structure. Similarly, Table 20 provides a breakdown of tropical cyclones by Saffir-Simpson category for catalog years that have triggered the parametric structure for the 10,000 annual scenarios of potential tropical cyclone activity. In this case, the majority of the triggering events have reached Saffir-Simpson category of 5 (central pressure less than 920 mb) while the storm is within the specified boundaries.

Table 19: Contribution to expected loss for parametric structure by earthquake magnitude

Magnitude	% Contribution to Loss
Less than 6.0	0.0%
6.0 – 6.4	0.0%
6.5 – 6.9	5.2%
7.0 – 7.4	17.1%
7.5 – 7.9	23.3%
8.0 and Greater	54.4%

Table 20: Contribution to expected loss for parametric structure by Saffir-Simpson category

S. S. Category (Central Pressure)	% Contribution to Loss
1 (Greater than 980 mb)	0.0%
2 (979 – 965 mb)	0.0%
3 (964 – 945 mb)	0.0%
4 (944 – 920 mb)	11.9%
5 (Less than 920 mb)	88.1%

A.3 Discussion of Basis Risk of Parametric Prototype Structures

It is important to understand that in a 1st generation parametric structure, recoveries depend solely on the parameters of qualifying events, and not on the actual losses sustained from qualifying events. AIR uses the term **basis risk** to denote the amount of difference there can be between a parametric risk transfer and actual losses. Since an extensive, reliable historical record of actual losses due to natural catastrophes rarely exists, modeled losses are often used in lieu of actual losses to estimate the **basis risk** of a parametric solution.

AIR quantifies **basis risk** of a parametric risk transfer by comparing it to a similar modeled loss structure using a 10,000 year stochastic catalog of simulated events and losses. Table 21 and Table 22 compare the 1st generation parametric structure prototypes described in Section A.2 with equivalent modeled loss structures for earthquake and tropical cyclone, respectively. The first row in the table compares the years that contain triggering events in catalog against the years that either attach or do not attach under a similar modeled loss structure. That is, the first row quantifies the percentage of years in the catalog that would trigger the parametric structure as well as attach the modeled loss structure (Yes/Yes), and the years that would trigger the parametric structure but not cause the modeled loss structure to recover (Yes/No). The second row shows the percentage of years that would not trigger the parametric structure but would cause a modeled loss recovery (No/Yes), and the years that would neither trigger the parametric structure nor attach the modeled loss structure (No/No).

When constructing a parametric risk transfer, great consideration is paid to minimizing **basis risk**. Optimizing a parametric structure involves maximizing the Yes/Yes and No/No values and minimizing the Yes/No and the No/Yes values. This can be achieved by varying the boundaries of the boxes and the event parameter threshold values as can be seen in Table 16 and 17.

Table 21: Earthquake Parametric Structure Basis Risk

		% of Years in Catalog Yielding a Modeled Loss Recovery		
		YES	NO	TOTAL
% of Years in Catalog Triggering a Parametric Payout	YES	1.42%	0.51%	1.93%
	NO	0.58%	97.49%	98.07%
	TOTAL	2.00%	98.00%	100.00%

Table 22: Tropical Cyclone Parametric Structure Basis Risk

		% of Years in Catalog Yielding a Modeled Loss Recovery		
		YES	NO	TOTAL
% of Years in Catalog Triggering a Parametric Payout	YES	0.83%	0.94%	1.77%
	NO	1.17%	97.06%	98.23%
	TOTAL	2.00%	98.00%	100.00%

About AIR Worldwide Corporation

AIR Worldwide (AIR) is the scientific leader and most respected provider of risk modeling software and consulting services. AIR founded the catastrophe modeling industry in 1987 and today models the risk from natural catastrophes and terrorism in more than 90 countries. More than 400 insurance, reinsurance, financial, corporate, and government clients rely on AIR software and services for catastrophe risk management, insurance-linked securities, detailed site-specific wind and seismic engineering analyses, and agricultural risk management. AIR is a member of the Verisk Insurance Solutions group at Verisk Analytics (Nasdaq:VRSK) and is headquartered in Boston with additional offices in North America, Europe, and Asia.

About Asian Disaster Preparedness Center (ADPC)

As a leading regional resource center, Asian Disaster Preparedness Center (ADPC) works towards the realization of disaster reduction for safer communities and sustainable development in Asia and the Pacific. Since its inception in 1986, ADPC has been recognized as the major independent center in the region for promoting disaster awareness and the development of local capabilities to foster institutionalized disaster management and mitigation policies. ADPC was originally established as an outreach center of the Asian Institute of Technology after a feasibility study conducted jointly by two agencies of the United Nations, the Office of the United Nations Disaster Relief Coordinator (current the UN Office for the Coordination of Humanitarian Affairs) and the World Meteorological Organization in January 1986. Funding for the study was provided by the United Nations Development Program in response to requests from countries in the region for international assistance to strengthen their national disaster management systems. Thus, the initial role conceived for the center was mandated by an expressed need to assist countries of the Asia and the Pacific region in formulating their policies and developing their capabilities in all aspects of disaster management.