Government of Jamaica

Climate Risk Assessment Methodology

for projects in the

Public Investment Management System

Public Investment Management System

Version August 2024

THIS DOCUMENT WILL BE REVIEWED AND REVISED AS REQUIRED

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Table of Contents

Tables

1. Introduction

1.1 Background

The Government of Jamaica (GOJ) has prioritized the strengthening of Jamaica's Public Investment Management System (PIMS), as part of its public financial management reform agenda. Over the past decade, the GOJ has implemented various actions in this regard and, more recently, is seeking to implement several reform measures that are supported by the Resilience and Sustainability Facility (RSF)[1] of the International Monetary Fund (IMF).

In December 2022, in support of the RSF, the IMF conducted a Climate Public Investment Management Assessment (C-PIMA) for Jamaica that sought to understand the feasibility, urgency, and robustness of Jamaica's climate policies and priorities. Through the C-PIMA and other policy engagements, the RSF distilled Jamaica's climate priorities into twelve (12) reform measures (RMs) that constitute the conditionality for the RSF arrangement. The twelve (12) RMs are grouped into three (3) pillars, namely: (i) Building Fiscal and Physical Resilience to Natural Disasters and Climate Change; (ii) Increasing Energy Efficiency and Promoting Renewable Energy; (iii) Greening the Financial Sector.

In September 2023, Rebel was retained by the Inter-American Development Bank (IDB) to undertake a Consultancy to help Jamaica's Public Investment Appraisal Branch (PIAB) respond to RM3: Climate Impact Assessment (under Pillar 1). The Consultancy includes the development of this document to define methodology to conduct climate impact assessments in Jamaica, to be incorporated within the PIMS.

1.2 Objective

The objective of this document is to develop a "Climate Risk Assessment Methodology" for Jamaica's Public Investment Management System (PIM) pre-investment appraisal process, managed by PIAB. The methodology is intended to be implemented during the Project Concept and Project Proposal Stages for all PIM projects and incorporated within GOJ's PIMS handbook. Elements of the methodology are already integrated into the PIAB Project Concept Submission Form and Project Proposal Submission Form.

The methodology is designed to ensure that public investment projects undertake progressively more sophisticated assessments of their climate risk as they progress through the PIM process. Projects with higher climate risk levels will require further analysis. The methodology also provides guidance on how to integrate examination of proposed climate adaptation measures into separate economic (i.e., Cost-Benefit Analysis) and financial appraisal studies conducted for some projects. The progressive nature of the methodology, as projects move through the pre-investment appraisal process of the PIMS, is shown in the figure below.

[1] The International Monetary Fund's (IMF) Resilience and Sustainability Facility (RSF) provides longer-term, affordable financing to address longer-term challenges, including climate change and pandemic preparedness. The IMF recently approved an arrangement for Jamaica under the RSF to strengthen physical and fiscal resilience to climate change, advance decarbonization of the economy, and manage transition risks. The RSF is expected to catalyze funding for climate priorities from other official lenders and the private sector. To that end, the RSF is supporting a set of reform measures that are expected to increase the prospects for privately funded investment. The Inter-American Development Bank is supporting the Government of Jamaica via the Ministry of Finance (MOF) in completing these reform measures.

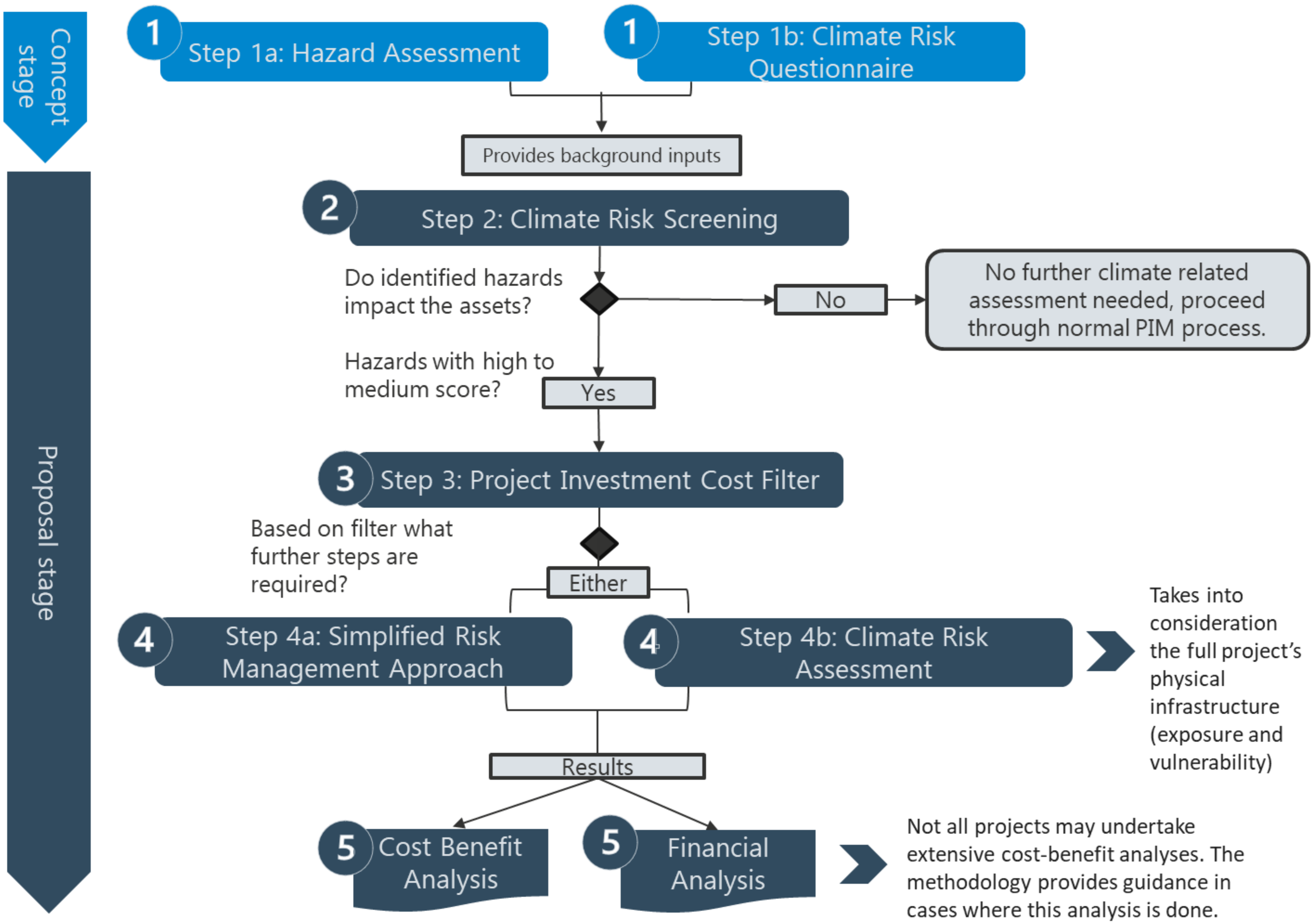


Figure 1: Overview of Climate Risk Assessment Methodology by PIMS Pre-investment Appraisal Stage

2. **Key Concepts and Definitions**

For the purpose of this document, the following terms and definitions apply.

Adaptive capacity: ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Adaptation to climate change: process of adjustment to actual or expected climate and its effect.

Climate: statistical description of weather in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years

Climate change: change in climate that persists for an extended period, typically decades or longer.

Climate projection: simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models.

Climate Risk: The physical risks of a project result from the dynamic relationship of the three core components of risk, i.e., hazard, exposure, and vulnerability. All three components may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making. The definition of the risk components, as defined by IPCC, are provided below[2].

Risk	Hazard	The potential occurrence of a natural or human-induced physical event or trend, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision and environmental resources.
	Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
	Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Climate-related hazards: hazards caused by extreme weather, atmospheric conditions and typically range from hours to days. These hazards account for both the current scenarios of natural hazards, as well as changes in frequency and magnitude of these hazards as a consequence of climate change.

Geophysical hazards: processes that originate from internal earth processes. These hazards are not as influenced by climate variables or human action, and the potential occurrence of an event can span over many centuries.

Impact: effect on natural and human systems.

[2] See IPCC Glossary <https://apps.ipcc.ch/glossary/>

Indicator: quantitative, qualitative, or binary variable that can be measured or described, in response to a defined criterion.

Sensitivity: the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change.

The relationships of the various risk components related to adaptation options is illustrated in

Figure **2**.

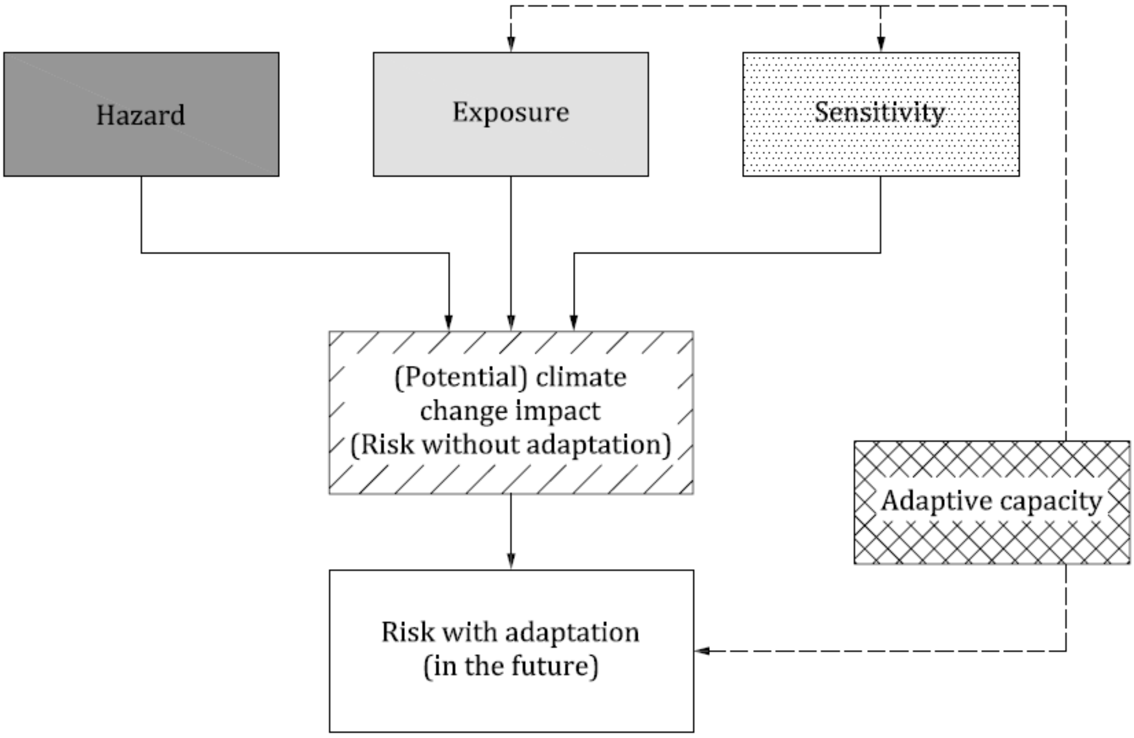


Figure 2: Relationships of the main components to define climate change risk (ISO 14090, 2021)

3. **Scope of Guidance**

The following contains technical guidance on assessing the risk to public investment projects because of the potential impacts of climate change. It is intended that the guidance applies to all public investment projects, as defined in **Box 1**, that are processed through Jamaica's Public Investment Management System.

Box 1: Definition of Public Investment in Jamaica[3]

Characteristics of Public Investments

i. Non-recurrent expenditure on goods, works and services;

ii. Carried out by any public entity within the **specified public sector** on its own, or by one or more such public entities in conjunction with one or more non-public entities through PPPs; and

iii. Aimed at accumulating new physical or intangible assets or enhancing human resource capacities, or improving or rehabilitating existing physical or intangible assets or human resource capacities, to achieve development objectives.

Definition of Public Investments

i. Public investment requiring:

   a. planning

   b. execution

   c. monitoring and evaluation;

ii. Carried out as an integrated set of activities; and

iii. Aimed at meeting a development objective at a specific cost and within a defined timeframe.

The Specified Public Sector refers to all entities within the public sector (i.e., Ministries, Departments and Agencies (MDAs)), with the exception of those certified by the Auditor General as primarily carrying out functions that are of a commercial nature.

The methodology necessitates that public investment projects undertake progressively more sophisticated assessments of their climate risk as they progress through the public investment management (PIM) process. Projects with higher climate risk levels will require further analysis (refer to Table 1 and

Figure **1**).

At the Project Concept Stage, all projects will undertake a climate risk questionnaire and a "Climate Risk Screening", irrespective of their climate risk profile.

At the Project Proposal Stage, if the Project Concept Stage screening determines that a project is medium to high risk for one or multiple hazards, then the project will need to undergo a "Post-Climate

[3] See: PIMS Regulatory Framework 20221028 accessed [https://www.mof.gov.jm/about-us/public-investment-appraisal-branch/]

Risk Screening Filter", which will determine whether a project undertakes a more detailed "Climate Risk Assessment" *or* whether the project can undertake the "Simplified Climate Risk Management Approach."

Table 1: Overview of Climate Risk Assessments Required at various stages during the PIM Lifecycle

PIM Phase	Type of Climate Risk Assessment	Application
Project Concept	Step 1a – Hazard Assessment Using the suggested data sources and provided template, screen project's exposure for hazards. Note: Project proponents can make use of the separate Risk Register excel spreadsheet (Appendix 2) to aid with this step.	All projects
	Step 1b – Climate Risk Questionnaire Based on the hazards identified in Step 1a, project proponents answer relevant questions from questionnaire focused on assessing the risk related to potential impacts of climate change. This step seeks to diagnose the project's hazard risk preliminarily and qualitatively.	All projects
Project Proposal	Step 2 – Climate Risk Screening The goal of this step is to conduct a high-level screening to determine whether the project has a medium to high risks for certain hazards. If yes, project proponents will need to undertake additional risk analysis. Notes: Project proponents can make use of the separate Risk Register excel spreadsheet (Appendix 2) to aid with this step. If the project location has not changed, project proponents may use the hazard assessment information compiled in Step 1a. If the project location has changed, project proponents will need to update the hazard assessment.	All projects
	Step 3 – Post Climate Risk Screening Filter This step screens projects that have medium to high risks based on size so that not all such projects need to proceed to developing a Climate Risk Assessment (CRA)—only projects with ≥3 billion Jamaican dollars	Those projects that flag as having a 'medium' to 'high' risk in the Step 2 screening.

	proceed to a full CRA whereas projects smaller than this threshold develop a simplified risk management approach.	
	Step 4a – Simplified Climate Risk Management Approach This step seeks to guide project proponents in developing a risk management approach to minimize the impacts of identified climate risks on the project, based on the information from Step 2 – Climate Risk Screening.	Those projects that flag as having a 'medium' to 'high' risk in the Step 2 screening but that were filtered in Step 3 for the Simplified Climate Risk Management Approach.
	Step 4b – Climate Risk Assessment In the Climate Risk Assessment, the physical climate risk is estimated for each system element of the project. The risk arises from each climate-related hazard that may affect the performance and durability of the project. The assessment has to be conducted for the current situation and subsequently for different future scenarios based on the expected lifespan of the projects.	Those projects that flag as having a 'medium' to 'high' risk in the Step 2 screening and that were filtered in Step 3 for the CRA.
	Step 5: Integration of Adaptation Measures into Appraisal Analyses Guidance on how to integrate the findings of the CRA into the cost benefit analysis and financial feasibility analysis.	Supplemental methodology and step for those projects undertaking this analysis. *Not required.

4. **Project Concept Stage**

4.1 Step 1a: Hazard Assessment

4.1.1 Goal

The Hazard Assessment seeks to help project proponents identify whether their project is exposed to climate and geo-physical hazards.

4.1.2 Time and Resources Needed

- Anticipated time to complete: 30 minutes - 1 hour.
- Level of expertise required: Project level understanding; ability to use open-source datasets. This step will involve the PIAB team working with project proponents collaboratively.
- Suggested data sources: see Appendix 1 for suggested data sources for each hazard.
- How to convey information: Project proponents should make use of the excel-based Risk Register (Appendix 2) that accompanies this methodology to help with this step.

4.1.3 Proposed Methodology

The **Hazard Assessment**, considers the hazard occurrence in terms of frequency and intensity at the project location.

- Key question it tries to answer: Does the hazard occur in my project area now, and in the future?

The goal of the Hazard Assessment during the Project Concept Stage is to help project teams determine whether the proposed project is exposed to key climatic and geophysical hazards.

The project is evaluated for the key hazards under the Jamaica PIM Climate Screening as listed in Table 2 The screening determines if the hazards occur at the location and/or cause negative impacts to the performance and durability of the project.

Table 2: Hazards for Review under the Public Investment Management Climate Screening[4]

Climate-related hazard	
Fluvial flood	Fluvial (or riverine) floods occur when intense precipitation over an extended period of time causes a river to overflow. The rivers and streams in Jamaica are prone to flooding during the rainy season, which usually occur from May to June and September to November.
Coastal flood	Coastal flooding is caused by the rise of water levels along the coast due to storm surges or tidal waves triggered by storm events, or sea level rise. Jamaica is highly exposed to coastal flooding during the hurricane season, which lasts from June to November.

[4] These hazards align with those that will be included as part of the forthcoming J-SRAT tool, which eventually will be able to be used by project proponents in conducting their climate screens. In the interim, Appendix 1 of this methodology document suggests global opensource datasets that can be used.

Pluvial[5] flood	Pluvial flooding is caused by intense or prolonged rainfall that exceeds the drainage capacity of the urban area, resulting in surface water accumulation and runoff. Jamaica has a tropical climate with high rainfall during the rainy season and hurricanes.
Hurricane	Hurricanes are intense tropical cyclones that form over warm ocean waters and produce strong winds, heavy rainfall, storm surges, and coastal erosion. Jamaica is located in the Atlantic hurricane belt, frequently experiencing hurricanes between June and November with an average of one hurricane every two years.
Drought	A drought is a period of abnormally low rainfall that can affect water availability and quality. Droughts leads to water shortages and agricultural losses as groundwater is the main supply for the country's water demand[6]. The period from December to March is considered the dry season. The dry period is sometimes prolonged depending on weather patterns, climate variability, and El Niño, which reduces rainfall in the Caribbean region.
Wildfire	A wildfire, forest fire, or a bushfire is an unplanned, uncontrolled and unpredictable fire in an area of combustible vegetation.
Geophysical hazard[7]	
Earthquake	Earthquakes are sudden movements of the earth's crust that produce ground shaking, liquefaction, landslides, tsunamis, and fires. Jamaica is situated along the boundary of the Caribbean and North American tectonic plates, which makes it vulnerable to seismic activity.
Landslides	Landslides are mass movements of soil, rock, or debris that occur when the slope of an area is unstable. Landslides are common Jamaica, and can be triggered by earthquakes, heavy rainfall, hurricanes, or human activities.

4.1.3.1 Hazard Assessment

Some hazards, such as drought and heavy rain, can occur anywhere. Other hazards are location-specific and can therefore be eliminated from the Climate Risk Screening based on the project's geographic location, such as storm surge for inland locations. The hazard assessment determines the occurrence and intensity of the key hazard at the project location in the current and future climate using the best available datasets for Jamaica.

The key hazards are classified using a simple qualitative rating scheme comprising of four classes (very low, low, medium, and high) as shown in **Error! Reference source not found.**. In cases where a hazard is determined to be non-existent at the project location, an "N/A" is given. The hazard classification is described in Appendix 1 per key hazard for a recommended dataset.

The PIAB team will help project proponents in conducting the Hazard Assessment, following the template found in Appendix 2.

[5] As there are no publicly available data sets centered on Jamaica for this hazard, it is suggested to integrate review of this hazard once J-SRAT is available.

[6] https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID-CCIS_Climate-Risk-Profile-Jamaica.pdf

[7] Geological or geophysical hazards originate from internal earth processes. Examples are earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses and debris or mud flows. (source: UNDRR)

Table 3: Climate Screening Hazard Exposure Score Methodology

Hazard rating	Description
N/A	The event is not existing in the project area.
Very low	The event is extremely rare or almost non-existent, with an extremely low likelihood of occurrence.
Low	The event is infrequent, occurring sporadically or with a low likelihood.
Medium	The event is moderate in frequency, occurring periodically or with a moderate likelihood.
High	The event is frequent or continuous, occurring regularly or with a high likelihood.

4.2 Step 1b: Climate Risk Questionnaire

4.2.1 Goal

The climate risk questionnaire focuses on assessing the risk related to the potential impacts of climate change. It aims to help project proponents diagnose the project's hazard risk preliminarily and qualitatively.

4.2.2 Time and Resources Needed

- Anticipated time to complete: Less than 15 minutes.
- Level of expertise required: No specific expertise required.
- Suggested data sources: Build on the results of Step 1a.

4.2.3 Proposed Methodology

As this stage, as part of developing a project concept for submittal to PIAB, project proponents will need to complete the 'Climate Screening Questions' found in Table 4 and embedded directly in the 'Concept Submission Form'.

Based on the results of Step 1a, project proponents should answer questions pertaining to hazards in their project area. The Yes/No questions focus on the geophysical and climate-related hazards present in Jamaica that could impact project performance and durability of a project. In addition to this screening questions, project proponents should summarize the potential impacts of key climate and geophysical hazards to their project for hazards where "Yes" is selected (see Box 2 for example).

Table 4: Project Concept Stage Climate Screening Questions

#	Hazard	Question	Select Yes / No
1	**Coastal flood**	Is your project situated in a coastal area and susceptible to the impacts of coastal erosion or waves caused by hurricanes?	
2	**Hurricanes**	Is your project impacted by the damage, failure, or business disruption caused by extreme wind events?	
3	**Coastal flood**	Is your project located in a low-lying coastal area that is exposed to the risk of coastal flooding from increased water levels caused by storm surges or tsunamis?	
4	**Fluvial flood**	Is your project situated near a river or a stream that is prone to river flooding?	
5	**Pluvial flood**	Is your project situated in urban area and susceptible to the impacts of pluvial flooding?	
6	**Drought**	Is your project dependent on water resources that are affected by droughts which can adversely impact water availability and quality?	
7	**Landslides**	Is your project located on or near a slope that is susceptible to landslides, which are mass movements of soil, rock, or debris?	
8	**Wildfires**	Is your project located in an area with flammable vegetation and susceptible to the impacts of wildfires?	
9	**Earthquakes**	Is your project affected by the potential structural damage or disruption from earthquakes?	

Box 2: Example of Summary of the potential impacts of key climate and geophysical hazards

The following presents a summary of the impacts for a hypothetical road improvement project near the coast, which answered yes to questions 1, 3, 7.

Example impact narrative:

1. Question 1: Due to the project's geographic location, it is susceptible to the impacts of storm surges or waves caused by hurricanes. This could lead to parts of the road being eroded by intense wave impact.
2. Question 3: The road crosses low-lying coastal areas prone to flooding from increased water levels caused by storm surges/tsunamis. This could make the road unpassable and decrease the expected lifetime as it is exposed to storm surges.
3. Question 7: The road crosses non-vegetated slopes situated close to the road and are susceptible to landslides. Occurrence of such impacts could lead to the road being unpassable and damaged.

5. **Project Proposal Stage**

5.1 Step 2: Climate Risk Screening

5.1.1 Goal

The 'Climate Risk Screening' is a high-level assessment that seeks to help project proponents identify climate and geo-physical hazard risks facing a project, using data sources.

5.1.2 Time and Resources Needed

- Anticipated time to complete: 2-3 hours.
- Level of expertise required: Project level understanding; ability to use open-source datasets. This step will involve the PIAB team working with project proponents collaboratively.
- Suggested data sources: see Appendix 1 for suggested data sources for each hazard.
- How to convey information: Project proponents should make use of the excel-based Risk Register (Appendix 2) that accompanies this methodology to help with this step.

5.1.3 Proposed Methodology

The following 'Climate Risk Screening', to be conducted during the Project Concept Stage will help project teams determine:

- Whether to pursue the project at all (a project with high climate risk might be determined as too risky)
- Whether the project location and/or scope needs to be changed (to minimize the risk)
- Which in-depth analysis is required in the next stage (to reserve appropriate time, expertise, and budget)

The Climate Risk Screening is to identify the project's exposure and vulnerability to potentially relevant hazards and the intensity of the risk that may affect the project during its expected lifetime. The project is evaluated for the key hazards under the Jamaica PIM Climate Screening as listed in **Error! Reference source not found.**. The screening determines if the hazards occur at the location and/or cause negative impacts to the performance and durability of the project.

If the project has no or low risks to climate hazards, then no additional climate-related assessments are required during the Project Proposal Stage. If this step determines that the project has medium to high risk for certain hazards, then the project must be screened based on its size to determine the project's next steps during the Project Proposal Stage.

The 'Climate Risk Screening' includes three components to determine risk:

1. **Hazard Assessment** considers the hazard occurrence in terms of frequency and intensity at the project location. Project proponents can use the results of the hazard assessment conducted as part of Step 1a; however, if the project location has changed then this assessment will need to be refreshed as a new location may change hazard exposure. (Please refer to Section 4.1.3.1 for complete information on how to conduct the hazard assessment).
   Key question it tries to answer: What is the likelihood of occurrence of various climate risk events (hazards) in my project area now, and in the future?

2. **Vulnerability Assessment** assesses the vulnerability of the project at construction and post-construction phases, considering the potential negative impacts to the performance and durability of the project.

   Key question it tries to answer: How significant would the damage to my project be if any of the climate risk events (hazards) would occur at either construction or post construction (i.e., implementation) phases?

3. **Risk assessment** is classified using a risk matrix combining the hazard rating with the vulnerability rating. Projects will receive a risk rating for construction and post construction phases.

   Key question it tries to answer: What is the project's risk profile for each of the hazards and combined?

5.1.3.1 Hazard Assessment

Please refer to Section 4.1.3.1 for more information on how to complete the hazard assessment. If the project location has ***not*** changed from concept to proposal stage, the hazard assessment conducted at the project concept stage (Step 1a) can be used. If the project's location has changed between concept and proposal stage, project proponents should review their hazard assessments to ensure that they are still accurate.

5.1.3.2 Vulnerability Assessment

The fact that a hazard can potentially occur at the location of the project does not automatically imply that this hazard can cause adverse effects. Assessing a project's vulnerability focuses on determining its susceptibility to damage as well as the lack of capacity to cope or adapt. For example, a new road is generally not vulnerable to drought periods, as the road itself does not depend on water resources.

Therefore, project proponents should consider which system elements of the project can be impacted by the identified hazards at all and if these potential adverse effect(s) could significantly affect the performance of the project. In this context, we recommend that you subdivide the project into system elements that are decisive for their functionality. For example, for an industrial site, this could include buildings, building parts, or the workforce. This procedure is helpful to not overlook any possible impact areas of the climate-related hazard and to identify where possible climate risks may exist. These are also the system elements where adaptation solutions can be implemented later on.

The methodology proposes that project proponents apply a 'lifecycle framework' when examining a project's vulnerability.

Further, as a project's vulnerability may evolve depending on the project phases – i.e., whether it is during construction or post-construction – vulnerability should be assessed by project phase.

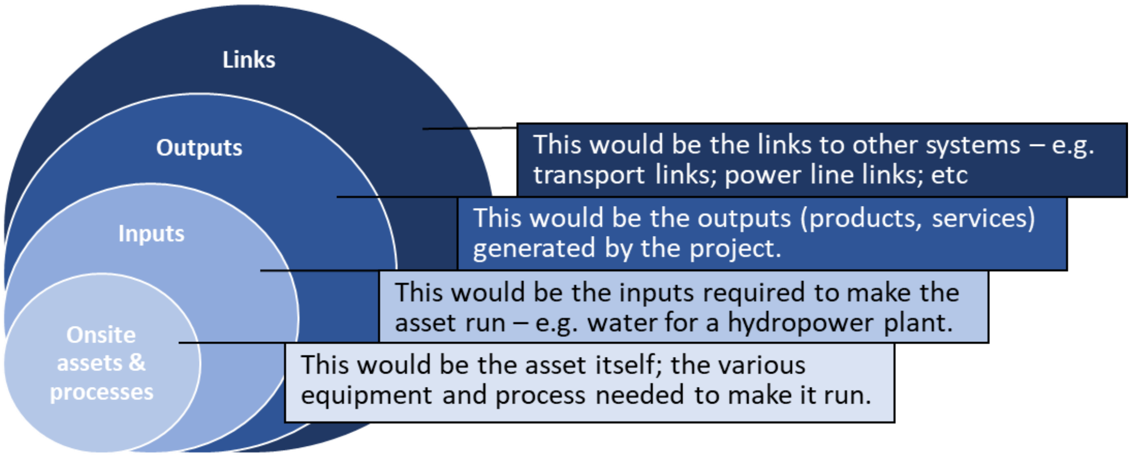


Figure 3: Lifecycle Framework[8]

This framework examines vulnerability through four lenses relating to a project's value chain:

i. Onsite assets and processes;

ii. Inputs;

iii. Outputs;

iv. Links.

Organizing the review in this way can help ensure examination of a project's vulnerability from all dimensions. Not all projects will require examination of all aspects – e.g., some projects, perhaps a road, will not have many required inputs and thus, it does not make sense to examine project inputs. Project proponents should evaluate for themselves whether examining the vulnerability of a specific project aspect is necessary. If project proponents determine that a specific project aspect/or aspects do not make sense to review for vulnerability in the context of their projects, then those aspects can be excluded from the analysis. **Error! Reference source not found.** provides some guiding questions to help with this step.

[8] Climate Resilient Public Private Partnerships, Inter-American Development Bank, 2020.

Table 5: Guiding Questions for Lifecycle Vulnerability Assessment

Project Aspect	Guiding Questions
Onsite Asset and Processes	What key onsite assets are critical to the functioning of the infrastructure and the delivery of the associated services? Are these assets and/or services vulnerable to any of the hazards present in your project area (per the Screening-level Exposure Assessment)?
Project – related inputs	Are there any key inputs, e.g., water, power, maintenance, necessary to make the project run? Are these inputs vulnerable to the any of the hazards present in your project area (per the Screening-level Exposure Assessment)?
Expected project outputs	Is the project expected to generate any outputs – either a good (e.g., a manufactured product) or service (e.g., transit service, electricity, health service)? Would the delivery of these outputs (i.e., goods or services) be vulnerable to any of the hazards present in your project area (per the Screening-level Exposure Assessment)?
Links to other systems	Does the adequate functioning of the project require links to other critical infrastructure systems? For example, does the functioning of the project require links with key transport networks, or energy transmission lines. If hazards present in your project area occurred, would they impact the other systems (e.g., transport, energy transmission) upon which your project relies?

The project's vulnerability to a hazard is scored using a simple qualitative scoring scheme comprising four classes (minor, moderate, major, and catastrophic) as shown in Table 6. In conducting the scoring to define the potential impacts per hazard, it is recommended to rely on subject matter experts with sector-specific knowledge and local understanding. Impacts can be rated based on the project aspect's susceptibility and capacity to cope. **Appendix 3** lists potential climate hazard impacts for different sectors which can guide the definition of the vulnerability of project aspects.

This step is a helpful step to identify where further work may be required to reduce or manage these hazard impacts and can help inform the process of dialogue, consultation, and analysis during project design.

Table 6: Vulnerability Assessment Scoring

Vulnerability rating	Description
Insignificant	No adverse effect to the assets.
Minor	The asset is somewhat susceptible to the hazard, but it has sufficient capacity to cope and adapt. There may be some minor and localized damage or disruption, but the overall impact is limited.
Moderate	The asset is more susceptible to the hazard, and it has less capacity to cope and adapt. There may be significant damage or disruption, but the overall impact is still manageable with maintenance or minor repairs.
Major	The asset is highly susceptible to the hazard, and it has very little capacity to cope and adapt. There is a high likelihood of severe damage or disruption which require major repairs and maintenance.
Catastrophic	The asset is essentially defenseless against the hazard. There is a certainty of severe damage or disruption which require remediation and restoration.

5.1.3.3 Risk Assessment

The risk ratings are calculated for all considered hazards for each location as risk may differ geographically or per system element or depending on project phase. The risk is classified using a risk matrix combining the hazard rating with the vulnerability rating comprising four classes (very low, low, medium, and high) as shown in Table 7 and Table 8.

The teams can rely on the template found in Appendix 2 to help with this assessment.

If **all** project risks are either very low or low, the project team can continue with project development with no need for additional climate risk studies or measures. However, bear in mind that this is a high-level risk screening and thus, climate and geophysical risks to the project should continue to be monitored as it is developed and implemented.

If the project has any medium or high hazard risks, it should continue to the 'Project Investment Cost Filter' (Step 3) to determine next steps. Projects that do not have medium to high risks to hazards (and only have very low or low risks) are not required to undertake any additional climate related efforts. These projects can continue through the normal PIMS process.

Table 7: Risk Matrix

Exposure to hazard		Vulnerability: Very low	Vulnerability: Low	Vulnerability: Medium	Vulnerability: High
Exposure to hazard	High	Low	Medium	High	High
	Medium	Low	Medium	Medium	High
	Low	Very low	Low	Medium	Medium
	Very low	Very low	Very low	Low	Medium

Table 8: Scoring Methodology for Project Climate Risk[9]

Risk Level by Hazard	What achieves this score	How this pertains to project risk
Very Low	Very low +Minor, Very low + Moderate, Low + Minor	If **ALL** risks fall in this category the project is deemed as very low risk. The project team can continue with project development with no need for additional climate risk studies or measures. However, bear in mind that this is a high-level risk screening and thus, monitor the climate and geophysical risks to the project as it is developed and implemented.
Low	Medium + Minor; Low + Moderate; Very low + Major, High + Low;	If **ALL** risks fall in this category the project is deemed as low risk. The project team can continue with project development with no need for additional climate risk studies or measures. However, bear in mind that this is a high-level risk screening and thus, monitor the climate and geophysical risks to the project as it is developed and implemented.
Medium	High + Very Low; Medium + Low; Medium + Medium; Low + Medium; Low + High	If **ANY** climate or geophysical risks fall in this category, the project is deemed **MEDIUM** risk. The project team is encouraged to build on the screening through additional studies, consultation, and dialogue.
High	High + High; High + Medium; Medium + High;	If **ANY** climate or geophysical risks fall in this category, the project is deemed **HIGH** risk. Project team strongly encouraged to conduct a more detailed risk assessment and to explore measures to manage or reduce those risks.

[9] Methodology adapted from: Adapted from: IDB Disaster Risk Policy Guidelines, 2008. Available at: http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=360026

5.2 Step 3: Project Investment Cost Filter

Conducting a CRA, even if only for key relevant hazards, is time and resource intensive. This step filters the projects by investment costs so that not all projects that were identified as having medium to high risks to hazards in Step 2, need to proceed to developing a full CRA. As per, Table 11, only the largest projects by investment cost are required to undertake a full CRA, all others undertake the more qualitative simplified risk management approach.

Table 9: Project Investment Cost Threshold

Total Project Investment Cost	Next Steps
≥3 billion Jamaican dollars	Proceed to full Climate Risk Assessment (Step 4b)
<3 billion Jamaican dollars	Proceed to Simplified Risk Management Approach (Step 4a)

5.3 Step 4a: Simplified Risk Management Approach

Step 4a applies to those projects that have medium or high hazard risks, as per Step 2: Climate Risk Screening and for which, as per Step 3: Project Investment Cost Filter, a CRA is not required.

5.3.1 Goal

The goal of this step is for project proponents to use the data gathered in Step 2: Climate Risk Screening as well as sector and project expertise **to develop a risk management approach to minimize the impacts of identified climate risks on the project**.

5.3.2 Time and Resources Needed

- Anticipated time to complete: 3-4 hours.
- Level of expertise required: Sector expertise; project expertise / knowledge.
- Suggested data sources: Outputs of Climate Risk Screening.

5.3.3 Proposed Methodology

Based on an understanding of expected and current climate change impacts and vulnerabilities, per Step 2: Climate Risk Screening, project proponents should determine the best approach to managing the risks.

For each medium or high climate risk identified in the Step 2: Climate Risk Screening, a risk management approach should set out clearly how each identified risk will be addressed with adaptation options, which follows the mechanism of either mitigate, transfer, accept or control as defined in Table 10.

Table 10: Taxonomy of climate adaptation options

Climate Adaptation Option	Description	Example
Mitigate	This represents management measures to be implemented in order to reduce or eliminate the risk to the Project.	Build seawalls to protect coastal areas from flooding. Expanding urban green space to mitigate the heat island effect.
Transfer	This is a risk reduction option that shifts risk from the project to another party.	Paying someone else to accept the risk (e.g. to purchase of an insurance coverage for climate-related damage).
Accept	This involves accepting the risk and collaborating with others sharing responsibility for absorbing negative impacts of risks (Government, other projects and local community).	Relocating communities or infrastructure to less vulnerable areas. Floodproofing buildings to withstand flooding. This can include elevating buildings or using water-resistant materials.
Control	This involves developing an alternative strategy to reduce the probability of occurrence or the severity of the consequences of climate-related risk (e.g., crop failure), but is usually linked to a higher cost.	The use of drought-resistant crop varieties to reduce irrigation water needs or building dams to manage water resources.

Using the final two columns found in the Climate Risk Screening Template (see Appendix 2) as a guide, the project proponent, together with technical experts as needed, should discuss for each hazard flagged as medium to high risk:

1. Whether any existing risk management tools exist for the project and / or whether the project has some adaptive capacity
2. Which adaptation option makes sense for the project.

To identify effective adaptation options, you need to know the framework conditions for climate adaptation within the project. Adaptation solutions depend on the adaptive capacity of the project, which consists of the ability of a system to adjust to the current and future impacts. A relevant factor for the adaptive capacity is the resource availability, such as the financial resources, working time of professionals, technical requirements. Furthermore, the in-place processes, structures and knowledge contribute to the adaptive capacity. Knowing the adaptive capacity, potential adaptation options can be identified realistically and in a targeted manner.

The following questions are helpful to identify potential adaptation options:

- **Existing risk management**: what adaptation options and resources are already incorporated in the design to reduce the identified climate risks? How are these resources likely to change in the future (based on existing plans)?
- **Management approach:** what adaptation options can be implemented to effectively reduce the residual climate risks and what measures are missing?

To better determine adaptive capacity, it can help to use indicators such as the budget or people available to implement adaptation solutions, the number of employees trained to deal with extreme weather, the existence of a heat (-health) action plan, or the capacity of drainage systems. Knowledge of this data may be in different government departments. Therefore, it makes sense to include the relevant departments in the adaptive capacity assessment and adaptation planning.

For projects that complete Step 4a Simplified Risk Management approach, it is recommended that project teams integrate relevant climate findings into further project analysis, as modeled in Step 5: Integration of Adaptation Measures into Appraisal Analyses, prior to submission of the project to PIAB under the standard PIMS pre-investment appraisal and approval processes.

5.4 Step 4b: Climate Risk Assessment

5.4.1 Goal

In the CRA, the physical climate risk is estimated for each system element of the project. The risk arises from each climate-related hazard that may affect the performance and durability of the project. The assessment must be conducted for the current situation and subsequently for different future scenarios based on the expected lifespan of the projects.

The sensitivity of the project to climate-related hazards must usually be assessed by the respective people with knowledge of the different components of the project. However, the processing and preparation of suitable climate data for a Climate Risk Assessment requires specialist expertise for the preparation of suitable climate data and their explanation.

The assessment seeks to identify and consider potential adaptation options to minimize the climate risk facing the project.

5.4.2 Time and Resources Needed

- Anticipated time to complete: Several days.
- Level of expertise required: Expert-level.
- Suggested data sources: Best available studies, National Spatial Data Management Division data.[10]

5.4.3 Proposed Methodology

Key steps of a Climate Risk Assessment:

1. Understand the significant interrelationships between the climate-related hazards and the system elements.
2. Gather information on current and future climate-related hazards.

[10] It is understood that MDAs could request relevant data from the National Spatial Data Management Division, which may have a collated version of data pertaining to relevant hazards to Jamaica.

3. Gather information on the sensitivity of the possibly affected system elements.
4. Identify potential adaptation options.

It is necessary to document each outlined step and decision. Such documentation provides evidence of your thorough consideration.

5.4.3.1 Understand the significant interrelationships between the climate-related hazards and the system elements

Many impacts of climate-related hazards are obvious, such as damage to buildings from flooding or storm events. Other impacts of climate-related hazards occur in succession or reinforce each other. It is not possible to fully investigate all impact relationships leading to physical climate risks. However, a robust climate risk assessment requires a basic understanding of how climate-related hazards can affect the system elements of each project and lead to significant impacts on performance. For reasons of proportionality, we suggest building on existing knowledge about past impacts of climate-related hazards to understand substantial impact relationships.

Not all impacts of climate-related hazards occur in a direct manner; many occur in succession. For example, storm events can damage energy infrastructure and cause power outages. If there is insufficient backup power supply, this can indirectly paralyze production processes. Furthermore, risks can exacerbate each other. Some risks even arise only through the combined effect of several climate hazards. For instance, the combination of drought, storm, and temperature-related pests can lead to an increased risk of falling trees. Some risks are also amplified by successive hazards; for example, the risk of flooding is intensified when heavy rainfall hits dried-out soils.

To familiarize yourself with the impact relationships of climate-related hazards, it is useful to ask the following guiding questions:

- Has the investigation object been adversely affected or nearly affected by impacts of climate-related hazards in your project or in comparable project in the last one or two decades?
- How did these adverse effects arise? (directly/through successive impacts/through combined hazards)
- What could have happened if the climate-related hazards had been stronger or had occurred simultaneously?

5.4.3.2 Gather information on current and future climate-related hazards

For projects with a lifetime of more than ten years, future climate-related hazards should be assessed. Assessing different future scenarios helps to understand the risk of the hazards in the future and subsequently adaptation solutions can be derived for different time periods.

For any given project, the decision of what types of climate scenarios and projections to develop is based on several factors, including the need to account for a wide range of uncertainty, time frames, budget sizes, and data availability. In all cases, understanding the history of climate (temperature, rainfall, storm surges, and extreme weather events) is always a necessary first step.

Identifying the relevant climate variables

Climate data rarely represent an assessed hazard directly; rather, climate parameters are used as indicators to assess climate-related hazards. For example, the number of heat days with maximum temperatures above 30 °C may be an indicator for heat waves. Depending on the investigated impacts of the climate-related hazard, different indicators are useful. For example, for the impact of heat waves on human health, not only the presence of heat days is important, but also whether it cools down at night and how long the heat lasts. A suitable indicator could therefore be the occurrence of a certain number of consecutive heat days and tropical nights (minimum temperature above 20 °C). Specialist expertise is required for the preparation of suitable climate data and their explanation for a climate risk assessment.

Current Climate Baseline

Looking at past changes and events is a good starting point for analyzing current climate-related hazards. If a certain extreme weather event has disrupted operations more frequently in recent years and if climate change is likely to make such events more frequent and/or intense, then it is probable that such disruptions will happen more frequently in the next decade (if no action is taken). However, it is important to bear in mind that trends are often not linear, and that the climate can exhibit a high degree of variability.

Future scenarios

The assessment of future climate hazards requires information about possible future climate change – based on the information about the current state of these hazards. Future scenarios include the IPCC's Representative Concentration Pathway (RCP) scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5. However, for a Climate Change Risk Assessment, not all scenarios have to be considered to represent the existing range of future scenarios. Until mid-century the differences between scenarios are often smaller than the bandwidth within one scenario. Therefore, it is sufficient to compare an optimistic and a pessimistic case representing the existing range of climate model outcomes without investigating all four scenarios.

To gather information on the significance of future climate-related hazards, you can ask the following guiding questions:

- How can the frequency and the intensity of each climate-related hazard change in the future in the region of the project and in the surrounding region/across regions?
- How wide are the ranges of future scenarios? What could be a worst and best case?

The interpretation of climate data must take place individually for each climate-related hazard.

5.4.3.3 Gather information on the sensitivity of the possibly affected system elements

Sensitivity is the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. For a robust climate risk assessment, we recommend you consider the sensitivity for each system element of the project. The sensitivity towards the remaining hazards can be considered based on two guiding questions:

- If relevant system elements of the project have already been impacted or nearly impacted by the particular climate hazard: To which degree was each system element negatively impacted or would have been impacted?
- To which degree would each relevant system element be negatively impacted if the hazard occurred (as experienced by comparable projects)?

In addition to the experience available for the project, extreme events (e.g. loss or damage) of other comparable existing project (e.g. other production sites) with high intensity should be used as a basis for answering the guiding questions. Information on losses and damage at comparable projects or locations should also be included in the evaluation, if available and useful.

Potential impacts of climate hazard on the transport infrastructure as an example are presented in Table 11.

Table 11: Potential impacts of climate hazards on road transport infrastructure

Climate variable	Potential climate impacts (without adaptation)
Sea level rise and storm surges	• Damage to highways, roads, underground tunnels, and bridges due to • Flooding, inundation in coastal areas, and coastal erosion • Damage to infrastructure from land subsidence and landslides • More frequent flooding of underground tunnels and low-lying infrastructure • Erosion of road base and bridge supports • Reduced clearance under bridges • Decreased expected lifetime of highways exposed to storm surges
Increase in intense precipitation events	• Damage to roads, subterranean tunnels, and drainage systems due to flooding • Increase in scouring of roads, bridges, and support structures • Damage to road infrastructure due to landslides • Overloading of drainage systems • Deterioration of structural integrity of roads, bridges, and tunnels due to • increase in soil moisture levels
Increases in drought conditions for some regions	• Damage to infrastructure due to increased susceptibility to wildfires • Damage to infrastructure from mudslides in areas deforested by wildfires
Increase of hurricane intensity	• Damage to road infrastructure and increased probability of infrastructure • failures • Increased threat to stability of bridge decks • Increased damage to signs, lighting fixtures, and supports

5.4.3.4 Identify potential adaptation options

The CRA findings are used for planning, mainstreaming, implementing strategies and measures for adaptation to climate risks. Based on an understanding of expected and current climate change impacts and vulnerabilities, a wide range of adaptation options can be identified to reduce the identified climate risks. **This step creates a list of potential adaptation options for identified medium or high climate risks.**

For each medium or high climate risks identified in the Step 2: Climate Risk Screening, a risk management approach should set out clearly how each identified risk will be addressed with adaptation options which follow the mechanism of either mitigate, transfer, accept or control as defined in Table 12.

Table 12: Taxonomy of climate adaptation options

Climate Adaptation Option	Description	Example
Mitigate	This represents management measures to be implemented in order to reduce or eliminate the risk to the Project.	Build seawalls to protect coastal areas from flooding. Expanding urban green space to mitigate the heat island effect.
Transfer	This is a risk reduction option that shifts risk from the project to another party.	Paying someone else to accept the risk (e.g., to purchase an insurance coverage for climate-related damage).
Accept	This involves accepting the risk and collaborating with others sharing responsibility for absorbing negative impacts of risks (Government, other projects and local community).	Relocating communities or infrastructure to less vulnerable areas. Flood proofing buildings to withstand flooding. This can include elevating buildings or using water-resistant materials.
Control	This involves developing an alternative strategy to reduce the probability of occurrence or the severity of the consequences of climate-related risk (e.g., crop failure), but is usually linked to a higher cost.	The use of drought-resistant crop varieties to reduce irrigation water needs or building dams to manage water resources.

In order to identify effective adaptation options, you need to know the framework conditions for climate adaptation within the project. Adaptation solutions depend on the adaptive capacity of the project, which consists of the ability of a system to adjust to the current and future impacts. A relevant factor for the adaptive capacity is the resource availability, such as the financial resources, working time of professionals, technical requirements. Furthermore, the in-place processes, structures and knowledge contribute to the adaptive capacity. Knowing the adaptive capacity, potential adaptation options can be identified realistically and in a targeted manner.

The following questions are helpful to identify potential adaptation options:

- What resources are available to adapt to the identified climate risks and how are these resources likely to change in the future (based on existing plans)?
- What adaptation options can be implemented to effectively reduce the identified climate risks and what measures are missing?

To better determine adaptive capacity, it can help to use indicators such as the budget or people available to implement adaptation solutions, the number of employees trained to deal with extreme weather, the existence of a heat (-health) action plan, or the capacity of drainage systems. Knowledge of this data may be in different government departments. Therefore, it makes sense to include the relevant departments in the adaptive capacity assessment and adaptation planning.

It is important to recognize that in some cases, the best may be beyond the scope of the project or beyond the authority of the given line ministry to implement. For example, realigning roads away from areas prone to flooding may be the most appropriate option in some situations but may be difficult to address within the project. Similarly, watershed reforestation may be the most appropriate option to counter pluvial flooding, but the area may fall outside the scope of authority.

For projects that complete Step 4b Climate Risk Assessment, project teams must integrate the climate findings into further project analysis, as modeled in Step 5: Integration of Adaptation Measures into Appraisal Analyses, prior to submission of the project to PIAB under the standard PIMS pre-investment appraisal and approval processes.

5.5 Step 5: Integration of Adaptation Measures into Appraisal Analyses

Note: This step models the typical pre-investment appraisal analysis required for projects prior to submission to PIAB under the standard PIMS pre-investment appraisal and approval processes.

Generally, at the Project Proposal Stage, many projects undertake a cost-benefit and financial feasibility analysis. While the PIAB does not have a strict requirement on whether to conduct a full cost-benefit analysis the following guidelines may be helpful to project teams undertaking this analysis. It is also noted that cost-benefit analysis is only one tool available to project teams. Depending on project scope and context, other tools may also be appropriate, including cost effectiveness and least cost analysis.

5.5.1 Integration into Cost-Benefit-Analysis

Building on the CRA (described in Section 5.3), project teams should identify potential adaptation measures to reduce or minimize the project's risk level. It is recommended that adaptation measures are identified for all hazards with a high or medium risk level. Teams should engage technical experts to assist in determining which adaptation measures may be suitable and their potential to change the project's vulnerability. In cases in which no adaptation measures have been identified that can lower the project's risk profile, teams should consider changing the project site to lower the exposure and/or modifying the scope of the project to lower the vulnerability to climate risk. If a project has already included adaptation in the original design and/or only hazards with low risk level have been identified, adaptation measures do not have to be considered in further analyses. Overall, the costs associated with adaptation measures must be substantiated by their benefits (or reduced costs).

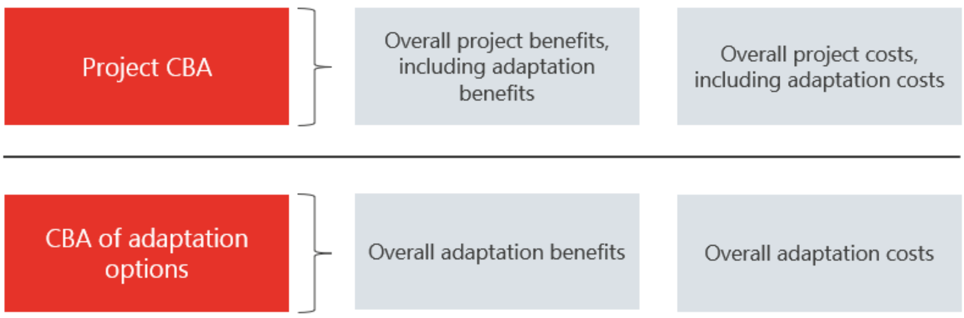
Typically, during the appraisal processes, a cost-benefit analysis (CBA) is used to evaluate financial or economic feasibility, considering the business and societal costs and benefits of a public investment project (e.g., whether the project creates economic value for an organization or society) in a structured manner. CBAs assess whether a project is economically feasible by examining all the costs and benefits associated with a project compared to a situation in which the project is not carried out. A CBA must reflect the impacts of climate risk and climate adaptation measures. As part of the CBA, teams will be able to assess whether the benefits resulting from the adaptation measures over the whole lifecycle of a given project and its deliverables offset the additional costs. The impacts of the adaptation measures on the residual climate and climate change risk should also be considered.

The following methodology provides a guide for teams to conduct a **stand-alone CBA of alternative climate adaptation options**, which **compares—at the project level—the costs and benefits of no action (base case) against the costs and benefits of including climate adaptation measures in a project (project alternatives) to determine the most economically viable option.**

It is important to note that the same methodology may be used to integrate the costs and benefits of adaptation measures into a **project CBA** (see Figure 4)**.** However, a **project CBA evaluates whether the benefits of a project outweigh the costs by comparing the project alternative(s) against the situation without the project (base case).** Therefore, while the methodologies are the same, the definition of base case and project alternative(s) compared is different. Further, the project CBA also includes an additional step to consider residual climate risks and climate change risks (i.e., the climate risks and climate change risks that remain after implementation of adaptation measures).

It should be noted that while a detailed CBA of climate adaptation options may be warranted in some cases, in others, the appraisal of adaptation options may only require expert judgment.

Figure 4. CBA of Climate Adaptation Options vs. Project BCA



The methodology consists of four phases, which are summarized and described in detail below (see Figure 5). In applying the methodology, it is advised that teams engage experts with a comprehensive understanding of the project and expertise in climate risk and adaptation.

Figure 5. Phases in CBA Methodology

1. Definition of the Base Case and Project alternatives

In this phase, teams should define the project with adaptation measures ("project alternative") and without adaptation measures ("base case").

- ✓ The **project alternative** entails the incorporation of adaptation measures into the project. While a higher level of adaptation usually provides better protection against hazards, it often comes at increased costs. The analysis considers the extent to which adaptation measures are included in the project as a variable. The goal is to identify the optimal level of protection that maximizes net benefits or achieves the highest benefit-to-cost ratio.
- ✓ The **base case** is the most probable situation in the absence of adaptation measures in the project. The base case includes any adaptation measures already part of the original project or implemented outside of the project (e.g., future regulations for adaptation).

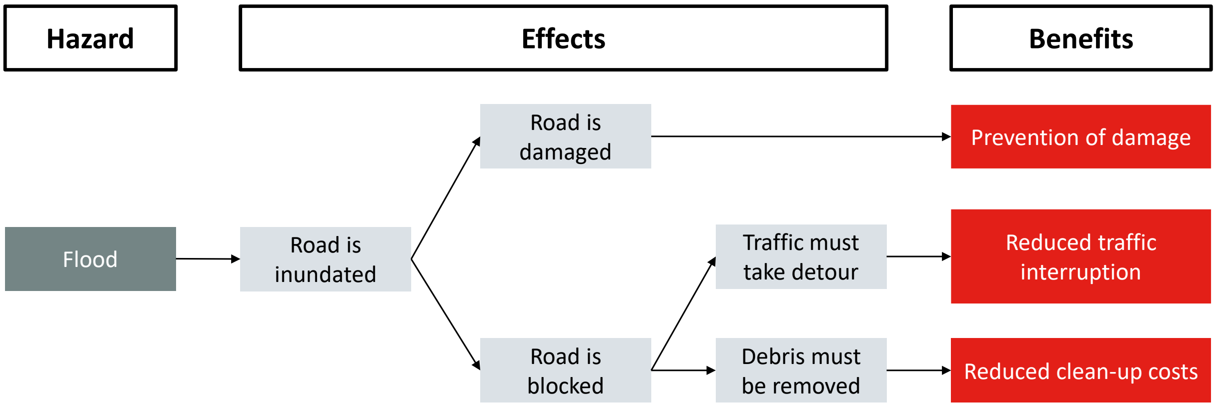
As part of Phase 1, the team should **define the time horizon of the CBA**. Teams should consider two time horizons: (i) the economic life of the project asset and the adaptation measures, and—in the case of PPPs—(ii) the concession period. Additionally, teams should account for the potential impacts of climate change on the climate hazards identified in Section 5.3 by **considering different climate change scenarios** (i.e., more or less severe). Considering climate adaptation measures may have substantial upfront construction costs, but their benefits may be back-loaded, teams should **set an adjusted discount rate**.[11] It is also recommended to vary the discount rate in the sensitivity analysis to avoid underestimating the long-term benefits of adaptation.

2. Identification and Operationalization of Effects

In Phase 2, teams should develop a thorough summary of all positive and negative effects associated with the project alternative relative to the base case. This phase considers the effects that significantly impact the resources of the economy. The effects should be described qualitatively, conveying their expected direction and severity.

In order to obtain a **comprehensive overview of all measures, qualitative effects, and their operationalization**, it is recommended that teams develop a **cause-effect tree** to identify and classify effects. Figure 6 below provides an example of a cause-effect tree. By developing a cause-effect tree, teams may also prevent double-counting effects. It is recommended that all effects be described qualitatively compared to the base case.

Figure 6. Example of a cause-effect tree



The benefits of adaptation can be grouped into three dividends. It is recommended that teams **identify the effects within each category** (see Box 3 for examples of adaptation benefits).

Box 3: Key examples of adaptation benefits

At the project level, the integration of specific adaptation measures can provide multiple benefits, also referred to as the **triple dividend.**[12]

- ✓ The **first dividend is avoided losses and damages** caused by climate change risks, as adaptation measures may lower the frequency and magnitude of climate risk events. For example, less damages, reduced downtime and disruption, and enhanced reliability of the project.

[11] Some literature suggests that using a lower discount rate can better capture the intergenerational equity and long-term and often non-market benefits of adaptation measures. More in general, several economic feasibility methodologies recommend the use of a lowered minimum economic rate of return as discount rate for projects with predominantly social or environmental benefits. This is why we recommend considering using such lower – adjusted – discount rate.

[12] The Global Commission on Adaptation 2019. Adapt Now: A Global Call for Leadership on Climate Resilience. https://gcaorg/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/

- ✓ The **second dividend are the positive economic co-benefits** derived from reducing risk, enhancing productivity, and spurring innovation through adaptation measures (e.g., protected areas may be suitable for real estate development due to flood protection infrastructure). Examples include decreased energy costs as a resulting of improved insulation against extreme temperatures or the increase in property values.
- ✓ The **third dividend is the social and environmental benefits** of climate adaptation measures. While avoiding losses is the predominant motivation for investing in adaptation, economic, social, and environmental benefits are more certain and immediate as they accrue on an ongoing basis from the time of investment and are independent of future climate conditions. Examples include the recreational uses of adaptation measures or enhanced biodiversity.

3. Quantification and Valuation of Costs and Benefits

In Phase 3, teams should **translate the identified effects of the adaptation measures into monetary values** in order to compare them with the costs of the adaptation measures. Therefore, the costs of adaptation measures must be estimated by a technical expert.

Based on the cost estimates, a **quantitative indicator** should be defined for each operationalized effect. Notably, the definition of indicators is specific to the project and hazards and contingent upon the availability of data. Once defined, each quantitative indicator is matched with a **monetization factor**. Box 4 describes the main options for monetization.

Examples of quantitative indicators:
- ✓ reduced detour hours (h)
- ✓ size of road protected (m2)
- ✓ avoided flood meters (m)

Generally, due to time and data constraints, not all effects can be monetized. However, it is strongly advised that all effects be integrated into the CBA, whether qualitatively described, quantified, or monetized. It is important to note that the latter are not necessarily "larger" than qualitatively described effects.

Box 4: Main options for monetization

- ✓ **Market prices** can be used when assessing indicators related to products or services traded in open markets. For instance, damages to buildings may be calculated by considering the local construction costs, determine the additional labor's value using labor costs within the relevant sectors, or valuing the avoided heat strokes by estimating the price of medical treatment. It is crucial that these prices accurately reflect the societal costs. For example, water prices may be heavily subsidized, thus failing to represent the true costs to society.
- ✓ **Non-market valuation** techniques are necessary when the benefit under consideration lacks a direct market (e.g., health improvements due to reduced water or air pollution) or when existing markets are distorted (e.g., due to highly subsidized water prices). In such cases, there are no market prices to gauge the value, so alternative methods are utilized to measure people's willingness to pay. One such method is the stated preference (also known as contingent valuation) approach, where the value of a good or service is determined through surveys in which consumers state how much they would pay for it in specific scenarios. Another method for ascertaining willingness-to-pay is the travel-cost method, a revealed preference technique. This method estimates the value of, for instance, a public park based on the costs consumers incur to visit it (e.g., travel distance, mode of transportation, and time

spent). The value is revealed through consumer behavior. For detailed examples, you can refer to the ADB's Guide to Cost-Benefit Analysis for Development.

- ✓ **Benefit transfer** involves the valuation based on values from a different location or context (e.g., another country) when no suitable monetization factor is available in the location being studied. The values from the alternative location are then adapted to the local context (e.g., accounting for purchasing power). This approach is generally less preferred for valuation, as the effects' values often differ significantly between cities, regions, or countries. Nevertheless, it can sometimes become the only viable valuation method, particularly when market prices are not readily accessible to the public, and determining willingness-to-pay requires substantial resources.

4. Comparison of Benefits to Costs

Phase 4 consists of the **comparison of the benefits to the costs**. In other words, addressing the question: Do the benefits outweigh the additional costs of incorporating adaptation measures into a project? Considering that only some benefits can be monetized, it is advisable to exercise caution when relying on valuation metrics like the net present value (NPV). While the NPV may serve as the central piece in communicating results, a comparison of the NPV alone will not capture the benefits that could not be quantified or monetized (some of which may be more important). Therefore, to present a comprehensive overview of the adaptation benefits, it is essential to describe all significant benefits, even if only qualitatively.

Besides assessing benefits, teams should **define the beneficiaries** of climate adaptation. Examining the distribution of benefits may support the case for investment in climate adaptation from a social standpoint.

Finally, teams should **analyze the sensitivity of the results** using a series of variables (e.g., time horizon, discount rate, adaptation costs, adaptation benefits)—applied individually or in combination. The sensitivity analysis or “stress test” seeks to ensure the robustness of the results amidst uncertainty.

5. Consideration of residual climate risk and climate change risk

As previously noted, beyond the benefits and costs of the adaptation measures, the full project CBA will need to **consider residual climate risks and climate change risks**, as these risks will result in direct costs / damage and often in indirect costs (externalities) associated with operational disruption too. Box 5 describes the methods that can be used to consider the impact of residual climate risk and climate change risk.

Box 5: Methods to consider impacts of residual climate risk and climate change risk

1. **Deterministic analysis**

   Deterministic analysis results in a value per climate risk (for example based on the calculation of probability x damage for a specific risk) or a bundle of risks (for example based on a contingency in a cost estimate or an insurance premium) or alternatively the impact of climate risk on the cost estimates and projected benefits.

2. **Sensitivity analysis**

   Sensitivity analysis is a technique used to assess the impact of varying specific input parameters or assumptions on the outcomes of a project, which helps in understanding how changes in these individual factors can affect the economic feasibility of the project as a whole. Sensitivity analysis can be used on the assumptions regarding the value of climate risks and/or the impact of climate risks on the project's cost estimates and projected benefits.

3. **Probabilistic analysis (if extensive climate data and expertise is available)**

   Probabilistic analysis produces a risk spread including a confidence level. There are software programs available to run a probabilistic analysis. The assumptions needed for a probabilistic analysis are 1) the probability distribution for the likelihood of occurrence of the hazard and 2) the probability distribution for the impact of the hazards, and 3) correlations between risks.

4. **Scenario analysis (if climate scenarios are available)**

   Scenario analysis involves identifying and evaluating the economic feasibility of a project under potential future (deterministic) climate scenarios.

Methods 1 and 2 below are commonly used and are recommended (in combination). Should more climate data and expertise be available, then methods 3 and 4 can also be considered.

It is important to note that the results of the CBA serve as an input for decision-making, rather than dictating a specific decision. Teams should communicate results beyond individual economic viability indicators. In order to account for all underlying assumptions, both qualitative and monetized benefits should be presented alongside costs. This approach is preferred over summarizing the comparison of benefits to costs using a single indicator (e.g., NPV).

Checklist

- ☐ Include the costs of climate adaptation measures
- ☐ Include the (direct and indirect) positive and negative impacts of climate adaptation measures
- ☐ Include the potential co-benefits climate adaptation measures
- ☐ Include the direct costs of residual climate risks and climate change risks
- ☐ Include the indirect costs (externalities) associated with operational disruption due to climate risks and climate change risks
- ☐ Include a stress test on the residual climate risks

5.5.2 Integration into Financial Feasibility Studies

A financial feasibility study or business case is used to evaluate financial feasibility, considering the financial costs and revenues of a public investment project in a structured manner. Climate hazards such as floods, landslides, or tropical storms can seriously impact the financial feasibility of a project, depending on its exposure and vulnerability. The main climate risk effects on financial feasibility are listed in Box 6 below.

Box 6: Climate risk effects on financial feasibility

- The occurrence of climate risk events can directly generate damage, and therefore, additional costs.
- Climate hazards can severely slow down completion, potentially resulting in additional construction costs and delaying the start of operation and, thereby, revenue generation.
- Long-term stresses, such as more frequent droughts, can affect operations and reduce revenue potential or increase operational costs.
- Adding climate risk mitigation measures usually increases capital costs but might ascertain benefits or reduce operational costs—keeping the project financially feasible, while reducing risks.
- In addition to direct effects on the project's business case, climate hazards and stresses can also impact markets or suppliers of a project. For example, by leading to higher supply costs or lower market demand.

A project financial feasibility study must reflect the financial effects not only of climate risk but also of climate adaptation measures. As part of the financial feasibility study, teams will need to assess whether the financial effects on revenues, costs, and risk profile resulting from the adaptation measures over the whole lifecycle of a given project offset the additional costs.

The following methodology provides a guide for teams to conduct a stand-alone financial feasibility analysis of alternative climate adaptation options, which assesses the financial feasibility of climate adaptation measures in a project to determine the most financially feasible adapation option.

It is important to note that the same methodology may be used to incorporate adaptation measures into a project's financial feasibility study. However, the project feasibility study considers all costs, revenues and risks associated with the entire project and, therefore, includes a broader set of costs and revenues, as well as the residual climate risks and climate change risk profile (i.e., the climate risks and climate change risks that remain after implementation of adaptation measures).

It should be noted that while a stand-alone financial feasibility study of climate adaptation options may be warranted in some cases, in others, the appraisal of adaptation options may only require expert judgment.

The methodology consists of four phases, which are summarized and described in detail below (see

Figure 7). In applying the methodology, it is advised that teams engage experts with a comprehensive understanding of the project and expertise in climate risk and adaptation.

Figure 7. Phases in Financial Feasibility Study

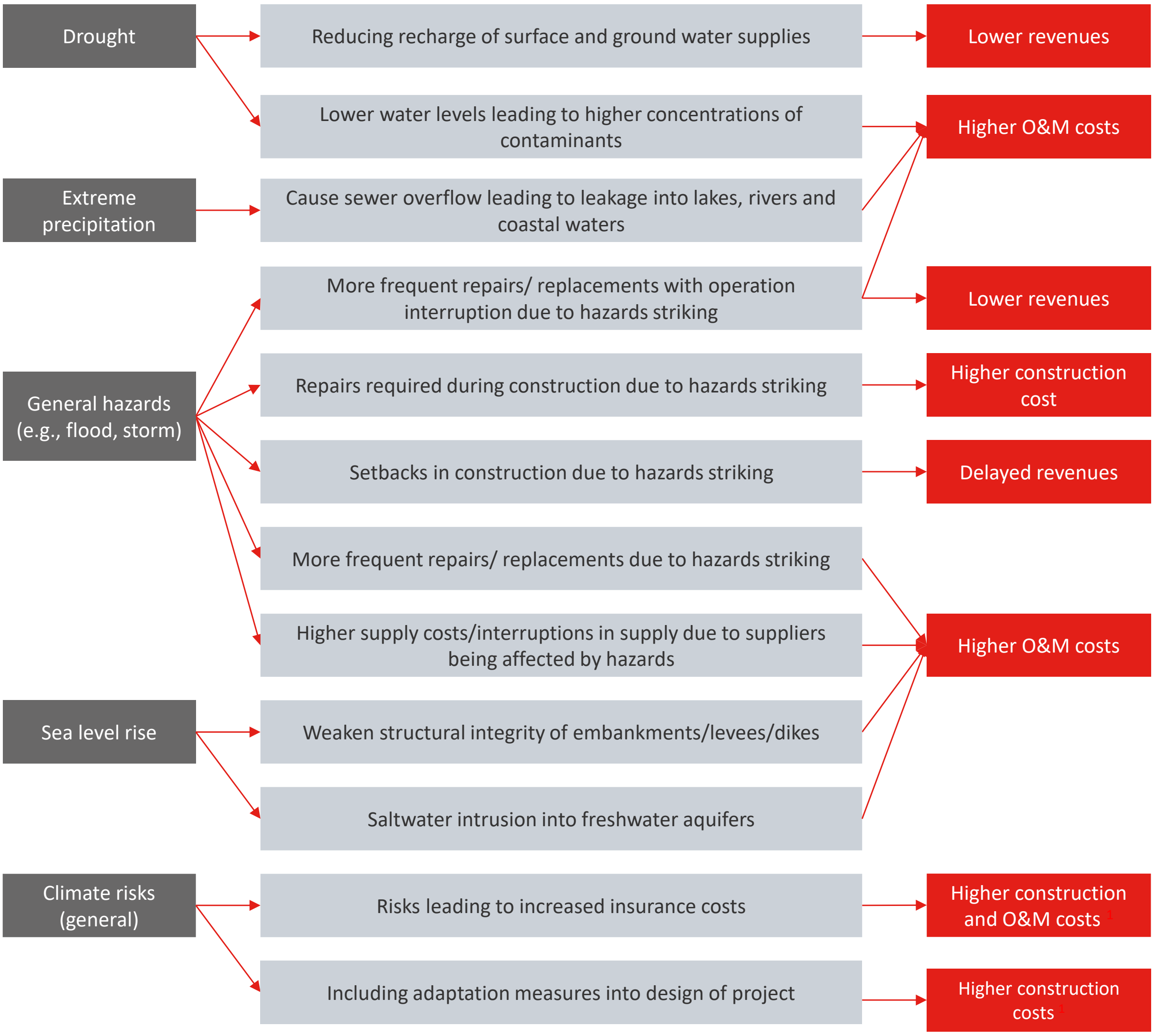
1. Project Scoping and Definition

In this phase, teams should define the adaptation measures and their geographic and technical scope. As part of phase 1, teams should define the time horizon of the financial feasibility study. Teams should consider two time horizons: (i) the economic life of the project asset and the adaptation measures, and—in the case of PPPs—(ii) the concession period.

2. Identification and Operationalization of Effects

In phase 2, teams should develop a thorough summary of all financial effects associated with the adaptation measures. The effects should be described qualitatively, conveying their expected direction and severity. In order to obtain a comprehensive overview of all measures, qualitative effects, and their operationalization, teams can develop a cause-effect tree to identify and classify effects, just like for the BCA. Figure 8Figure 6 below provides an example of a cause-effect tree.

Figure 8. Example of a cause-effect tree for a water project



3. Monetization of Effects on Costs, Revenues and Risk Profile

In Phase 3, teams should translate the identified effects of the adaptation measures into monetary values in order to compare them with the costs of implementing the adaptation measures. The costs of adaptation measures must be estimated by a technical expert.

Generally, due to time and data constraints, not all effects can be monetized. However, it is strongly advised that all effects be integrated into the financial feasibility analysis, whether qualitatively described, quantified, or monetized. It is important to note that the latter are not necessarily "larger" than qualitatively described effects.

4. Calculation of Net Present Value of Effects

Phase 4 addresses the question: are the adaptation measures financially feasible? Considering that not all effects can be monetized, it is advisable to exercise caution when relying on valuation metrics like the net present value (NPV). While the NPV may serve as the central piece in communicating results, an NPV alone will not capture the effects that could not be monetized.

Finally, teams should analyze the sensitivity of the results using a series of variables (e.g., time horizon, discount rate, costs, effects on revenues)—applied individually or in combination. The sensitivity analysis or "stress test" seeks to ensure the robustness of the results amidst uncertainty.

5. Consideration of residual climate risk and climate change risk

As previously noted, beyond the financial impacts of the adaptation measures on project revenues and costs, a financial feasibility study will need to consider residual climate risks and climate change risks, as these risks will result in direct costs / damage and often in indirect costs (externalities) associated with operational disruption too.

Box 7 describes the methods that can be used to consider the impact of residual climate risk and climate change risk.

Box 7: Methods to consider impacts of residual climate risk and climate change risk

1. **Deterministic analysis**

   Deterministic analysis results in a value per climate risk (for example, based on the calculation of probability x damage for a specific risk) or a bundle of risks (for example, based on a contingency in a cost estimate or an insurance premium) or, alternatively, the impact of climate risk on the cost estimates and projected revenues.

2. **Sensitivity analysis**

   Sensitivity analysis is a technique used to assess the impact of varying specific input parameters or assumptions on the outcomes of a project, which helps in understanding how changes in these individual factors can affect the financial feasibility of the project as a whole. Sensitivity analysis can be used on the assumptions regarding the value of climate risks and/or the impact of climate risks on the project's cost estimates and projected revenues.

3. **Probabilistic analysis (if extensive climate data and expertise is available)**

   Probabilistic analysis produces a risk spread, including a confidence level. There are software programs available to run a probabilistic analysis. The assumptions needed for a probabilistic analysis are 1) the probability distribution for the likelihood of occurrence of the hazard, 2) the probability distribution for the impact of the hazards, and 3) correlations between risks.

4. **Scenario analysis (if climate scenarios are available)**

   Scenario analysis involves identifying and evaluating the financial feasibility of a project under potential future (deterministic) climate scenarios.

Methods 1 and 2 below are commonly used and are recommended (in combination). Should more climate data and expertise be available, methods 3 and 4 can also be considered.

Checklist

- ☐ Include the costs of climate adaptation measures
- ☐ Include the (direct and indirect) positive and negative effects of climate adaptation measures
- ☐ Include the direct costs of residual climate risks and climate change risks
- ☐ Include a stress test on the residual climate risks

Appendix 1 Hazard Datasets and Classification

The data in this appendix is to be used when conducting the exposure assessment for your project as part of Step 2: Climate Risk Screening.

This appendix recommends hazard datasets together with an approach for a qualitative hazard classification (very low, low, medium, and high) for the key hazards of Jamaica. The hazard classification thresholds are developed based on the range of hazard values of the available hazard datasets, subject matter expertise and published thresholds where available.

Some of the recommended datasets (flooding and hurricanes) are modeled datasets that use a probabilistic approach which provide multiple recurrence intervals (return periods) of the hazard. Others (landslides and droughts) use a deterministic approach to provide an individual map or value of hazard intensity or susceptibility. For hazards with multiple recurrence intervals available, a return period is chosen for the classification depending on the timescale of the potential occurrence of an event.

The recommended datasets are easily accessible through online tools, where most hazards can be visualized using the Global Systemic Risk Assessment Tool (G-SRAT). G-SRAT is currently the preferred tool for hazard classification, but it is expected to be replaced soon by the Jamaica Systemic Risk Assessment Tool (J-SRAT), which is scheduled to be launched in the first quarter of 2024. J-SRAT will provide significantly more detailed data on flooding, as certain areas are underrepresented in the currently proposed data. If better flood data is available for a specific region or if it's known to be flood-prone, it is recommended to adjust the hazard classification accordingly. Currently, no adequate and easily accessible datasets are available for pluvial flooding, but this hazard is part of J-SRAT and is expected to be added in a later stage.

Below is a guidance, per hazard, on how to do the ***exposure*** classification for your project.

Fluvial (River) flooding (WRI Aquaduct Data, 2020)

The intensity of the flood describes the flood extent around the river and drainage network and the associated maximum water depth.

The scenario RP100 years is taken as a conservative reference to define the hazard level. The intensity thresholds are based on typical thresholds of expected damages of buildings and substantial risk to human life.

The dataset is accessible through: https://global.infrastructureresilience.org/view/hazard

The current data from WRI underrepresents flooding in certain areas. Therefore, if better flood data is available for a specific region or if it is known to be flood-prone, it is recommended to adjust the hazard classification accordingly.

Table 13: Steps for using the G-SRAT database for river flooding

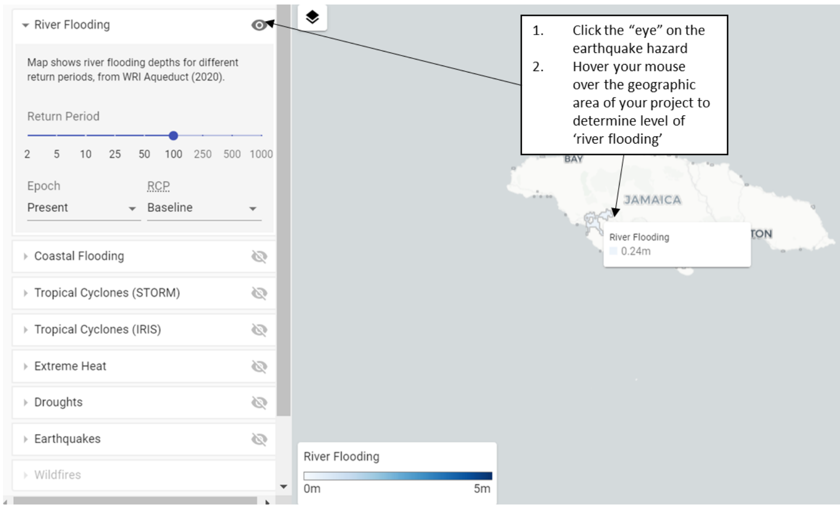
Step 1	Zoom into Jamaica
Step 2	Visualize the river flooding layer by clicking on the “eye” icon next to river flooding.
Step 3	Select a return period of 100 years.
Step 4	Examine the “present” epoch at RCP baseline by hovering mouse over project area to determine presence of river flooding and define level. Using scoring classification found in Table 14 to determine hazard level. 
Step 5	Examine the 2050 epoch at RCP 8,5 by hovering mouse over project area to determine presence of river flooding and define level. Using scoring classification found in Table 14 to determine hazard level.

Table 14: Scoring Classification, Fluvial/River flooding

Rating	Value	Description
• Very low	< 0.5 m	Typically resulting in limited damage to outdoor areas or low-lying structures.
• Low	0.5 –1.0 m	Flood mitigation by sandbags and other preliminary measures are no longer possible and this level of flooding can cause water intrusion into ground floor of buildings. This is a typical height of tables and light switches.
• Medium	1.0 – 2.0 m	Ground floors of many structures may be submerged, causing damage to walls, electrical systems, and contents. Critical utilities and equipment located in low-lying areas may also be impacted.
• High	≥ 2.0 m	The first floor and its interior are completely flooded. Flood waters can disrupt essential services.

Coastal flooding (WRI Aquaduct Data, 2020)

The intensity of the flood describes the flood extent around the coastal perimeter and the associated maximum water depth. The scenario RP100 years is taken as a conservative reference to define the hazard level. The intensity thresholds are based on similar as for the river flood and are based on typical thresholds of expected damages of buildings and substantial risk to human life.

The dataset is accessible through: https://global.infrastructureresilience.org/view/hazard

The current data from WRI underrepresents flooding in certain areas. Therefore, if better flood data is available for a specific region or if it is known to be flood-prone, it's recommended to adjust the hazard classification accordingly.

Table 15: Steps for using the G-SRAT database for river flooding

Step 1	Zoom into Jamaica
Step 2	Visualize the coastal flooding layer by clicking on the "eye" icon next to coastal flooding.
Step 3	Select a return period of 100 years.
Step 4	Examine the "present" epoch at RCP baseline by hovering mouse over project area to determine presence of coastal flooding and define level. Using scoring classification found in Table 16 to determine hazard level.
Step 5	Examine the 2050 epoch at RCP 8,5 by hovering mouse over project area to determine presence of river flooding and define level. Using scoring classification found in Table 16 Table 14 to determine hazard level.

Table 16: Scoring Classification, Coastal Flooding

Rating	**Value**	**Description**
• Very low	< 0.5 m	Typically resulting in limited damage to outdoor areas or low-lying structures.
• Low	0.5 –1.0 m	Flood mitigation by sandbags and other preliminary measures are no longer possible and this level of flooding can cause water intrusion into ground floor of buildings. This is a typical height of tables and light switches.
• Medium	1.0 – 2.0 m	Ground floors of many structures may be submerged, causing damage to walls, electrical systems, and contents. Critical utilities and equipment located in low-lying areas may also be impacted.
• High	≥ 2.0 m	The first floor and its interior are completely flooded. Flood waters can disrupt essential services.

Pluvial flooding

Currently, a pluvial flood dataset for Jamaica is not readily available. However, it is anticipated that this dataset will become available for the current and future climate within the J-SRAT. The intensity of the flood is envisioned to be described by the flood extent around the project and the associated maximum water depth for the scenario RP100 years. The intensity thresholds are similar to those for the fluvial flood and are based on typical thresholds of expected damages of buildings and substantial risk to human life.

Table 17: Scoring Classification, Fluvial Flooding

Rating	Value	Description
• Very low	< 0.5 m	Typically resulting in limited damage to outdoor areas or low-lying structures.
• Low	0.5 –1.0 m	Flood mitigation by sandbags and other preliminary measures are no longer possible and this level of flooding can cause water intrusion into ground floor of buildings. This is a typical height of tables and light switches.
• Medium	1.0 – 2.0 m	Ground floors of many structures may be submerged, causing damage to walls, electrical systems, and contents. Critical utilities and equipment located in low-lying areas may also be impacted.
• High	≥ 2.0 m	The first floor and its interior are completely flooded. Flood waters can disrupt essential services.

Drought

As droughts are most relevant for agriculture-related projects, a specific index is identified for the agricultural sector, the Agricultural Stress Index (ASI) developed by FAO and based on 10-day satellite data of vegetation and land surface temperature at 1 km resolution. The historical frequency of the number of years since 1984 with >30% of the cropland affected is chosen.

The dataset is accessible through:
https://www.fao.org/giews/earthobservation/country/index.jsp?lang=en&type=11111&code=JAM#

By choosing the following selections:

Seasonal Indicators | Vegetation Indicators | Precipitation Indicators

Cropland | Grassland

Near Real Time (10 days) | Annual Summary | **Historic Drought Frequency** | Crop-growing Season

Season 1 | Season 2

Rating	Value	Description
• Very low	<5%	Drought conditions affecting 30% of cropland occur with a 5% probability each year.
• Low	5-10%	Drought conditions affecting 30% of cropland occur with a 5-10% probability each year.
• Medium	10-15%	Drought conditions affecting 30% of cropland occur with a 10-15% probability each year.
• High	>15%	Drought conditions affecting 30% of cropland occur with a >15% probability each year.

It is anticipated that this dataset will be replaced by the drought data for the current and future climate that becomes available in the J-SRAT.

Hurricanes (STORM dataset from Bloemendaal et al (2020))

The intensity of cyclones is described by the peak wind velocity. For the classification an intensity threshold of 80 km/h is applied, which corresponds to Beaufort scale 9 and is described as a strong/severe gale where slight structural damage is expected. The other classes are determined with the categorization of the Saffir-Simpson scale and their relation to expected damage. There are no community standards used for the return periods. The scenario RP100 years is taken as conservative reference to define the hazard level.

This data that populates the G-SRAT database does not provide granularity for Jamaica. Currently, for all scenarios it shows wind speed of roughly 45m/s, which translates to 162km/h, which would classify as a medium hazard score. It is impractical to further differentiate wind speeds across the island with the available data since hurricanes can approach from various directions, and the leeward side of the island can vary depending on the hurricane's point of entry. This suggests that risk differences are solely determined by vulnerability scores.

Rating	Value	Description
• Very low	80-90 km/h	Slight structural damage.
• Low	90-150 km/h	Widespread damage to well-constructed homes and large branches of trees.
• Medium	150-200 km/h	Some structural damage to small buildings and many trees uprooted.
• High	≥ 200 km/h	Catastrophic damage with complete roof failure.

Earthquake

The earthquake data used for classification is the Seismic Hazard in peak ground acceleration (PGA) with a 10% probability of being exceeded in a 50-year interval, which translated to a return period of 475 years, from the G-SRAT data source. This return period is a typical choice for seismic design codes for buildings. The European Macroseismic Scale (ENS98) rates the intensity based on the effects of shaking on humans and structures, and the environment where intensity VI corresponds to a 0.1 g and intensity VII to 0.2 g.

The dataset is accessible through: https://global.infrastructureresilience.org/view/hazard

Table 18: Steps for using the G-SRAT database for earthquakes

Step 1	Zoom into Jamaica
Step 2	Visualize the earthquake layer by clicking on the "eye" icon next to earthquake.
Step 3	Hover your mouse on top of your location to define the Seismic Hazard and classify your project based on the classification found in Table 19.

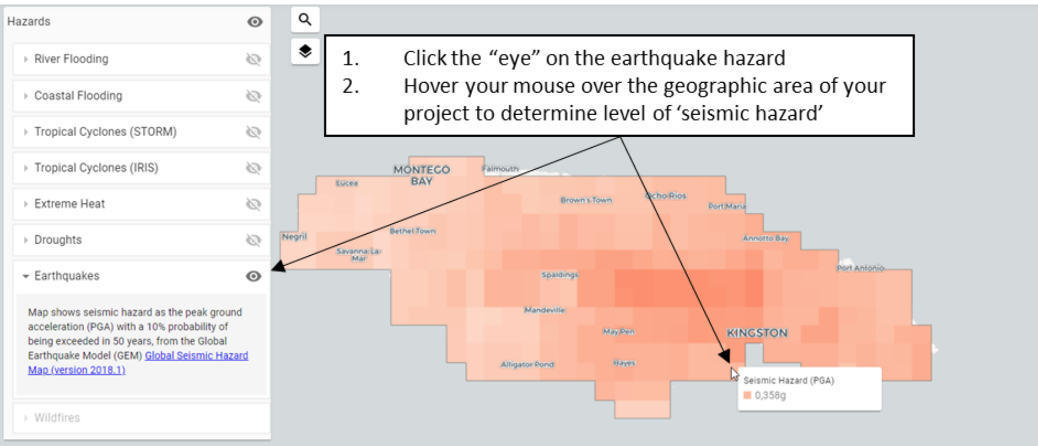


Table 19: Scoring Classification, Earthquakes

Rating	Value	Description
• Very low	< 0.05 g	Swinging of hanging objects, minor hair-line crack may appear in buildings.
• Low	0.05 –0.1 g	Slightly damaging' effects to structures, such as fine cracks in plaster, and can be felt by most people
• Medium	0.1 – 0.2 g	People are frightened, cracks appear in buildings, and chimney start collapsing.
• High	≥ 0.2 g	People are panicked, many buildings suffer damage.

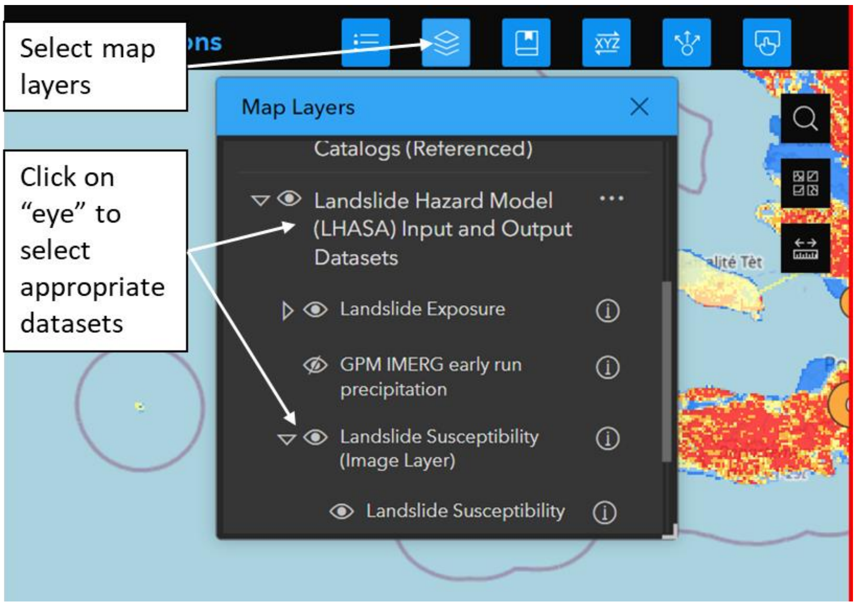
Landslides

The landslide data used for classification is the global Landslide Hazard Model (LHASA) of NASA. This dataset provides a landslide susceptibility map with provided classes of the relative probability of landslide occurrence.

The dataset is accessible through: https://landslides.nasa.gov/viewer

Note, this dataset only provides access to current information on hazards and does not provide future scenarios (i.e., RCP 8.5).

Table 20: Steps to using NASA landslide data set

Step 1	Zoom into Jamaica
Step 2	Select the 'Landslide Hazard Model (LHASA) Input and Output Datasets' > 'Landslide Susceptibility (Image Layer)' in the Map Layers 

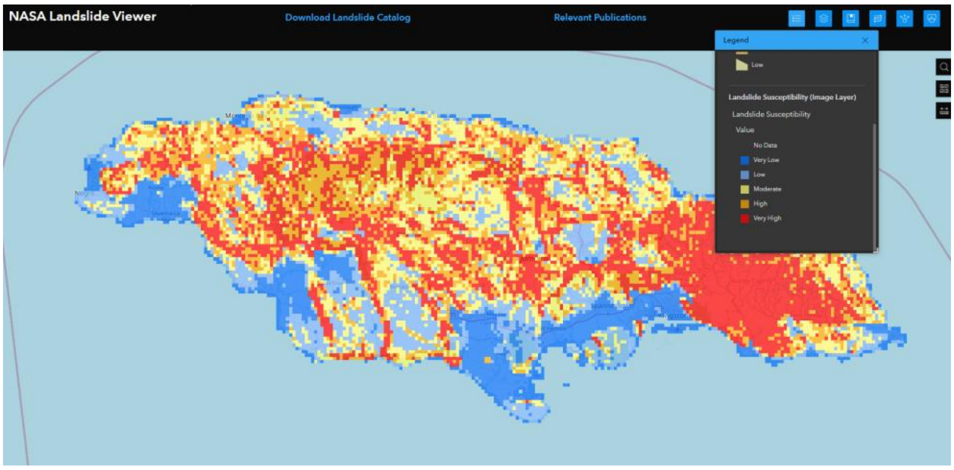
Step 3	Now you should see the landslide data as illustrated below and visualize the legend to classify your project based on the classes in Table 21. 

Table 21: Scoring Classification, Landslides

Rating	Value	Description
Very low	Very low (1 LSI)	Very low likelihood. These regions often have stable geological conditions, gentle slopes, and sufficient vegetation cover.
Low	Low (2 LSI)	Low likelihood. These regions have some factors that could contribute to landslides, such as moderate slopes or minor geological weaknesses.
Medium	Moderate (3 LSI)	Medium likelihood. These regions often have a combination of factors that could trigger landslides, such as moderately steep slopes, varied geology, or limited vegetation cover.
High	High, very High (4-5 LSI)	High likelihood. These regions have steep slopes, unstable geology, and a lack of vegetation cover.

Wildfires

Given Jamaica's high island-wide wildfire risk, no additional data is required to assign the wildfire hazard scoring. All projects will be rated as 'high'.

This 'high' score is rated based on the Fire Weather Index (FWI) from CSIRO (2017). The Canadian FWI is commonly used in research and management applications across the world and consists of six fuel moisture and fire behavior indices calculated from ambient temperature, relative humidity, wind speed, and 24-h rainfall.

Appendix 2 Climate Risk Screening Template

Please see separate excel spreadsheet, titled "PIAB Climate Risk Screening Template version 2024"

<table>
<tr><th colspan="3">Exposure to Hazard
(N/A, Very Low, Low, Medium, High)</th><th rowspan="3">Project Aspect</th><th colspan="2">Vulnerability
(Insignificant, Minor, Moderate, Major, Catastrophic)</th><th colspan="4">Risk
(Very Low, Low, Medium, High)</th><th rowspan="3">Existing Risk Management</th><th rowspan="3">Management Approach
(Mitigate/Transfer/Accept/Control)</th></tr>
<tr><th rowspan="2">Current</th><th rowspan="2">Future (RCP8.5)</th><th rowspan="2">Commentary</th><th rowspan="2">Construction</th><th rowspan="2">Post-construction</th><th colspan="2">Construction phase</th><th colspan="2">Post-construction phase</th></tr>
<tr><th>Current</th><th>Future (RCP8.5)</th><th>Current</th><th>Future (RCP8.5)</th></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td>1: Onsite</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2: Inputs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3: Outputs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4: Links</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td>1: Onsite</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2: Inputs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3: Outputs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4: Links</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Appendix 3 Potential Impacts of Climate Hazards

This appendix lists potential climate hazard impacts on different sectors.

3.1 Transport sector

Climate hazard	Potential impacts on the transport sector
Temperature increase	• Deterioration of pavement integrity, such as softening, traffic-related rutting, and migration of liquid asphalt due to increase in temperature (sustained air temperature over 32 °C is identified as a significant threshold) Thermal expansion of bridge expansion joints and paved surfaces
Temperature increase and precipitation decrease	• Corrosion of steel reinforcements in concrete structures due increase in surface salt levels in some locations.
Sea level rise and storm surges	• Damage to highways, roads, underground tunnels, and bridges due to flooding, inundation in coastal areas, and coastal erosion • Damage to infrastructure from land subsidence and landslides • More frequent flooding of underground tunnels and low-lying infrastructure • Erosion of road base and bridge supports • Reduced clearance under bridges • Decreased expected lifetime of highways exposed to storm surges
Increase in intense precipitation events	• Damage to roads, subterranean tunnels, and drainage systems due to flooding • Increase in scouring of roads, bridges, and support structures • Damage to road infrastructure due to landslides • Overloading of drainage systems

	• Deterioration of structural integrity of roads, bridges, and tunnels due to increase in soil moisture levels
Increases in drought conditions	• Damage to infrastructure due to increased susceptibility to wildfires • Damage to infrastructure from mudslides in areas deforested by wildfires
Increase of storm intensity	• Damage to road infrastructure and increased probability of infrastructure failures • Increased threat to stability of bridge decks • Increased damage to signs, lighting fixtures, and supports
Increase in wind speed	• Suspension bridges, signs, and tall structures at risk from increasing wind speeds

Source: Asian Development Bank. (2011). Guidelines for Climate Proofing Investment in the Transport Sector: Road infrastructure projects. [Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects (adb.org)]

3.2 Energy sector

Climate hazard	Potential impacts on the energy sector
Fossil Fuel Extraction and Transport	
Precipitation increase; flooding	• Reduced coal quality (higher moisture content of opencast mining) • Increased coal availability (e.g., if coal seam fires are extinguished) • Reduced output (if floods affect mines) or availability (if floods affect transport)
Drought or precipitation decrease	• Reduced coal availability (less water for mine air conditioning and operations, higher probability of seam fires) • Reduced shale oil or gas availability (very large water demands for drilling and removing drilling mud) • Soil shrinkage due to drought could affect oil and gas pipelines
Storm strength and/or frequency increase	• Reduced coal production (if storms affect opencast excavation equipment) • Reduced oil production (if storms affect coastal or offshore oil platforms)

Thermal Power	
Precipitation increase or decrease	• Increase could cause reduced coal quality (and combustion efficiency) due to higher moisture content of coal • Decrease could affect availability of freshwater for cooling (all thermal systems).
Higher air temperature	• Lowered generation efficiency • Decreased integrated gasification combined cycle system efficiency (converting coal to gas) • Lowered combined cycle gas turbine efficiency
Higher wind speed	• Damage to infrastructure • Wider pollutant dispersion
Sea level rise	• Increased sea levels and storm surges could damage coastal infrastructure
Extreme events (including flooding)	• Hurricanes can destroy infrastructure and disrupt supplies and offshore activities • Possible soil erosion and damage to facilities
Nuclear Power	
Precipitation Changed river flows Higher air temperature	• Insufficient cooling water (drought, temperature, competing uses), particularly for inland plants • Decreased generation efficiency (temperature rise) for inland plants • Loss of on-site power, leading to severe interruptions and safety and operations for inland and coastal plants
Sea level rise Floods Extreme events	• Flooding from heavy rainfall, storm surges, or sea level rise • Catastrophic failure with radioactive leaks and widespread evacuations of population, particularly for coastal locations
Hydropower	

Precipitation (including drought)	• Changing annual or seasonal patterns can affect river flows and water levels behind dams, either reducing or increasing power output • Siltation can reduce reservoir storage capacity • Increased uncertainty in water flows can affect power output and generation costs
Extreme events (floods)	• Floods can damage or destroy infrastructure
Higher air temperature, wind speeds, and humidity	• Can increase surface evaporation, reducing water storage and power output
Wind Power	
Wind speed	• Changes in wind speed can reduce generation (turbines cannot operate in very high or very low winds) • Within operational wind speeds, output is greatly affected by wind speed. • Changes in wind patterns and duration affect output (e.g., ability to forecast output)
Storm surges	• Damage to offshore wind farms
Extreme events	• Damage to infrastructure • Difficult access to offshore locations (e.g., for maintenance)
Solar Photovoltaic Power	
Temperature increases	• Lowers cell efficiency and energy output • Lowers capacity of underground conductors if high ambient temperature increases soil temperature
Precipitation increases	• Can wash away dust (short term) but reduces panel efficiency (less solar radiation)
Wind speed; turbidity	• Increased efficiency and output with cooling effect of wind

	• Scouring of panel and lower output if air is gritty/dusty
Cloud cover	• Increase lowers efficiency/output • Rapid fluctuations in cloud cover can destabilize grid
Extreme events	• Can damage systems (flooding)
Biomass Energy and Biofuels	
Floods/ precipitation	• Land degradation/erosion with possibly lower fuel supply and less electricity output
Precipitation or temperature changes	• Temperature and rainfall changes could increase or decrease electricity output depending on feedstock productivity • Higher rainfall can increase moisture content of feedstock, lowering energy content • Changing precipitation patterns could affect availability of freshwater for cooling
Extreme events	• Possible damage to fuel supplies and generation infrastructure
Transmission and Distribution	
Temperature increase	• Can reduce electricity carrying capacity of lines • Can increase losses within substations and transformers
Precipitation and flooding	• Heavy rains and flooding can undermine tower structures through erosion • Drought can increase dust damage
High wind speeds	• Strong winds can damage transmission and distribution lines
Extreme events (flood, hurricanes, drought)	• High temperatures, storms, erosion, or flooding can damage control systems through loss of information and communications technology service or reduce quality of service

	• Storms can do devastating damage to power transmission and distribution networks

Source: Asian Development Bank. (2013). Guidelines for Climate Proofing Investment in the Energy Sector. https://www.adb.org/sites/default/files/institutional-document/33896/files/guidelines-climate-proofing-investment-energy-sector.pdf

3.3 Agriculture sector

Climate hazard	Potential impacts on the agriculture sector
Temperature increase	• Modification in crop suitability and productivity (heat stress). • Increased in weeds, crop pests and disease outbreaks. • Changes in crop water requirements. • Increase risk of wildfire. • The quantity and quality of yield critically depend on the number of days that a crop is exposed to temperatures exceeding specific thresholds during critical growth stages (i.e., flowering, pollination, fruiting, or grain filling).
Increase in intense precipitation events	• Damages to crops. • Increased waterlogging, inability to cultivate lands. • Damage to the drainage system due to flooding. • Increased extent and intensity of erosion and waterlogging. • Increased pest incidence.
Increases in drought conditions	• Lower yields from crop damage, stress, and/or failure. • Loss of arable land as a result of land degradation and wind erosion. • Increased risk of wildfires.

Increase in the frequency of floods and droughts	• Crop failure and damage to crops due to flooding. • Yield decreases. • Land degradation and soil erosion, loss of arable land. • Increased competition for water (drought).
More frequent strong hurricanes	• Damage to crops and rural infrastructure.
Sea level rise and storm surges	• Damage to crops and rural infrastructure due to flooding. • Seawater intrusion, loss of arable land, salinization of water supply (groundwater in particular).

Source: Asian Development Bank. (2012). Guidelines for Climate Proofing Investment in Agriculture, Rural Development and Food Security. https://www.adb.org/sites/default/files/institutional-document/33720/guidelines-climate-proofing-investment_0.pdf

3.4 Water and Sanitation sector

Climate hazard	Potential impacts on the water and sanitation sector
Temperature increase	• May increase water demand for industrial use; cooling in energy generation or irrigation • May increase algal blooms and pathogens and decrease dissolved oxygen, necessitating enhanced wastewater treatment. • May lead to higher levels of evapotranspiration for irrigation
Increase in drought conditions	• Due to drought can lead to higher concentrations of contaminants as well as can reduce recharge to surface and groundwater supplies thereby impacting water pumping needs.
Extreme events (flooding, hurricane)	• May lead to increased runoff which can introduce new contaminants into the water supply, increasing the pollutant load. • May lead to sewers overflowing, resulting in floods of combined sewer systems.

3.5 Solid Waste sector

Climate hazard	Potential impacts on the solid waste sector
Temperature increase	• Increased odor and pest activity requiring more frequent waste collection • Overheating of collection vehicles requiring additional cooling capacity, including to extend engine life • Overheating of sorting equipment • Altered decomposition rates • Increased risk of fire at disposal sites
Increase in intense precipitation events or drought conditions	• Flooding of disposal sites, collection routes and landfill access roads, making them inaccessible • Increased stress on collection vehicles and workers from waterlogged waste • Increased need for enclosed or covered sorting facilities • Increased leachate that needs to be collected and treated
More frequent strong hurricanes	• Dispersal of waste from collection sites, collection vehicles, processing sites, and landfills • Reduced access to collection and landfill access routes due to damage and debris
Sea level rise and storm surges	• Potentially increased waste in a concentrated area as people crowd into higher elevations within an urban area • Damage to low-lying processing facilities • Increased need for sorting and recycling to minimize waste storage needs • Deterioration of impermeable lining • Water infiltration of pit leading to possible overflow of waste • Permanent inundation of collection, processing, and disposal infrastructure

Source: USAID (2011). Solid Waste management. Addressing climate change impacts on infrastructure.
https://www.climatelinks.org/sites/default/files/asset/document/Infrastructure_SolidWasteManagement.pdf