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ESIA Addendum

Climate Change Risk Assessment

0730380

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ACRONYMS AND ABBREVIATIONS

Acronyms	Description
CAPE	Convective Available Potential Energy
°C	Degree Celsius
CCRA	Climate Change Risk Assessment
CMIP	Coupled Model Intercomparison Project
CV	Coefficient of Variability
DTU	Technical University of Denmark
ECMWF	European Centre for Medium-Range Weather Forecasts
ECP	Energy and Climate Policy
EIA	Environmental Impact Assessment
ESHS	Environmental, Social, Health and Safety
FES	Finite Element Solution
FOD	Foreign Object Damage
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas

Acronyms	Description
GLOFRIS	Global Flood Risk with IMAGE Scenarios
GTSM	Global Tide and Surge Model
GTSR	Global Tide and Surge Reanalysis
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
km^2	Squared kilometres
LIS	Lighting Imaging Sensor
m/s	Meters per second
NOAA	National Oceanic and Atmospheric Administration
PCR-GLOBWB	Grid-based Global Hydrology and Water Resources Model
RCP	Representative Concentration Pathways
SEDAC	Socioeconomic Data and Applications Center
SLR	Sea level rise
TCFD	Task Force on Climate-Related Financial Disclosures
TRMM	Tropical Rainfall Measuring Mission
UNEP	The United Nations Environment Programme
USGS	United States Geological Survey
W m-2	Watt per square meter
WBG	World Bank Group
WBGT	WetBulb Globe Temperature
WGI	Working Group I
WRI	World Resources Institute

1. INTRODUCTION

Climate change is now widely and globally recognized as one of the most significant international environmental challenges. In terms of response and adaption to climate change, a range of international and national policies and legislations have been introduced and implemented to encourage the development of renewable energy, reduce greenhouse gas (GHG) emissions, and combat the impacts of climate change.

Cambodia Airport Investment Co., Ltd. (“CAIC” or the Client) has requested ERM Siam Co. ltd. (ERM) to perform a climate change risk assessment for the development of the new international airport in Phnom Penh, Cambodia.

In addition, the Climate Change Physical Risk on the Project is evaluated and mitigation measures to reduce such risk are proposed.

2. DOCUMENT PURPOSE/ OBJECTIVE

The primary objective of this report is to follow a methodical process to identify and analyze hazards directly linked to climate change within the specific context of the Project.

Subsequently, an evaluation of Project-specific vulnerabilities and exposure related to the hazard will be conducted for each individual Project component.

The risk assessment will be provided based on understanding of the potential impact considering vulnerability, hazard, and exposure. Climate hazard trends in combination with Project-specific exposure and vulnerability are assessed to identify climate risks and their materiality to the Project.

Finally, a series of mitigation measures are proposed to reduce the risk level to the Project.

3. PROJECT DESCRIPTION

The Project site is about 23 km from Phnom Penh. The total land area is 2,600 hectares, located in Kandal Stung District and Sa'ang District of Kandal province, and Bati District of Takeo Province. The Project facilities include the main building (terminal) and (other support facilities (control tower, runway, and taxiway, etc.).

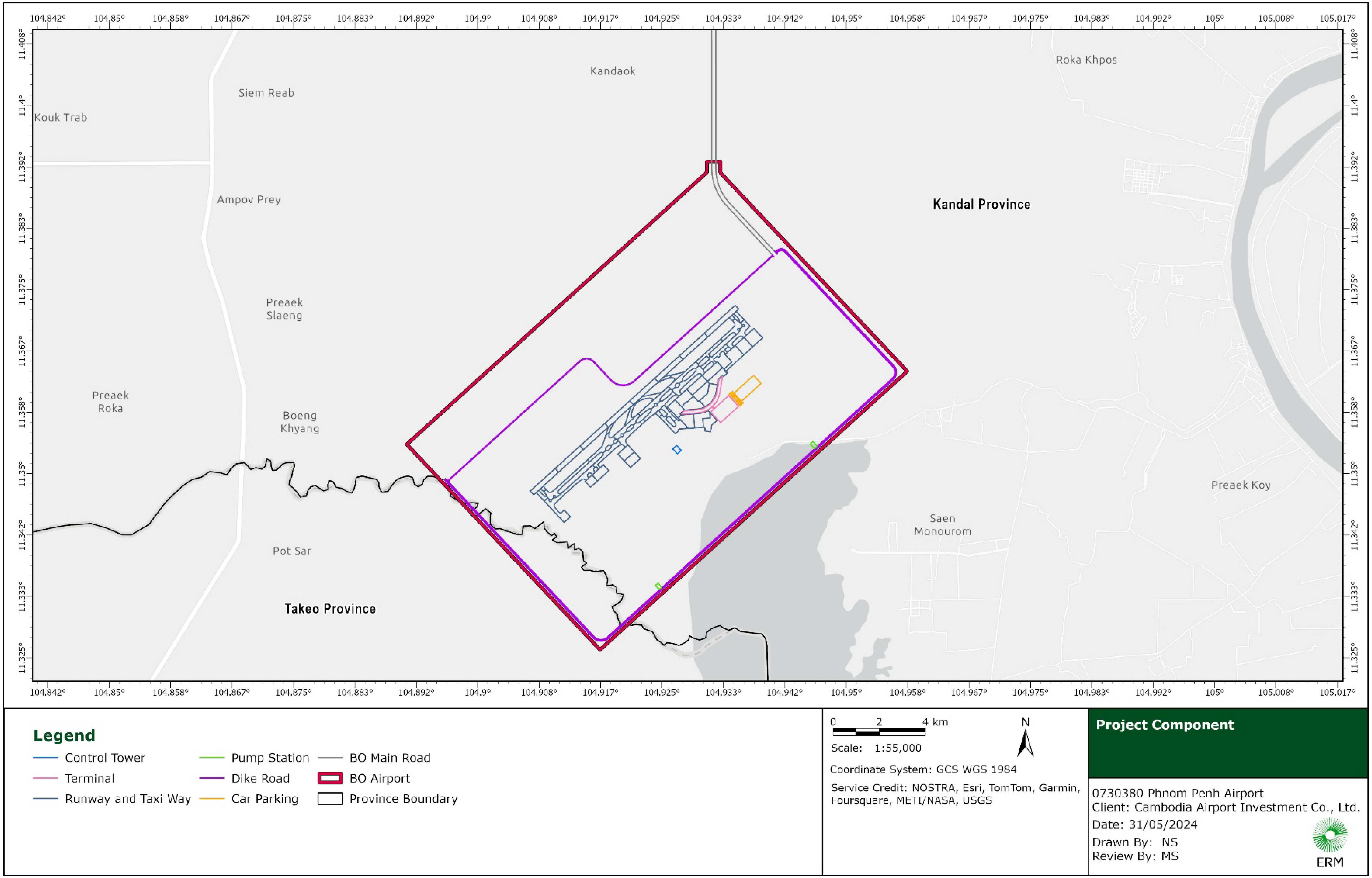

FIGURE 3.1 PROJECT COMPONENT

4. METHODOLOGY

The key objective of this assessment is to understand the potential high-level physical risks to the Project from climate change. The methodology constituted of three (3) major steps as given below:

Step 1: Desktop Review of the baseline natural hazards

For the first step, a desktop-based review of prominent natural hazards was undertaken at the Project locations offshore as well as onshore. The natural hazards are then evaluated and categorized based on potential to cause damage to the natural environment due to intensity / severity and frequency.

Step 2: Evaluation of climate change projections

This second step involved evaluation projections for various climate variables such as temperature, sea level and precipitation. The climate change projections data involved multi-model mean climate change projections published under Coupled Model Intercomparison Project 6 (CMIP-6)[1], which is a recognized standard by the Intergovernmental Panel on Climate Change (IPCC). The climate change scenarios for which the data was evaluated involved RCP 8.5 over timelines of 2030 and 2050.

Step 3: Qualitative estimation of future hazards and physical risks

The third step involved use of the future projections on natural hazards to evaluate the potential risks in future. Qualitative estimation of future natural hazards was also conducted based on changes in indicator climate variables which are likely to affect a particular natural hazard, and baseline natural hazards in cases where future hazard level was not readily available. Hazard level in combination with exposure and vulnerability levels are used to estimate the physical risk to the Project.

It should be noted that this is a high-level review of publicly available information, and no detailed site-specific analysis or modelling has been undertaken. Hence, further investigation may be warranted to quantify the risks in more detail for consideration of adaptation measures.

Further, the qualitative evaluation of the impacts of climate change on natural hazards is an exercise of educated speculation and professional judgement. The likely changes in natural hazards presented here are based on the possible relation between the natural hazards and climatic parameters.

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[1] Under the World Climate Research Programme (WCRP) the Working Group on Coupled Modelling (WGCM) established the Coupled Model Intercomparison Project (CMIP) as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access. This framework enables a diverse community of scientists to analyze GCMs in a systematic fashion, a process which serves to facilitate model improvement. CMIP6 is the latest phase of the project, and it involves a large number of modeling groups from around the world. It involves more modeling groups, uses advanced emissions scenarios considering socioeconomics, and features more sophisticated climate models. CMIP6 offers a wider range of experiments for a deeper look at climate change.

What are the Representative Concentration Pathways (RCP)?

RCPs usually refer to the portion of the concentration pathway extending up to the year 2100, for which Integrated Assessment Models produced corresponding emission scenarios. Each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term “pathway” emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

Four (4) RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the Fifth Intergovernmental Panel on Climate Change (IPCC) Assessment as a basis for the climate predictions and projections are as follows:

RCP2.6 One pathway where radiative forcing peaks at approximately 3 W m^{-2} before 2100 and then declines (the corresponding ECP assuming constant emissions after 2100);

RCP4.5 and RCP6.0 Two intermediate stabilization pathways in which radiative forcing is stabilized at approximately 4.5 W m^{-2} and 6.0 W m^{-2} after 2100 (the corresponding ECPs assuming constant concentrations after 2150);

RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 W m^{-2} by 2100 and continues to rise for some amount of time (the corresponding ECP assuming constant emissions after 2100 and constant concentrations after 2250).

4.1 HAZARD CATEGORIZATION

Hazard is defined by the IPCC AR6[2] as:

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, ecosystems, and environmental resources.

Open access databases have been reviewed to assess the hazard level at the Project site. As different sources present different classifications, ERM has reorganized those into three levels: low, medium, and high.

The below table presents the classification of the hazard level used in this report.

TABLE 4.1 CATEGORIZATION OF NATURAL HAZARDS

Hazard (Criteria for Categorization)	Original Categorization	Report Categorization
Water Availability		
Water Stress Source: WRI-Aqueduct Water Risk Atlas 4.0 *Based on the ratio of total water demand to available renewable water resources (surface and groundwater)*	Low: < 10%	Low: <20%
	Low-Medium: 10-20%	
	Medium-High: 20-40%	Medium: 20-40%
	High: 40-80%	High: >40%
	Extremely High: >80%	
Inter Annual Variability Source: WRI-Aqueduct Water Risk Atlas *(Based on coefficient of variability (CV) as ratio of standard deviation of the available water and the mean available water during the period of 1979-2019 on monthly and annual basis)*	Low: <0.25	Low: <0.25
	Low-medium: 0.25-0.50	Medium: 0.25-0.5
	Medium-high: 0.50-0.75	High: >0.5
	High: 0.75-1.00	
	Extremely High: >1.00	
Seasonal Variability Source: WRI-Aqueduct Water Risk Atlas *(Based on coefficient of variability (CV) as ratio of standard deviation of the annual available water and the annual mean available water during the period of 1979-2019)*	Low: <0.33	Low: <0.33
	Low-medium: 0.33-0.66	Medium: 0.33-0.66
	Medium-high: 0.66-1.00	High: >0.66
	High: 1.00-1.33	
	Extremely High: >1.33	
Water Depletion	Low: <5%	Low: <5%-25%
	Low-medium: 5–25%	

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[2] IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

Hazard (Criteria for Categorization)	**Original Categorization**	**Report Categorization**
Source: WRI-Aqueduct Water Risk Atlas *(Based on ratio of total water consumption to available renewable water resources (surface and groundwater))*	Medium-high: 25–50%	Medium: 25-50%
	High: 50–75%	High: >50%
	Extremely high: >75%	
Floods Inland and Coastal		
Riverine Flood Risk Source: WRI-Aqueduct Water Risk Atlas *(Based on population exposed to floods per 1,000 people)*	Low: 0-1/1,000 (people)	Low: 0-2/ 1,000
	Low-Medium: 1-2/1,000	Medium: 2-6/ 1,000
	Medium-High: 2-6/1,000	
	High: 6-10/1,000	High: > 6/ 1,000
	Extremely High: >10/1,000	
Coastal Flood Risk Source: WRI-Aqueduct Water Risk Atlas *(Based on population exposed to floods per 1,000,000 people)*	Low: 0-9/ 1,000,000 (people)	Low: 0-9/ 1,000,000
	Low-Medium: 9-70/ 1,000,000	Medium: 9-300/ 1,000,000
	Medium-High: 70-300/ 1,000,000	
	High: 300-2000/ 1,000,000	High: >300/ 1,000,000
	Extremely High:>2000/ 1,000,000	
Flood Hazard Map Source: WRI-Aqueduct Flood Tool *(Based on depth of inundation in meters)*	No original categorization	Low: ≤0.5m
		Medium: 0.5-1.5m
		High: > 1.5m
Flood Hazard Map Source: FM Global *(Based on probability of flood occurring each year for a given flood return period)*	Moderate: Locations in a 500-year flood zone with a chance of at least 0.2% of experiencing a flood each year	Medium
	High: Locations in a 100-year flood zone with a chance of at least 1% of experiencing a flood each year	High
Landslides		
Landslides Susceptibility Source: Think Hazard[3]	Very Low	Low
	Low	

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[3] GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

Hazard (Criteria for Categorization)	Original Categorization	Report Categorization
(The classify hazards based on probabilistic data in Think Hazard)	Medium	Medium
	High	High
Landslides Hazard Source: Think Hazard[4] *(The classify hazards based on probabilistic data in Think Hazard)*	Low	Low
	Moderate	Medium
	High	High
	Very High	
Extreme Heat Source: Think Hazard *(Based on widely accepted heat stress indicator, the Wet Bulb Globe Temperature (°C))*	Very Low: <25°C	Low: under 28°C
	Low: >25°C	
	Medium: >28°C	Medium: between 28 and 32°C
	High: >32°C	High: above 32°C
Cyclone and Hurricane Intensity Source: UNEP global Risk Data Platform *(Cyclone categories based on damage potential as classified by Saffir-Simpson Scale)*	Category 1: 119-153 km/h	Low: 119-153 km/h
	Category 2: 154-177 km/h	Medium: 154-177 km/h
	Category 3: 178-208 km/h	High: above 178 km/h
	Category 4: 209-251 km/h	
	Category 5: ≥252 km/h	
Wind Speed Source: Global Wind Atlas *(Based on damage potential of wind speed (m/s) with reference to the Beaufort's scale)*	0: <1 m/s	Low: ≤ 11 m/s
	1: 1-2 m/s	
	2: 2-3 m/s	
	3: 4-5 m/s	
	4: 6-8 m/s	
	5: 9-11 m/s	
	6: 11-14 m/s	Medium: 11-21 m/s
	7: 14-17 m/s	
	8: 17-21 m/s	
	9: 21-24 m/s	High: ≥ 21 m/s
	10: 25-28 m/s	
	11: 29-32 m/s	
	12: >33 m/s	
Sea Level Rise	No original categorization	Low: 1-50cm
		Medium: 51-150cm

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[4] GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

Hazard (Criteria for Categorization)	Original Categorization	Report Categorization
Source: CLIMsystems, Sea Level Rise for Cities *(Combined processes of local (absolute) sea level rise and local vertical land movement expressed in centimetres)*		High: 151-200cm
Lightning Source: Lighting Imaging Sensor (LIS) on TRMM Science Data *(Lightning Density average between 1998 and 2013 expressed as Flashes per km^2)*	No original categorization	Low:1-20 Medium: 21-60 High: >61

4.2 EXPOSURE AND VULNERABILITY CATEGORIZATION

Exposure and vulnerability of the Project are necessary to determine the risk level.

Vulnerability is defined by the IPCC AR6[5] as:

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.

Exposure is defined as:

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.

Details of the Project location, design of components, buildings and infrastructures, activities of Project personnel are used to determine the exposure of the Project to the hazards. Vulnerability can then be assessed in more detail, drawing on Project design information and standards together with any other factors which may provide resilience, e.g., pre-existing flood prevention measures.

The combination of exposure and vulnerability is categorized in three levels: low, medium, high.

4.3 RISK CATEGORIZATION

Risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Such interaction is complex and subject to uncertainty, therefore, ERM has performed a qualitative evaluation based on educated speculation and professional judgement.

The relation between hazard, vulnerability and exposure is presented in the table below.

TABLE 4.2 CLIMATE CHANGE RISK LEVEL

		Hazard		
		Low	**Medium**	**High**
Exposure x Vulnerability	**Low**	**Low**	**Low**	**Low**
	Medium	**Low**	**Medium**	**Medium**
	High	**Medium**	**High**	**High**

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[5] IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

5. PHYSICAL RISK ASSESSMENT

5.1 WATER AVAILABILITY

Availability of water in the airport boundary was assessed based on data from the online water risk assessment tool WRI-Aqueduct Water Risk Atlas for Water Stress, Seasonal Variability, and Inter-annual Variability. The description of the parameters assessed is provided in the table below.

TABLE 5.1 LIST OF PARAMETERS FOR EVALUATION OF BASELINE WATER AVAILABILITY

No.	**Parameter**	**Definition**
1	Baseline Water Stress	Baseline water stress is defined as the ratio of the total annual water withdrawals to the total available annual water renewable supply, accounting for upstream consumptive use. Higher values indicate more competition among users.
2	Seasonal Variability	Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year.
3	Inter Annual Variability	Inter-annual variability measures the average between year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations in available supply from year to year.

5.1.1 BASELINE HAZARD

5.1.1.1 WATER STRESS

The baseline water stress map is presented in ***Figure 5.1***. Based on the WRI information, the specific location of the Project is Mekong basin. The water stress shows 'Low to Medium' indicating the water demand slightly exceeds the available amount in the area. However, considering the hazard categorization (***Table 4.1***) due to water stress is categorized to be "Low".

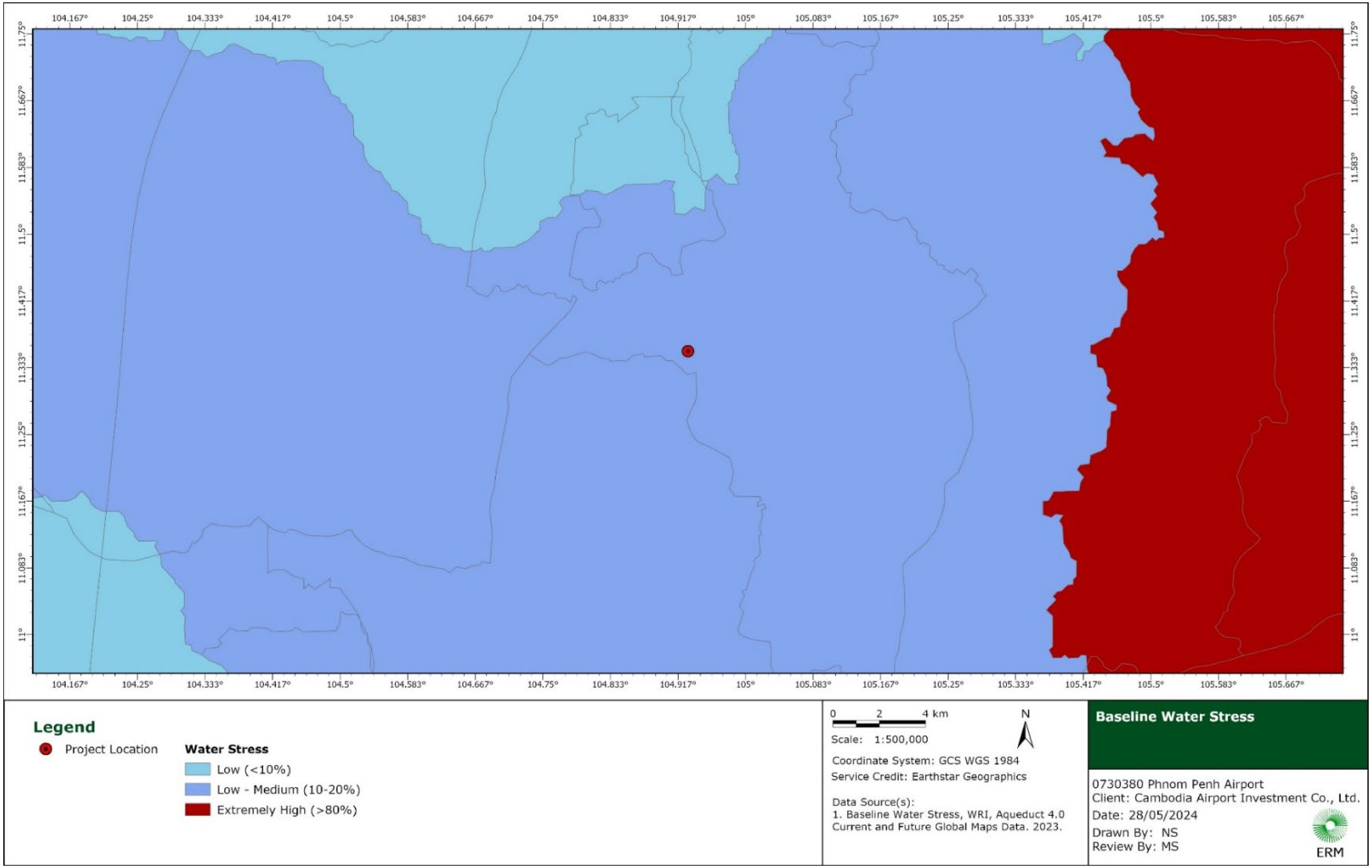

FIGURE 5.1 BASELINE WATER STRESS

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.1.2 SEASONAL VARIABILITY

Seasonal Variability map presented in ***Figure 5.2*** indicates the likelihood of variations in water availability over different months within a year as 'Low to Medium'. This indicates that the supply of water over different months does not vary significantly. Considering the baseline hazard due to seasonal variability as shown in the ***Table 4.1,*** the hazard level is categorized to be **"Medium".**

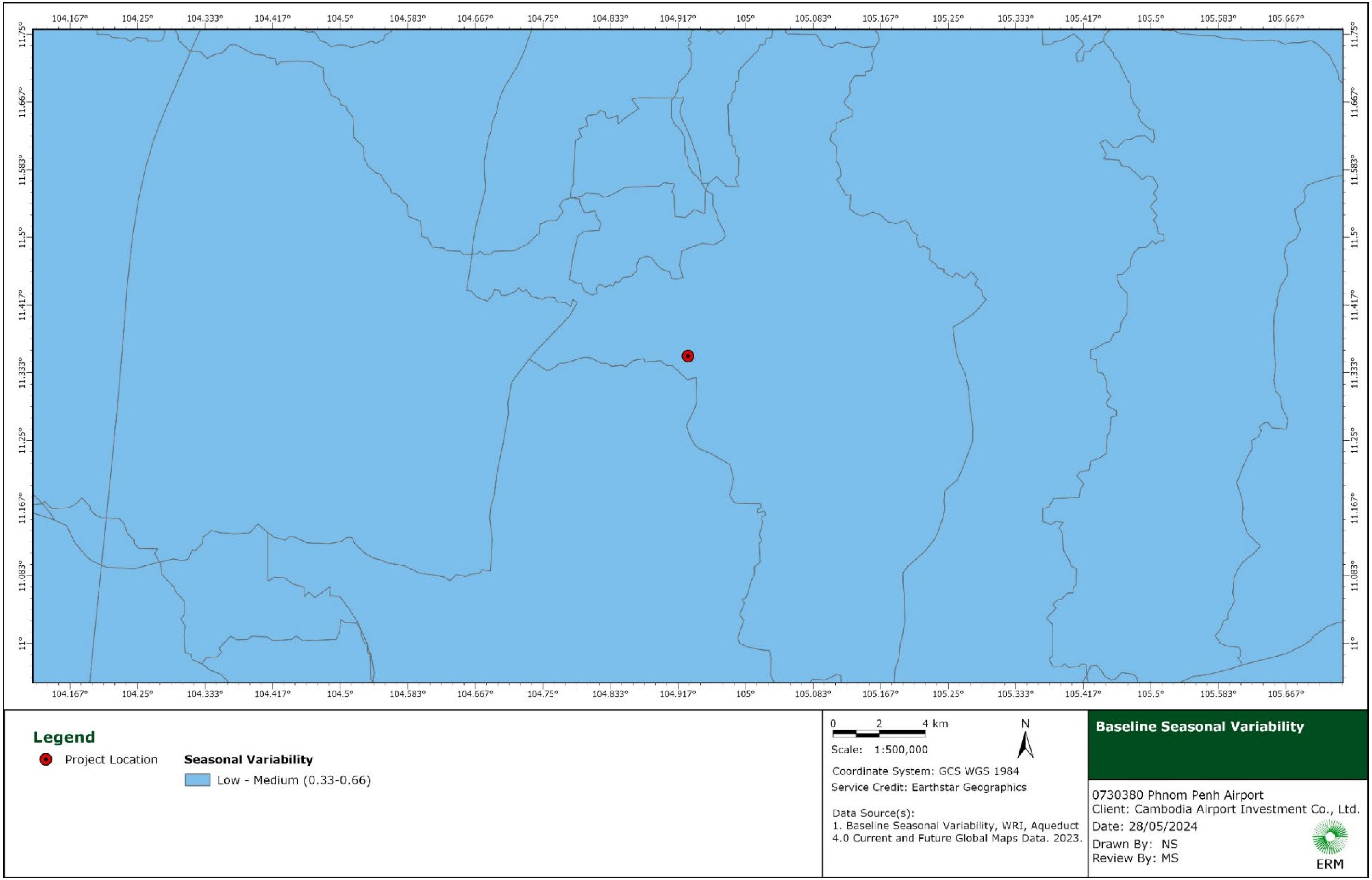

FIGURE 5.2 BASELINE SEASONAL VARIABILITY

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.1.3 INTER-ANNUAL VARIABILITY

Inter-Annual Variability map presented in ***Figure 5.3*** indicates the variations in water availability over different years is ‘Low’. This indicates that the supply of water over different years is likely to be similar to seasonal variation. The baseline hazard due to inter-annual variability is categorized as “**Low**” (***Table 4.1***).

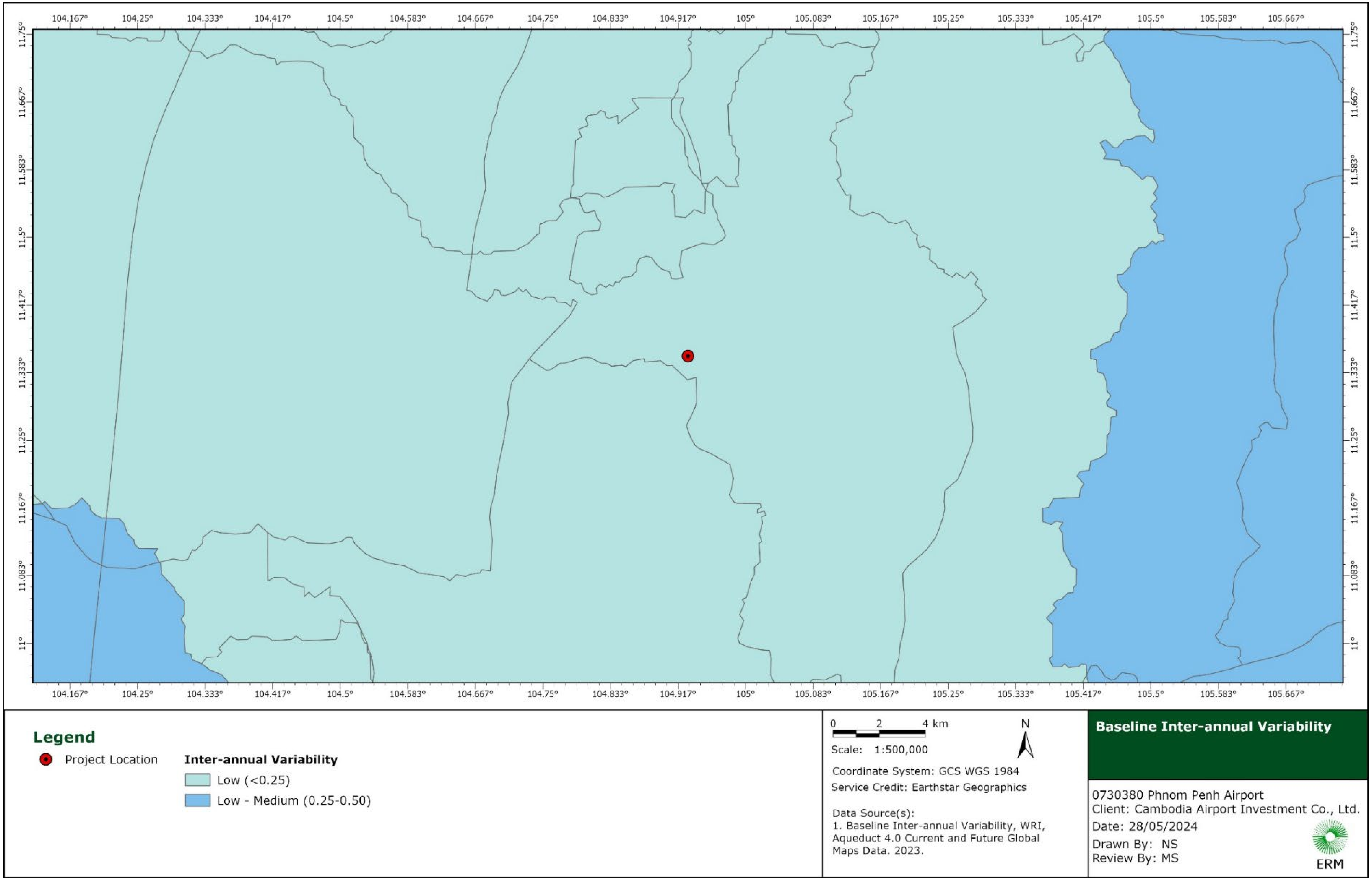

FIGURE 5.3 BASELINE INTER-ANNUAL VARIABILITY

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.1.4 HAZARD OF BASELINE WATER AVAILABILITY

Based on the baseline water stress, seasonal variability, and inter-annual variability, identify a region characterized by a consistently reliable water source. There is a sufficient amount of water that meets the majority of requirements, and the differences in water levels from season to season or year to year are not significant.

In conclusion, based on the evaluation of baseline water stress, seasonal variability, and inter-annual variability, the hazard due to availability of water is considered to be "**Medium**" on a conservative basis based on the medium hazard level associated to seasonal variability.

5.1.2 CLIMATE CHANGE PROJECTION

Water availability was assessed based on the evaluation of projections for water depletion, water stress, and seasonal variability under climate change scenario. The water availability will be assessed by using the "pessimistic" scenario (SSP5 RCP8.5) for both near-term and long-term periods (i.e. 2030 and 2050). The data were obtained from the WRI-Aqueduct Water Risk Atlas.

Water depletion measures the level of how humans consume water from accessible sources of fresh water. A higher depletion number indicates an increased demand for water supplies. The projection shows 'Low' in 2030 and 'Low to Medium' in 2050, meaning the current pace of water consumption is not significantly impact the overall supply of freshwater resources until 2030. However, competition for water resources could exist, especially during dry periods or with growing demand in 2050.

Further, water stress is projected to be 'Low to Medium' under all climate change scenarios as presented in ***Figure 5.4*** and ***Figure 5.5***. This means a rising shortage of water due to increased demand. Seasonal variability is projected to be 'Low to Medium' for all climate change scenarios as presented in ***Figure 5.6*** and ***Figure 5.7*** indicates a similar seasonal variability in the future.

Consider the hazard categorization in the ***Table 4.1***, the water depletion and water stress will be classified as 'Low', and the water seasonal variability remain 'Medium'.

Based on the information for the three (3) indicators, an imbalance between supply and demand could occur leading to a water shortage. Hence, the hazard of water availability in the future is conservatively considered to be **"Medium"**.

5.1.2.1 PROJECTIONS OF WATER STRESS

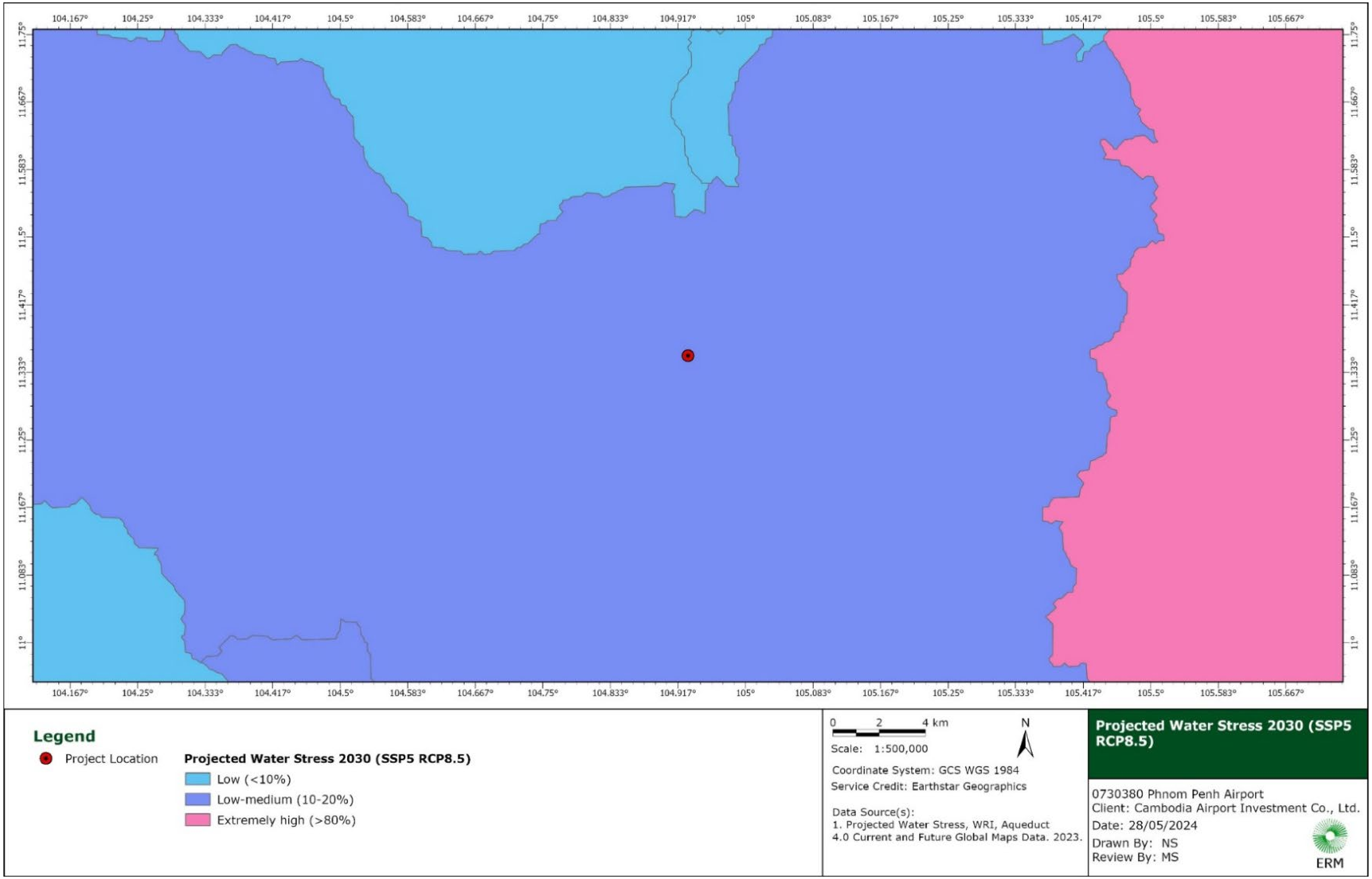

FIGURE 5.4 PROJECTIONS OF WATER STRESS DURING 2030 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

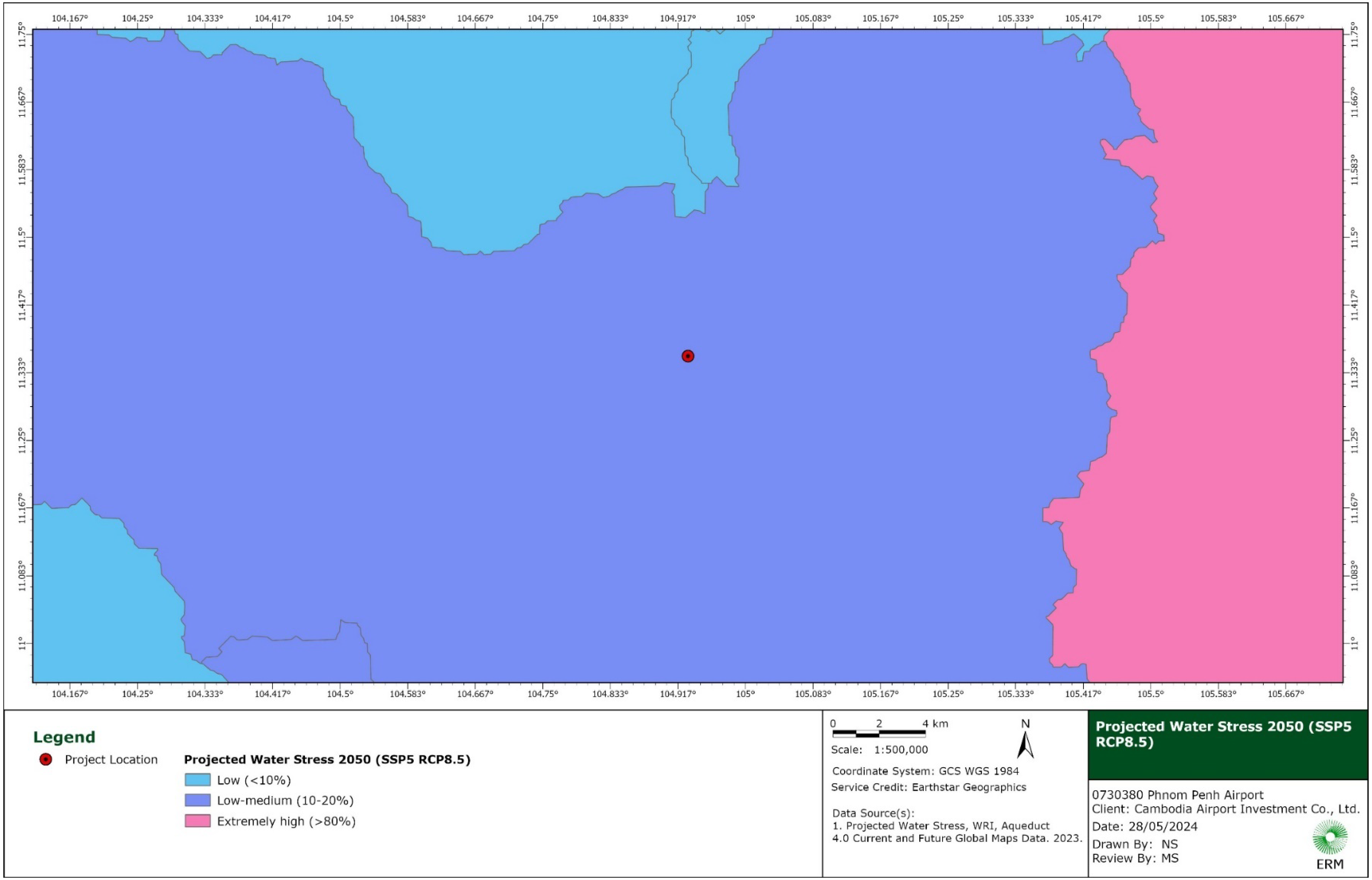

FIGURE 5.5 PROJECTIONS OF WATER STRESS DURING 2050 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.2.2 PROJECTIONS OF SEASONAL VARIABILITY

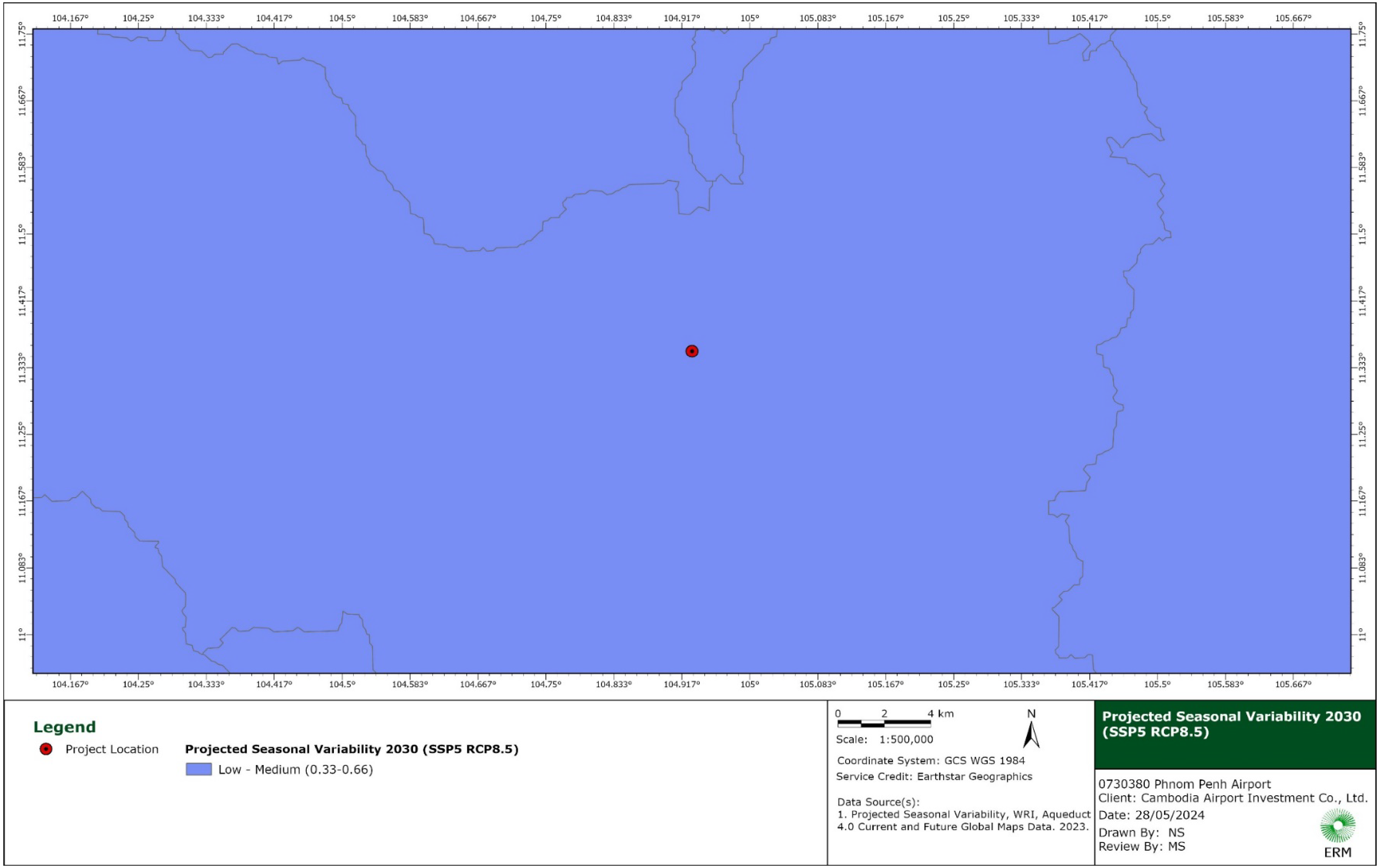

FIGURE 5.6 PROJECTIONS OF SEASONAL VARIABILITY DURING 2030 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

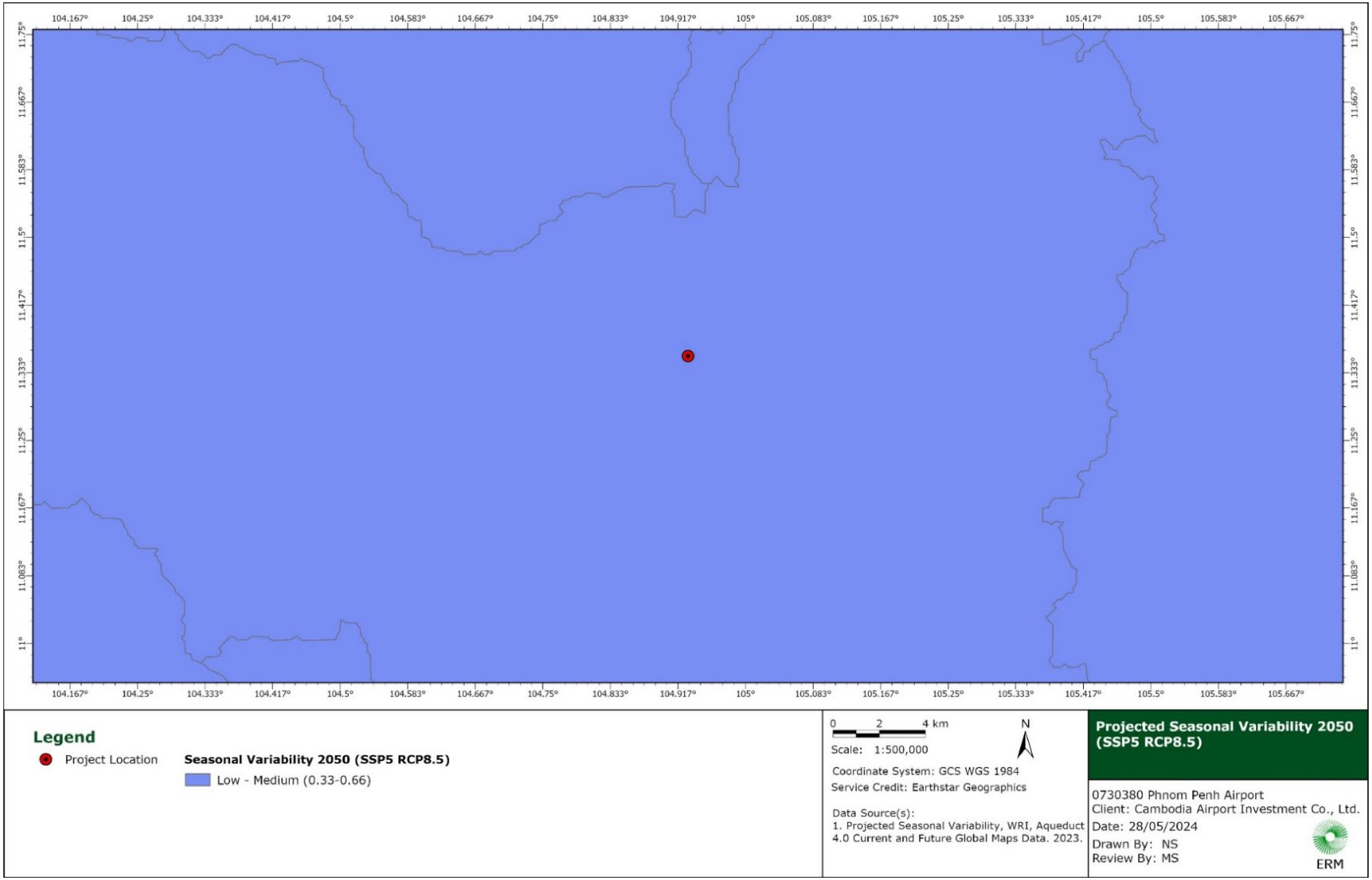

FIGURE 5.7 PROJECTIONS OF SEASONAL VARIABILITY DURING 2050 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.2.3 PROJECTIONS OF WATER DEPLETION

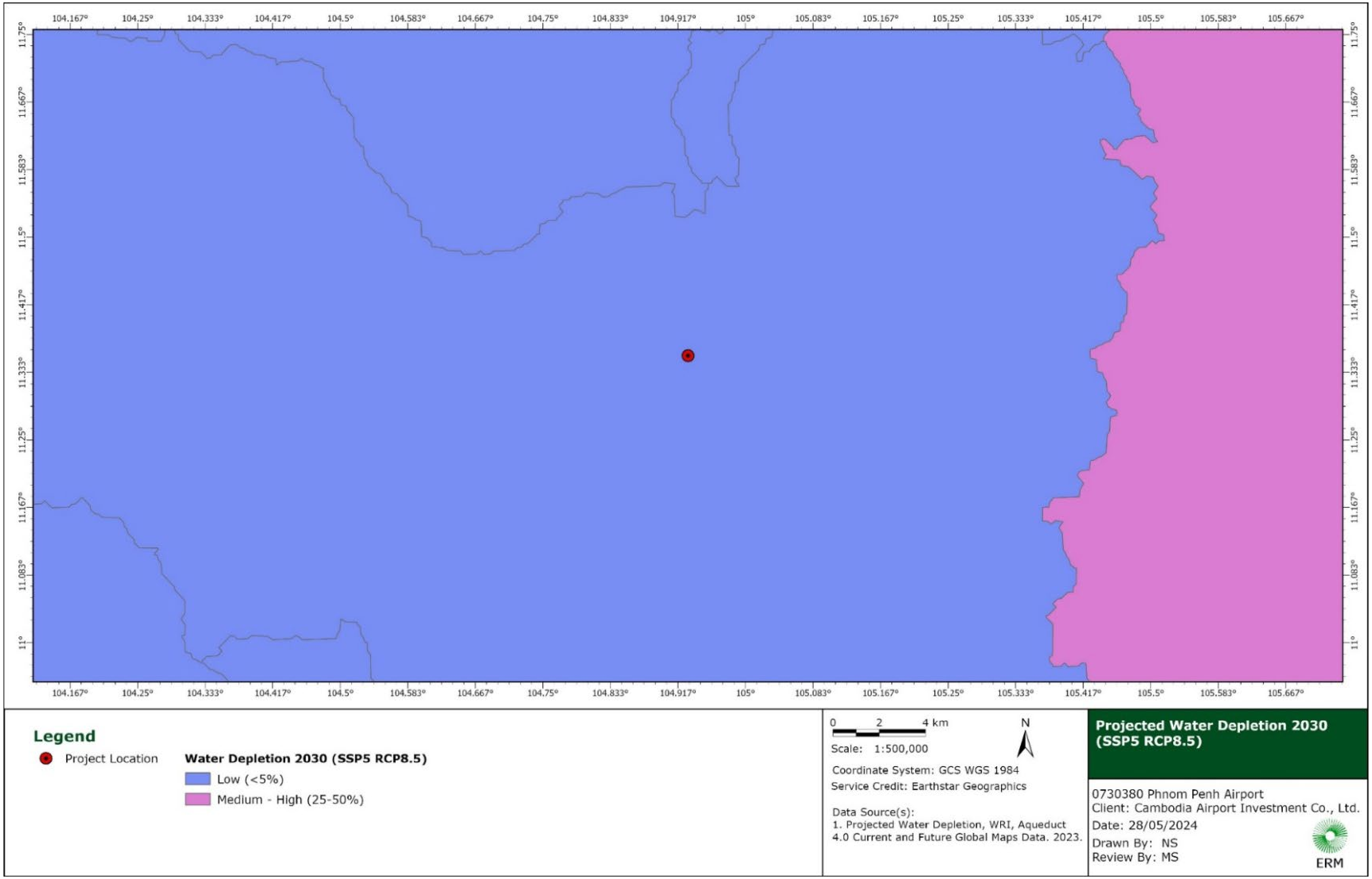

FIGURE 5.8 PROJECTIONS OF WATER DEPLETION DURING 2030 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

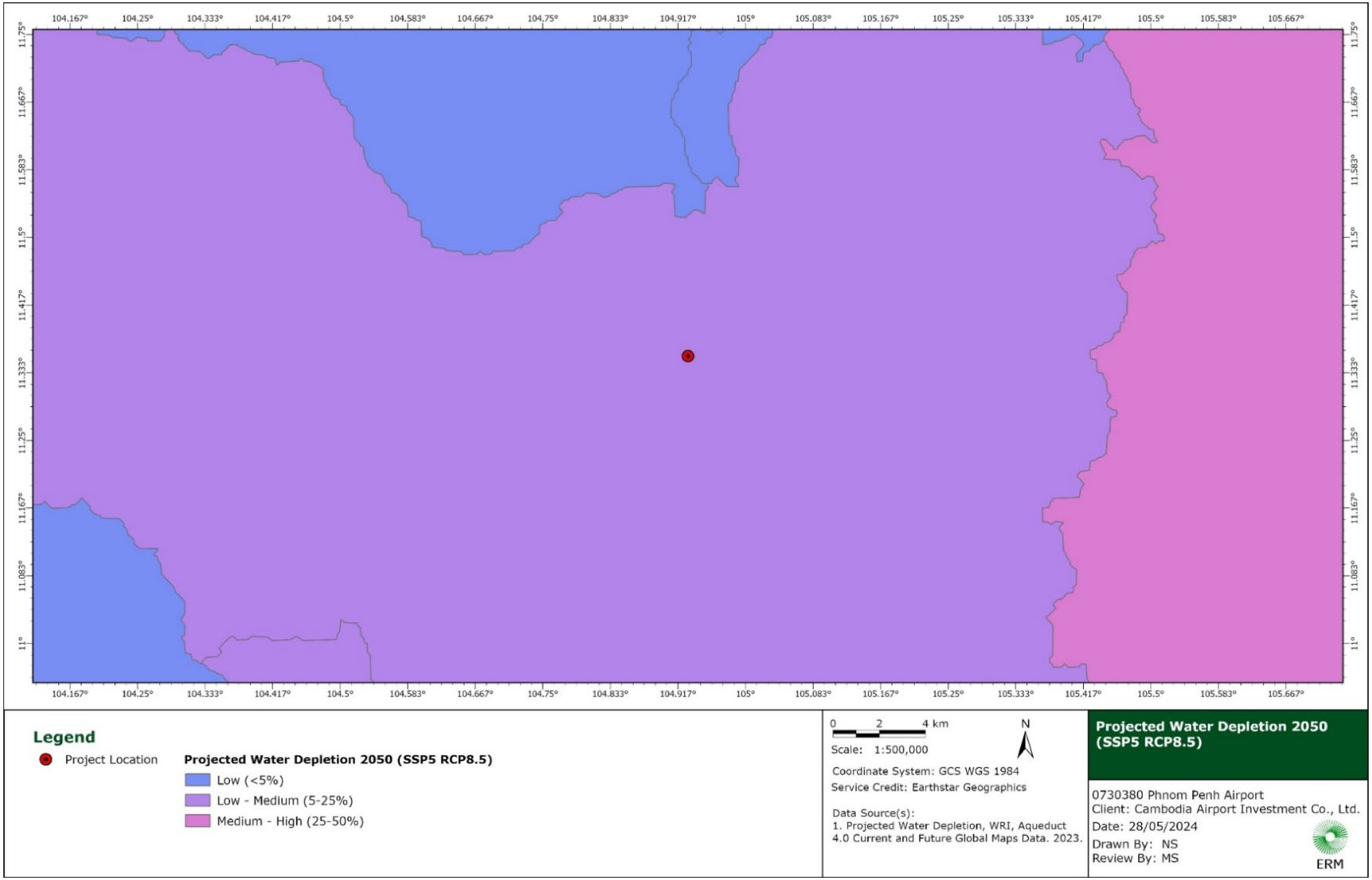

FIGURE 5.9 PROJECTIONS OF WATER DEPLETION DURING 2050 FOR RCP 8.5

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

5.1.3 EXPOSURE AND VULNERABILITY

According to the EIA conducted by E&A (November 2020), water will be supplied to each building in the airport, particularly at the passenger terminal in the washrooms, toilets, cafeteria, restaurants, air conditioning, fire extinguishers, and so on. Additionally, water will be required for gardening and road maintenance. During the operation phase, the potable and non-potable water requirement will be 3,288 m^3/day and 6,680 m^3/day in 2030 and 2050, respectively. Firefighting will also require water supply for 4,755 m^3/day and 4,817 m^3/day in 2030 and 2050, respectively.

Water availability will be determined by natural water sources such as the canal and irrigation near the airport during both the dry and rainy seasons. The potable water is to be supplied by the Phnom Penh municipality distribution network. Wastewater treatment will provide an additional 1,530 m^3/day. This high-water consumption exposes the Project to water constraints. Water scarcity can cause substantial disruptions in airport operations. However, the Project's implementation of water retention for collection and wastewater treatment for reuse mitigates its susceptibility to water availability fluctuations.

Based on the information provided above, the Project's exposure and vulnerability will be considered as **"Medium"**.

5.1.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.2 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR WATER AVAILABILITY

	Baseline		**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Low**		**Low**	**Low**
Exposure x Vulnerab. Level	**Medium**		**Medium**	**Medium**
Risk Level	**Medium**		**Medium**	**Medium**
Implications for the Project	Terminal	Terminal requires water for many purposes; sanitary, catering service, cleaning, fire extinguishing, etc. However, the water availability is expected to have a "Medium" risk for the terminal since the potable water will be supplied by the Phnom Penh municipality distribution network. Other water consumption can be received from natural resources and water treatment. However, the consumption of water should be measured to maintain efficient operation and passenger comfort at the terminal.		

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
	Runway and Taxi way	For the runway and taxiway, water is mostly used for cleaning purposes. The water will come from the Project reservoir or wasted water treatment. Water consumption for the runway and taxiway is expected to be minimal.	
	Control Tower	The control tower may require minimal water for personnel use and cleaning.	
Key Potential Impacts	▪ Temporary operation disruption of sanitary facilities, stores, and firefighting equipment. ▪ Runway and taxiway deterioration		
Implemented Mitigations	▪ Develop a Water Management Plan that identifies opportunities for the reduction and recycle of water within the airport. ▪ Explore the potential use of rainwater harvesting to increase the available water supply		

5.2 FLOOD

Floods can be defined as the overflow of water resulting in the submergence of dry lands. Floods can be categorized as inland and coastal in nature. Inland flooding may be caused due to heavy rainfall, resulting in high run-off leading to water accumulation in low lying areas, or overtopping of water bodies such as rivers, streams, lakes, ponds, and tanks. Coastal flooding is a result of the ingress of the ocean or sea water via the coastal and/or estuarine systems onto open land. This could be a standalone of the combined effect of tides, surges, and increases in the sea surface elevation.

Floods are likely to result in widespread local as well as regional level destruction. This can be caused due to submergence, washing away, and damage to infrastructure, buildings, structures, sewerage systems, damage to power transmission and power generation, loss of agricultural land and crops, contamination of freshwater sources, propagation of waterborne diseases, and loss of life. Flood hazard in the present assessment was assessed based on the review of open-source data for different flooding parameters as presented in the below table.

TABLE 5.3 PARAMETERS USED FOR EVALUATION OF BASELINE FLOOD HAZARD

No.	Parameter	Description
1	Riverine Flood Risk Map[6]	Riverine flood risk is the percentage of the population that is expected to be impacted by Riverine flooding in an average year, taking into account existing flood-protection standards.

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[6] WRI- Aqueduct Flood Hazard Maps. Available at https://www.wri.org/research/aqueduct-30-updated-decision-relevant-global-water-risk-indicators

No.	Parameter	Description
2	Riverine Flood Hazard Map[7]	To calculate the river hazard layers for the individual return periods, the GLOFRIS model[8] was used. GLOFRIS uses a global hydrological model, PCR-GLOBWB [9], with a river and floodplain routing scheme to make long-term simulations of discharges and flood levels for several climate conditions. The meteorological datasets of the European Union Water and Global Change Program[10] and the Inter-sectoral Impact Model Intercomparison Project[11] were used to force PCR-GLOBWB over various time periods, between 1950 and 2099.
3	Flood Hazard Map[12]	The flood maps prepared by FM-Global are based on historical data, physical hydrology and hydraulic data accounting for external factors such as rainfall, evaporation, snowmelt, and terrain.
4	Coastal Flood Risk Map[13]	Coastal flood risk is a measure of the percentage of population expected to be affected by Coastal flooding in an average year, accounting for existing flood protection standards. Higher values indicate greater proportion of the population is expected to be impacted by flooding.
5	Coastal Flood Hazard Map[14]	To estimate coastal hazard, the Global Tide and Surge Reanalysis (GTSR) dataset[15] was used as a database of extreme water levels. GTSR is a global dataset of daily sea levels (due to tide and storm surge) for 1979–2014, based on the hydrodynamic Global Tide and Surge Model (GTSM). Surge is simulated using wind and pressure fields

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[7] WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

[8] Ward, P.J,. Hessel C. W, Kuzma, S., Bierkens M. F.P., Bouwman, A., De Moel, H., Díaz Loaiza, A., Eilander, D., Englhardt, J., Erkens, G., Gebremedhin, E.T., Iceland, C., Kooi, H., Ligtvoet, W., Muis, S., Scussolini, P., Sutanudjaja, E.H., Van Beek, R., Van Bemmel, B., Van Huijstee, J., Van Rijn, F., Van Wesenbeeck, B., Vatvani, D., Verlaan, M., Tiggeloven T., and Luo, T., 2020, Aqueduct Floods Methodology. Available at: https://www.wri.org/publication/aqueductfloods-Methodology

[9] Sutanudjaja, E.H., van Beek, R., Wanders, N., Wada, Y., Bosmans, J.H.C., Drost, N., van der Ent, R.J., de Graaf, I.E.M., Hoch, J.M., de Jong, K., Karssenberg, D., Lopez Lopez, P., Peßenteiner, S., Schmitz, O., Straatsma, M.W., Vannametee, E., Wisser, D., Bierkens, M.F.P., 2018. PCR-GLOBWB 2: a 5 arcmin global hydrological and water resources model. Geosci. Model Dev. (GMD) 11, 2429–2453. https://doi.org/ 10.5194/gmd-11-2429-2018.
(15) (PDF) Random forests-based error-correction of streamflow from a large-scale hydrological model: Using model state variables to estimate error terms. Available from: https://www.researchgate.net/publication/356755509_Random_forests-based_error-correction_of_streamflow_from_a_large-scale_hydrological_model_Using_model_state_variables_to_estimate_error_terms [accessed Jan 26 2022].

[10] Weedon, Graham & Gomes, S. & Viterbo, Pedro & Shuttleworth, W. & Blyth, Eleanor & Österle, H. & Adam, J. & Bellouin, N. & Boucher, Olivier & Best, M.. (2011). Creation of the WATCH Forcing Data and Its Use to Assess Global and Regional Reference Crop Evaporation over Land during the Twentieth Century. Journal of Hydrometeorology. 12. 823-848. 10.1175/2011JHM1369.1.

[11] Hempel, Sabrina & Frieler, Katja & Warszawski, Lila & Schewe, Jacob & Piontek, Franziska. (2013). A trend-preserving bias correction – The ISI-MIP approach. Earth System Dynamics Discussions. 4. 49. 10.5194/esdd-4-49-2013.

[12] FM Global. Available at https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map

[13] WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

[14] WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

[15] Muis, S., M. Verlaan, H. C. Winsemius, J. C. J. H. Aerts, and P. J. Ward (2016), A global reanalysis of storm surge and extreme sea levels, Nat. Commun., 7(11969), 1– 11. doi:10.1038/ncomms11969

No.	Parameter	Description
		from the European Centre for Medium Range Weather Forecasts (ECMWF) Re-analysis-Interim (ERA-Interim) dataset[16]. Tide is simulated using a separate model, the Finite Element Solution 2012 (FES 2012) model[17].

5.2.1 BASELINE HAZARD

5.2.1.1 RIVERINE AND COASTAL FLOOD HAZARD

The baseline riverine flood hazard and the riverine flood risk are presented in ***Figure 5.10***. Catchment level riverine flood risk based on population and economic exposure to floods was reported to be 'Extremely High'. Moreover, the riverine hazard map indicates a low flood hazard with an estimated inundation depth range between 0.5 m to more than 1.5 m near the airport boundary.

The coastal inundation map representing the depth of inundation under a flood with 100-year return period indicated no inundation in the airport boundary. Together with the coastal flood risk was reported to be 'Low to Medium' as presented in ***Figure 5.11***. Based on the distance between the airport and the coast (>100 km), the coastal flood hazard is considered as "Low"

Moreover, the flood hazard zone was compiled using the Natural Hazard toolkit created by FM Global. The Worldwide Flood Map currently displays flood zones with high (100-year) and moderate (500-year) hazards. It indicates a high probability of occurrence of flood hazards in the airport boundary as shown in ***Figure 5.12***.

Based on the hazard categorization in ***Table 4.1***, the flood risk will be "High" and "Low" for the riverine flood risk and coastal flood risk respectively.

However, considering the worst-case scenario, the hazard due to flooding is considered to be **"High"** on a conservative basis based on the 'High' hazard level associated to riverine flood hazard.

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[16] Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A.C.M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A.J., Haimberger, L., Healy, S.B., Hersbach, H., Hólm, E.V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A.P., Monge-Sanz, B.M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553-597. https://doi.org/10.1002/qj.828

[17] Carrere, Loren & Lyard, F.. (2003). Modeling the barotropic response of the global ocean to atmospheric wind and pressure forcing Comparisons with observations. Geophysical Research Letters. 30. 10.1029/2002GL016473 .

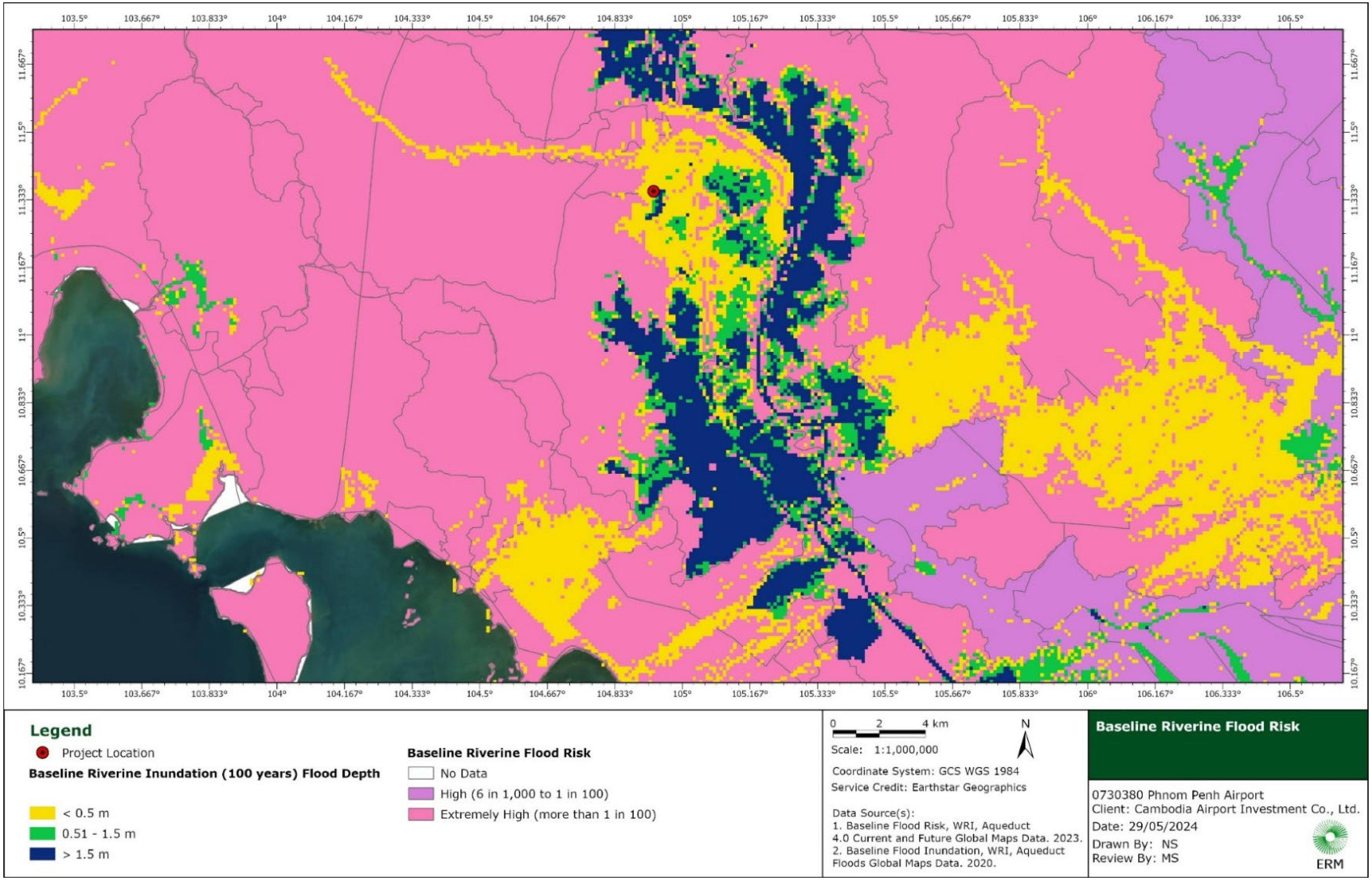

FIGURE 5.10 BASELINE RIVERINE FLOOD HAZARD (INUNDATION) AND RIVERINE FLOOD RISK MAP

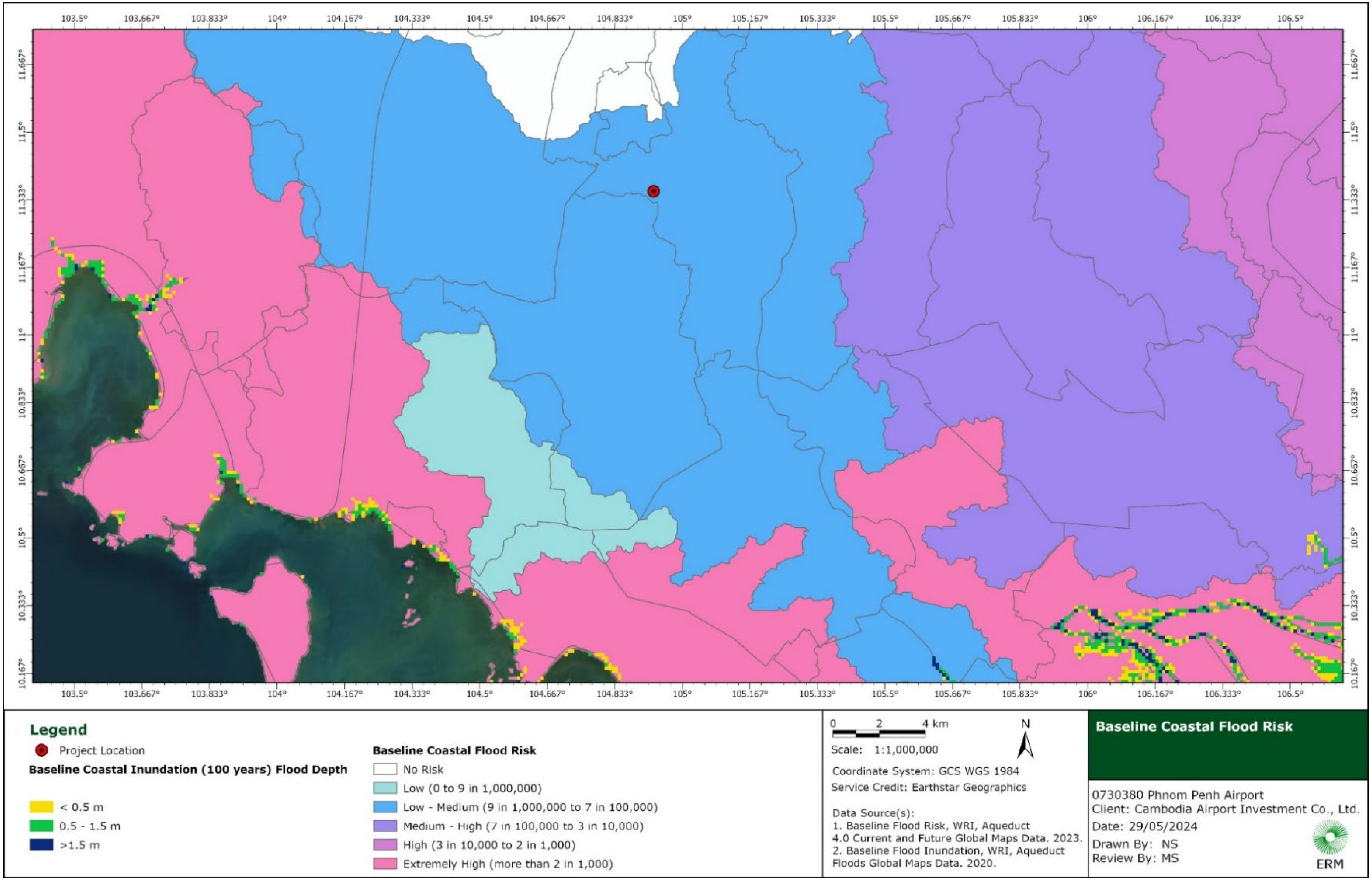

FIGURE 5.11 BASELINE COASTAL FLOOD HAZARD (INUNDATION) COASTAL FLOOD RISK MAP

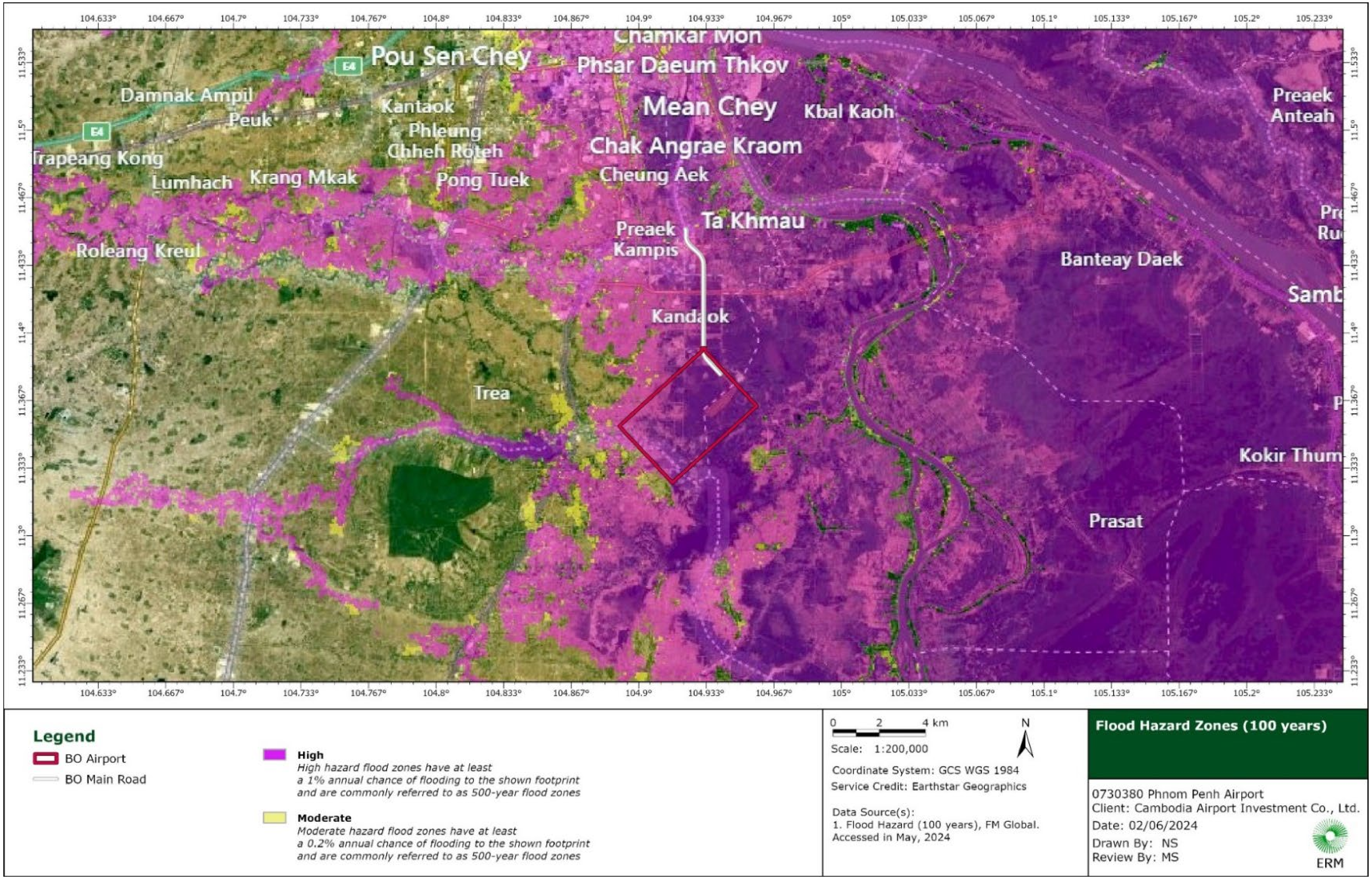

FIGURE 5.12 BASELINE FLOOD HAZARD MAP

Source: FM Global All Rights Reserved. Available at: *https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map#*

5.2.2 CLIMATE CHANGE PROJECTIONS

Flood risk maps under climate change scenario from WRI-Aqueduct Flood Tool were evaluated to assess the future flood hazard under climate change scenario. ***Figure 5.13*** and ***Figure 5.14*** present the coastal flood maps with no inundation for climate change scenarios of RCP 8.5 2030 and 2050 respectively. ***Figure 5.15*** and ***Figure 5.16*** present the riverine flooding for climate change scenarios of RCP 8.5 2030 and 2050 respectively. Accordingly, the flood hazard due to riverine flooding is projected to remain 'High' with flood inundation depth 0.5 m to more than 1.5 m.

Moreover, the Project is located in the floodplain of Mekong/Bassac River. The Project ground elevation level ranges from 1 m to 10 m. Hence, if the flood inundation is higher than 1.5 m, the Project could experience flooding risk. Hence, the overall flood hazard is considered to remain same as the baseline i.e. “High”

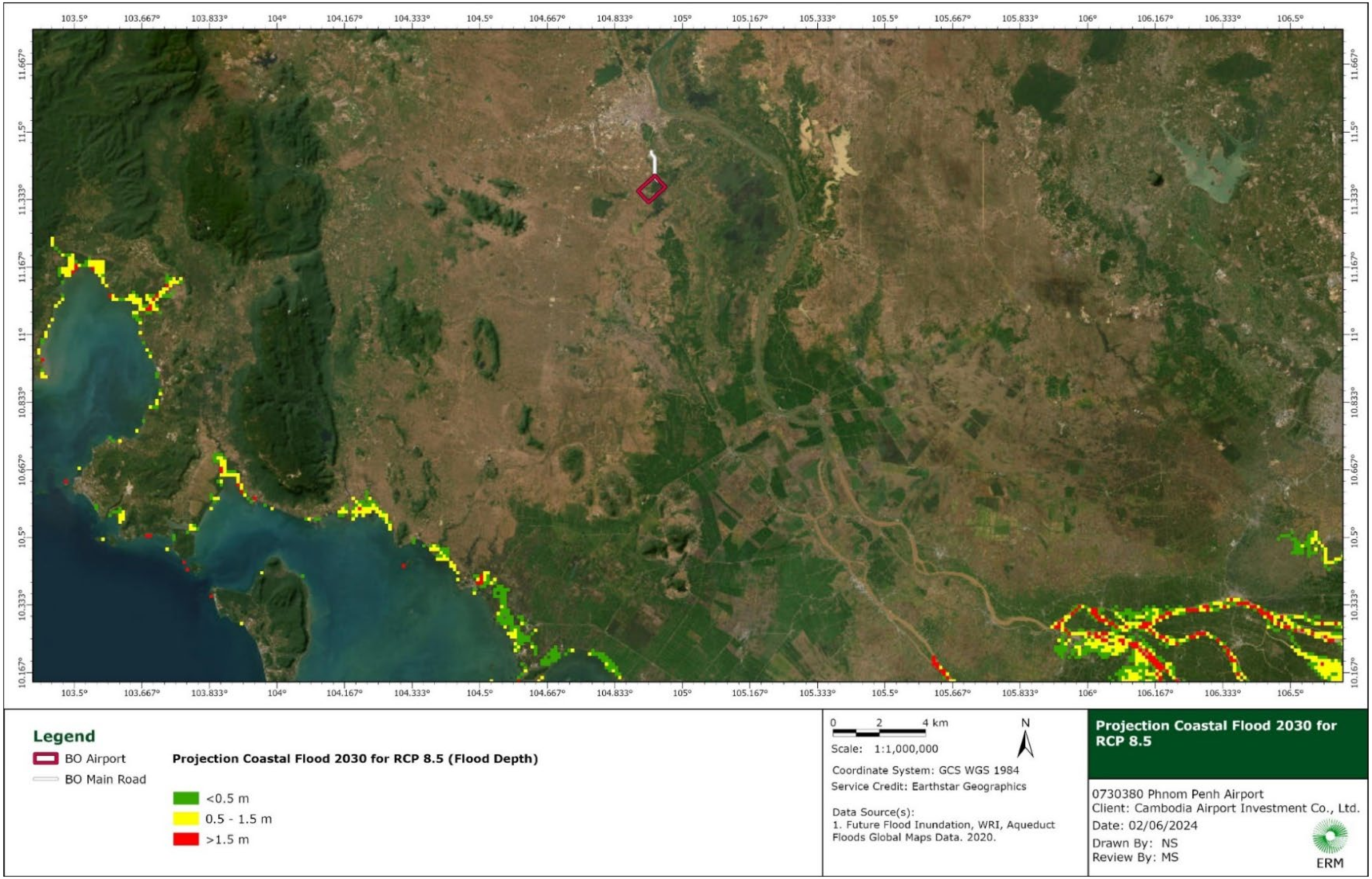

FIGURE 5.13 PROJECTIONS OF COASTAL FLOOD HAZARD 2030 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at https://www.wri.org/applications/aqueduct/floods/

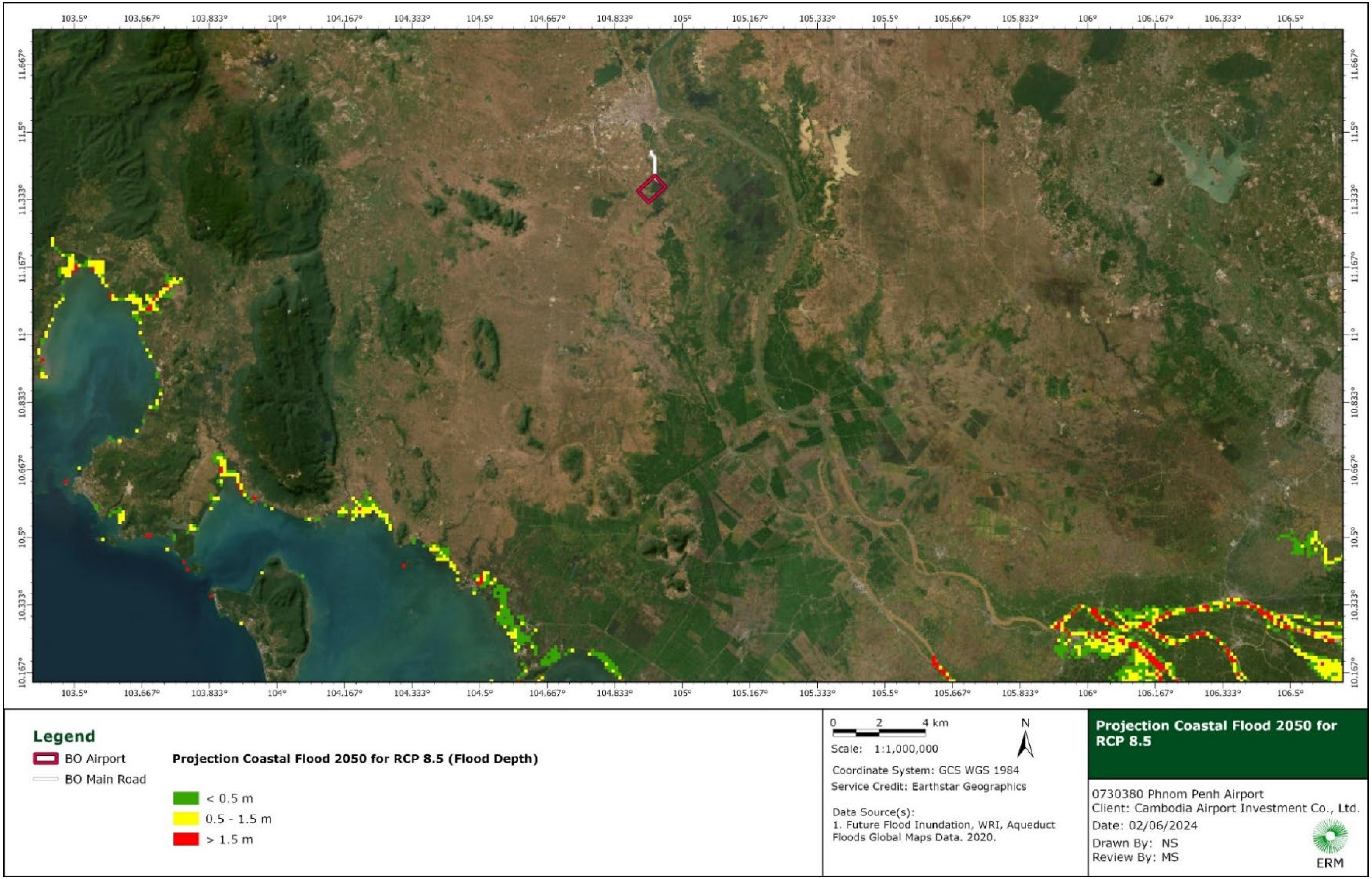

FIGURE 5.14 PROJECTIONS OF COASTAL FLOOD HAZARD 2050 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at https://www.wri.org/applications/aqueduct/floods/

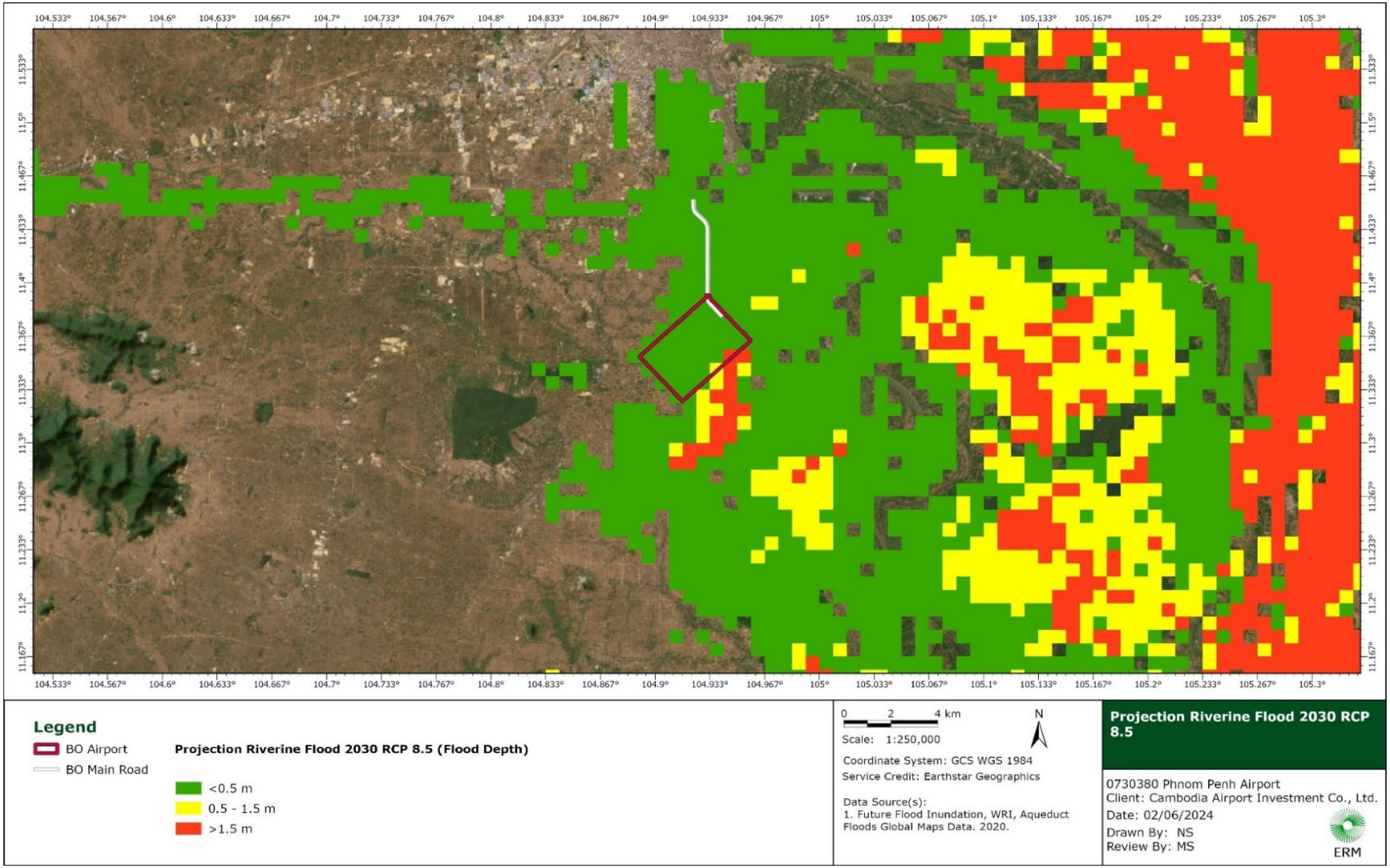

FIGURE 5.15 PROJECTIONS OF RIVERINE FLOOD HAZARD 2030 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at https://www.wri.org/applications/aqueduct/floods/

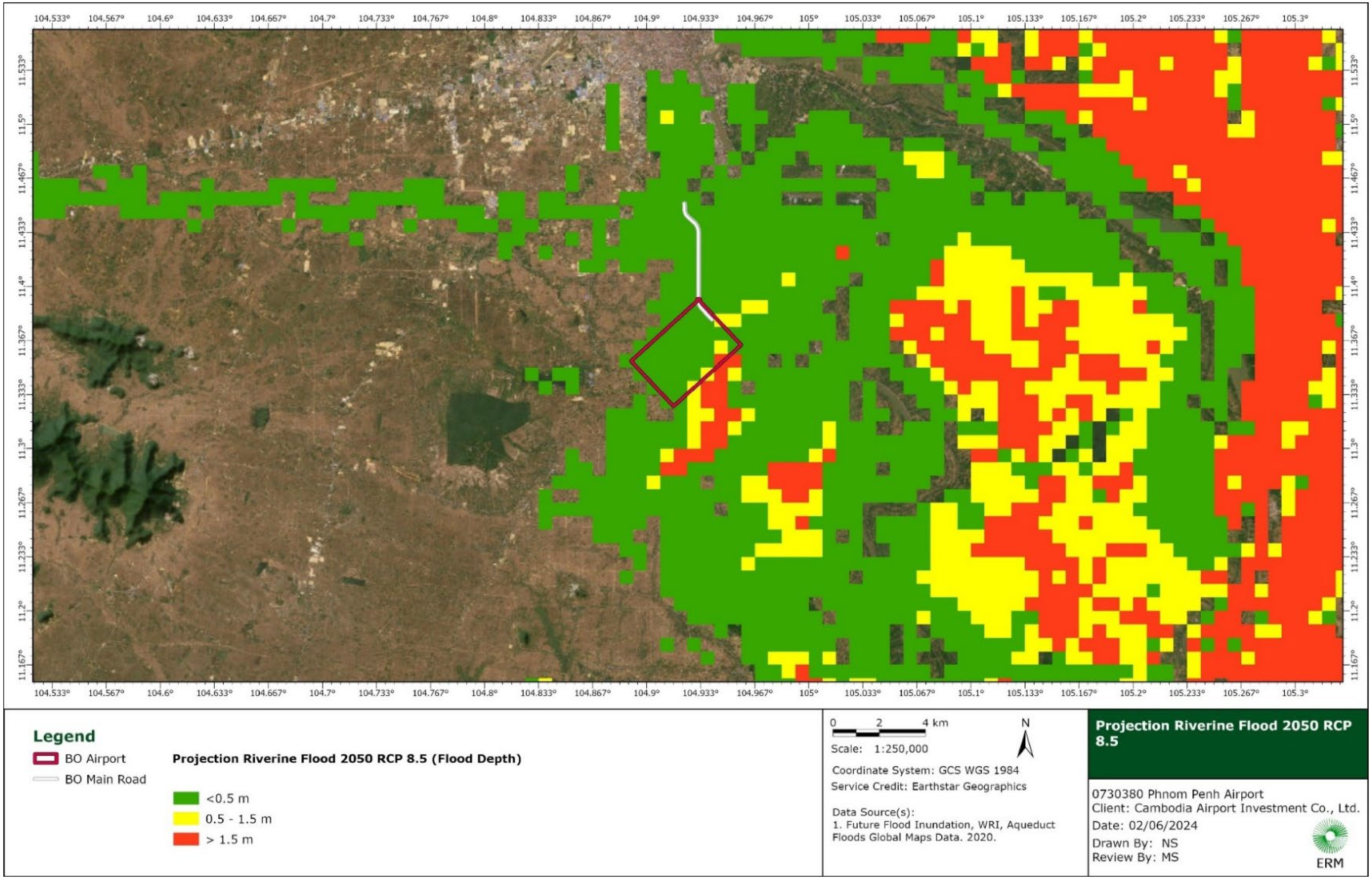

FIGURE 5.16 PROJECTIONS OF RIVERINE FLOOD HAZARD 2050 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at https://www.wri.org/applications/aqueduct/floods/

5.2.3 EXPOSURE AND VULNERABILITY

The airport occupies a relatively low-lying area next to the Bassac River, susceptible to seasonal river flooding, which makes the airport exposed to the movement of water on the runway. Typically, floods would disrupt the operation of the airport, preventing the planes from landing or taking off. However, a flood risk assessment was conducted in the EIA, this assessment identified a series of mitigation measures for drainage and flood prevention to safeguard the Project facilities from flooding. The flood protection will include by developing on key infrastructure designation includes:

Final formation grading: Being in a polder allows for drainage design to prioritize water flow. The final ground level will slope slightly towards retention ponds (approximately + 7.5 for the central area to approximately + 3 m for the retention area), with the furthest areas needing to be higher to accommodate the distance.

Dike and Ring Drain: A channel will run along the inside of the dike to collect water from retention ponds and connect them to pumping stations.

Collector Drain: Concrete canals will be built around the airport to collect rainwater. A central collector drain will gather water from between runways and direct it to a main drain.

Retention Ponds: A 160-hectare area will be designated for retention ponds to store excess rainwater.

Pump Stations: Pumps will be used only when the amount of rainwater exceeds the capacity of the retention ponds. They will remove excess water in an environmentally friendly way. The proposed pump capacity lies between 6 and 8 m^3/s.

However, there is a possibility of extremely heavy rainfall exceeding their capacity. If the pumps are overwhelmed or malfunction during such an event, flooding could still occur. Hence, it is important to acknowledge the potential limitations and ensure proper maintenance to minimize the risk of flooding events.

Furthermore, flooding may have a potential indirect impact on passengers by disrupting the transport route from the city to the airport. To address this concern, according to the information from Khmer Times news[18] [19], Overseas Cambodia Investment Corp (OCIC) stated that the Project will construct an expressway (flyover) directly connecting the city center to the new airport. The flyover is expected to be done after the new airport is done. This elevated roadway will mitigate disruptions to passenger access caused by flooding in surrounding areas.

Considering the information provided, the Project exposure and vulnerability level is categorized as **"Medium".**

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[18] Capital's new airport construction largely unaffected by days of deluges, Khmer Times. Accessed via https://www.khmertimeskh.com/50774849/capitals-new-airport-construction-largely-unaffected-by-days-of-deluges/

[19] Expressway announced linking city centre to new Phnom Penh International Airport, Khmer Times. Accessed via https://www.khmertimeskh.com/50798316/expressway-announced-linking-city-centre-to-new-phnom-penh-international-airport/

5.2.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.3 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR FLOOD

<table>
<tr><th></th><th colspan="2">Baseline</th><th>RCP 8.5 - 2030</th><th>RCP 8.5 - 2050</th></tr>
<tr><td>Hazard Level</td><td colspan="2">High</td><td>High</td><td>High</td></tr>
<tr><td>Exposure x Vulnerab. Level</td><td colspan="2">Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Risk Level</td><td colspan="2">Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td rowspan="3">Implications for the Project</td><td>Terminal</td><td colspan="3">Flooding can cause damage to the terminal facility. However, the drainage systems have been deployed so, the terminal is not expected to be affected by flooding</td></tr>
<tr><td>Runway and Taxi way</td><td colspan="3">Flooding can inundate runways and taxiways, which would severely disrupt airport operations by preventing aircraft from landing and departing. Further mitigation measures may be necessary to ensure operational continuity.</td></tr>
<tr><td>Control Tower</td><td colspan="3">Flooding poses a high risk to the control tower, potentially damaging both the structure and critical electrical systems. This could render the tower inoperable. However, the drainage systems in place provide protection, reducing the likelihood of operational failure.</td></tr>
<tr><td>Key Potential Impacts</td><td colspan="4">▪ Based on the mitigation measures established in the EIA, negligible potential impacts have been identified</td></tr>
<tr><td>Implemented Mitigations</td><td colspan="4">▪ Since the Project already has a Flood Management Plan, it's crucial to conduct regular reviews to identify areas for improvement and ensure the plan remains applicable. However, the project located in high flood risk, hence the flood management plan shall be reassessed frequently or every post flood event.
▪ Regularly checking the drainage system and pump station helps ensure the infrastructure operates at maximum capacity.
▪ To supplement the constructed drainage systems, the project shall employ natural alternatives such as the installation of retention ponds to absorb excess water naturally. These approaches reduce runoff, reduce tension in drainage systems, and improve long-term flood resistance.
▪ Flood modeling is needed performed at the project site to forecast future flood levels. Previous Environmental Impact Assessment (ESIA) research included flood risk in the design of permanent dikes and ground levels; however, further modeling will provide a better understanding of potential flood scenarios. The dikes shall be constructed to a height of +9.7 meters above mean sea level (msl) for the year 2040 and elevated to +11.0 msl for long-term protection[20].
▪ Establish effective waste management protocols to prevent soil waste, debris, and additional waste from blocking waterways during site clearance operations.</td></tr>
</table>

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[20] ESIA Report of New Phnom Penh International Airport (NPPIA). 2020

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
	▪ Collaborate with local emergency management agencies and meteorological departments to stay informed about weather forecasts and flood warnings.		

5.3 LANDSLIDES

As per the USGS, a landslide is defined as the movement of a mass of rock, debris, or earth down a slope. Several factors are responsible for occurrence of landslides. Some of these are poor mechanical stability, heavy rainfall events, geological formation, earthquake, vibration (mechanical) and slope, and could be influenced largely by human activities at a local level. Some of the human activities which are likely to cause or aggravate landslides are deforestation, cultivation, construction, vibration from heavy machinery and traffic, blasting and mining activities, and large and unstable earthwork/ excavation.

Landslides can cause wide stream damage such as disruption of infrastructure in form of roads and highways, damage to structures/buildings, power transmission lines and burial or damage of settlements resulting in loss of life.

Landslides have been assessed using two features: susceptibility and hazard.

Landslide susceptibility describes the structural properties of terrain and geomorphology that make an area prone to landslide, e.g. geology, slope angle, elevation etc. However, an area prone/susceptible to landslide needs a trigger to manifest the landslide event. Precipitation is the most common trigger, but it can be initiated by earthquake or human event as well. The combination of susceptibility and availability of triggers is used to estimate the landslide hazard.

In this assessment, the landslide hazard at the airport boundary was evaluated based on the landslides due to precipitation as precipitation is anticipated to be influenced by climate change.

An area can be highly susceptible to landslide but low hazard when there are limited triggers, for example a slopy area with scarce vegetation but in an arid region. Similarly, an area can be of low landslide susceptibility but high landslide hazard if there is the potential for a sufficiently large trigger. The Global Facility for Disaster Reduction and Recovery provides data landslides hazard due to precipitation. The data is in the form of raster images with land slide hazard classified in four classes: Very low, Low, Medium, and High.

5.3.1 BASELINE HAZARD

Figure 5.17 shows a map of landslide hazard based on mean annual precipitation. According to the map, the airport is located in an area with no landslide risk.

A separate analysis, presented in ***Figure 5.18***, indicates that overall landslide susceptibility in the study area is ‘Low’. This means landslides rarely occur in the area.

Consider the hazard categorization as shows in ***Table 4.1***, the hazard level is considered as "Low”.

Moreover, it was reported that the total baseline landslides hazard is ‘very low’ as ***Figure 5.19***. Based on the information from public databases and site observations, the hazard level for landslides is categorized as **“Low”**.

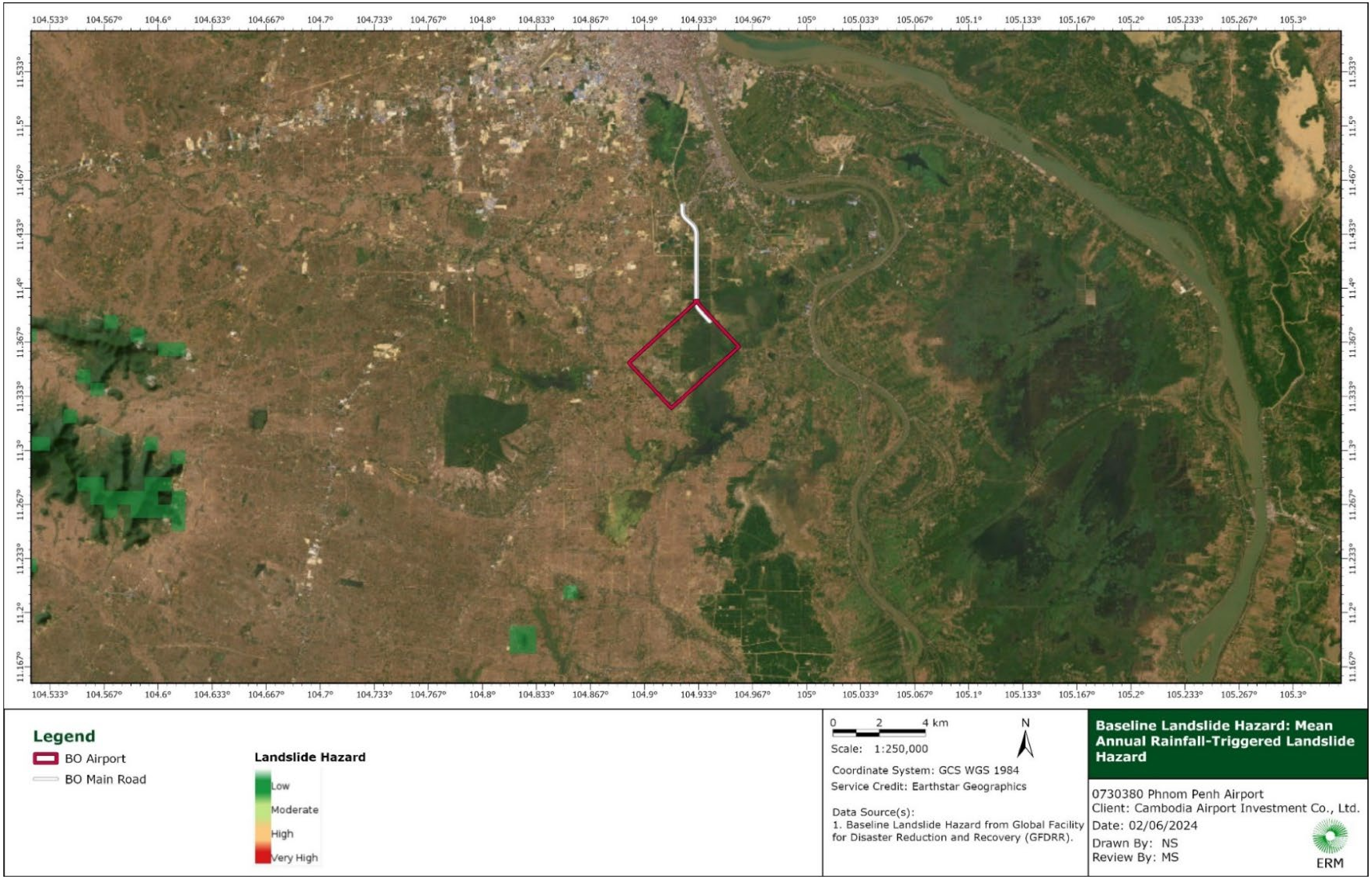

FIGURE 5.17 BASELINE LANDSLIDE HAZARD: MEAN ANNUAL RAINFALL-TRIGGERED LANDSLIDE HAZARD

Source: Global Facility for Disaster Reduction and Recovery (GFDRR). Available at https://www.geonode-gfdrrlab.org/

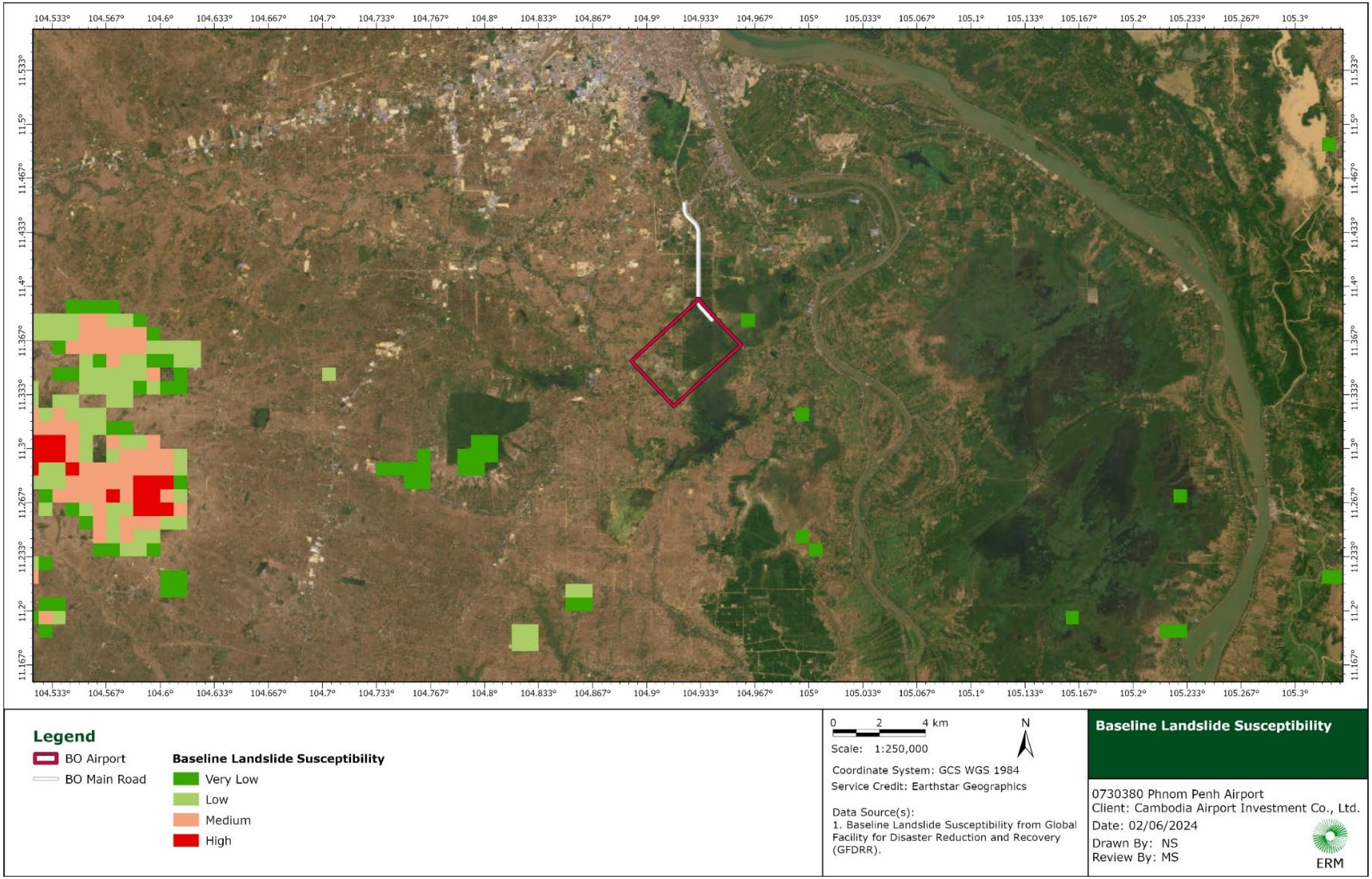

FIGURE 5.18 BASELINE LANDSLIDE SUSCEPTIBILITY

Source: Global Facility for Disaster Reduction and Recovery (GFDRR). Available at https://www.geonode-gfdrrlab.org/

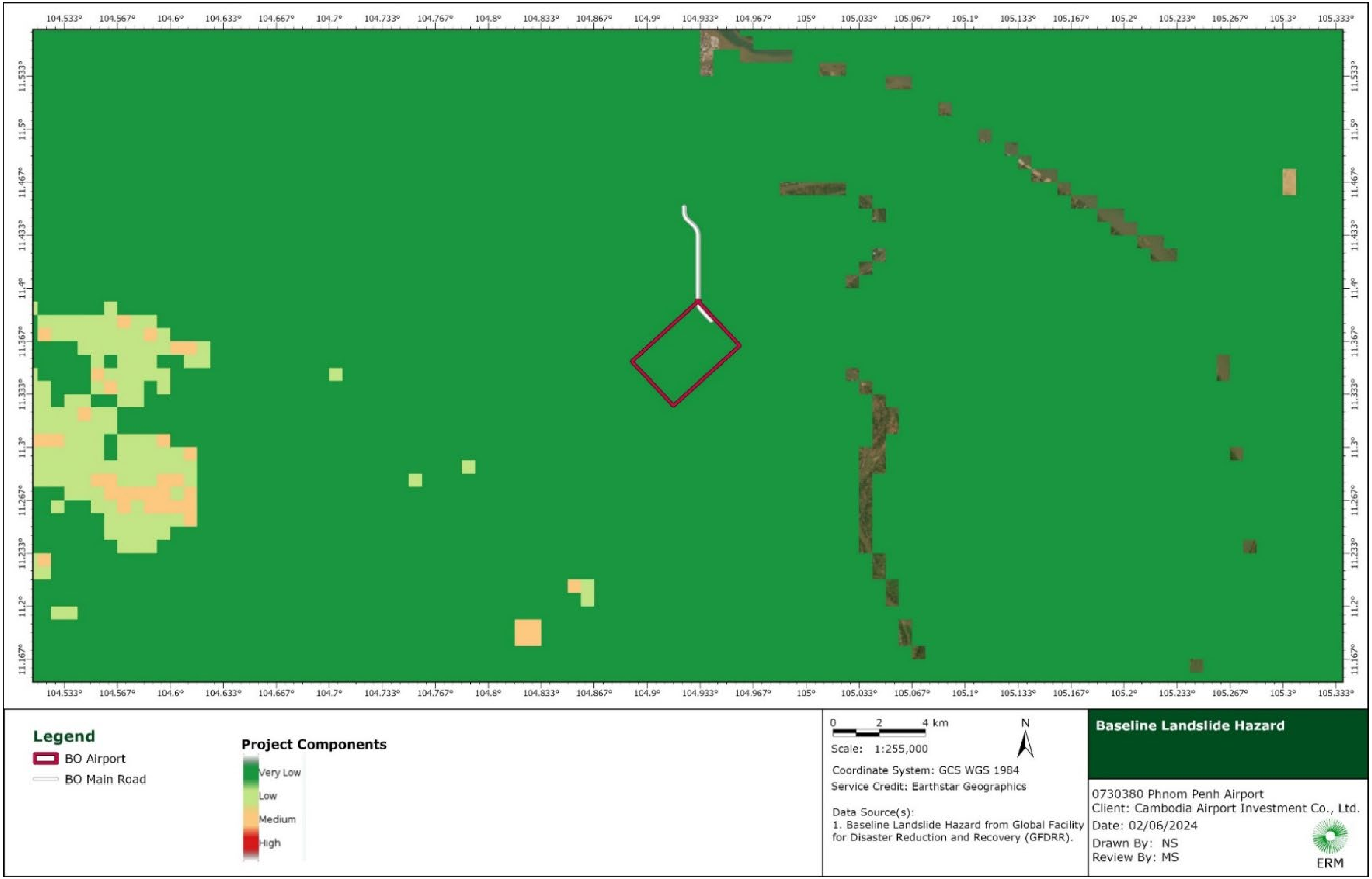

FIGURE 5.19 BASELINE LANDSLIDE HAZARD

Source: Global Facility for Disaster Reduction and Recovery (GFDRR). Available at https://www.geonode-gfdrrlab.org/

5.3.2 CLIMATE CHANGE PROJECTIONS

The likelihood of landslides can be monitored by tracking rainfall patterns. Heavier rainfall events can increase the risk of landslides.

However, since the airport is located on flat terrain, landslides are much less likely to be a concern in this area.

Therefore, considering the specific characteristics of the Project location, the risk of landslides appears to be **"Low"** under climate change projection.

5.3.3 EXPOSURE AND VULNERABILITY

The Project has no exposure to and vulnerability to landslides as its structure requires a wide and flat surface to operate. The airport includes a buffer around its facility that further reduces any risk of landslide reaching the runway, taxiway, and any other Project facility.

Considering the factors mentioned above, the level of exposure and vulnerability is assigned as **"Low"**.

5.3.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.4 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR LANDSLIDES

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Low**	**Low**	**Low**
Exposure x Vulnerab. Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	Terminal	Given the flat area and structure of the terminal, no implications were identified.	
	Runway and Taxiway	Given the flat area and structure of the runway and taxiway, no implications were identified.	
	Control Tower	Landslides may damage power lines and communication cables, affecting critical services which include air traffic control and lighting systems. However, it is not expected that landslides would have an impact on the control power due to the low risk of landslides.	
Key Potential Impacts	▪ It is not expected that landslides would have an impact on the Project due to the wide flat surface of the airport located in a lowland flat area.		
Implemented Mitigations	▪ None required.		

5.4 EXTREME HEAT

Extreme heat is defined based on the maximum extreme heat hazard level for the selected area. Hazard level reflects expected frequency of extreme heat conditions, using simulations of long-term variations in temperature and expert guidance. Extreme heat is assessed using a widely accepted heat stress indicator, the Wet Bulb Globe Temperature (°C)[21]. The WetBulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). It differs from the heat index, which takes into consideration temperature and humidity and is calculated for shaded areas. The WBGT has an obvious relevance for human health, but it is relevant in all kinds of Projects and sectors, including infrastructure related, as heat stress affects personnel and stakeholders, and therefore the design of buildings and infrastructure. In general, the WBGT is a relevant enough proxy to quantify the strain on physical infrastructure (energy, water, transport), such as increased demands for water and electricity, which may also affect decisions related to infrastructure.

5.4.1 BASELINE HAZARD

The hazard of extreme heat was evaluated on a regional level using the Think Hazard report in Kandal Stung District and Sa'ang District of Kandal province, and Bati District of Takeo Province[22]. In the airport boundary, the extreme heat hazard is classified as 'Medium' based on modeled heat information provided by ThinkHazard tool as illustrated in ***Figure 5.20***. The extreme heat hazard 20-year return period is approximately 32°C. The classification is based on hazard categorization as presented in ***Table 4.1***. Hence, the extreme heat hazard is categorized as **"Medium"**.

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[21] ThinkHazard. 2020. Sumba Timur: https://thinkhazard.org/en/report/18158-indonesia-nusatenggara-timur-sumba-timur/EH

[22] Think Hazard. [Available at: https://thinkhazard.org/]

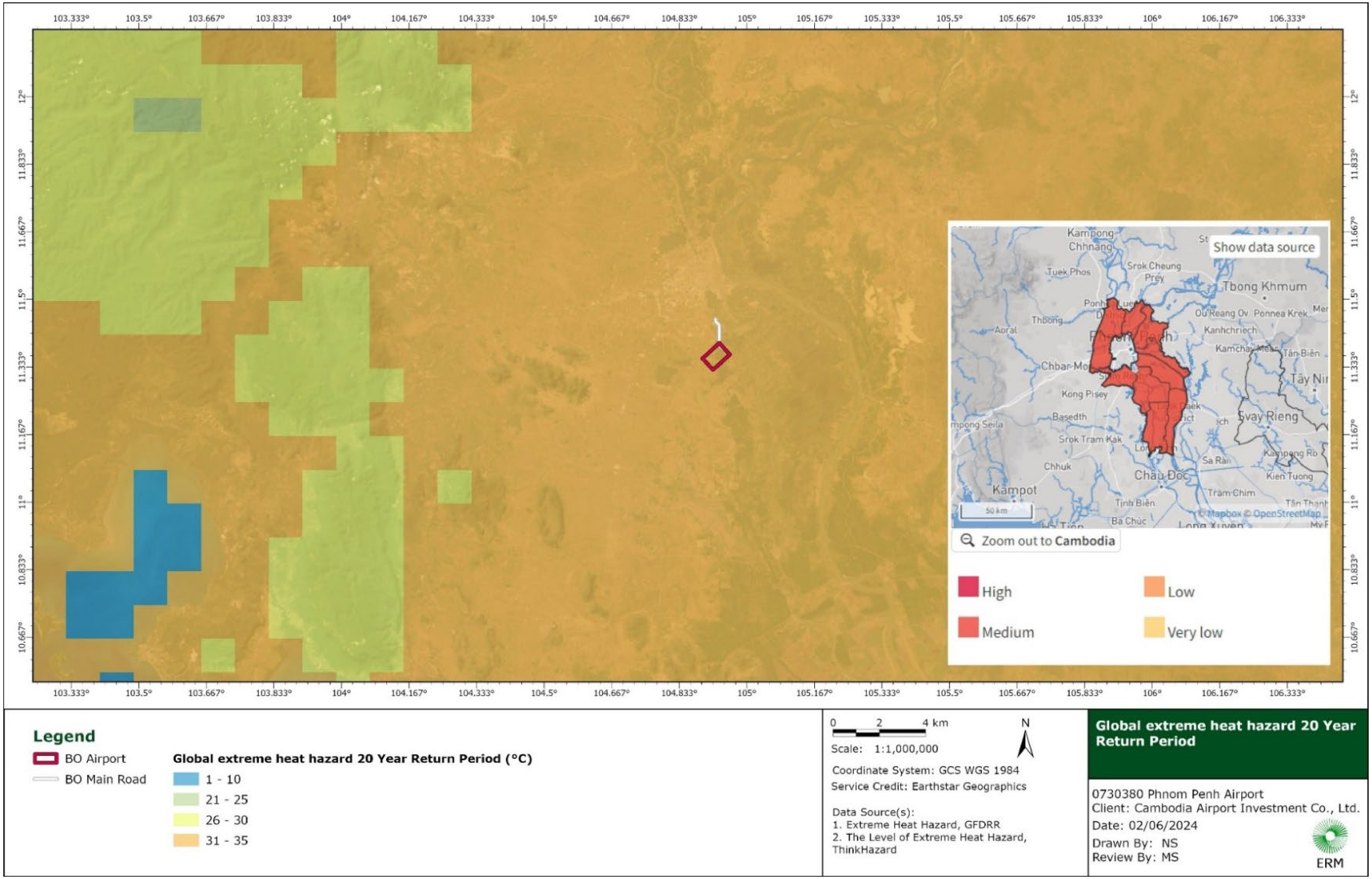

FIGURE 5.20 EXTREME HEAT HAZARD

Source: ThinkHazard. Available at https://thinkhazard.org/en/ and Global Facility for Disaster Reduction and Recovery (GFDRR). Available at https://www.geonode-gfdrrlab.org/

5.4.2 CLIMATE CHANGE PROJECTIONS

Climate change projections indicate an increase in maximum temperature and warm spell duration.

In the short-term outlook (2041~2050) for temperature and extreme climate events, it is predicted that the average maximum of daily max-temperature will increase by +1.4°C to +1.66°C in the RCP 8.5 scenario[23] compared to the 1995~2014 average.

The World Bank Group's (WBG) climate country profile for Cambodia Projects a significant increase in the number of extremely hot days by mid-century. According to the report, the average annual number of days with a Heat Index exceeding 35°C is expected to rise nationally from the 1995-2014 reference period to 60.17 days (range: 39.43 to 87.01 days) over 2020-2039, and further increase to 82.87 days (range: 46.73 to 124.53 days) by midcentury[24].

Based on the information above and considering the baseline extreme heat temperature and the projected temperature increase, the temperature will exceed 32°C which is the 'High' level of the extreme heat hazard level.

Accordingly, the hazard due to extreme heat is considered to be **"High"** under future climate change scenarios.

5.4.3 EXPOSURE AND VULNERABILITY

Climate change is expected to cause an increase in the frequency and intensity of extreme heat occurrences.

Extreme heat poses significant challenges for airport operations in Cambodia. Passengers waiting in hot terminals face a heightened risk of heat exhaustion and heatstroke, particularly vulnerable groups like young children and the elderly. This risk extends to ground operations staff who work outside or directly exposed to the heat.

Beyond passenger and staff well-being, extreme heat can also damage critical equipment. There is also a risk that buildings designed for temperate rises will be unable to maintain cool during heat waves, leading equipment to overheat and threaten workers[25]. Increasing ambient temperatures due to climate change may also affect the structural integrity of the runways causing them to buckle and creating safety hazards for aircraft. However, considering the materials designed by using heat resistance or reflective surface materials can also help reduce heat absorption[26].

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[23] Climate Change Knowledge Portal for Development Practitioners and Policy Makers. Available at https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-projections. Accessed in May, 2024.

[24] Climate Change Country Profile, Cambodia by World Bank Group (WBG). Accessed on 05 June 2024 via https://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/16814-WB_Cambodia%20Country%20Profile-WEB.pdf

[25] Here are all the ways climate change will ruin your flight, Look forward to disruptions related to heat, wind, and water by Kate Baggaley. Accessed via https://www.popsci.com/climate-change-travel-flying-planes/

[26] How Airports Can Plan For & Overcome Extreme Weather Conditions, Michael Tanser, i6 Group Ltd. Access via https://www.i6.io/blog/how-airports-can-plan-for-and-overcome-extreme-weather-conditions

The impact of heat extends to aircraft performance as well. Hotter air has lower density, reducing the lift an aircraft can generate. For every 3 degrees Celsius increase in temperature, planes lose 1% of their initial lift[27]. This translates to limitations on the maximum weight an aircraft can safely take off with. Additionally, reduced lift due to hot air may necessitate increased takeoff distances and slower climb rates[28].

Hence, heat significantly impacts the takeoff phase of flight, increasing the risk of accidents due to factors such as reduced air density, engine performance degradation, and longer required takeoff distances. It is crucial for airports and aviation authorities to consider these impacts when planning for operational procedures, runway design, and safety measures.

Considering the information provided, the Project's exposure and vulnerability level is categorized as **"Medium".**

5.4.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.5 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR EXTREME HEAT

<table>
<tr><th></th><th colspan="2">Baseline</th><th>RCP 8.5 - 2030</th><th>RCP 8.5 - 2050</th></tr>
<tr><td>Hazard Level</td><td colspan="2">Medium</td><td>High</td><td>High</td></tr>
<tr><td>Exposure x Vulnerab. Level</td><td colspan="2">Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Risk Level</td><td colspan="2">Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td rowspan="2">Implications for the Project</td><td>Terminal</td><td colspan="3">Extreme heat may make airport waiting rooms, offices, and workstations uncomfortable and risky for passengers and crew. Terminal building design by insulation and passive cooling can help maintain cooler interior temperatures.</td></tr>
<tr><td>Runway and Taxiway</td><td colspan="3">Extreme heat could affect the well-being of personnel working on the maintenance period or ground operation. The worker should consider having heat protection equipment during the operation and maintenance time. High temperatures can make waiting areas uncomfortable, leading to increased fatigue and discomfort among passengers,</td></tr>
</table>

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[27] Why high temperatures can make planes too heavy to take off. By Jacopo Prisco, CNN. Access via https://edition.cnn.com/travel/article/climate-change-airplane-takeoff-scn/index.html

[28] Hot Weather Operations by Skybrary. Accessed on 05 June 2024 via https://skybrary.aero/articles/hot-weather-operations

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
		particularly those who board on the ground or wait in outdoor areas.	
	Control Tower	Sensitive electronic equipment used for air traffic control, communication systems, and security screening could malfunction due to excessive heat. Cooling systems and insulation must be optimized to maintain operational efficiency and safety of equipment in high temperatures.	
Key Potential Impacts	▪ Heat stress or heat exhaustion for personnel operating for the ground operation staff and passengers. ▪ Higher temperatures decrease air density, reducing lift for aircraft. This requires longer runways for takeoff which possibly causing flight delays due to the safety of aircraft taking off ▪ Heat-sensitive ground equipment, including fuel trucks, baggage handling systems, and airside vehicles, may experience a higher risk of breakdowns or malfunctions.		
Implemented Mitigations	▪ Use building materials designed to withstand high temperatures, such as heat-reflective glass and insulating materials, to maintain safe internal temperatures in control towers, terminals, and other facilities. ▪ Construct taxiways with materials designed to withstand extreme temperatures and reduce the risk of deformation or damage. ▪ Integrate building insulation techniques and incorporate passive cooling techniques in terminal and control tower and utilizing natural ventilation systems to promote airflow, helping to cool interior spaces design to maintain cooler interior temperatures. ▪ Establish air-conditioned shelters or shaded rest areas for airport staff and passengers to escape extreme heat, especially for those involved in outdoor activities like ground operations. ▪ Utilize real-time data to optimize flight plans based on current temperature conditions and conduct regular training sessions for airport staff on recognizing symptoms of heat stress and implementing the emergency response plan for protection of workers and passengers.		

5.5 CYCLONE AND HURRICANE

As per the American Meteorological Society, a cyclone or hurricane is a large-scale air mass that rotates around a strong centre of low atmospheric pressure. Tropical cyclones are formed over oceans due to conducive and coinciding conditions such as warm sea surface temperatures, atmospheric instability, high humidity in the lower and middle levels of troposphere, Coriolis force to develop low pressure centre and low vertical wind shear. Cyclones bring high wind speeds and heavy downpour with them, which are likely to cause disruption to infrastructure, structures, flooding and other damage to buildings and natural environment.

For this assessment, cyclone hazard at the airport boundary was evaluated based on cyclone intensity United Nations Environment Programme (UNEP) Global Data Platform, cyclone frequency data from Socioeconomic Data and Applications Center (SEDAC), and historical hurricane tracks data from National Oceanic and Atmospheric Administration (NOAA).

5.5.1 BASELINE HAZARD

The cyclonic storms are generally classified into five (5) categories based on Saffir-Simpson categorization of hurricanes as summarized in ***Table 5.6***.

Figure 5.21 and ***Figure 5.22*** present the cyclone intensity, and historical hurricane track maps within the airport boundary. The historical data is generally available since 1842 as per NOAA29. Looking at the specific Project location, the airport boundary has never experienced cyclones. Furthermore, a review of historical tracks captured by NOAA since 1842 indicates 4 storms (including one (1) tropical storm and eight (8) tropical depressions have passed within 100 km radial distance from the Project (11.3539°N, 104.9291°E).

The maximum wind speed recorded within a 100 km radius of the Project location was reported to be 55.56 km/h (30 knots) during the tropical storm GILDA in 1959 (as per NOAA) as presented in ***Figure 5.23***.

Based on these maps, cyclone hazard was evaluated as **"Low"**.

TABLE 5.6 SAFFIR-SIMPSON CATEGORIZATION OF CYCLONE/HURRICANE

Hurricane Category	Wind Speed Criteria (km/h)
Tropical Storm	<119
Category 1	119-153
Category 2	154-177
Category 3	178-208
Category 4	209-251
Category 5	>251

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[29] National Oceanic and Atmospheric Administration (NOAA). Available at https://coast.noaa.gov/hurricanes

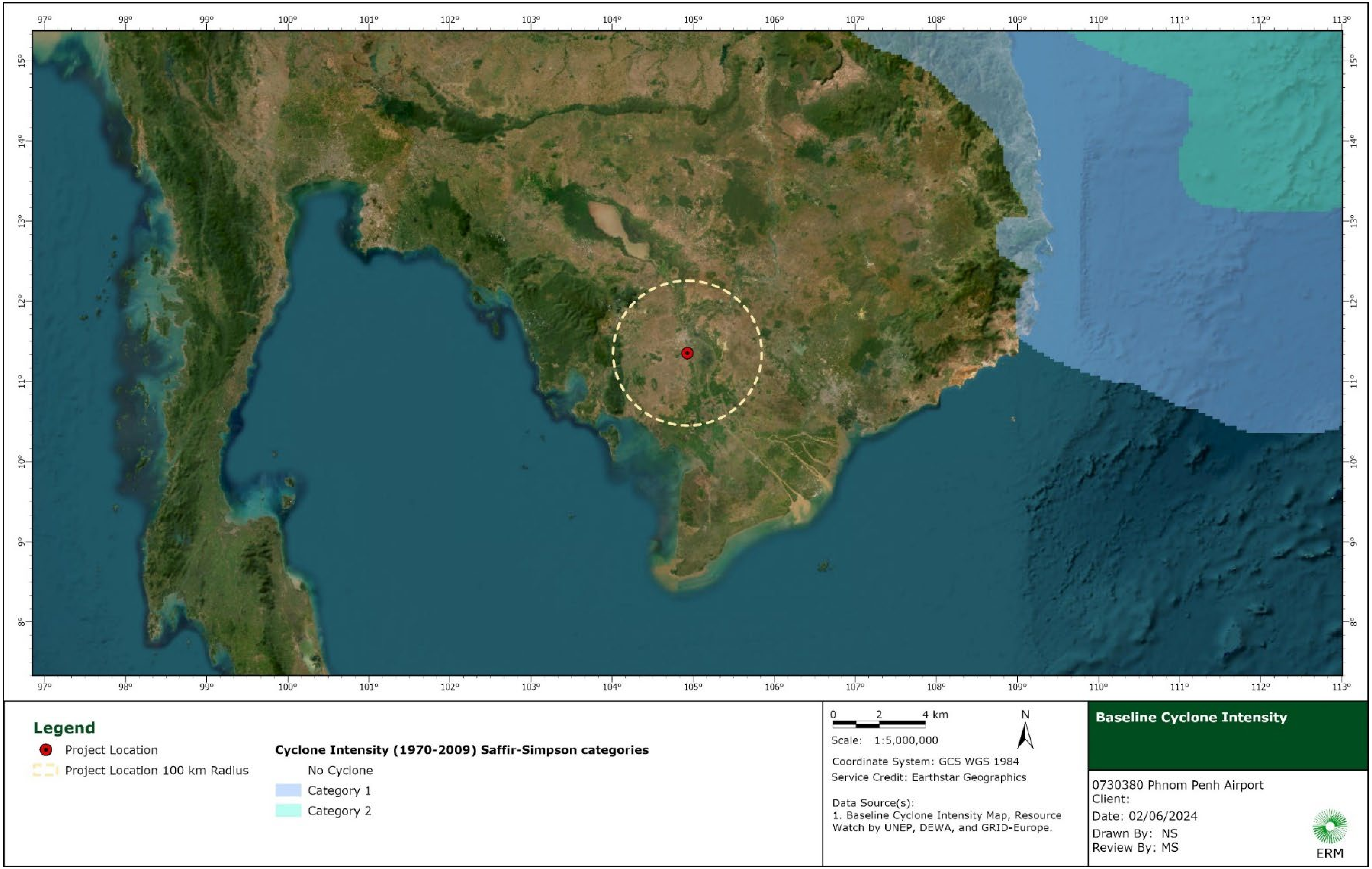


FIGURE 5.21 BASELINE CYCLONE INTENSITY MAP

Source: Modified from International Best Track Archive for Climate Stewardship (IBTrACS) from NOAA. Available at: [Index of /data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/shapefile (noaa.gov)]

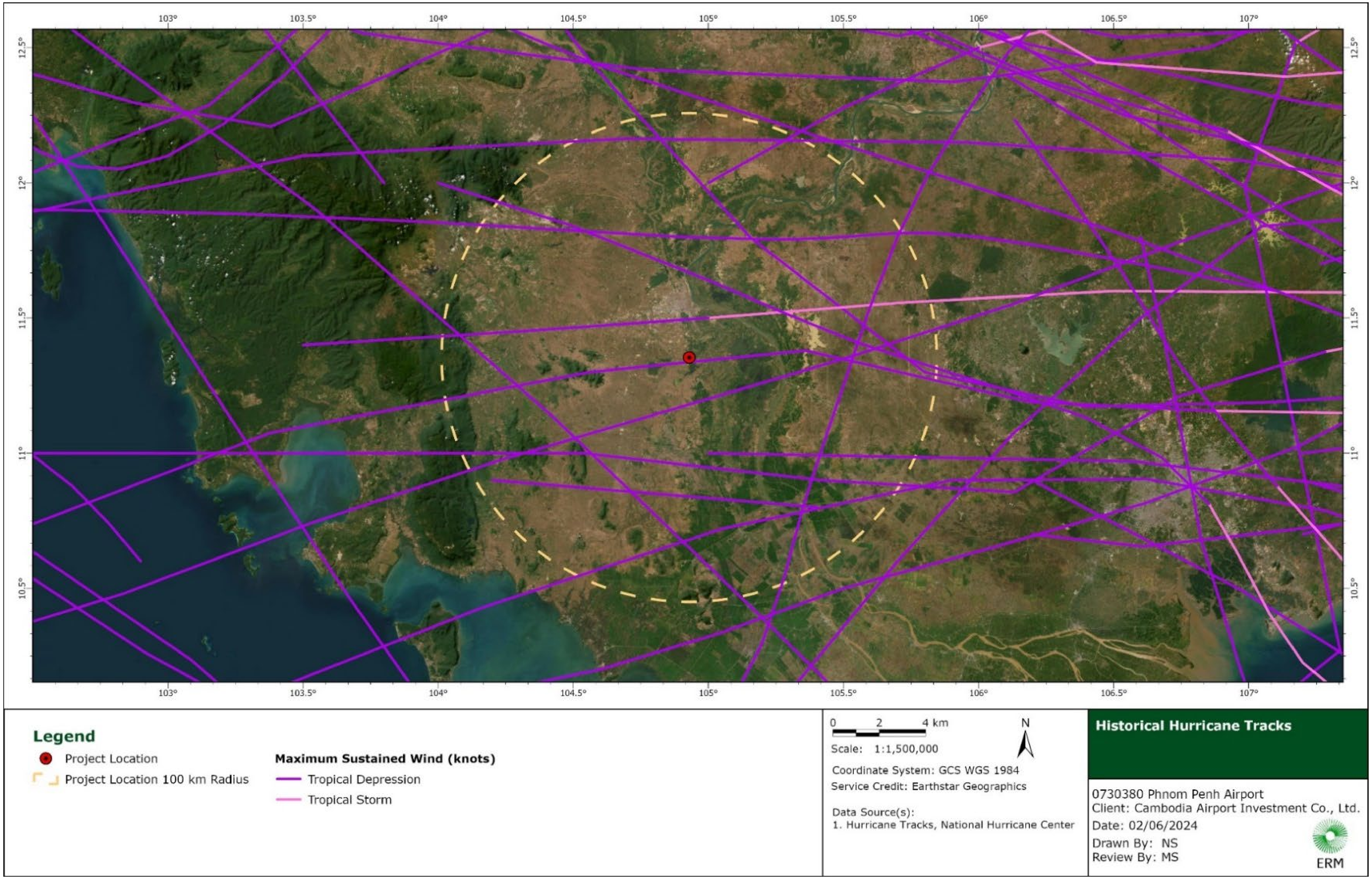
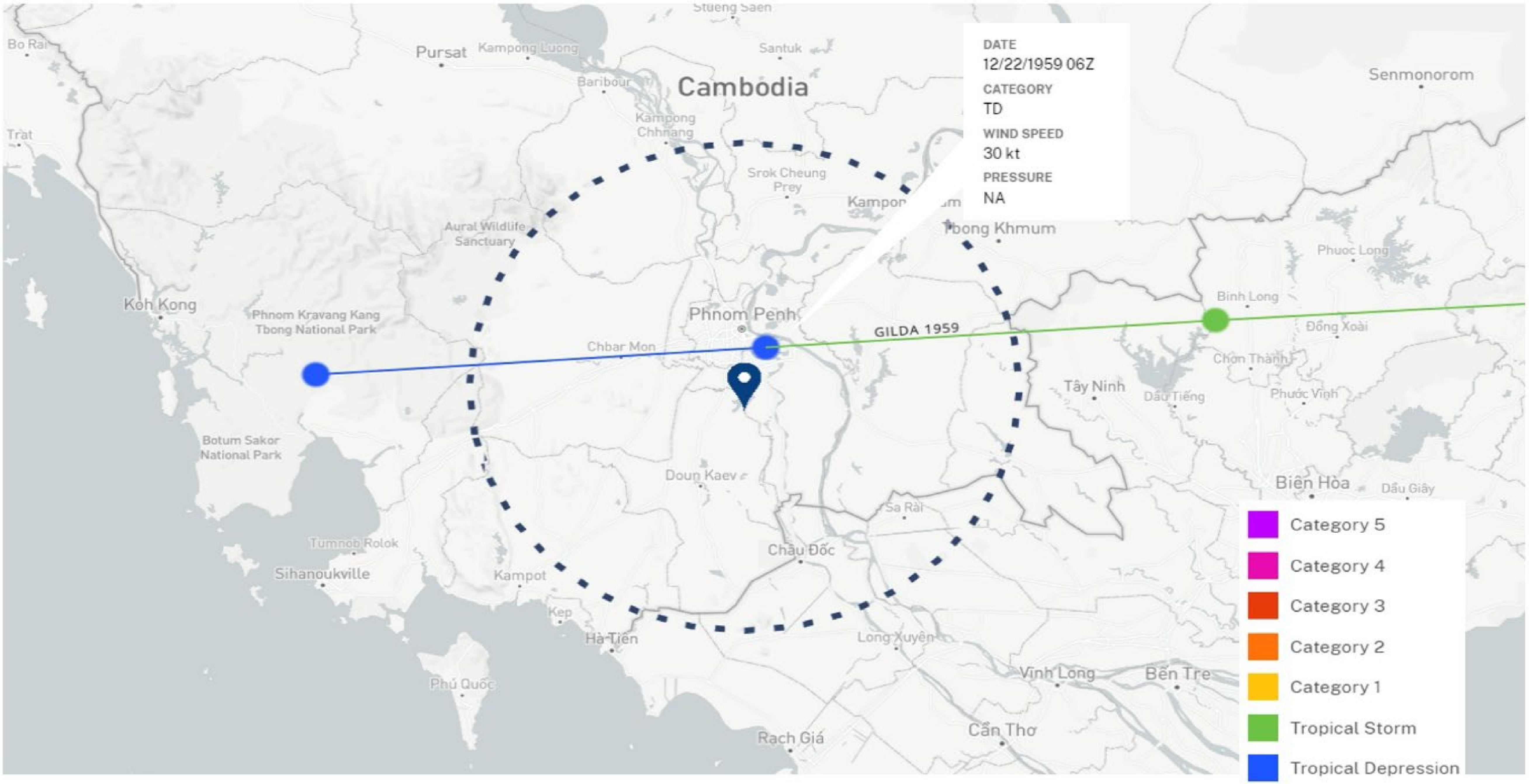


FIGURE 5.22 HISTORICAL HURRICANE TRACKS MAP

Source: International Best Track Archive for Climate Stewardship (IBTrACS) from NOAA. Available at: Index of /data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/shapefile (noaa.gov)



Highest Wind Speed due to Cyclone within 100km Radius of the Project Location

0730380 Phnom Penh Airport	Client: Cambodia Airport Investment Co., Ltd.

Source: National Oceanic and Atmospheric Administration (NOAA). Available at https://coast.noaa.gov/hurricanes

ERM

FIGURE 5.23 HIGHEST WIND SPEED DUE TO CYCLONE WITHIN 100KM RADIUS OF THE PROJECT LOCATION

Source: Source: National Oceanic and Atmospheric Administration (NOAA). Available at https://coast.noaa.gov/hurricanes

5.5.2 CLIMATE CHANGE PROJECTIONS

Tropical cyclones or Typhoons occur in most of the tropical oceans and present significant threat to coastal communities and infrastructure. Every year about 90 cyclones or Typhoons are reported to occur globally. Further, this number is reported to remained pretty constant since the period of geostationary satellites (1970s). However, changes in inter-annual and multi-decadal frequency within individual ocean basin are reported to be substantial.

Literature review indicated the detection of trends in cyclone or typhoons occurrences (frequency and intensity) is a challenge due to: i) Changes in observation technology, ii) variations in protocol for identification of cyclones or Typhoons in different ocean basins, iii) limited availability of homogeneous data (30-40 years).

Global reanalysis of tropical cyclone or typhoons intensity using homogenous satellite data indicated increasing trend in intensity of cyclones, with a suggestive link between cyclone or typhoons intensity and climate change. However, these observations based on 30 years' period are reported to be insufficient to conclusively provide the evidence for long term trend.

Climate change studies suggested likely increase in peak wind intensity and near storm precipitation in future tropical cyclones and decrease in overall frequency of cyclones. Spatial resolution of some of the earlier models used in AR4 is generally reported to be too coarse to simulate tropical cyclones. The recent advances in downscaling techniques are reported to indicate some level of success in simulating/ reproducing observed tropical cyclone characteristics. However, it should be noted that there exists limitations and high uncertainty in simulation of tropical storms.

The report noted similar remarks stating that the limited period of 30-40 years of observations is not enough to conclusively distinguish anthropogenic induced changes with decadal changes in overall cyclone frequencies. Further studies conducted for detection of Category 4 and 5 cyclones over recent decades indicated increasing trend. However, these changes in frequency are reported to vary from one ocean basin to another. Studies conducted with higher degree of warming indicated decreasing trend in total number of tropical cyclones while increase in Category 4-5 cyclones.

Based on the public information review found that the frequency and intensity of tropical cyclones in Southeast Asia are expected to increase significantly in the future. The northern parts of the ASEAN region are prone to tropical cyclones. Cambodia, Lao PDR, the Philippines, Thailand and Viet Nam face risk from the Western Pacific and Myanmar faces tropical cyclone risk from the Indian Ocean[30].

However, it's important to acknowledge Cambodia's specific situation. Historically, the country has been impacted by tropical storms rather than full-fledged cyclones. These

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[30] Transboundary Disaster Risk Assessment and Scenario Planning for Tropical Cyclones and Droughts in the ASEAN Region. The ASEAN Secretariat Jakarta. Accessed via https://asean.org/wp-content/uploads/2024/02/Transboundary-Disaster-Risk-Assessment-and-Scenario-Planning-Report.pdf

tropical storms tend to be less severe. Furthermore, considering the inland location of the Project, it is expected a lower storm power than coastal areas.

Based on the fact that due to the Cambodia's location, the country is not directly in the path of cyclones, it is assessed that the future hazard level is **"Low"** for all future climate scenarios.

5.5.3 EXPOSURE AND VULNERABILITY

Cyclones and hurricanes pose a significant threat to Southeast Asian airports, even for regions like Cambodia typically experiencing milder tropical storms. These storms bring destructive winds that can directly damage airport buildings. Intense rainfall leads to flash flooding, overflowing drainage systems, and reducing visibility – all hindering safe landings and takeoffs. Wind gusts hurl debris can threaten aircraft, ground equipment, and personnel. Debris on runways and taxiways creates landing hazards, while flooding renders them unusable. Additionally, flooding and power outages disrupt communication systems and equipment crucial for air traffic control and passenger services. These combined factors can significantly disrupt air travel, leading to flight delays or cancellations.

Strong wind can influence individual airports differently depending on their design and surrounding topography. Based on the literature, a crosswind above about 40 mph (64.37km/h) and a tailwind above 10 mph (16.09 km/h) can start causing problems and stop commercial aircraft from taking off and landing[31]. According to the baseline maximum wind speed (55.56 km/h), the Project consider to be low vulnerability for the runway, taxiway, terminal and control tower.

However, the Project is not exposed to cyclones and hurricanes since it is not located in the area that is prone to experienced hurricanes and cyclones.

This minimizes the chance of the Project encountering the destructive forces of these storms.

The potential effect of tropical storms is delivering heavy rain that can result in flooding events. This specific hazard is discussed in ***Section 5.2***.

Considering the information provided, the Project's exposure level is categorized as **"Medium".**

5.5.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.7 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR CYCLONE AND HURRICANE

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Low**	**Low**	**Low**

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[31] Aircraft Maximum Wind Limits, FlightDeskFriend via https://www.flightdeckfriend.com/ask-a-pilot/aircraft-maximum-wind-limits/#:~:text=There%20is%20no%20single%20maximum,to%20take%2Doff%20or%20land.

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Exposure x Vulnerab. Level	**Medium**	**Medium**	**Medium**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	Terminal	Strong winds and flying debris can damage the roofs, windows, and facades of terminals	
	Runway and Taxiway	Heavy rain and flash floods are storm threats, but airport drainage systems can help mitigate runway and taxiway impacts.	
	Control Tower	High wind speed may lead to small damage to the control tower. High winds may cause physical damage to the control tower structure, including windows, antennae, and other critical components. However, the Project is located in the low cyclones and hurricane hazards, so the control tower is unlikely to experience significant damage from cyclones or hurricanes.	
Key Potential Impacts	Strong winds can bring the flying debris that can be risky to the passengers and staff Flight delay and cancelation Electrical blackout and can disrupt the communication and other operation in the airport		
Implemented Mitigations	Regular maintenance of backup power generators Regularly removal of vegetation surrounding the airport and establish a storm debris disposal strategy		

5.6 WIND SPEED

Winds are defined as large scale movement of gases in the earth's atmosphere. These are typically caused by differences in atmospheric pressure on earth surface and atmosphere. Depending upon the pressure gradient, winds of various speeds are propagated. Although winds are felt at a local scale, these are largely influenced by complex process at a regional and global scale.

Winds of high speed are likely to cause damage to natural and built environment, the extent of which depends upon magnitude of their velocity and pressure differential. High winds can cause damage to high rise structures, swaying of bridges or other structures, also leading to collapse, uprooting of trees, propagation of dust, migration of air borne contamination, spreading of wildfires, etc.

For the purpose of this assessment, average wind speed data from Global Wind Atlas 2.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU) in partnership with the World Bank Group, was utilized. Additionally, wind speed study in the EIA conducted by E&A (November 2020) will be reviewed. The basic wind speed corresponds to maximum wind speed on a 100-year return period[32].

5.6.1 BASELINE HAZARD

However, the average wind speed at the airport boundary was reported approximately 2.8 m/s at 10 m height as presented in ***Figure 5.24***. Based on average and hourly wind speed data, the baseline hazard due to average wind speed for the area is considered to be 'Low'.

Based on the EIA conducted by E&A (November 2020), wind speed data was collected from the Pochentong Station of the Ministry of Water Resources and Meteorology over a nine-year period, from 2009 to 2018. The average wind speed during this timeframe was 9.5 m/s at 10 m height.

Nonetheless, refer to the study in the EIA conducted by E&A (November 2020) and the hazard categorization in ***Table 4.1*** the extreme wind speed is categorized as 'Low'.

Therefore, the risk associated with the maximum wind speed is considered **"Low"**.

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[32] Hahm, J.H., Jeong, H.Y, Kwak, K.H., 2019. Estimation of Strong Wind Distribution on the Korean Peninsula for Various Recurrence Periods: Significance of Nontyphoon Conditions. Advances in Meteorology, Article ID 8063169 https://doi.org/10.1155/2019/8063169

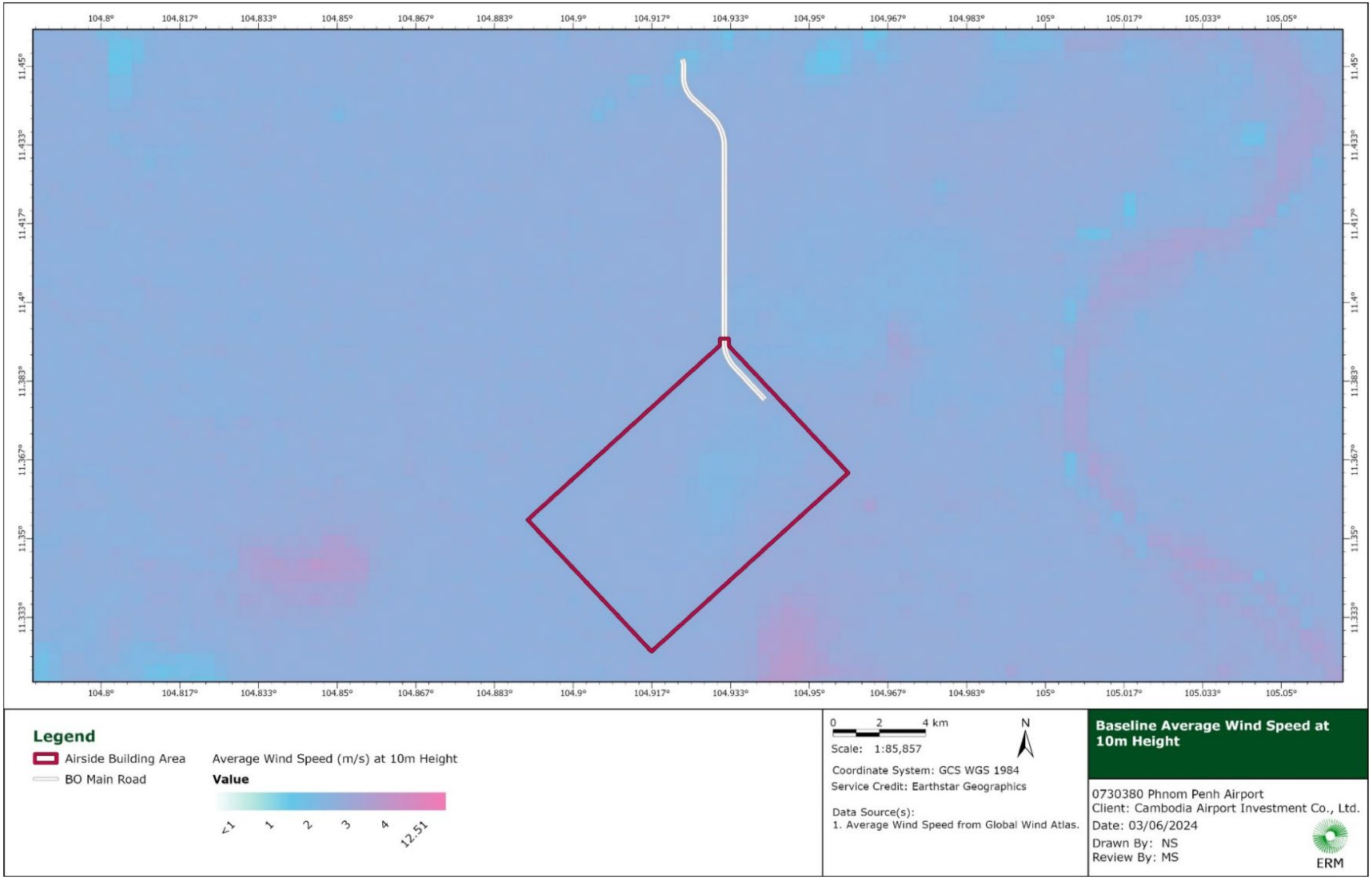

FIGURE 5.24 BASELINE AVERAGE WIND SPEED MAP

Source: Global Wind Atlas. Available at https://globalwindatlas.info/en

5.6.2 CLIMATE CHANGE PROJECTIONS

The climate models for wind speed indicate a high degree of uncertainty with models projecting increase, decrease, or no change in the future. However, a recent study from the IPCC has modeled the future projection of surface wind across the globe[33]. According to the IPCC interactive atlas, the Mekong region may be subject to an increase of surface wind speed both on the near term (2040) and medium term (2060). The increase of wind speed is between 1.3% and 1.9%. Furthermore, the surface wind change will be approximately 3.5% as shown in ***Figure 5.25***.

Considering the limited information available, the wind hazard under a climate change scenario is considered to be **"Low"** for both the average speed and maximum speed.

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[33] Gutiérrez, J.M., R.G. Jones, G.T. Narisma, L.M. Alves, M. Amjad, I.V. Gorodetskaya, M. Grose, N.A.B. Klutse, S. Krakovska, J. Li, D. Martínez-Castro, L.O. Mearns, S.H. Mernild, T. Ngo-Duc, B. van den Hurk, and J.-H. Yoon, 2021: Atlas. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L.Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K.Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. Interactive Atlas available from Available from http://interactive-atlas.ipcc.ch/

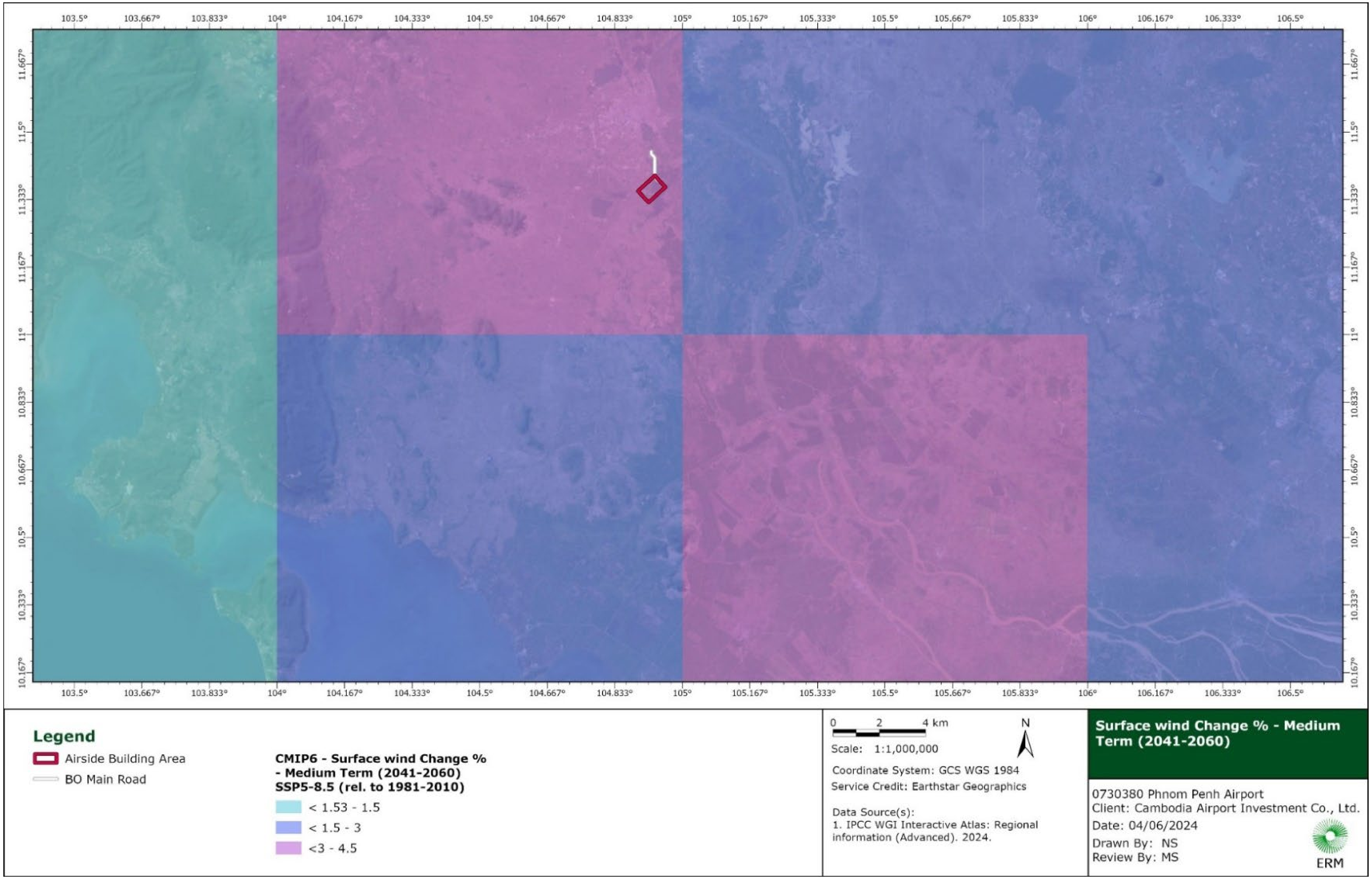

FIGURE 5.25 SURFACE WIND CHANGE % - MEDIUM TERM (2041-2060)

Source: IPCC WGI Interactive Atlas. Available at: https://interactive-atlas.ipcc.ch/

5.6.3 EXPOSURE AND VULNERABILITY

Airports are inherently exposed to strong winds due to their open environment. This can damage terminal and control tower roofs, windows, and facades, potentially compromising their structural integrity. Additionally, windblown debris creates safety hazards for landings and takeoffs, while strong gusts can even affect aircraft control during these critical phases.

The vulnerability of airport facilities depends on several factors. Buildings designed to withstand high winds will suffer less damage. Regularly clearing vegetation and managing surrounding areas minimizes debris hazards. Finally, implementing safe operating procedures for high winds helps mitigate risks. Additionally, aircraft delays due to high winds often occur solely during take-off and landing. Based on the article found, nearly every flight encounters high winds at some stage during its ascent or descent. Considering this, crosswinds exceeding 55 km/h (Approximately) typically prevent aircraft from taking off or landing[34]. Unmitigated wind hazards can lead to infrastructure damage, flight disruptions, and even safety risks.

However, considering that the Project is located in a low risk of extreme wind hazard, the Project's exposure level is categorized as **"Low"** based on the given information above.

5.6.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.8 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR WIND HAZARD

<table>
<tr><th colspan="2"></th><th>Baseline</th><th>RCP 8.5 - 2030</th><th>RCP 8.5 - 2050</th></tr>
<tr><td colspan="2">Hazard Level Average Wind Speed</td><td>Low</td><td>Low</td><td>Low</td></tr>
<tr><td colspan="2">Hazard Level Maximum Wind Speed</td><td>Low</td><td>Low</td><td>Low</td></tr>
<tr><td colspan="2">Exposure x Vulnerability Level</td><td>Low</td><td>Low</td><td>Low</td></tr>
<tr><td colspan="2">Risk Level</td><td>Low</td><td>Low</td><td>Low</td></tr>
<tr><td rowspan="2">Implications for the Project</td><td>Terminal</td><td colspan="3">Strong winds can damage roofs, windows, and facades, affecting structural integrity. Due to low extreme wind speed risk, the airport terminal is not expected to be at risk.</td></tr>
<tr><td>Runway and Taxiway</td><td colspan="3">High wind speed may lead to create safety hazards for landing and takeoff. Strong winds can cause foreign object debris (FOD) to fly onto the runway and taxiway,</td></tr>
</table>

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[34] What wind speed delays flights? Maximum wind limits for an aircraft. Robert Schrader. Accessed via https://www.skyscanner.com/tips-and-inspiration/what-windspeed-delays-flights

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
		causing serious injury to air carrier personnel or equipment damage. However, maintenance and clearing of vegetation around the airport minimize windblown debris hazards.	
	Control Tower	The strong wind speed can carry a flying object, causing damage to the control tower such as breaking windows. This may also pose safety risks to personnel who are operating the facilities. However, due to the low extreme wind speed risk, the control tower is not expected to be at risk.	
Key Potential Impacts	▪ Infrastructure damage to airport buildings, requiring costly repairs. ▪ Critical operations could affect airport functionality causing flight delay or cancellation. ▪ Potential accidents to Project personnel		
Implemented Mitigations	▪ Airports should prioritize the use of wind-resistant materials and the integration of robust engineering practices. ▪ Conduct foreign object debris control program to prevent risk caused by flying objects. ▪ Conduct regular inspections after any extreme weather event. ▪ Accurate wind monitoring during operation for air traffic control ▪ Implement restrictions for work during high-speed wind conditions. ▪ Prevent falling and flying objects during high wind speeds by ensuring workers use tethering and secure while working.		

5.7 SEA LEVEL RISE

Sea level rise is the phenomenon of increasing or rise in the sea surface elevation. The two (2) main reasons attributed to this phenomenon are 1) the added water from melting ice sheets and glaciers and 2) the thermal expansion of seawater as it warms-up. This is primarily due to global warming, resulting in accelerated melting of glaciers and snow. Impacts of sea level rise may further intensify or reduce due to vertical land movement. Current and future sea level rise is set to have a number of impacts, particularly on coastal systems. Such impacts include increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of land/property and coastal habitats, increased flood risk and potential loss of life/ property, loss of nonmonetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions. Some of the most vulnerable entities to sea level rise are habitations along the coastal regions, island nations/states and coastal ecosystems.

5.7.1 BASELINE HAZARD

No baseline hazard due to sea level (rise) was considered as it is a phenomenon driven by climate change. Therefore, hazard due to sea level rise was only evaluated under climate change scenario.

5.7.2 CLIMATE CHANGE PROJECTIONS

For the purpose of present assessment, the hazard due to sea level rise is evaluated based on the sea level rise projections from Sea Level Rise for Cities Tool from Climsystems[35]. Accordingly, the sea level rise compared to 1995 level at the airport boundary is projected to remain the same until 2100. ***Figure 5.26*** presents the map of sea level rise near the airport boundary.

Considering that the sea level rise will be zero until 2100, there is no hazard in the airport boundary.

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[35] Sea Level Ris for Cities. Access via https://slr-cities.climsystems.com/

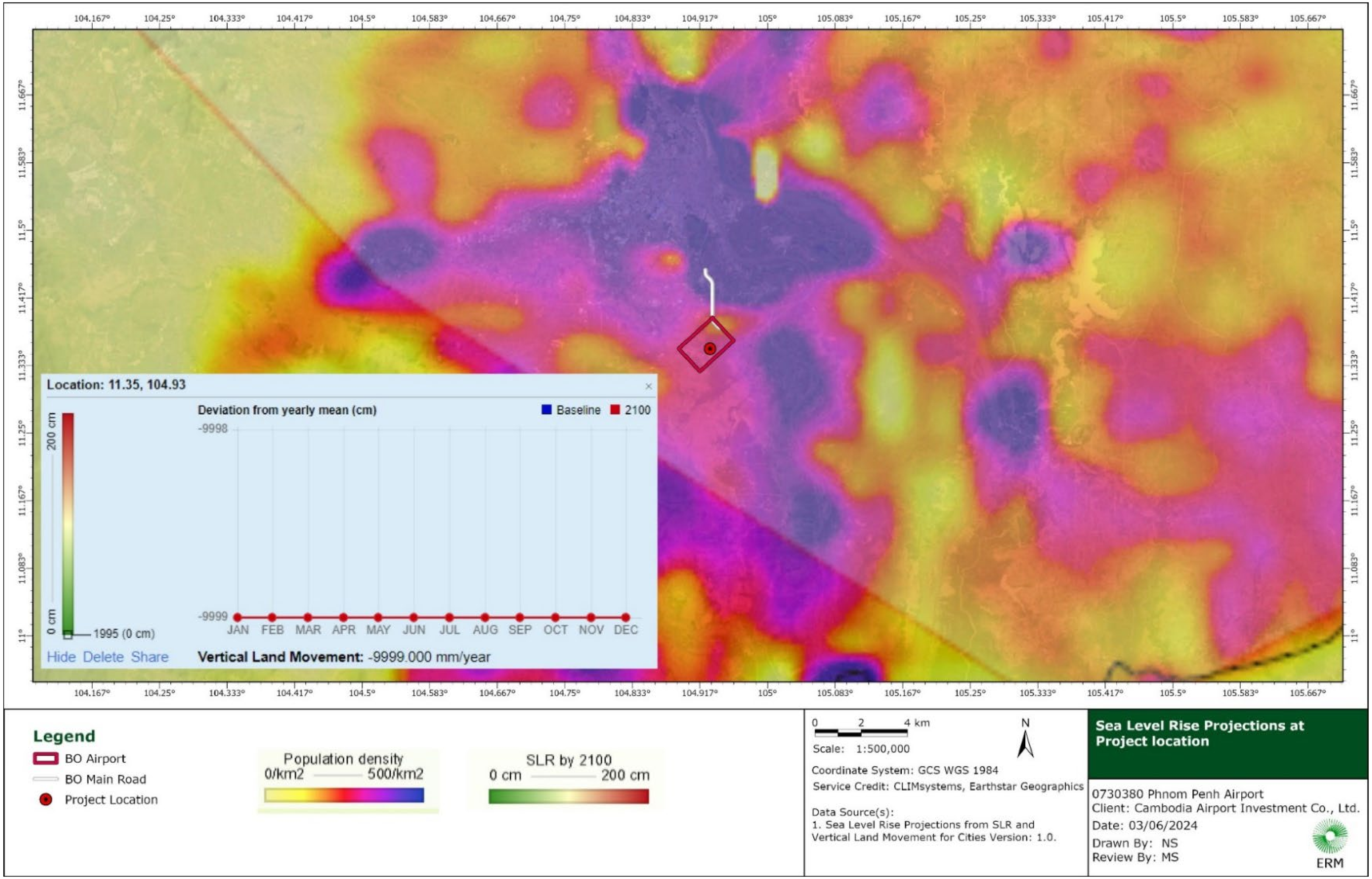

FIGURE 5.26 MAP FOR SEA LEVEL RISE PROJECTIONS AT PROJECT LOCATION

Source: SLR and Vertical Land Movement for Cities Version: 1.0. Available at https://slr-cities.climsystems.com/

5.7.3 EXPOSURE AND VULNERABILITY

The airport boundary is located over 100 kilometers from the coast, meaning it has **"Low"** vulnerability and exposure from sea level rise.

5.7.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.9 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR SEA LEVEL RISE

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Not Applicable**	**Not Applicable**	**Not Applicable**
Exposure x Vulnerab. Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	Terminal	No implications as located far from areas susceptible to sea level rise.	
	Runway and Taxiway	No implications as located far from areas susceptible to sea level rise.	
	Control Tower	No implications as located far from areas susceptible to sea level rise.	
Key Potential Impacts	▪ None identified		
Implemented Mitigations	▪ None identified		

5.8 LIGHTNING

Lightning is an electrical discharge caused by imbalances between storm clouds and the ground, or within the clouds themselves. Most lightning occurs within the clouds.

During a storm, colliding particles of rain, ice, or snow inside storm clouds increase the imbalance between storm clouds and the ground, and often negatively charge the lower reaches of storm clouds.

Objects on the ground, like steeples, trees, and the Earth itself, become positively charged creating an imbalance that nature seeks to remedy by passing current between the two charges.

Lightning is extremely hot. A flash can heat the air around it to temperatures five times hotter than the sun's surface. This heat causes surrounding air to rapidly expand and vibrate, which creates the pealing thunder that is heard a short time after seeing a lightning flash.

Lightning can cause both destruction of infrastructure and lives. About 2,000 people are killed worldwide by lightning each year. Hundreds more survive strikes but suffer from a variety of lasting symptoms, including memory loss, dizziness, weakness, numbness, and other life-altering ailments[36].

For this assessment, data from the Tropical Rainfall Measuring Mission (TRMM) lightning Imaging Sensor (LIS) was used. TRMM LIS was a space-based lightning sensor aboard the Tropical Rainfall Measuring Mission satellite.

The TRMM LIS instrument recorded the time of occurrence of a lightning event, measured the radiant energy and estimated the location during both day and night conditions with high detection efficiency.

5.8.1 BASELINE HAZARD

Vaisala's Interactive Global Lightning Density Map is a space-based lightning detection system using Global Lighting Dataset GLD360 which is real-time data from the industry's most accurate global detection network.

The lightning flash density map presented in ***Figure 5.27*** indicates the density of lightning flashes to be 32 events km-2 year-1 during the period 2016 - 2023 at the airport boundary. Very limited information is available in the public domain regarding the hazard classification of lightning.

However, considering the hazard categorization in ***Table 4.1***, the hazard in the airport boundary can be assumed as "Medium".

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[36] National Geographic, N.D. https://www.nationalgeographic.com/environment/natural-disasters/lightning/

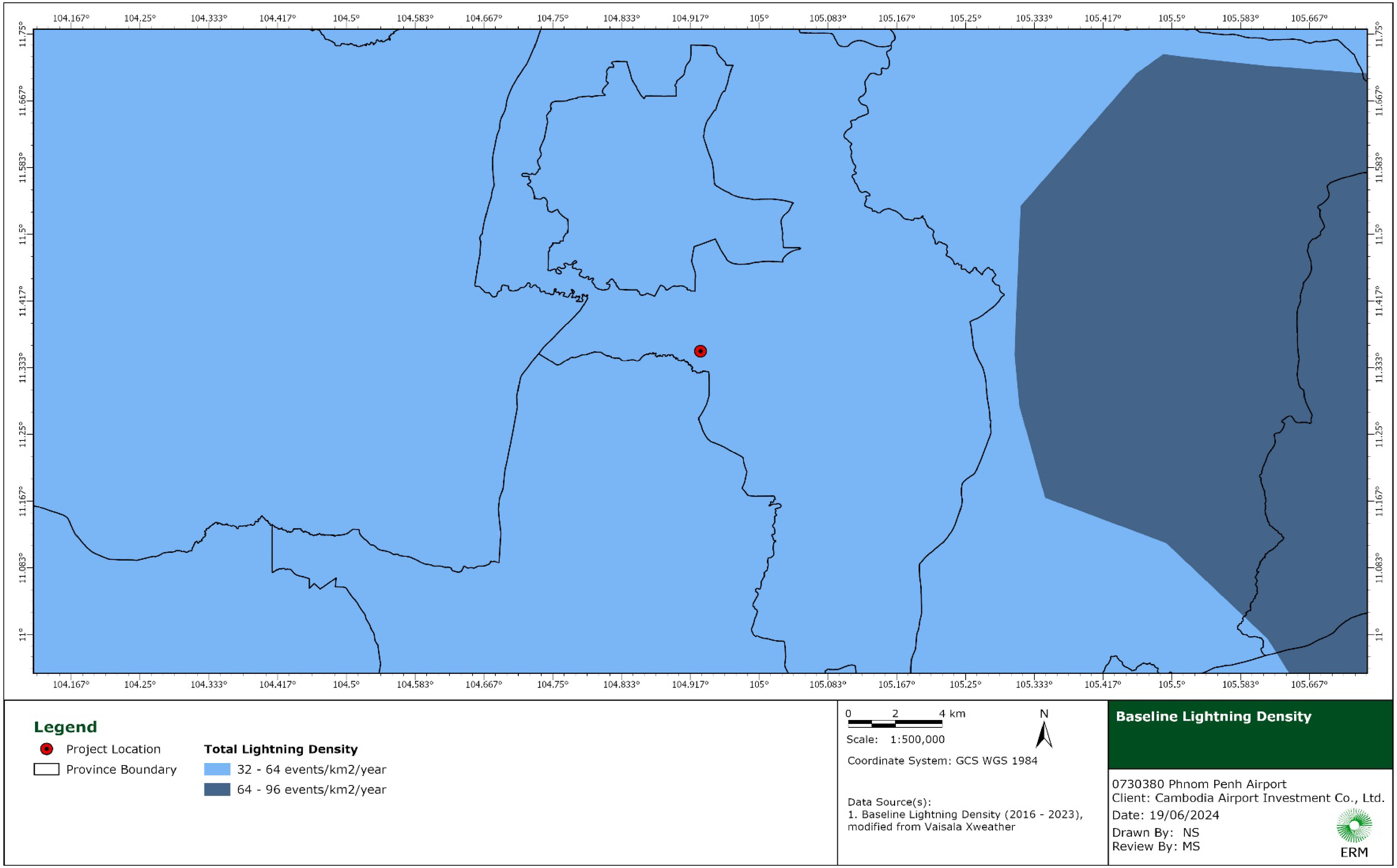


FIGURE 5.27 BASELINE LIGHTNING DENSITY MAP

Source: Vaisala's Interactive Global Lightning Density Map. Available at: https://interactive-lightning-map.vaisala.com/?_ga=2.13283636.2075757537.1656405986-847756934.1656405986

5.8.2 CLIMATE CHANGE PROJECTIONS

There are no direct projections available for lightning. However, as lightning usually occurs during thunderstorms, any changes in occurrences of thunderstorm are considered as measure for changes in lightning in future.

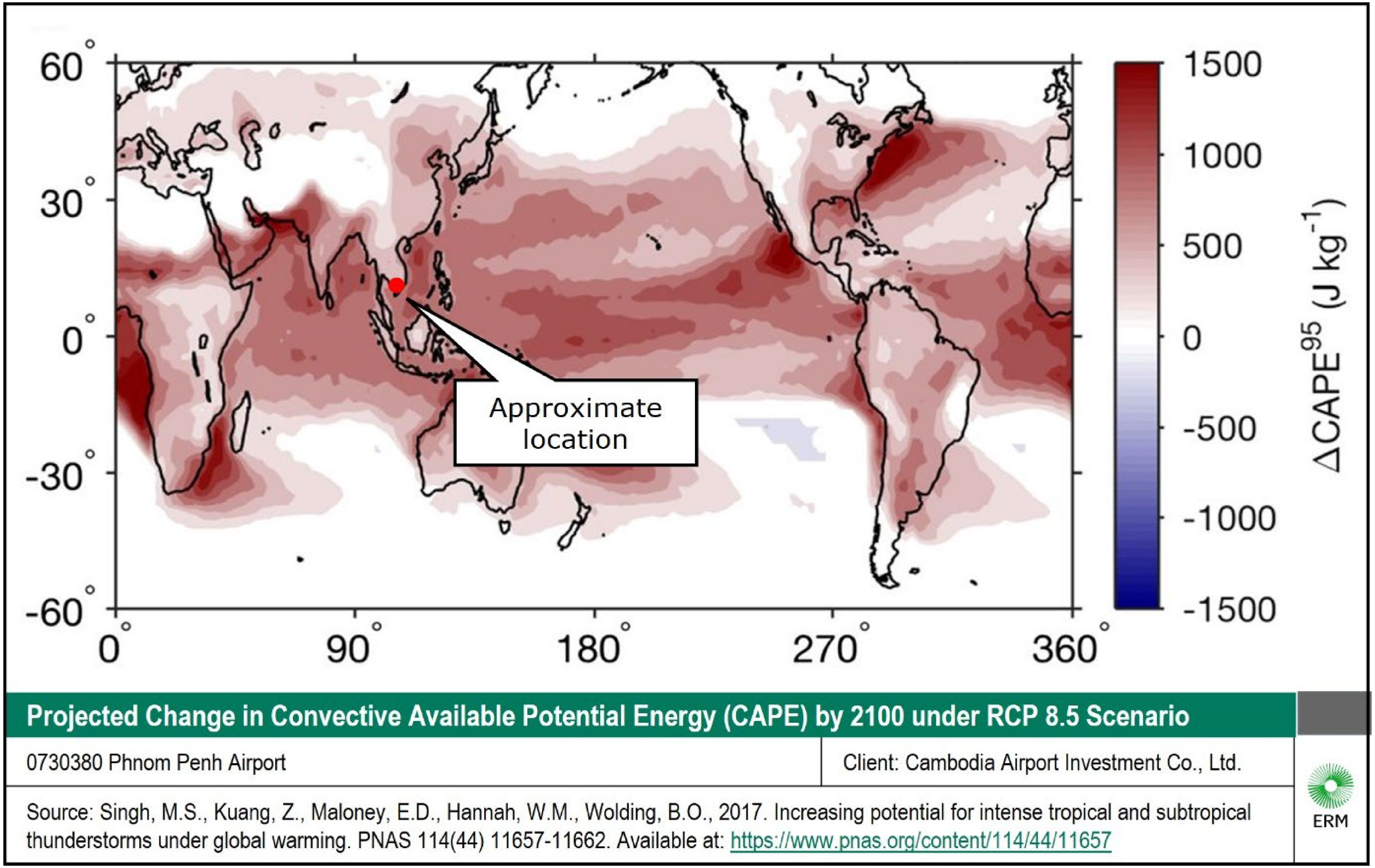
Literature review indicates that predicting changes in thunderstorm directly is difficult task, and hence generally changes in large scale environmental conditions conducive to thunderstorms are used as an indirect measure. One such factor is convective available potential energy (CAPE), which is a measure of maximum kinetic energy obtainable by an air parcel lifted adiabatically from near surface. CAPE is also reported to be important large-scale indicator for the potential lightning.

Literature review indicates tropical and subtropical CAPE extremes increasing sharply with warming across ensembles of GCMs participating in CMIP6. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere.

CAPE at Project site is likely to increase by 500 - 1000 J/kg by 2100 for RCP 8.5 scenario as presented in ***Figure 5.28***. In general, the studies indicate an increase in potential for intense thunderstorms in a warming atmosphere. ***Figure 5.29*** presents the likely increase in a number of days per year with conditions favorable for severe thunderstorm by end of the century. Accordingly, the projected increase in number of days with conditions favorable for formations of thunderstorms is reported to be between 20-30/year by 2100 under RCP 8.5 scenario. Hence, an increase in lightning activity/frequency may be experienced in the future.

It is possible that the probability of lightning events may increase to 52-62 events/year, based on the projected increase of thunderstorm day in ***Figure 5.29***. This indicates that the projection risk of lightning hazards can range from ‘Medium’ to ‘High’.

Considered the worst-case scenario, it is assessed a future risk of lightning to be a **“High”** hazard level at the Project location.



Projected Change in Convective Available Potential Energy (CAPE) by 2100 under RCP 8.5 Scenario

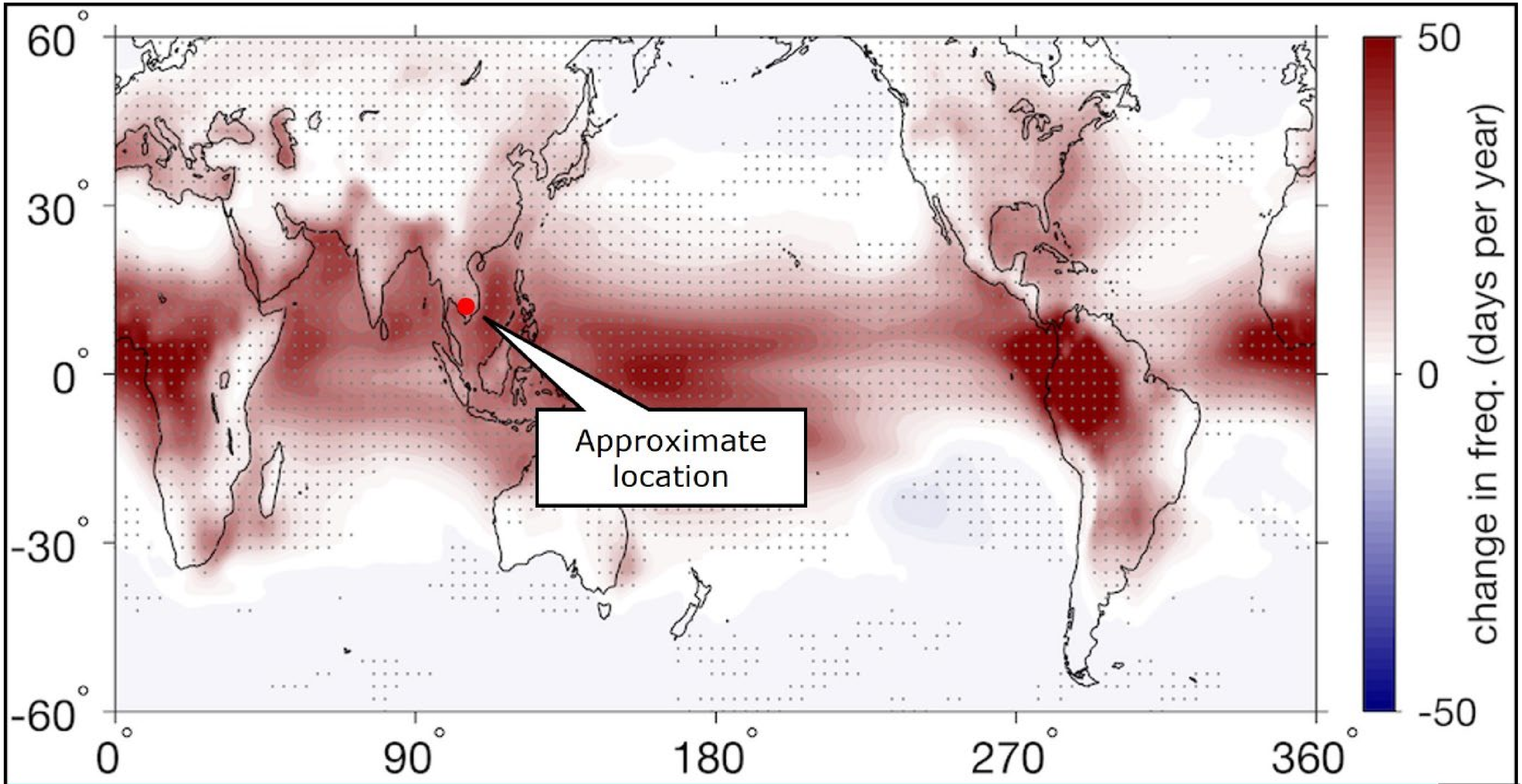
0730380 Phnom Penh Airport

Client: Cambodia Airport Investment Co., Ltd.

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

FIGURE 5.28 PROJECTED CHANGE IN CONVECTIVE AVAILABLE POTENTIAL ENERGY (CAPE) BY 2100 UNDER RCP 8.5 SCENARIO

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657



Projected Change for frequency of intense tropical and subtropical thunderstorms by 2100 under RCP 8.5

0730380 Phnom Penh Airport

Client: Cambodia Airport Investment Co., Ltd.

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

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FIGURE 5.29 PROJECTED CHANGE FOR FREQUENCY OF INTENSE TROPICAL AND SUBTROPICAL THUNDERSTORMS BY 2100 UNDER RCP 8.5 SCENARIO

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

5.8.3 EXPOSURE AND VULNERABILITY

Based on the literature, almost all airports in the world are impacted by thunderstorm activity[37].

Several factors make airports vulnerable to lightning strikes. Airports rely heavily on electronic equipment for communication, navigation, and surveillance. A lightning strike can disrupt or damage this equipment, causing delays and safety hazards. Airport facilities such as communications systems, electrical circuits, powerlines, and airfield electrical systems can be affected by lightning strikes. Lightning strikes can be dangerous for ground crew workers, potentially causing temporary pilot incapacitation through flash blindness, and may even lead to engine shutdowns. Ground handling staff are more exposed to the elements, and the vast fuel stores and active refueling of aircraft increase the risk. According to the literature, many airports (54% of respondents) cease ground operations upon lightning detection within 8 kilometers radius[38].

Airports are vast open spaces with tall structures like control towers and hangars, making them prime targets for lightning strikes.

While most airports utilize storm surge alerting systems and real-time weather tracking to mitigate the potential risks posed by lightning strikes, these weather events can still lead to operational disruptions and flight delays when lightning is present.

Hence, the exposure and vulnerability of the Project are considered to be **"High"**.

5.8.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE 5.10QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR LIGHTNING

	Baseline	**RCP 8.5 – 2030**	**RCP 8.5 – 2050**
Hazard Level	**Medium**	**Medium**	**High**
Exposure x Vulnerab Level	**High**	**High**	**High**
Risk Level	**High**	**High**	**High**
Implications for the Project	Terminal	Lightning strikes may lead to structural damage or blackout. However, the terminal should have built-in lightning protection (surge arrestors, grounding) to minimize damage.	
	Runway and Taxiway	The runway and Taxiway are a large open area that has a higher risk of lightning strikes. Lightning can be dangerous for the ground worker. If there is risk of lightning in the area,	

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[37] How do you stop/resume airfield operations when lightning strikes, UBIMET. Accessed on 4 June 2024 via https://www.ubimet.com/en/industries/aviation-weather-forecasting-industry-solutions/lightning-safety-at-airports/

[38] The Ultimate Lightning Guide for Airport Operations, Earth Networks. Accessed via https://www.earthnetworks.com/the-ultimate-lightning-guide-for-airport-operations/#:~:text=They%20suggest%20using%20a%203,from%20becoming%20a%20heaping%20mess.

	Baseline	RCP 8.5 – 2030	RCP 8.5 – 2050
		the worker should stop and move to the safety area. This can cause the operation to be disrupted or worse case, it can lead to life threatening for the worker.	
	Control Tower	The control tower can be damaged by lightning strikes. The design should follow national standards to prevent lightning damage such as installing lightning arresters which mitigate the impacts of lightning strikes.	
Key Potential Impacts	▪ Possibility of structural damage such as electrical circuit which can lead to power blackout. ▪ The lightning can harm the staff who work in the open area. ▪ The lightning strike can cause a fire that might be dangerous to Project facilities.		
Implemented Mitigations	▪ Follow international standards when designing the Project component such as lightning protection systems. ▪ Implement extreme weather monitoring for lightning detection or warning systems. ▪ Establish working procedures during thunderstorms or lightning events to determine when to evacuate or change work activities (e.g. Restriction on working at height) to protect personnel and property from lightning strikes. ▪ Yearly inspections after every thunderstorm event of the lightning protection system to ensure the system is operational. Repairs to be made as soon as possible when this is not functioning (e.g. change of lightning card)		

6. CONCLUSION

A Climate Change Risk Assessment was performed for the airport Project located located in Kandal Stung District and Sa'ang District of Kandal province, and Bati District of Takeo Province. The Climate Change Risk Assessment consisted of a review of current and future physical hazards in the airport boundary. The future projections were evaluated based on the Representative Concentration Pathways (RCP) 8.5 over timelines of 2030 and 2050. The assessment identified potential high-risk levels for lightning in 2050 scenarios.

Lightning poses a high risk to the Project, with potential consequences including structural damage (e.g., electrical circuits leading to power outages), danger to staff working outdoors, and fires that could threaten Project facilities.

Mitigation measures include Airports implementing a comprehensive strategy to safeguard personnel, equipment, and aircraft from lightning strikes. This includes following international standards when designing lightning protection systems for airport structures. Extreme weather monitoring systems with lightning detection or warning capabilities are crucial for issuing timely warnings. During thunderstorms or lightning events, established working procedures guide decisions on evacuation or modifying work activities, such as restricting work at heights, to ensure safety from lightning strikes. Finally, yearly inspections of the lightning protection system after every thunderstorm event are essential to ensure its functionality. Any identified issues, like needing to change a lightning rod, should be repaired as soon as possible.

A summary of the key potential impacts and proposed mitigations is provided below in ***Table 6.1***.

TABLE 6.1 SUMMARY OF RISK LEVEL AND PROPOSED MITIGATION MEASURES

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
Water Availability	**Hazard Level**	**Low**	**Low**	**Low**	▪ Temporary operation disruption of sanitary facilities, stores, and firefighting equipment. ▪ Runway and taxiway deterioration	▪ Develop a Water Management Plan that identifies opportunities for the reduction and recycle of water within the airport. ▪ Explore the potential use of rainwater harvesting to increase the available water supply	**Low**
	Exposure x Vulnerab. Level	**Medium**	**Medium**	**Medium**			
	Risk Level	**Medium**	**Medium**	**Medium**			
Flood	**Hazard Level**	**High**	**High**	**High**	▪ Based on the mitigation measures established in the EIA, negligible potential impacts have been identified	▪ Since the Project already has a Flood Management Plan, it's crucial to conduct regular reviews to identify areas for improvement and ensure the	**Low**

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Exposure x Vulnerab. Level	**Medium**	**Medium**	**Medium**		plan remains applicable. However, the project located in high flood risk, hence the flood management plan shall	🟩

	Risk Level	**Medium**	**Medium**	**Medium**		be reassessed frequently or every post flood event. ▪ Regularly checking the drainage system and pump station helps ensure the infrastructure operates at maximum capacity. ▪ To supplement the constructed drainage systems, the project shall employ natural alternatives such as the installation of retention ponds to absorb excess water naturally. These approaches reduce runoff, reduce tension in drainage systems, and improve long-term flood resistance. ▪ Flood modeling is needed performed at the project site to forecast future flood levels. Previous Environmental Impact Assessment (ESIA) research included flood risk in the design of permanent dikes and ground levels; however, further modeling will provide a better understanding of potential flood scenarios. The dikes shall be constructed to a height of +9.7 meters above mean sea level (msl) for the year 2040 and elevated to +11.0 msl for long-term protection[39]. ▪ Establish effective waste management protocols to prevent soil waste, debris, and additional waste from	🟩

Hazard		**Baseline**	**RCP 8.5**		**Key Potential Impacts**	**Mitigation Measures**	**Residual Risk Level**
			2030	**2050**			
		🟨	🟨	🟨		blocking waterways during site clearance operations. - Collaborate with local emergency management agencies and meteorological departments to stay informed about weather forecasts and flood warnings.	🟩
Landslides	**Hazard Level**	**Low**	**Low**	**Low**	- It is not expected that landslides would have an impact on the Project due to the location of the Project located in the low risk of landslides.	- None required.	**Low**
	Exposure x Vulnerab. Level	**Low**	**Low**	**Low**			
	Risk Level	**Low**	**Low**	**Low**			

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[39] ESIA Report of New Phnom Penh International Airport (NPPIA). 2020

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
Extreme Heat	Hazard Level	Medium	High	High	▪ Heat stress or heat exhaustion for personnel operating for the ground operation staff and passengers. ▪ Higher temperatures decrease air density, reducing lift for aircraft. This requires longer runways for takeoff which possibly causing flight delays due to the safety of aircraft taking off ▪ Heat-sensitive ground equipment, including fuel trucks, baggage handling systems, and airside vehicles, may	▪ Use building materials designed to withstand high temperatures, such as heat-reflective glass and insulating materials, to maintain safe internal temperatures in control towers, terminals, and other facilities. ▪ Construct taxiways with materials designed to withstand extreme	Low
	Exposure x Vulnerab. Level	Medium	Medium	Medium			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	Medium	Medium	Medium	experience a higher risk of breakdowns or malfunctions.	temperatures and reduce the risk of deformation or damage. ▪ Integrate building insulation techniques and incorporate passive cooling techniques in terminal and control tower and utilizing natural ventilation systems to promote airflow, helping to cool interior spaces design to maintain cooler interior temperatures. ▪ Establish air-conditioned shelters or shaded rest areas for airport staff and passengers to escape extreme heat, especially for those involved in outdoor activities like ground operations. ▪ Utilize real-time data to optimize flight plans based on current temperature conditions and conduct regular training sessions for airport staff on recognizing symptoms of heat stress and implementing the emergency response plan for protection of workers and passengers.	🟩

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
Cyclone and Hurricane	**Hazard Level**	**Low**	**Low**	**Low**	▪ Strong winds can bring the flying debris that can be risky to the passengers and staff ▪ Flight delay and cancelation ▪ Electrical blackout and can disrupt the communication and other operation in the airport	▪ Regular maintenance of backup power generators ▪ Regularly removal of vegetation surrounding the airport and establish a storm debris disposal strategy	**Low**
	Exposure x Vulnerab. Level	**Medium**	**Medium**	**Medium**			
	Risk Level	**Low**	**Low**	**Low**			
Wind Speed	**Hazard Level Average Wind Speed**	**Low**	**Low**	**Low**	▪ Infrastructure damage to airport buildings, requiring costly repairs. ▪ Critical operations could affect airport functionality causing flight delays or cancellations. ▪ Potential accidents to Project personnel	▪ Airports should prioritize the use of wind-resistant materials and the integration of robust engineering practices. ▪ Conduct foreign object debris control program to prevent risk caused by flying objects. ▪ Conduct regular inspections after any extreme weather event.	**Low**
	Hazard Level Maximum Wind Speed	**Low**	**Low**	**Low**			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Exposure x Vulnerability Level	**Low**	**Low**	**Low**		▪ Accurate wind monitoring during operation for air traffic control ▪ Implement restrictions for work during high-speed wind conditions. ▪ Prevent falling and flying objects during high wind speeds by ensuring workers use tethering and secure while working.	
	Risk Level	**Low**	**Low**	**Low**			
Sea Level Rise	**Hazard Level**	**Not Applicable**	**Not Applicable**	**Not Applicable**	▪ None Identified	▪ None Identified	**Low**
	Exposure x Vulnerab. Level	**Low**	**Low**	**Low**			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	Low	Low	Low			
Lightning	Hazard Level	Medium	Medium	High	▪ Possibility of structural damage such as electrical circuit which can lead to power blackout. ▪ The lightning can harm the staff who work in the open area. ▪ The lightning strike can cause a fire that might be dangerous to Project facilities.	▪ Follow international standards when designing the Project component such as lightning protection systems. ▪ Implement extreme weather monitoring for lightning detection or warning systems. ▪ Establish working procedures during thunderstorms or	Low
	Exposure x Vulnerab Level	High	High	High			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	High	High	High		lightning events to determine when to evacuate or change work activities (e.g. Restriction on working at height) to protect personnel and property from lightning strikes. ▪ Yearly inspections after every thunderstorm event of the lightning protection system to ensure the system is operational. Repairs to be made as soon as possible when this is not functioning (e.g. change of lightning card)	🟩

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