TECHNICAL DOCUMENTATION

Physical Risk: Floods

Scientific Climate Ratings
An EDHEC Venture

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About Scientific Climate Ratings

Scientific Climate Ratings is a new venture born from EDHEC's Climate Finance applied research ecosystem. It delivers forward-looking ratings that quantify the financial materiality of climate risks for infrastructure companies and investors worldwide. Leveraging high-resolution geospatial data, proprietary climate risk models, and the world's largest financial dataset for infrastructure assets, Scientific Climate Ratings evaluates both transition risks (linked to the shift toward a low-carbon economy) and physical risks (arising from climate hazards such as floods, storms, heatwaves, and wildfires).

The ratings offer a dual perspective:

- Potential Climate Exposure Ratings assess current exposure to future climate risks under a "continuity" scenario, reflecting the most likely pathway based on today's global policies and trends.
- Effective Climate Risk Ratings go further by integrating climate risk data into financial valuation models across multiple scenarios — each weighted by its probability of occurrence — to estimate the financial effects of climate-related risks until 2035 and 2050.

While initially focused on infrastructure, Scientific Climate Ratings will soon extend its methodology to the listed equities segment, applying the same scientific rigor and forward-looking approach to a broader set of financial assets.

Scientific Climate Ratings aims to set a new standard in climate risk management — driving informed and responsible decision-making for a more resilient future.

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This document summarises the development of the physical risk damage model on **Floods**, which is part of the ***Potential Climate Exposure Rating (PCER)*** and the ***Effective Climate Risk Rating (ECRR)***. It explains the general approach, provides the data sources used, justifies the methodology, and presents the results. For general information on the Scientific Climate Ratings, please see the respective technical documentations.

All procedures were developed by the *EDHEC Climate Institute*, hereafter referred to as ECI or “we.”

1. General Approach

Floods are one of the most common effects of climate change, accounting for up to 44 percent of all climate events between 2000 and 2019 (UNDRR, 2020). As of June 2025, we cover fluvial, pluvial, and coastal floods. Table 1 provides definitions for these flood types.

Table 1: Definitions of fluvial, pluvial, and coastal flood

Flood type	Definition and common causes (based on IPCC, 2022)
Fluvial flood	Occurs when a river or stream overflows, causing a temporary inundation of a normally dry land, also known as river flood.
Pluvial flood	Occurs when the generation of surface runoff surpasses the rates at which water can infiltrate the ground and the drainage systems can accommodate (Miller & Hutchins, 2017). Often happens during extreme precipitation events. Also known as a surface water flood.
Coastal flood	Refers to the inundation of land areas adjacent to coastal regions due to rising water levels. Such flooding arises from the combined effects of elevated water levels resulting from tides and storm surges, coupled with the presence of powerful waves, which in turn overwhelm coastal defences (Wolf, 2008). Rising sea levels and the topography of an area can further exacerbate the flooding.

To quantify physical risks stemming from floods, our approach follows a stepwise progression from sourcing inputs on assets and hazards to the geospatial transformation. This results in quantified physical metrics, representing the potential damage for each asset. Figure 1 summarises our approach, which we elaborate on in the methodology sections.

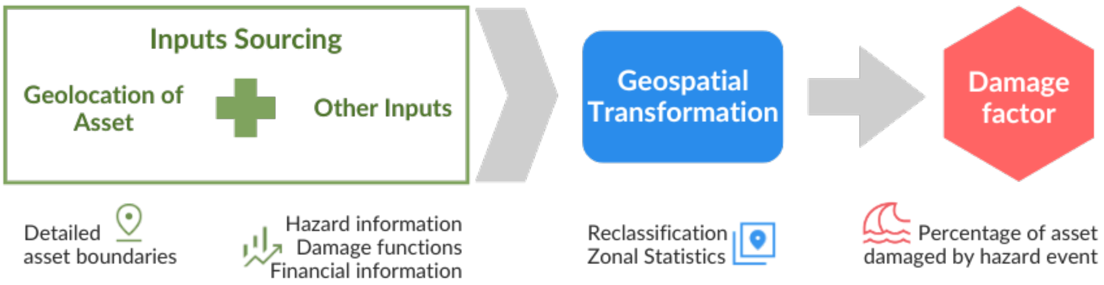


Figure 1: General approach for calculating physical hazard risks

2. Data Sources

To provide quantified flood risk metrics for specific physical assets, three key data points are needed:

- We include **financial information** for each identified asset (e.g., total asset value and revenue) as extracted from *infra*Metrics[1] to quantify the financial impact of each physical risk on the asset.
- Global **climate hazard information** (e.g., hazard maps) illustrates which areas would be affected to what extent by a particular hazard and, hence, specifies the proximity to a potential hazard.

[1] infraMetrics is EIPA's index and data platform, offering asset-level investment metrics for private infrastructure across more than 20 markets by sector, business risk, and corporate structure peer groups. In our models, we update this data on a quarterly basis.

    - For floods, the considered global climate hazard information is based on a global flood database (see Table 2 for our data source).
- We also use **detailed asset boundaries** to define each asset's size and geolocation. These boundaries are prepared, checked, and updated regularly.

Combined, these inputs are proxies for an asset's *exposure* (i.e., the presence of assets in settings that could be adversely affected by hazard events) and account for its *vulnerability* (i.e., the propensity of an asset to be adversely affected by a hazard event) to a flood event.

Table 2: *Sources for flood hazard maps*

Hazard type	Hazard unit	Maps resolution	Underlying data and models
Flood (fluvial, pluvial and coastal)	Flood depth in meters	Global 10m by 10m	Hazard maps for different return periods based on a global flood database (Moody's RMS, 2023).
		Global 1km by 1km	Hazard maps from Aqueduct Floods available for two Representative Concentration Pathways (RCP) scenarios (RCP4.5 and RCP8.5) for present (2020) and future (2030, 2050, 2080) time horizons (Ward et al., 2020).

Note: On demand of the IPCC, the scientific community developed one of the first scenarios – the Representative Concentration Pathways – to explore impacts of (future) greenhouse gas concentrations in the atmosphere on the climate. The RCP4.5 and RCP8.5 represent an intermediate and a worst-case scenario, respectively (Van Vuuren et al., 2011).

3. Methodology

We adopt the framework previously established by Bouwer (2013) and Muis et al. (2015), who consider three main factors when measuring physical risks:

- the changing nature of hazards (due to climate change and natural weather variations),
- assets' vulnerability (the probability that assets will be damaged due to a hazard), and
- their exposure (the placement and characteristics of assets that could be impacted by hazards).

To account for assets' vulnerability and exposure to a given hazard, we utilise damage functions, also known as fragility curves (Prahl et al., 2016). Two types of damage are estimated by damage functions – absolute and relative. The **absolute damage** approach considers the value of assets and outputs the estimated monetary damage of an item or a group of items. The **relative damage** approach quantifies damage as a fraction or percentage of damage against the total damage and, hence, outputs a ratio expressed in percentage instead of a monetary value (Ghimire & Sharma, 2020). Our work focuses on the relative damage approach and its respective damage functions. This allows us to quantify the proportion of damage to each asset first, which can subsequently be transformed into absolute damage.

The following sections explain the steps for calculating physical risks from floods, from identifying the location to measuring the damage, and projecting the growth of damages in climate scenarios.

3.1. Geospatial Transformation

To derive the expected damage from floods, we require several inputs. These inputs undergo a process known as **geospatial transformation**, in which individual data inputs are converted into the necessary format. Consequently, geospatial transformation involves a series of smaller processing steps, from reclassification to zonal statistics, that prepare the inputs unique to each asset.

These are the steps of the geospatial transformation needed to calculate damage from floods:

1. First, we extract detailed **geographical boundaries** of each asset and evaluate an asset's exact conditions and environment. This process, known as **geolocation**, involves manually checking that each asset is still operating and retrieving its address. We then proceed to draw the asset boundary and relevant geospatial outlines using a variety of commercial and open-source geographic information system platforms and map sources. Figure 2 shows an example of a geoshape extraction for Wellington International Airport.

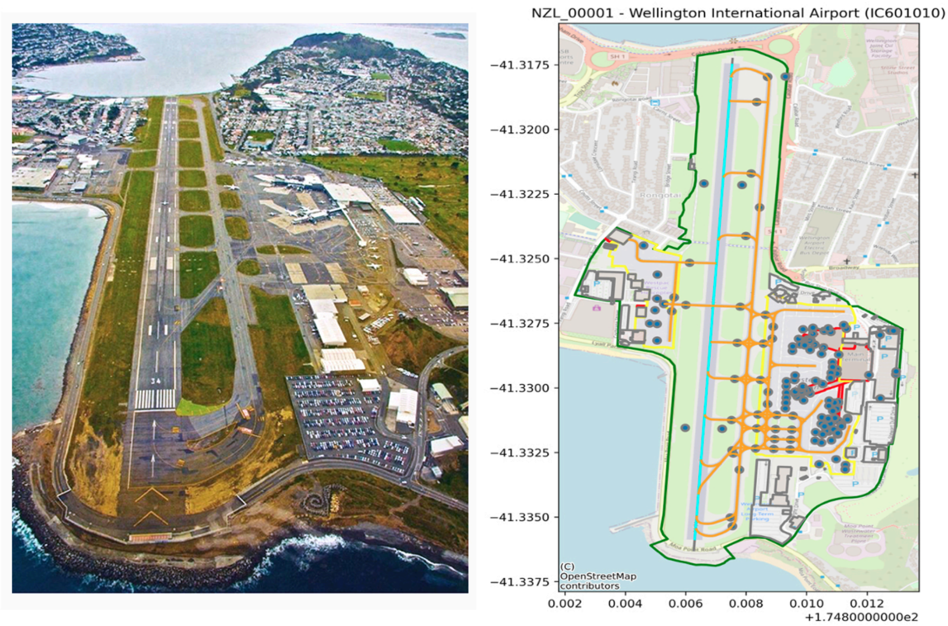


Figure 2: Example of a geoshape extraction for Wellington Airport

2. Second, we extract the expected maximum flood depth in metres for each pixel (i.e., a square patch of land) of the **flood hazard map**. Each pixel is transformed from flood depth to expected damage based on damage functions. This **reclassification** process defines the damage based on the asset type located in the given pixel.

   Damage functions are mathematical models that convert the severity of a physical hazard into the damage sustained by specific assets, considering the assets' exposure and vulnerability (Prahl et al., 2016). The output of these relative damage functions is the **damage factor**, typically defined as the ratio of repair costs to replacement costs (ibid.). The calculated damage factors range from 0 to 1, where 0 indicates no damage, and 1 signifies complete damage. In the latter case, the cost of repair is equivalent to the cost of replacement. Consequently, damage factors are interpreted interchangeably as the percentage of the asset value that requires repair or replacement.

3. Lastly, we apply **zonal statistics** to the asset's boundaries and the reclassified flood hazard map to derive asset-specific damage from floods. This approach overlays a given asset boundary on the corresponding flood hazard map and calculates the average of all damage values per pixel that fall within that boundary. The output provides an asset's expected flood damage for a given return period[2].

We developed our physical risk model for floods (as of December 2024) based on various research (see, e.g., Gabriels et al., 2021; Kellermann et al., 2015). It includes 32 damage functions to assess flood damage on relevant TICCS subclasses[3]. Generally, flood damage functions depend on the asset type and the hazard intensity. In practice, we use forward-looking maps that describe the intensity of flood hazards at various return periods.

3.2. Expected Damage from Floods

Based on the previous steps, we compute the average annual loss for a specific hazard type and based on the sum of all return periods (considering that every year, there is a specific probability for flood hazard events of various return periods to happen). For this, we compute the expected damage (expressed in percentage) for each asset by combining the damage factors for all return periods into one overall damage factor value for a particular hazard. To calculate the average annual loss in monetary terms, we multiply the expected damage by the total asset value. This is also referred to as the **expected damage value**. To calculate the expected damage for a given year, we combine the damage factor with a hazard's probability of happening (Bressan et al., 2024; see also Wilks, 2011).

In our calculation, we draw a clear relationship between an event's likelihood, needed for calculating expected damage, and its cumulative frequency, which is often easier to work with for risk modelling. With this perspective shift from individual probabilities to cumulative frequencies, we use a more intuitive and practical approach to modelling physical risks. This provides a solid foundation for assessing hazards and their associated damages in a probabilistic framework.

[2] The return period estimates the average time interval between occurrences of a hazard event of a defined size or intensity. To obtain return periods, statistical estimates are first calculated for a range of all possible hazard events based on historical observations. If a particular hazard event value has a 1% frequency of occurrence, it has a one in a hundred probability of occurrence at any given year and is hence known as the 100-year return period.

[3] The Infrastructure Company Classification Standard (TICCS) provides investors with a frame of reference for approaching the infrastructure asset class. It offers an alternative to investment categories inherited from the private equity and real estate universe, which are less informative when classifying infrastructure investments (Scientific Infra, 2022). We focus only on relevant TICCS subclasses, which are theoretically exposed to physical risks. Accordingly, we exclude underground asset classes, like long-distance cables and most networks, from physical risk calculations.

3.3. Growth of Flood Damages in Climate Scenarios

In order to calculate flood damages for climate scenarios and make future predictions, we need to estimate the hazard intensity in future climate scenarios and adapt the expected damage accordingly. This is possible using the Aqueduct Floods dataset, which includes future horizons until 2080 (Ward et al., 2020). As this dataset has a lower resolution than our initial hazard maps, which may lead to inconsistencies, we calculate the average annual increase in flood event intensity for each return period, year, and scenario. For this, we include an area of 20 kilometres around each asset. Based on this information, we can then combine present flood intensity with the various average annual intensity increases to derive future intensities and flood damages.

4. Results

Our findings are precise and widely applicable, spanning across various sectors and countries.

4.1. Generic Radius vs Detailed Asset Boundaries

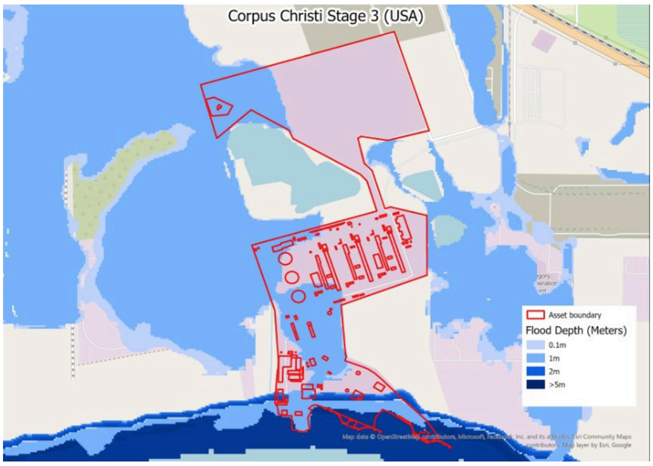
Typical market solutions assess physical risks using an approximate buffer and a single coordinate representing the asset's location (a point provided by the user). This simplified data results in risk estimations that are less accurate than those derived from detailed asset boundaries. We illustrate the benefits of our method with detailed asset boundaries in our example of the *Corpus Christi Stage 3* liquefaction plant in the United States and 100-year flood risk calculations. As shown in Figure 3, the generic radius approach has produced an underestimation of flood depth of more than four times compared to the detailed asset boundary approach.

As infrastructure assets can span over large, irregular areas (like airports or utilities) or stretch across hundreds of kilometres (such as roads and wind farms), physical risk metrics based on single-point or vector geolocation are unlikely to represent an asset’s physical risk exposures correctly. A more accurate assessment requires knowing the precise spatial footprint of assets and the varying levels of physical risk that could materialise across its entire length or area.

Figure 3: *Example of flood damage to the Corpus Christi Stage 3 liquefaction plant in the United States*

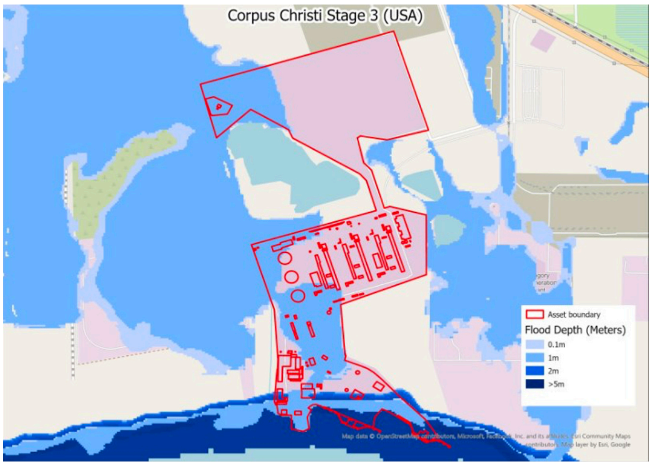
Typical solution: Generic buffer of 500 metres and resulting flood depth estimation.

Average flood depth: 0.2 metres
Physical Damage at Risk: 9.2%
Physical Value at Risk: USD 737 million
Annualised loss: USD 7.36 million



Our solution: Detailed asset boundary and resulting flood depth and risk estimation, which is more accurate.

Average flood depth: 0.89 metres
Physical Damage at Risk: 29.5%
Physical Value at Risk: USD 2.4 billion
Annualised loss: USD 24 million



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