Screening Level Natural Hazard and Climate Change Assessment in Jaisalmer District, Rajasthan

Adani Green Energy Limited

Final Report

14 December 2020

Project No.: 0577764

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Document details	The details entered below are automatically shown on the cover and the main page footer. PLEASE NOTE: This table must NOT be removed from this document.
Document title	Screening Level Natural Hazard and Climate Change Assessment in Jaisalmer District, Rajasthan
Document subtitle	Final Report
Project No.	0577764
Date	14 December 2020
Version	2.0
Author	ERM India Private Limited
Client Name	Adani Green Energy Limited

Document history

				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Draft	1.0	Shubhankar Khare, Tushar Agarwal	Aniket Jalgaonkar, Venkat Kolluru	Ajay Pillai	14 Dec 2020	Text
Final	2.0	Shubhankar Khare, Tushar Agarwal	Aniket Jalgaonkar, Venkat Kolluru	Ajay Pillai	14 December 2020	

Signature Page

14 December 2020

Screening Level Natural Hazard and Climate Change Assessment in Jaisalmer District, Rajasthan

Final Report

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EXECUTIVE SUMMARY

Adani Green Energy Limited (hereinafter referred to as 'AGEL' or 'Client') commissioned Environmental Resources Management (hereinafter 'ERM') to conduct Screening Level Natural Hazard and Climate Change Physical Risk Assessment for its proposed hybrid power projects in Rajasthan as given below.

- 390 MW: 101.2 MW Wind and 360 MW Solar in Fategarh
- 600 MW: 151.2 MW Wind and 2 X 300 MW Solar in Jaisalmer
- 700 MW: 510 MW Wind and 250 and 350 MW Solar in Jaisalmer

The assessment was required to be undertaken against international standards to meet the requirement in terms of providing lenders. Accordingly, present assessment was conducted in accordance with Equator Principle (EP) 4 guidelines of IFC as recommended in the Environmental and Social Due Diligence (ESDD) Report of the Project (dated 18 December 2020).

The assessment involved review of national level plans and commitments towards climate change followed by evaluation of natural hazards under baseline and climate change conditions.

National Climate Policies ad Framework

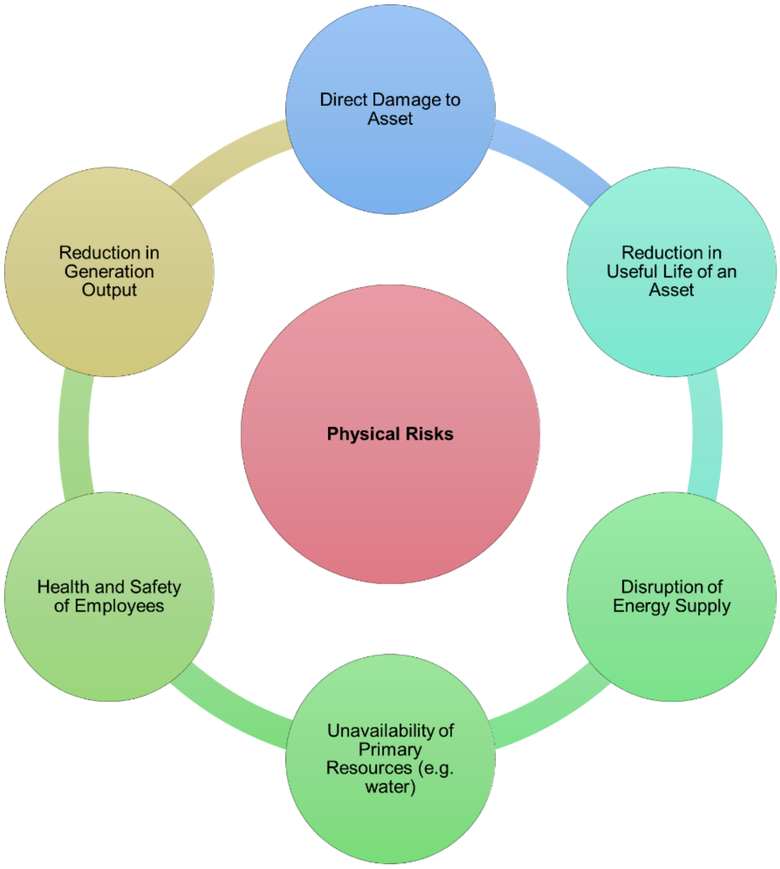
The review of national level action plans for climate change indicated promotion and implementation of renewable energy in general and solar energy projects in particular to reduce greenhouse gas emission, and providing power in the remote areas as one of the aims to address climate change related issues. India aims to produce 100GW of power by 2022 using solar energy, 60GW of power using wind energy by 2030. Accordingly, the proposed project can be considered to be in alignment with the national commitment for production of renewable energy.

Further, the national policy on disaster management recognises the natural disaster such earthquake, floods, river erosion, cyclones, and tsunamis etc. have detrimental effect on economy of the nation. The policy also recognises the need for systematic plan to manage these hazards involving six elements as: preparedness, response, prevention, mitigation, rehabilitation and recovery.

Approach and Methodology

As, some these hazards are climate driven, these are likely undergo changes as a result of climate change in future, in terms of intensification of likelihood or severity, affecting the project as presented in Figure E-1.

Figure E-1 General Implications of Climate Change on Wind and Solar Farms



Therefore, it becomes important to identify such hazards which are likely to affect the project locations under baseline and climate change condition.

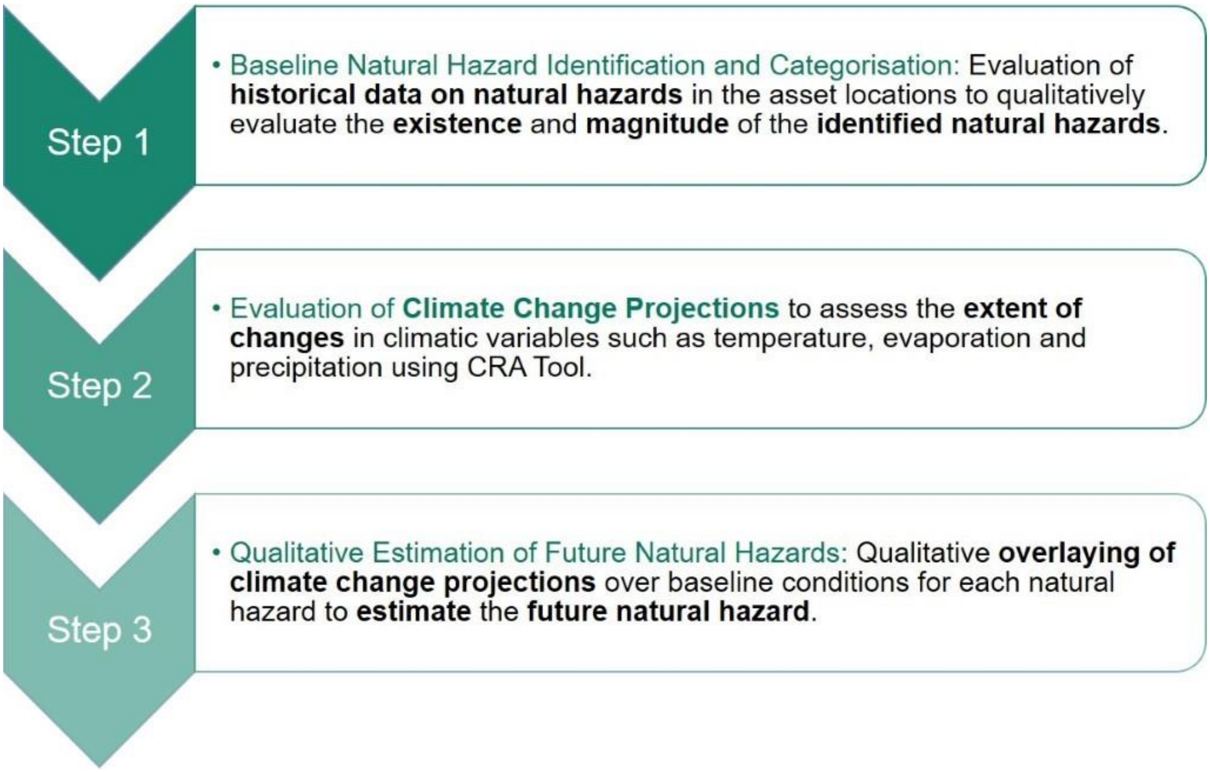
Accordingly, present assessment aims at Screening Level Natural Hazard and Climate Change Physical Risk Assessment for proposed projects identified above.

The present assessment is a high level qualitative screening exercise, involving application of scientific principles, and professional judgement based on the best available data sources and information in the open source.

As a part of this assessment following natural hazards were evaluated under baseline and climate change conditions using a three stepped approach as presented in Figure E-2 below

- Water Availability
- Riverine Flood
- Extreme Heat
- Cyclone
- Wind Speed
- Thunderstorm and Lightning

Figure E-2 Approach for the Present Assessment



The baseline hazards were evaluated based on the review of recognised global and national level open source databases/literature as presented in Table 1.2 of the report. The hazards were categorised in three four categories as No Hazard, Low, Medium, High, and Not classification. The hazards were categorised based on the conservative normalisation of hazard categories available in the original data sets or based on the potential of the hazard to inflict damage on built and natural environment, and health and safety as presented in Table 1.3 of the report.

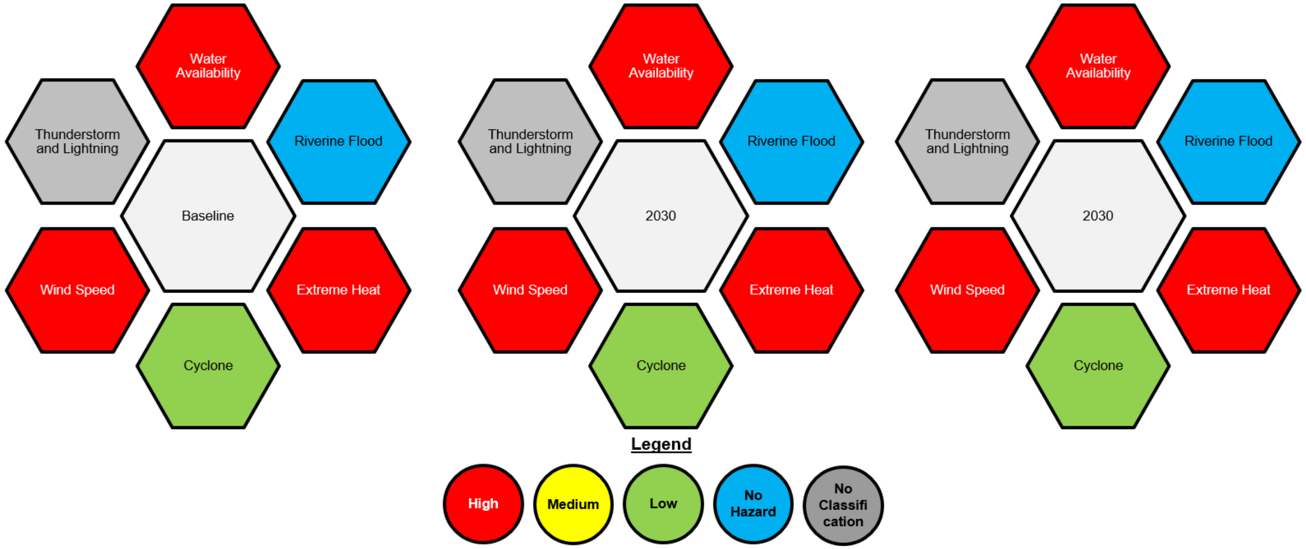
The likely changes in above hazards due to climate change were evaluated qualitatively for climate change scenarios of RCP 4.5 and RCP 8.5 during timeframes of 2030 and 2050, using CMIP-5 Climate Change Projections following the TCFD guidelines as recommended in EP-4. The likely changes in hazards are based on application of scientific principles, professional judgement and likely relation between natural hazards and the climate parameter.

The assessment indicated that water availability, extreme heat, and wind speed are likely to ‘High’ hazard under baseline and climate change conditions. Cyclones indicated ‘Low’ hazard in the region. Following the evaluation of natural hazards under baseline and climate change conditions, general recommendations were provided on implications, available control measures and additional recommendations for each of the natural hazard were provided as presented in Section 1.7 of the report.

Climate Hazard Assessment – Key Findings

Figure E-3 presents the summary of natural hazards under baseline and climate change scenarios of RCP 4.5 and RCP 8.5.

Figure E-3 Summary of Natural Hazards under Baseline and Climate Change Scenarios of RCP 4.5 and RCP 8.5



It should be noted that although the riverine flood presented 'No hazard' within Study area, localised flooding can happen due to changes in land used due to project development and extreme rainfall. Data on such localised flooding is not available and evaluation of such localised flooding need Site level assessment involving modelling studies. Therefore, although there is no riverine flood hazard indicated at project Site, the general implications of flood were identified, with recommendation for Site level flood risk assessment.

Implications Analysis

Based on the future natural hazard, projects implications were evaluated for the solar and wind power plant, infrastructure and components. Along with this, further preventive actions, management plans and adaptation measures were recommended. These are presented in Table 1.21 the main report.

1. SCREENING LEVEL CLIMATE CHANGE PHYSICAL RISK ASSESSMENT

1.1 Introduction

1.1.1 Purpose

Adani Green Energy Limited (hereinafter referred to as 'AGEL' or 'Client') plans to seek financing from international lenders for their three (3) hybrid power projects in Rajasthan (hereinafter referred to as Study Areas). These projects are summarised below;

- 390 MW: 101.2 MW Wind and 360 MW Solar in Fategarh
- 600 MW: 151.2 MW Wind and 2 X 300 MW Solar in Jaisalmer
- 700 MW: 510 MW Wind and 250 and 350 MW Solar in Jaisalmer

An Environmental and Social Impact Assessment (ESIA) was undertaken to meet the requirement in terms of providing lenders an assessment of project against international standards. Further, climate change physical risk assessment was recommended to understand the physical threats in terms of climate driven natural hazards likely to affect the said project. Accordingly, present assessment was performed with an aim of qualitative evaluation of the natural hazards likely to affect the said projects under present (baseline) and future scenarios (climate change scenarios) of projected greenhouse gas emissions.

This assessment was conducted in accordance with the requirements of The Equator Principles. The Equator Principles Financial Institutions (EPFIs) support the objective of the 2015 Paris Agreement and recognise that EPFI s have a role to play in improving the availability of climate related information, such as the Recommendations of the Task Force on Climate Related Financial Disclosures (TCFD[1]) when assessing potential transition and physical risks of the projects financed under the Equator Principles. Equator Principles states that the Climate Change Risk Assessment should be aligned with Climate Physical Risk and Climate Transition Risk categories of the TCFD (Equator Principles 2020).

EP-4 is a risk management process that facilitates the process of determining, assessing and managing environmental and social risks risk in financing major projects. It provides a minimum standard for due diligence to support responsible risk decision making. The key features of EP-4 which relate to physical risk assessment are summarised below-

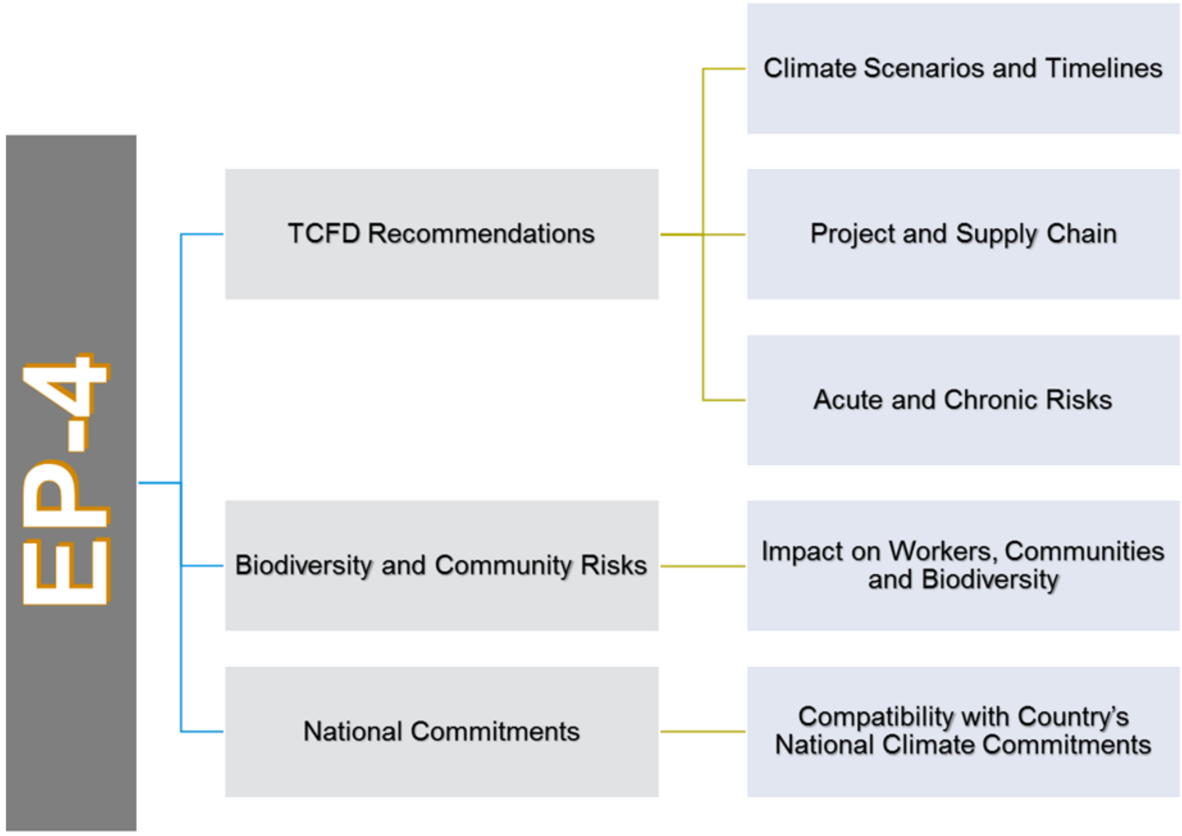
- The framework recognises the importance of biodiversity, human rights, and climate change. As per EP-4, negative impacts on project that affects ecosystem, communities, and the climate should be avoided where possible. If these impacts are unavoidable, then the process considers how these can be minimised, mitigated and/or offset.
- In reference to climate change, the EP-4 recommends the developer to include assessment of potential climate change risks as part of ESIA or other assessment. The depth and nature of the climate change risk assessment is reported to depend on the type of Project as well as the nature of risks, including their materiality and severity. Further, climate risk assessment is required to be aligned with climate change physical risk and climate transition risk categories of the TCFD. Additionally, the climate risk assessment is required to consider the Project's compatibility with the host country's national climate commitments, as appropriate.
- TCFD recommends assessment of financially material climate related physical risks including acute and chronic risks over different relevant time horizons and scenarios including 2°C or lower scenario. The assessment may include impacts on products and services, supply chain and/or

[1] TCFD, 2017. Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures. Available at: https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Annex-062817.pdf

value chain, adaptation and mitigation activities, investment in research and development, and operations.

Figure 1.1 provides an overview of EP-4 in particular relation to the physical risk assessment.

Figure 1.1 Key Components of EP-4 Related to Physical Risk Assessment



1.1.2 Objective

The assessment was conducted with following objectives:

- Evaluate and identify the potential hazards to the Project arising from current and future climate variables;
- To understand the likely implications of theses hazards on proposed project, communities and ecology in the surrounding area;
- To assess any implication of the project which may exacerbate climate change impacts on climate change of communities and ecology; and
- To evaluate how the present project considerations can accommodate potential impacts of climate change in terms of physical risks.

1.2 Site Setting and Study Area

The Site Setting of the three (3) proposed hybrid power projects located in Rajasthan is summarised below.

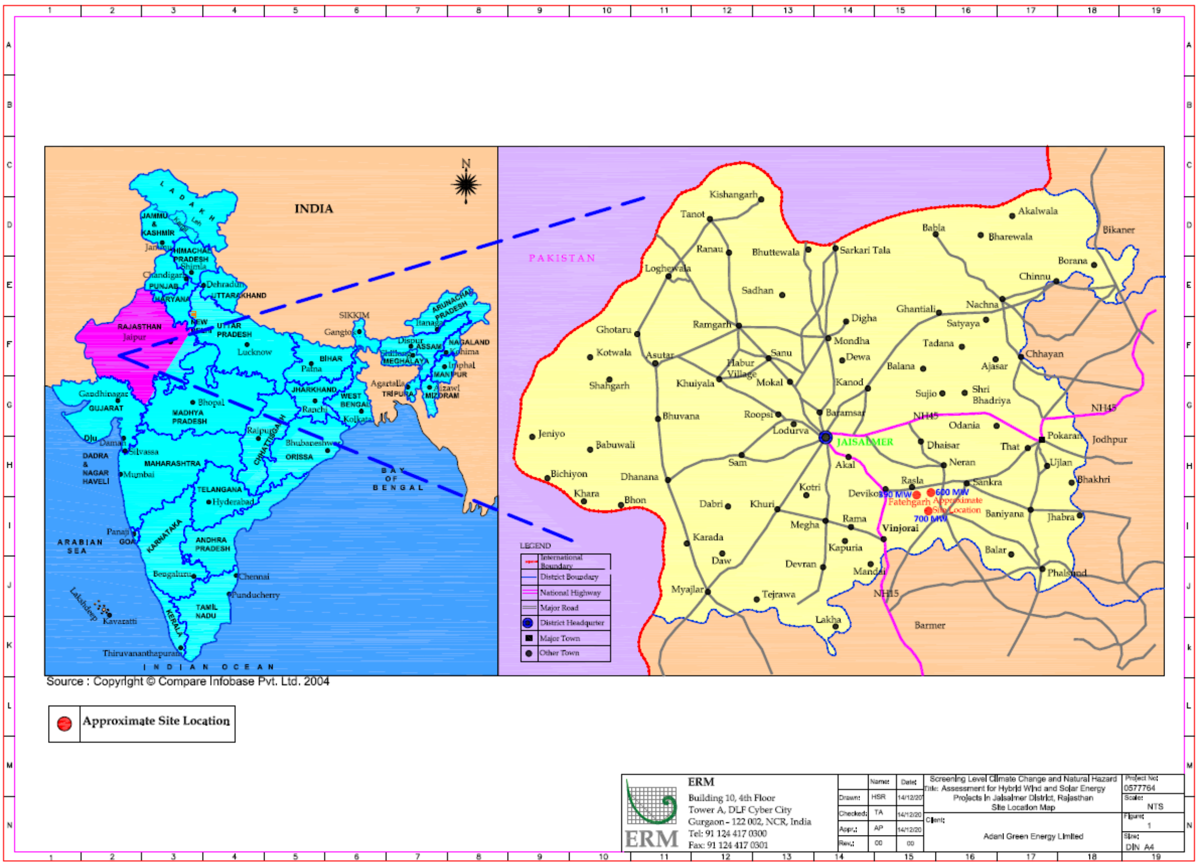
- 390 MW: 101.2 MW Wind and 360 MW Solar Farm: The proposed 390 MW Solar-Wind Hybrid Power Project is located on land ranging from flat to undulating private shrub/waste land, agricultural land and gravel land across 12 villages under Fatehgarh and Pokhran tehsil of Jaisalmer district in the state of Rajasthan. Elevation at project site ranges from 240 m to 320 m above mean sea level. The Project lies between the following coordinates:

- Northern most point: 26°53'29.90"N, 71°26'15.44"E
- Southern most point: 26°37'44.21"N, 71°36'54.17"E
- Western most point: 26°45'54.74"N, 71°23'0.58"E
- Eastern most point: 26°50'59.82"N, 71°38'12.22"E

- 600 MW: 151.2 MW Wind and 2 X 300 MW Solar Farm: The proposed 600 MW Solar-Wind Hybrid Power Project is located on land ranging from flat to undulating private fallow land, dunes, agricultural land (net area sown) and culturable waste land across 18 villages in Fatehgarh and Pokhran Taluka of Jaisalmer District in the state of Rajasthan. Elevation at project site ranges from 235 m to 330 m above mean sea level The Project lies between the following coordinates:
  - Northern most point: 26°54'37.97"N, 71°30'54.31"E
  - Southern most point: 26°33'1.66"N, 71°27'51.40"E
  - Western most point: 26°47'50.44"N, 71°21'33.92"E
  - Eastern most point: 26°43'28.50"N, 71°39'22.16"E
- 700 MW: 510 MW Wind and 250 and 350 MW Solar Farm: The proposed 700 MW Solar-Wind Hybrid Power Project is located on land ranging from flat to undulating private fallow land, dunes, agricultural land (net area sown) and culturable waste land across 47 villages in Fatehgarh, Jaisalmer and Pokhran Taluka of Jaisalmer District, and Sheo Taluka in Barmer District in the state of Rajasthan. Elevation at project site ranges from 235 m to 307 m above mean sea level The Project lies between the following coordinates:
  - Northern most point: 26°50'58.81"N, 71°26'25.45"E
  - Southern most point: 26°18'15.63"N, 71°26'10.63"E
  - Western most point: 26°28'34.30"N, 71°38'1.79"E
  - Eastern most point: 26°21'58.50"N, 71° 0'25.82"E

Figure 1.2 presents the approximate location of Site including all the three (3) hybrid solar and wind energy projects

Figure 1.2 Approximate Site Location Map of Wind and Solar Projects



The Area of Assessment for the Climate Change Risk Assessment (hereinafter referred to as 'CCRA') was selected based on the TCFD's recognition that physical risk can have a wide range of financial implications: supply chain disruption, impacts on availability of raw material and other natural resources, etc.

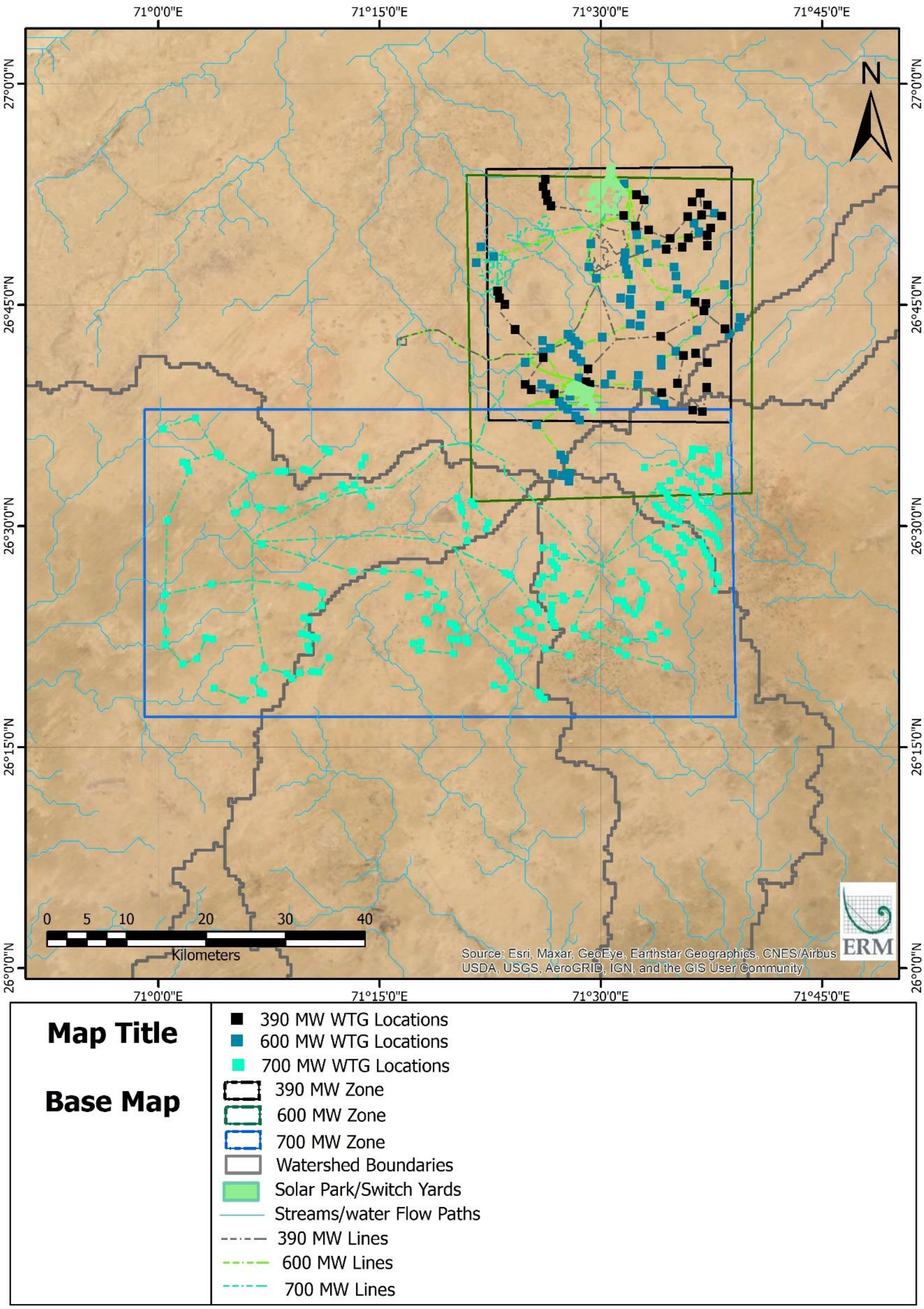
Accordingly, the study area was selected to include the major project components from all three (3) proposed hybrid projects (hereinafter referred to as 'Key Assets') as presented in Table 1.1 and the Project's supply chain network consisting of external transmission lines connecting to PGCIL substation.

Figure 1.3 presents the map of Study Area with the location of WTG's and solar panels.

Table 1.1 Key Project Assets

<table>
<tr><th>Study Area</th><th>Major Components</th></tr>
<tr><td>390 MW Plant</td><td rowspan="3">1. PV Modules
2. Wind Turbine (WTG)
3. Inverter
4. Transmission Lines and Towers
5. Storage Room
6. Site Office
7. Access Road</td></tr>
<tr><td>600 MW Plant</td></tr>
<tr><td>700 MW Plant</td></tr>
</table>

Figure 1.3 Map of Study Area with WTG's and Solar Panels

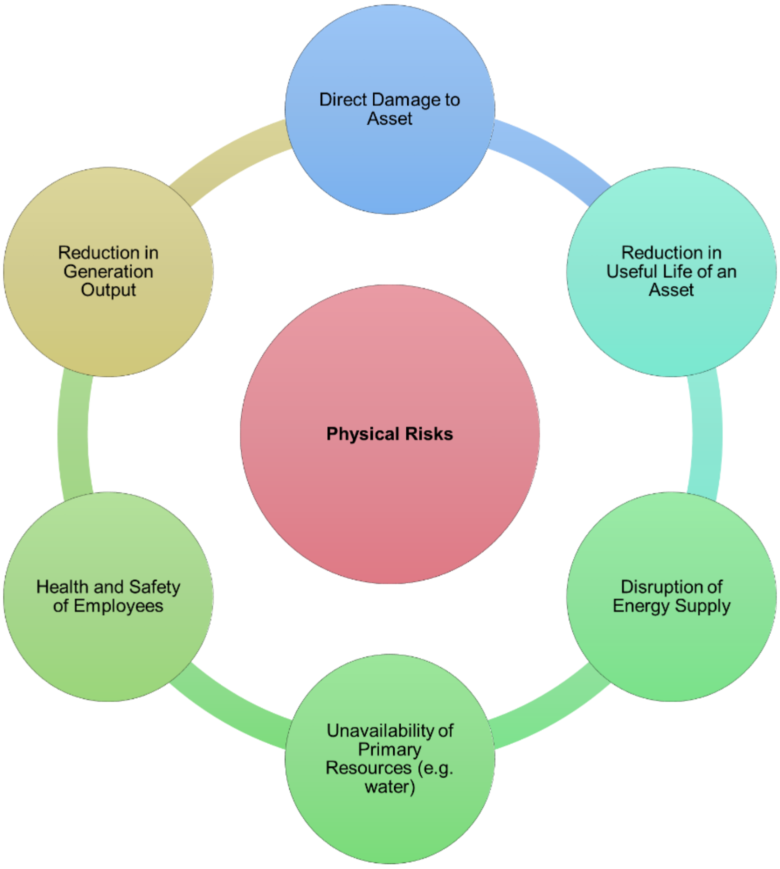


1.3 Climate Change Risks to Wind and Solar Farms

Climate change is causing more frequent and more severe extreme weather events, increasing the likelihood of critical coping thresholds being exceeded. Wind and Solar Energy projects may suffer infrastructure damage, project delays and constraints on water supplies, lost production, power supply transmission disruption and variability in energy demand. The health and safety of employees, business reputation, violation of regulatory standards, social license to operate and financial disruptions may become more prevalent.

Figure 1.4 presents the general risks on wind and solar energy projects as a result of climate change. Anticipated impacts of these climate changes were reported to be flooding, damage to building construction, disruption of energy transmission, increased insurance premiums, higher operating costs, early retirement of assets, decreased production capacity, and high variability in availability of water.

Figure 1.4 General Risks from Climate Change on Wind and Solar Farms



1.4 Methodology

The assessment in general starts with the collection of geospatial information for the Study Area to be assessed. Based on the geospatial information, baseline natural hazards and the climate change projection data were collected and collated. It should be noted that the present assessment utilizes data sources which are readily available and are open source. A brief description of the various steps performed in this study is provided below.

- The first step focuses on evaluation of historical data on natural hazards in the area of interest to evaluate the existence and magnitude of identified natural hazards. This assessment was performed qualitatively based on the availability of historical data. The potential impact of each natural hazard was evaluated on a scale of three levels categorized as **Low, Medium, and High.**

The hazard categorisation was based on the potential impact on built and natural environment considering intensity/ magnitude, and/or frequency of the hazard in the region.

- The second step constitutes evaluation of climate change projections to assess the extent of changes in climatic variables such as precipitation, and temperature. This provided information on any significant changes in temperature and precipitation in the upstream of the Site which may have impact on the Site operations in future.
- The third step involves the evaluation of baseline risk from each natural hazard; the outputs from climate change projections are overlaid qualitatively on the baseline conditions for each hazards to categorize the climate change risk using only the hazard intensity.

Figure 1.5 provides the framework for the current assessment for the extraction of historical and projected data, evaluation of baseline natural hazards and superimposition of climate change projections. The final output is in terms of a semi-quantitative hazard matrix which presents cumulative hazard levels for each study area under baseline and climate change scenario. Based on this outcome, ERM evaluated the high-level implications and the corresponding recommendations for the project components.

In short, the process of assessment of physical risks involves the evaluation of likely impacts from climate change projections on the existing baseline risks to inform the business units on potential future risks (Figure 1.6).

Figure 1.5 General Framework for a Natural Hazard and Climate Change Impact Assessment

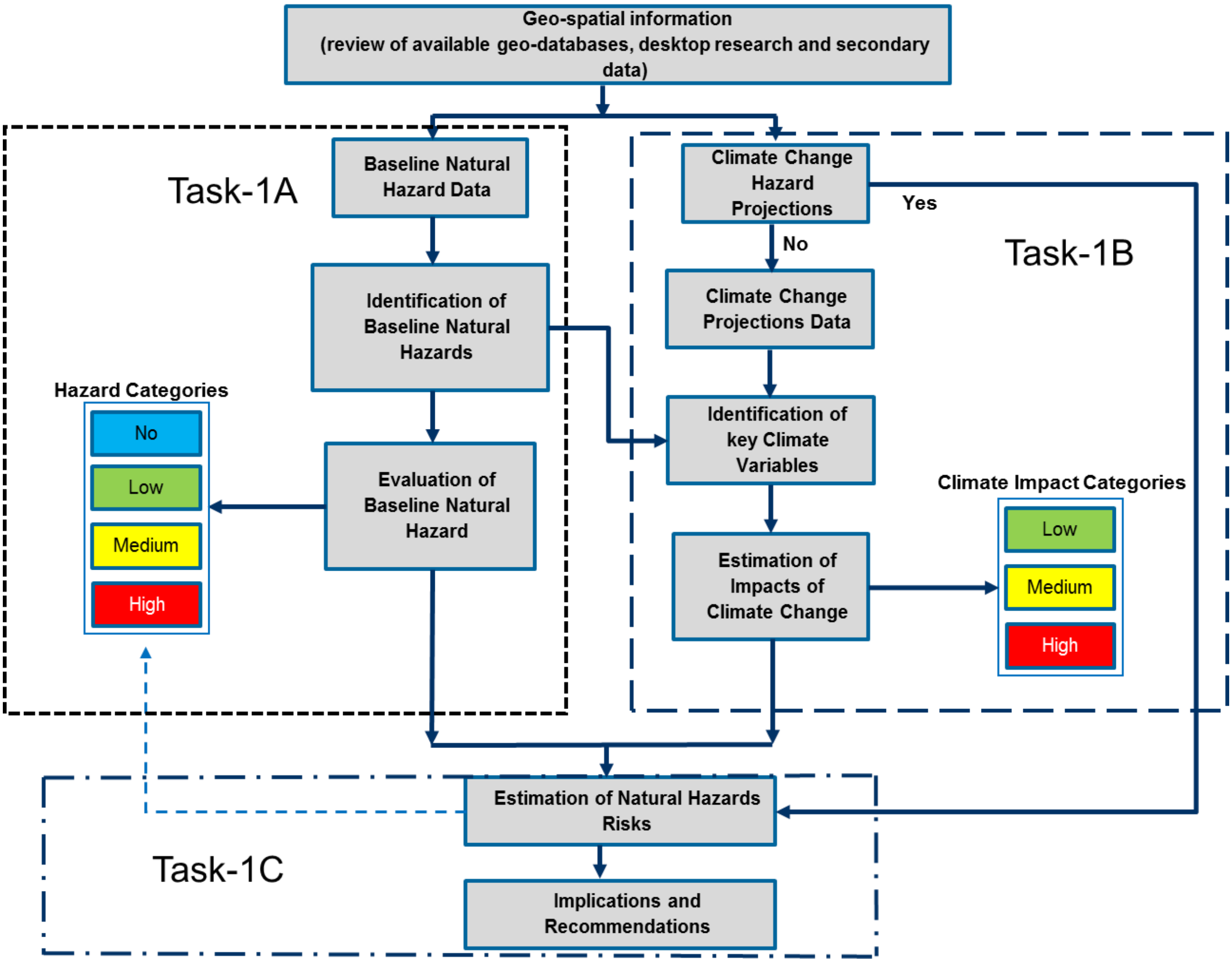
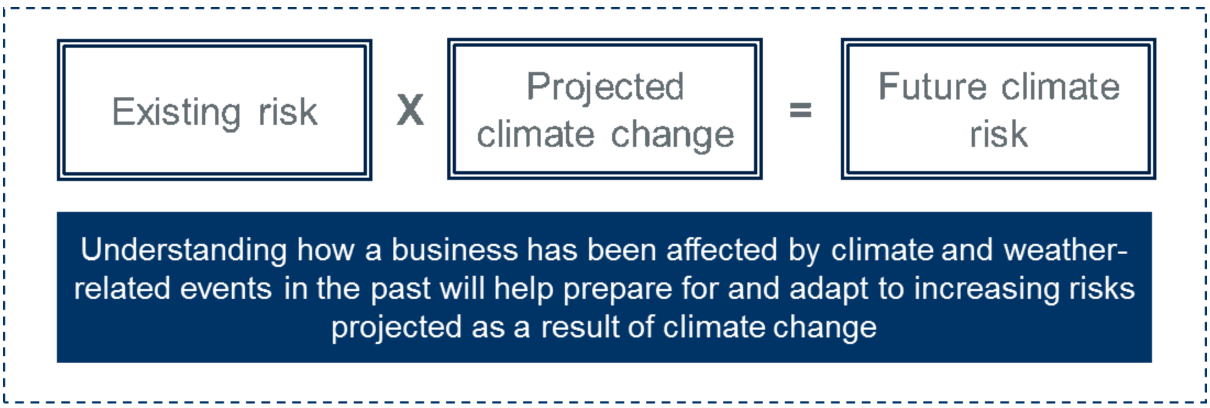


Figure 1.6 Process to Evaluate Threats Due to Natural Hazards under Climate Change Scenarios

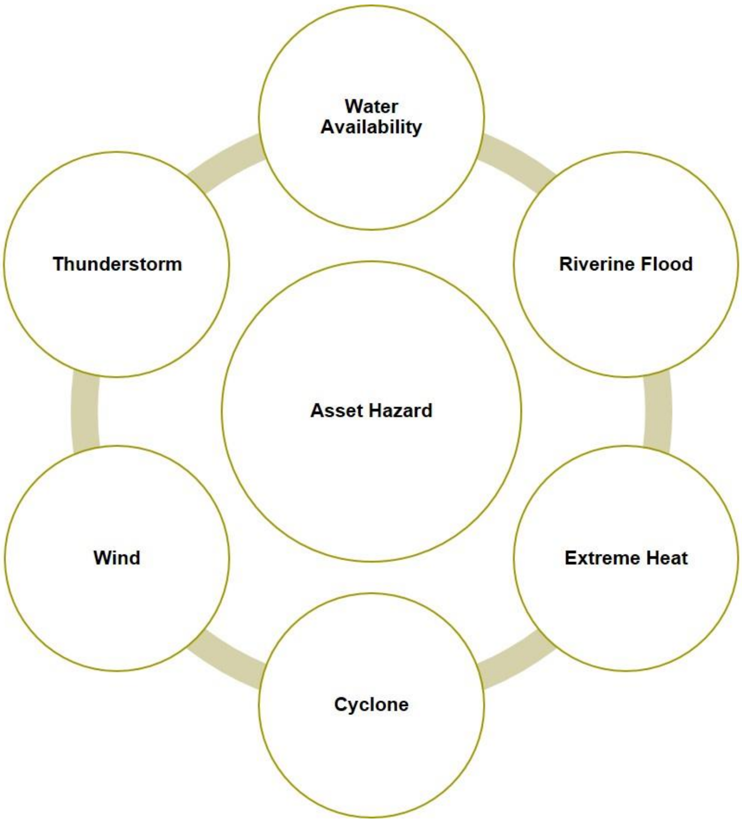


1.4.1 Baseline Natural Hazard Evaluation

Use of Global and National Databases

Various natural hazards as presented in Figure 1.7 were evaluated based on review of recognised global and national level databases/literature in this assessment. Elevation in the Study Area ranges from 235 m to 330 m above mean sea level with a minimum distance of ~420 km from the Arabian Sea in the south-west. The Study Area is located in Jaisalmer with flat to gentle slopes and is a part of the Great Indian Thar Desert. Most of the area in the district is barren, undulating with sand dunes sloping towards the Indus valley and the Runn of Kutchh. Based on the location of the study areas and general topography, hazards due to coastal flooding and landslides were not evaluated in the present assessment.

Figure 1.7 Hazards Evaluated in this Assessment



Various data sources used in the present assessment for evaluation of baseline natural hazard are presented in Table 1.2. Table 1.3 presents the criteria for categorisation and normalisation of hazard categories adopted in the present assessment.

Table 1.2 Data Sources used for Baseline Natural Hazard Evaluation

Natural Hazard	Factors Assessed	Data Sources
Water Availability	Water Stress	Hofste, R., S. Kuzma, S. Walker, E.H. Sutanudjaja, M.F.P. Bierkens, M.J.M. Kuijper, M. Faneca Sanchez, R. Van Beek, Y. Wada, S.G. Rodríguez and P. Rei. 2019. “Aqueduct 3.0: Updated DecisionRelevant Global Water Risk Indicators.” Technical Note. Accessed 9 June, 2020. Available at: https://www.wri.org/publication/aqueduct-30
	Seasonal Variability	
Flood	WRI-Aqueduct Flood Tool	Ward, Philip J,. Hessel C. Winsemius, Samantha Kuzma, Marc F.P. Bierkens, Arno Bouwman, Hans De Moel, Andrés Díaz Loaiza, Dirk Eilander, Johanna Englhardt, Gilles Erkens, Eskedar Tafete Gebremedhin, Charles Iceland, Henk Kooi, Willem Ligtvoet, Sanne Muis, Paolo Scussolini, Edwin H. Sutanudjaja, Rens Van Beek, Bas Van Bemmel, Jolien Van Huijstee, Frank Van Rijn, Bregje Van Wesenbeeck, Deepak Vatvani, Martin Verlaan, Timothy Tiggeloven and Tianyi Luo. 2020, Aqueduct Floods. Available at: https://www.wri.org/resources/data-sets/aqueduct-floods-hazard-maps
	Flood Hazard Map of India	Building Material and Technology Promotion Council (BMTPC) Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/flood.html
Extreme Heat	Extreme heat hazard level	ThinkHazard. 2020. Available at: https://thinkhazard.org/en/report/17848-india-rajasthan-jaisalmer/EH
Cyclone	Cyclone Tracks	NOAA Historical Hurricane Tracks Available at: https://coast.noaa.gov/hurricanes/#map=6.07/27.032/70.913&search=eyJzZWFyY2hTdHJpbmciOiJKYWlzYWxtZXIsIFJhamFzdGhhbiwgSW5kaWEiLCJzZWFyY2hUeXBlIjoiZ2VvY29kZWQiLCJvc21JRCI6IjE3OTg4NDciLCJjYXRlZ29yaWVzIjpbIkg1IiwiSDQiLCJIMyIsIkgyIiwiSDEiLCJUUyIsIlREIiwiRVQiXSwieWVhcnMiOltdLCJtb250aHMiOltdLCJlbnNvIjpbXSwicHJlc3N1cmUiOnsicmFuZ2UiOlswLDExNTBdLCJpbmNsdWRlVW5rbm93blByZXNzdXJlIjp0cnVlfSwiYnVmZmVyVW5pdCI6WyJNaWxlcyJdLCJzb3J0U2VsZWN0aW9uIjp7InZhbHVlIjoieWVhcnNfbmV3ZXN0IiwibGFiZWwiOiJZZWFyIChOZXdlc3QpIn0sImFwcGx5U3Rvcm1MYWJlbHNWaXNpYmxlIjp0cnVlfQ==
	Cyclone Intensity Maps	UNEP, 2013. Global Risk Data Platform: Tropical cyclones wind speed buffers footprint 1970-2009. Accessed 9 June 2020. Available at: https://preview.grid.unep.ch/index.php?preview=data&events=cyclones&evcat=4&lang=eng
Wind Speed	Average Wind Speed Map of the World	DTU (Technical University of Denmark). 2019. Global Wind Atlas 2.0. Accessed 9 June 2020. Available at: https://globalwindatlas.info
	Wind Hazard Map	Building Material and Technology Promotion Council (BMTPC) Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/wind-rj.html
Thunder storm	Thunderstorm Incidence map	Building Material and Technology Promotion Council (BMTPC) Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/th.html

Natural Hazard	Factors Assessed	Data Sources

Table 1.3 Categorisation of Natural Hazards

No.	Hazard	Original Categorization	Modified Categorization
1	**Water Availability**		
1.1	Water Stress Based on ratio of total water withdrawal to available renewable water resources (surface and groundwater)	Low: <10%	Low: <10%
		Low-Medium: 10-20%	Medium: 10-20%
		Medium-High: 20-40%	High: >20%
		High: 40-80%	
		Extremely High: >80%	
1.2	Seasonal Variability *Based on coefficient of variability as ratio of standard deviation of the annual available water and the annual mean available water during the period of 1960-2014*	Low: <0.33	Low: <0.33
		Low-Medium: 0.33-0.66	Medium: 0.33-0.66
		Medium-High: 0.66-1	High: 0.66-1
		High: 1-1.33	
		Extremely High: >1.33	
2	**Flood**		
2.1	WRI-Aqueduct Flood tool *Based on depth of inundation with reference to the impact on person walking through the flood water and standing vehicle as suggested by FEMA*	No classification	Low: <0.5 m
			Medium: 0.5-1.5 m
			High: >1.5 m
3	**Extreme Heat**		
3.1	Extreme Heat 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).	Very Low	Low
		Low	
		Medium	Medium
		High	High
4	**Cyclone**		

No.	Hazard	Original Categorization	Modified Categorization
4.1	Cyclone and Hurricane Cyclone categories based on damage potential as classified by Saffir-Simpson Scale	Category 1: 119-153 km/h	Low: Category 1 (119-153 km/h)
		Category 2: 154-177 km/h	Medium: Category 2 (154-177 km/h)
		Category 3: 178-208 km/h	High: ≥ Category 3 (178-208 km/h)
		Category 4: 209-251 km/h	
		Category 5: ⩾252 km/h	
5	**Wind Speed**		
5.1	Beaufort's Scale	Calm (0): < 1m/s	Low: ≤ 11m/s
		Light Air (1): 1-2 m/s	
		Light Breeze: (2) 2-3 m/s	
		Gentle Breeze (3): 4-5 m/s	
		Moderate Breeze (4): 6-8 m/s	
		Fresh Breeze (5): 9-11 m/s	
		Strong Breeze (6): 11-14 m/s	Medium: 11-21 m/s
		Near Gale (7): 14-17 m/s	
		Gale (8): 17-21 m/s	
		Strong Gale (9): 19-24 m/s	High: > 21 m/s
		Storm (10): 25-28 m/s	
		Violent Storm (11): 29-32 m/s	
		Hurricane (12): >32 m/s	
5.2	BMTPC Wind Hazard Categorization Based on basic wind speed (peak wind speed averaged over 3 sec for a 50 year return period)	Low damage: 33 m/s	Low: ≤ 33m/s
		Moderate Damage (Zone A): 39 m/s	Medium: 33-44 m/s
		Moderate Damage (Zone B): 44 m/s	High: > 44 m/s

No.	Hazard	Original Categorization	Modified Categorization
		High Damage: 47 m/s	
		Very High Damage (Zone A): 50 m/s	
		Very High Damage (Zone B): 55 m/s	

1.4.2 Climate Change Evaluation

Climate Change Projections

The analysis of future climate change involves assessment of a range of different indicators modelled as part of the IPCC 5th Assessment Report published in 2013 (IPCC, 2013). Emissions scenarios describe future releases of greenhouse gases, aerosols, and other pollutants into the atmosphere and provide inputs to climate models. Representative Concentration Pathways (RCPs) are consistent sets of projections of components of radiative forcing (i.e., the change in the balance between incoming and outgoing radiation to the atmosphere caused primarily by changes in atmospheric composition) that are meant to serve as input for climate modelling.

Climate change projection values are available for a number of climate variables at various time horizons in the future under different future greenhouse gas emissions scenarios. The assessment looks at projected change for the years 2030 (quarter-century), and 2050 (mid-century) where two (2) future emission scenarios, RCP 4.5 and RCP 8.5 were analysed.

The raw data was processed in order to obtain information for the relevant years and emission scenarios and to format it in a manner which could be uploaded into ArcGIS. The basic approach involved the following steps:

- First, the output from each climate model was averaged over time, giving a single value for the time period (i.e., an average value was obtained for 2030 for the period 2025-2035, and for 2050 over the period 2045-2055.
- This mean value was then averaged together with the corresponding values from all other models. This provided the 'Multi-Model-Mean' value to be used for this analysis. It should be noted that some models do not include projections for both RCP scenarios and therefore, the multi-Model-mean approach used in this assessment includes only those models that provided projections for both scenarios in order to ensure internal consistency.
- A baseline value, which is the time-averaged, model-averaged value of the variable from 1981-2000, was calculated. The baseline is the modelled baseline, and does not incorporate any observed values.

Differences from the baseline for 2030, and 2050 for the RCP 4.5 and the RCP 8.5 emissions scenarios were also calculated in this manner. Positive values indicate that the variable is projected to increase, while negative values indicate that the variable is projected to decrease.

1.4.3 Qualitative Estimation of Impact of climate Change

Based on the review of the climate projection data, percentage changes in climate indicators were evaluated. The impact of these changes on occurrence of natural hazards (intensity and/or frequency) was qualitatively evaluated based on the percentage changes in temperature and precipitation indicators to determine the extent of vulnerability under climate change conditions. Table 1.4 presents the impact criteria considered in the present assessment. Changes to future natural hazards were evaluated in comparison to the baseline natural hazards based on the changes in temperature (Warm Spell Duration Index, Average Temperature and Average Maximum Temperature) and precipitation (One Day Maximum Rainfall, Consecutive 5 days Maximum Rainfall, Number of Days with Heavy rainfall) parameters.

Table 1.4 Criteria for Evaluation of Climate Change Impacts

Type of Vulnerability	Temperature Parameters (Warm Spell Duration Index, Average Temperature, Average Maximum Temperature)	Precipitation (One Day Maximum Rainfall, Consecutive 5 days Maximum Rainfall, Number of Days with Heavy rainfall)
Low	<=5%	<=5%
Medium	5-10%	5-10%
High	>10%	>10%

1.5 Review of Climate Change and Disaster Management Policy in India

1.5.1 National Level Policies and Plans

1.5.1.1 National Action Plan on Climate Change (2008)

The Government of India launched National Action Plan on Climate Change (NAPCC) in 2008 outlining eight (8) National Missions on climate change[2]. These include:

1. National Solar Mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission for Sustaining the Himalayan Eco-system
6. National Mission for a Green India
7. National Mission for Sustainable Agriculture
8. National Mission on Strategic Knowledge for Climate Change

Under this purview the National Action Plan for Climate Change recognized following dimension to address the threats from climate change and sustain required economic growth of the country-

- Protection of Poor
- Sustainability
- Implementation
- International cooperation

The key National Missions and their objectives are listed under Table 1.5.

[2] http://cckpindia.nic.in/assets/NAPCC/NAPCC_Document.pdf

Table 1.5 Summary of National Missions Identified under NAPCC

Sr. No.	Mission Name	Mission Objectives
1	**National Solar Mission**	▪ To expand on renewable energy and reduce greenhouse gas emissions ▪ Enable decentralized distribution of power in remote areas, empowering people at grass root level ▪ R&D with international cooperation
2	**National Mission for Enhanced Energy Efficiency**	▪ Establishment of institutional mechanism such as Bureau of Energy Efficiency (BEE) ▪ It was aimed to save 10,000MW of energy by end of 2012. ▪ Promotion of energy efficient industries through certification and ▪ Promoting energy efficient appliances
3	**National Mission on Sustainable Habitat**	▪ Energy efficient buildings (better building materials and design) ▪ Management of solid waste (recycling and reuse) ▪ National program for R&D in bio-chemical conversion, waste water reuse, sewage utilization and recycling etc.
4	**National Water Mission**	▪ Aims to ensure integrated water resource management to conserve and minimize wastage of water and ensure equitable distribution ▪ It seeks to ensure considerable water supply in urban areas is met by recycled water and in coastal areas adoption of low temperature desalination technologies ▪ Rain Water harvesting
5	**National Mission for Sustaining Himalayan Ecosystem**	▪ Evolve management measures for sustaining and safeguarding the Himalayan Ecosystem ▪ Establishing observation and monitoring network
6	**National Mission for Green India**	▪ Enhancing ecosystem services including carbon sink

Sr. No.	Mission Name	Mission Objectives
		■ Targeted forest area of 33% against present are under forest as 23% ■ Afforestation of degraded areas ■ Corpus find of Rs. 6000 crore
7	**National Mission for Sustainable Agriculture**	■ Strategies for climate resilient agriculture ■ Development of new varieties of crops and cropping pattern to cope with long dry spells, flooding, and variable moisture capacity ■ Integration of traditional knowledge and modern technology involving IT, geospatial technology, and biotechnology ■ Improved productivity
8	**National Mission of Strategic Knowledge for Climate Change**	■ Conducting R&D in cooperation of global research communities ■ Targeted research areas socio-economics, health, demography, migration pattern, and livelihood of coastal communities.

The key takeaway is that the government of India is focused on enhancing activities under the National Missions with respect to adaptation, mitigation and capacity building and undertake additional interventions like launch of new Missions such as on Health and Coastal areas.

1.5.1.2 Nationally Determined Contributions (NDC's)

India has committed to the objectives of Paris Agreement through the following goals[3]-

- To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
- To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
- To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level.
- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.
- To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
- To mobilize domestic and new & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
- To build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies.

The key takeaway for the project is an increased emphasis from the government to rely on clean sources of energy including solar and wind energy to satisfy the energy demands of the country and reduce greenhouse gas emissions through the use of non-renewable forms of energy.

1.5.1.3 Climate Change Mitigation Actions

India's mitigation policies and actions must be understood in the context of its longstanding position that climate change is a global challenge, a position in accordance with the spirit of the UNFCCC. The following mitigation programmes were identified by various Ministries and Authorities[4].

- **Solar Energy** - To deploy 100 GW solar power by 2022.
- **Wind Energy** - Deployment of 60 GW Wind Energy by 2022 and stable at the same level until 2030.
- **Green Rating for Integrated Habitat Assessment (GRIHA)** - To recognize energy-efficient buildings, as well as to stimulate their large scale replication.
- **Green Energy Corridor Project** - Aims at synchronizing electricity produced from renewable sources, such as solar and wind, with conventional power stations in the grid.
- **International Solar Alliance (ISA)** - To provide a dedicated platform for cooperation among solar-resource-rich countries, through which the global community, including governments, bilateral and multilateral organizations, corporates, industry, and other stakeholders, can

[3] https://cckpindia.nic.in/indias-ndc/

[4] https://cckpindia.nic.in/mitigation-actions/

contribute to help achieve the common goal of increasing the use and quality of solar energy in meeting energy needs of prospective ISA member countries in a safe, convenient, affordable, equitable and sustainable manner.

- **National Smart Grid Mission** - Established to accelerate Smart Grid deployment in India.
- **REDD+ Reducing emissions** - To achieve additional carbon sequestration, emission reduction, improve forest based livelihoods, conservation of rare, endemic, and endangered species found in the area and improvement of watershed hydrology.
- **Climate Change Action Programme (CCAP)** - to create and strengthen the scientific and analytical capacity for assessment of climate change in the country, putting in place appropriate institutional framework for scientific and policy initiatives and implementation of climate change related actions in the context of sustainable development.

The key takeaway for the project is an increased emphasis from the government to rely on clean sources of energy including solar and wind energy to satisfy the energy demands of the country and reduce greenhouse gas emissions through the use of non-renewable forms of energy.

1.5.1.4 Climate Change Adaptation Actions

The adverse impacts of climate change on the developmental prospects of the country are amplified enormously by the existence of widespread poverty and dependence of a large proportion of the population on climate sensitive sectors for livelihood. A range of actions have been introduced to address it[5] which are given below:

- **National Adaptation Fund on Climate Change (NAFCC)** - NAFCC was launched in 2015-16 by Ministry of Environment, Forest and Climate Change (MoEFCC) to cover vulnerable sectors such as Water, Agriculture and Animal Husbandry, Forestry, Ecosystems and Biodiversity across the country. The overall aim of the fund is to support concrete adaptation activities which are not covered under on-going activities through the schemes of State and National Government that reduce the adverse effects of climate change facing community, sector and states. The Fund is meant to assist National and State level activities to meet the cost of adaptation measures in areas that are particularly vulnerable to the adverse impacts of climate Change.
- **Programmes/Schemes with Adaptation Co-benefits** - Programmes were identified by the government of India which provide additional benefits of climate change in the arenas of agriculture, agroforestry, water supply and sanitation, water conservation, food security, soil quality, heatwave management, Integrated Watershed Management Program (IWMP), National Vector Borne Disease Control Programme (NVBDCP), State Disaster Response Fund, and Coalition for Disaster Resilient Infrastructure (CDRI).

Among all the above actions, the most relevant actions in the context of this project include:

1. ***Guidelines for preparation of Action Plan – Prevention and Management of Heat-Wave 2019****- It aims for improving the capacity of the States to deal with heat wave management in a planned manner.*
2. ***State Disaster Response Fund*** *- Primary fund available with State Governments for responses to notified disasters. Disasters covered under SDRF: Cyclone, drought, earthquake, fire, flood, tsunami, hailstorm, landslide, avalanche, cloudburst, pest attack, frost and cold waves.*
3. ***Coalition for Disaster Resilient Infrastructure (CDRI)*** *- Aims to promote resilience of new and existing infrastructure systems to climate and disaster risks.*

5 https://cckpindia.nic.in/adaptation-actions/

1.5.1.5 Disaster Management (DM) Act, 2005

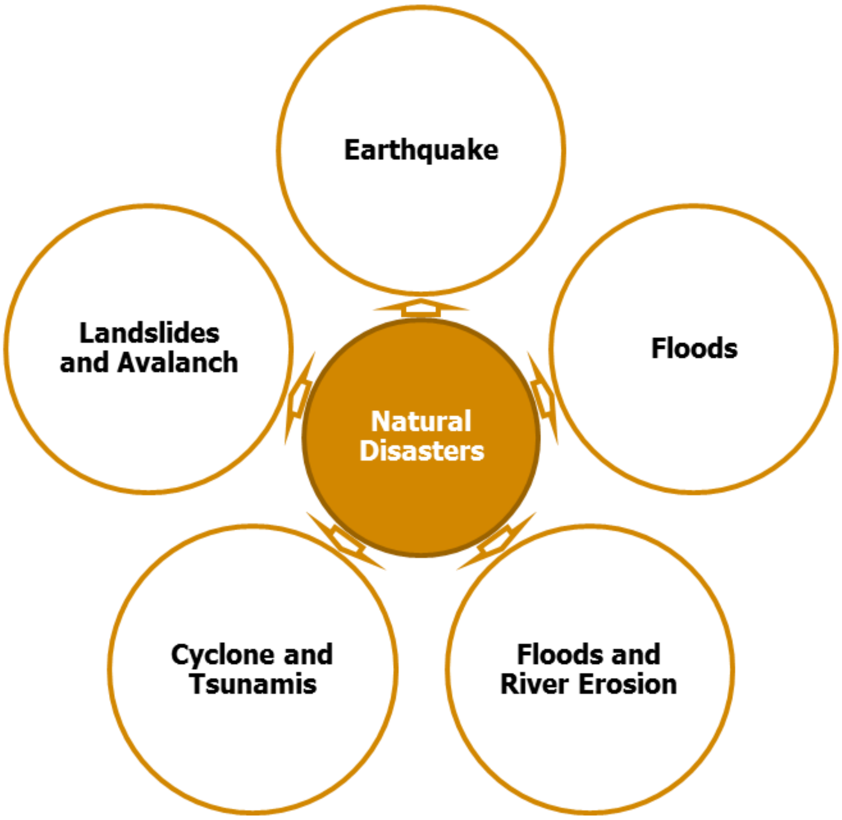
The Disaster Management Act, 2005 (DM Act 2005) lays down institutional and coordination mechanism for effective Disaster Management (DM) at the national, state, district and local levels. As mandated by this Act, the Government of India created a multi-layered institutional system consisting of the National Disaster Management Authority (NDMA) headed by the Prime Minister, the State Disaster Management Authorities (SDMA) headed by the respective Chief Ministers and the District Disaster Management Authorities (DDMA) headed by the District Collectors/ District Magistrate and co-chaired by Chairpersons of the local bodies.

1.5.1.6 National Policy on Disaster Management (NPDM), 2009

The National Policy on Disaster Management (2009) recognized that disasters have detrimental effects on economic development of the nation. Moreover the policy affirmed that the socially and economically weaker sections of the society are the most vulnerable to the natural disaster. Below are the key components of the policy:

- This policy considers the natural disasters such as earthquake, floods and river erosion, cyclones and tsunamis, and landslides and avalanches and emergencies of modern times such as Chemical, Biological, Radiological and Nuclear (commonly known as CBRN) emergencies. The key natural hazards identified under this policy are illustrated in Figure 1.8.
- The policy considers disaster management as a cyclic process consisting of six elements: prevention, mitigation, preparedness, response, rehabilitation, and recovery.
- It emphasises the need of an institutional structure for natural disaster management comprising central body of National Disaster Management Authority (NDMA) headed by Prime Minister of India, State Disaster Management Authorities (SDMAs) headed by respective Chief Ministers of the State, and District Disaster Management Authorities (DDMAs).

Figure 1.8 Natural Disasters considered under National Policy for Disaster Management



1.5.1.7 National Disaster Management Plan, 2019

The National Disaster Management Plan (NDMP)[6] provides a framework and direction to the Government agencies for all phases of disaster management cycle. The NDMP is a "dynamic document" in the sense that it will be periodically improved keeping up with the emerging global best practices and knowledge base in disaster management. It is in accordance with the provisions of the Disaster Management (DM) Act 2005, the guidance given in the National Policy on Disaster Management (NPDM) 2009, and the established National practices.

The NDMP recognizes the need to minimize, if not eliminate, any ambiguity in the responsibility framework. It, therefore, specifies who is responsible for what at different stages of managing disasters. It is meant to be implemented in a flexible and scalable manner in all phases of disaster management: a) Mitigation (prevention and risk reduction), b) Preparedness, c) Response and d) Recovery (immediate restoration and build-back beer). While the names of ministries/ departments of the Centre and State/UT having specific roles and responsibilities are mentioned in the Plan, in the spirit of the DM Act 2005 and the exigencies of humanitarian response, every ministry/ department and agency is expected to contribute to DM going beyond their normal rules of business. The key features of the NDMP are summarised below:

- Conforming to the national legal mandates - the DM Act 2005 and the NPDM 2009
- Participating proactively to realising the global goals as per agreements to which India is signatory - Sendai Framework for Disaster Risk Reduction (DRR), Sustainable Development Goals (SDGs) and Conference of Pares (COP21) Paris Agreement on Climate Change

[6] https://reliefweb.int/sites/reliefweb.int/files/resources/ndmp-2019.pdf

- Prime Minister's Ten Point Agenda for DRR articulating contemporary national priorities
- Social inclusion as a ubiquitous and cross-cutting principle
- Mainstreaming DRR as an integral feature
- The NDMP covers disaster management cycle for all types of hazards - natural and human-induced.
- The role of the central agencies is to support the disaster-affected State or the UT in response to requests for assistance in disaster management planning, preparedness, and capacity building, the central agencies will constantly work to upgrade Indian DM systems and practices as per global trends.
- The priories of the Sendai Framework and those related to DRR in SDGs and Paris Agreement have been integrated into the planning framework for Disaster Risk Reduction under the following Thematic Areas for Disaster Risk Reduction:
  - Understanding Risk
  - Inter-Agency Coordination
  - Investing in DRR – Structural Measures
  - Investing in DRR – Non-Structural Measures
  - Capacity Development and
  - Climate Change Risk Management
- The drought-prone and arid/semi-arid regions such as Rajasthan with low and uncertain rainfall need long-term water resource management strategies coupled with better management of dryland farming to effectively cope with recurring droughts.
- Climate change induced events such as cyclone, flood, landslide, drought, thunderstorm, lightening, etc., should be accounted for in disaster management.
- Integration of disaster risk reduction and climate change adaptation should be targeted.
- Involvement of private sector in disaster management and for businesses to integrate disaster risk into their management processes and involve the private sector in the areas of:
  - Technical support
  - Reconstruction effort
  - Risk management including covering risks to their own assets
  - Risk-informed investments in recovery efforts

1.5.2 State Level Policies and Plans

The government of Rajasthan formulated Climate Change Agenda for Rajasthan (CCAR) in 2010 for the State to take forward the provisions of the NAPCC (National Action Plan on Climate Change) and prepare for adaptation and mitigation at the State level. This was followed by the Rajasthan Environment Mission to identify priorities for climate change mitigation and adaption policy and action for the period 2010-2014. State specific missions for Rajasthan were identified along with relevant policies-

- Water resources
- Agriculture and animal husbandry
- Forestry and biodiversity
- Human health

- Enhanced energy efficiency and solar energy
- Urban governance and sustainable habitats
- Strategic knowledge for climate change

1.5.2.1 Rajasthan Action Plan on Climate Change (RAPCC)

The drafting of Rajasthan Action Plan on Climate Change (RAPCC) started in 2012 in concurrence with the guiding principles of Rajasthan Environment Mission, Environment Policy 2010 and Climate Change Agenda for Rajasthan (2010-14)[7]. The RAPCC remained a draft and was never implemented in effect. The guiding principles of RAPCC were focused on the following aspects-

- National priorities as identified in NAPCC
- State-specific risks, impacts and opportunities under changing climate.
- Stakeholder consultation

The state government has announced drafting of a new state action plan for climate change in 2019 which is yet to be finalised.

1.5.2.2 State Disaster Management Plan (SDMP), 2014

The SDMP for Rajasthan[8] was developed considering a holistic, pro-active, multi-disaster, multi-sector, multi-stakeholders, technology driven, participatory, dynamic process to build a disaster resilient State. The key objectives of the SDMP are enlisted below.

- Promoting a culture of prevention and preparedness, so that DM receives the highest priority at all levels.
- Ensuring that community is the most important stakeholder in the DM process.
- Encouraging mitigation measures based on state-of-the-art technology and environmental sustainability.
- Mainstreaming DM concerns into the developmental planning process.
- Putting in place a streamlined and institutional techno-legal framework for the creation of an enabling regulatory environment and a compliance regime.
- Developing contemporary forecasting and early warning systems backed by responsive and fail-safe communications and Information Technology (IT) support.
- Promoting a productive partnership with the media to create awareness and to contribute towards capacity development.
- Ensuring efficient response and relief with a caring approach towards the needs of the vulnerable sections of society.
- Undertaking reconstruction as an opportunity to build disaster resilient structures and habitats.
- Undertaking recovery to bring back the community to a better and safer level than the pre-disaster stage.
- Identification of the key hazards such as earthquakes, floods, hailstorms, frost, cloudburst, forest fires and sandstorms at a state level along with hazard profiling of wind speed, flood and droughts at the district level.

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7 http://moef.gov.in/wp-content/uploads/2017/09/Rajasthan.pdf

8 http://dmrelief.rajasthan.gov.in/documents/sdmp-eng.pdf

- Identification of hazard specific preventive, mitigation and preparedness strategies for droughts, flood, hailstorm, sandstorms, forest fires and heat and cold waves along with responsible agencies.
- Identification of measures to mitigate adverse impact of climate change in four broad sectors: I) water resources, ii) Agriculture and Animal Husbandry, iii) Forests and Bio diversity, and IV) Health enlisted in draft RAPCC. The plan gives broad strategies and enlists short term and long term measures for mitigation of climate change impacts on all the four sectors and also outlines other measures to counter climate change such as enhanced energy efficiency, building sustainable habitats and increasing strategic knowledge of climate change.
- Integration of Disaster Risk Reduction in national and state schemes/ services

1.5.3 Review of National or State Level Climate Change Data

The following book was reviewed to evaluate national and regional climate data under baseline and climate scenarios.

- Krishnan, R., Sanjay, J., Gnanaseelan, C., Mujumdar, M., Kulkarni, A., Chakraborty, S. (2020) Assessment of climate change over the Indian region: a report of the Ministry of Earth Sciences (MoES), Government of India. https://doi.org/10.1007/978-981-15-4327-2

Table 1.6 summarises the climate change data for India and the region surrounding the study area for precipitation, temperature, heatwave, droughts, dust storms and cyclones. Following is the summary of key climate indicator projections in the region surrounding the study area-

- Average temperature is projected to rise by approximately 4.4°C relative to the recent past (1976–2005 average), under the RCP8.5 scenario.
- The projected mean change in the frequency of heatwaves for the mid- and end-twenty-first century under RCP8.5 scenario relative to the historical reference period (1976–2005) are higher over the north-west region (more than 3 days per summer season) compared to other parts of India.
- The precipitation changes in the long-term are projected with an increment of over 10% over northwest and the adjoining territory of the nation.
- In RCP 8.5, very wet days to total wet day precipitation (R95PTOT), and the daily intensity index (SDII) are projected to rise by 15 and 40 %, by the end of the twenty-first century, whereas and maximum 5-day precipitation (RX5day) is projected to rise by more than 40 %.
- Climate models project high likelihood of increase in the frequency (>3 events per decade), intensity and area under drought conditions by the end of the twenty-first century under the RCP8.5 scenario.

Table 1.6 Summary of Observed and Projected Climatic Changes in India and Study Region

Climate Driver or Hazard	Observed Changes in India	Projected Changes in India	Projected Changes in Rajasthan or Regional Level
Average Temperature	India's average temperature has risen by around 0.7°C during 1901–2018.	By the end of the twenty-first century, average temperature over India is projected to rise by approximately 4.4°C relative to the recent past (1976–2005 average), under the RCP8.5 scenario	Similar to the India level data
Warm Day and Warm Night	In the recent 30-year period (1986–2015), temperatures of the warmest day of the year have risen by about 0.63°C	▪ By the end of the twenty-first century, warmest day temperature is projected to rise by approximately 4.7°C relative to the corresponding temperatures in the recent past (1976–2005 average), under the RCP8.5 scenario. ▪ By the end of the twenty-first century, the frequencies of occurrence of warm days and warm nights are projected to increase by 55% and 70%, respectively, relative to the reference period 1976-2005, under the RCP8.5 scenario.	No data was reported
Cold Night	In the recent 30-year period (1986–2015), temperatures of the coldest night of the year have risen by about 0.4°C	By the end of the twenty-first century, this temperature is projected to rise by approximately 5.5°C, relative to the corresponding temperatures in the recent past (1976–2005 average), under the RCP8.5 scenario.	No data was reported
Heatwaves	No data was reported	▪ The frequency of summer (April–June) heat waves is projected to be 3 to 4 times higher by the end of the twenty-first century under the RCP8.5	The projected mean change in the frequency of heatwaves for the mid- and end-twenty-first century under RCP8.5 scenario relative to

Climate Driver or Hazard	Observed Changes in India	Projected Changes in India	Projected Changes in Rajasthan or Regional Level
		scenario, as compared to the 1976–2005 baseline period. ■ The average duration of heat wave events is also projected to approximately double, but with a substantial spread among models.	the historical reference period (1976–2005) are higher over the north-west region (more than 3 days per summer season) compared to other parts of India
Average and Seasonal Precipitation	■ In the recent period 1951–2015 as well as 1986–2015 the annual rainfall series shows decreasing trend which is not statistically significant. ■ The summer monsoon precipitation (June to September) over India has declined by around 6% from 1951 to 2015. ■ The variability of northeast monsoon rainfall has increased in the period 1959–2016.	■ Indian summer monsoon precipitation is projected to increase by 5–10% by end of twenty-first century. ■ Indian winter monsoon precipitation is projected to increase between 10-35 % by the end of the twenty-first century.	The precipitation changes in the long-term are projected with an increment of over 10% over northwest and the adjoining territory of the nation.
Precipitation Indices	■ There has been a shift in the recent period toward more frequent dry spells (27% higher during 1981–2011 relative to 1951–1980) and more intense wet spells during the summer monsoon season.	■ Relative changes in the contribution of very wet days to total wet day precipitation (R95PTOT), the daily intensity index (SDII) and maximum 5-day precipitation (RX5day) with respect to 1976–2005 are projected to increase throughout the twenty-first century. ■ In RCP8.5, R95PTOT and SDII are projected to rise by 15 and 21%, by the end of the twenty-first century, whereas RX5day is projected to rise by 38%.	In RCP8.5, R95PTOT and SDII are projected to rise by 15 and 40 %, by the end of the twenty-first century, whereas RX5day is projected to rise by more than 40 %.
Drought	■ The overall decrease of seasonal summer monsoon rainfall during the last 6–7 decades has led to an increased	Climate models project high likelihood of increase in the frequency (>2 events per decade), intensity and area	Climate models project high likelihood of increase in the

Climate Driver or Hazard	Observed Changes in India	Projected Changes in India	Projected Changes in Rajasthan or Regional Level
	propensity for droughts over India. Both the frequency and spatial extent of droughts have increased significantly during 1951–2016. ■ The area affected by drought has also increased by 1.3% per decade over the same period.	under drought conditions in India by the end of the twenty-first century under the RCP8.5 scenario.	frequency (>3 events per decade), intensity and area under drought conditions by the end of the twenty-first century under the RCP8.5 scenario.
Dust storms and Thunderstorms	■ The annual mean frequencies of Andhi (local term to characterize severe dust storms) are higher over the Indian states of Rajasthan, Punjab, Haryana, and Delhi. ■ There is a decline in the dust loading of the atmosphere, or a decrease in intensity of dust storms, during the period 2000–2017 due to increasing pre-monsoon rains over the north-western states and the Indo-Gangetic Plains. ■ Analyses from the observations show a decline in number of thunderstorm days (1981–2010 relative to 1950–1980) by 34% over the Indian region, while there is a rise in short-span high-intensity rain occurrences (mini-cloudbursts) along the west coast of India (5 per decade)	■ It is generally correlated that the temperature increase associated with global climate change will lead to increased thunderstorm intensity and associated heavy precipitation events.	No data was reported
Cyclone	■ There has been a significant reduction in the annual frequency of tropical cyclones over the North Indian Ocean (NIO) basin since the middle of the twentieth century (1951–2018). In contrast, the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season has increased significantly (+1 event per decade) during the last two decades (2000–2018). However, a clear signal of	Climate models project a rise in the intensity of tropical cyclones in the NIO basin during the twenty-first century.	No data was reported

Climate Driver or Hazard	Observed Changes in India	Projected Changes in India	Projected Changes in Rajasthan or Regional Level
	anthropogenic warming on these trends has not yet emerged.		

1.6 Natural hazard and Climate Change Assessment

This section documents the baseline for natural hazards based on historical data from global, regional, and national databases followed by qualitative evaluation of impacts of climate change on natural hazards.

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

The likely changes in natural hazards presented here are based on the possible relation between the natural hazards and climatic parameters.

Elevation in the Study Area ranges from 235 m to 330 m above mean sea level with a minimum distance of ~420 km from the Arabian Sea in the south-west. The Study Area is located in Jaisalmer with flat to gentle slopes and is a part of the Great Indian Thar Desert. Most of the area in the district is barren, undulating with sand dunes sloping towards the Indus valley and the Runn of Kutchh. Based on the location of the study areas and general topography, hazards due to coastal flooding and landslides were not evaluated in the present assessment.

1.6.1 Water Availability

Jaisalmer is reported to be a water scarce district with incidents of water supply disruption from Indira Gandhi Canal reported in 2018 in certain villages[9]. Additionally, groundwater availability was generally reported to be low in the district[10].

Availability of water at the study area location was assessed based on data from online water risk assessment tool WRI-Aqueduct Water Risk Atlas for Water Stress, and Seasonal Variability. The description of parameters assessed is provided in Table 1.7.

Table 1.7 Indicators Assessed for Baseline Water Availability

S.No.	Parameter	Definition
1	Baseline Water Stress (BWS)	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 value indicate more competition among users.
2	Seasonal Variability (SV)	Seasonal variability indicates variation in water supply between months of the year.

1.6.1.1 Baseline

The baseline water stress map presented in Figure B-1 indicates ‘Extremely High’ water stress at Study Area. Higher water stress may be considered to indicate high competition for common water resource or lower availability of water in the area. Hence, the baseline hazard due to **water stress** is categorised to be ‘**High**’.

[9] https://timesofindia.indiatimes.com/city/jaipur/drinking-water-crisis-hits-jaisalmer-villages/articleshow/64086520.cms#:~:text=In%20dozens%20of%20villages%20in,started%20in%20drought%20affected%20villages.

[10] https://hindi.indiawaterportal.org/content/water-crisis-rajasthan/content-type-page/53102

Seasonal Variability as presented in Figure B-2 indicated variation between 'Medium-High' to 'Extremely High' for all study. Hence, baseline hazard towards water availability due to **seasonal variability** is considered to be '**High**'.

Accordingly, considering 'High' water stress and seasonal variability, overall hazard towards water availability under baseline conditions is considered to be '**High**'.

Table 1.8 summarises the baseline hazard for water availability for assets in the study area.

Table 1.8 Hazard due to Baseline Water Availability

Study Area	Baseline Hazard		Overall Baseline Hazard
	Water Stress	Seasonal Variability	
390 MW	High	High	High
600 MW	High	High	High
700 MW	High	High	High

1.6.1.2 Climate Change Projections

Further, projections for water stress and seasonal variability from WRI-Aqueduct were evaluated for RCP 4.5 and RCP 8.5 scenario for timeframes of 2030 and 2040. The projections for water stress under in 2030 under RCP 4.5 and RCP 8.5 and in 2040 under RCP 4.5 and RCP 8.5 are presented in Figure C-1, Figure C-2, Figure C-3, and Figure C-4 respectively. The projections for seasonal variability under in 2030 under RCP 4.5 and RCP 8.5 and in 2040 under RCP 4.5 and RCP 8.5 are presented in Figure C-5, Figure C-6, Figure C-7, and Figure C-8 respectively.

Due to unavailability of projections for 2050 timeframes, the projections for 2040 are considered to present water availability conditions in 2050.

Climate change projections for water stress indicated the water stress to remain 'Extremely High' for all study areas under all climate scenario and timeframes. Whereas, seasonal variability under all climate change scenarios and timeframes indicated a slight reduction. Climate change projection for seasonal variability indicated a variation between 'Medium-High' to 'High' in all study areas.

Accordingly, overall hazard towards water availability under all climate change scenarios and timeframes is considered to be '**High**'

Table 1.9 summarises the future hazard for water availability for assets in the study area.

Table 1.9 Future Hazard due to Water Availability

Study Area	Future Hazard								Overall Future Hazard			
	Water Stress				Seasonal Variability							
	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
390 MW	High	High	High	High	High	High	High	High	High	High	High	High
600 MW	High	High	High	High	High	High	High	High	High	High	High	High
700 MW	High	High	High	High	High	High	High	High	High	High	High	High

1.6.1.3 Project Implications

As per the ESIA report, the project requires water for the cleaning of Solar PV modules and domestic usage by the staff. Further, it was reported that the project will implement both dry and wet cleaning methods for module cleaning with 16 cycles of dry cleaning and 8 cycles of wet cleaning in a year. Accordingly, the estimated total water requirement by each project is presented in Table 1.10.

Table 1.10 Project Water Requirement

Study Area	Cleaning Water Requirement (KL/year)	Domestic Water Requirement (KL/year)
390 MW Plant	6810	1971 (@ 5.4 KLD for 365 days)
600 MW Plant	10642	1971 (@ 5.4 KLD for 365 days)
700 MW Plant	10580	1971 (@ 5.4 KLD for 365 days)

Water for the project is reported to be sourced from Indira Gandhi Nahar (Canal) Project. The canal starts from downstream of the confluence of the two (2) Himalayan Rivers: Beas and Sutlaj, near Harike. The canal project was developed with the objective of providing water for agriculture, drinking, and industrial activities in western Rajasthan. Further the canal project is reported to utilise about 0.93 Million-ha m of surplus of water of Ravi-Beas Rivers.[11]

Accordingly, considering the low water requirement of the proposed projects and sourcing of water from the canal project sourcing water from Himalayan Rivers, no major implications of local water availability on the project are envisaged.

Considering limited water requirement by the project and no other major water intensive activities including agriculture or industrial in the region along with a dedicated and reliable source of water for the project, no major impact of water utilisation of the project is expected on the local water availability.

[11] http://water.rajasthan.gov.in/content/water/en/indiragandhinahardepartment/AboutUs.html#

1.6.2 Riverine Floods

Floods can be defined as logging of excess water resulting in submergence of dry lands. Floods can be categorised 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 ingress of the ocean or sea water via the coastal and/or estuarine systems onto open land. This could be a standalone of combined effect of tides, surges and sea level rise. Coastal flooding was not evaluated in the study area due to its inland location and significant distance from the coast in the order of ~420 km.

Floods are likely to result in wide spread 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 fresh water sources, propagation of water borne diseases and loss of life.

For evaluation of baseline flood hazard, flood hazard map prepared by building Material and Technology Promotion Council (BMTPC) of India were reviewed. The flood hazard map provides a thematic representation of areas in India likely get flooded.

Further the riverine flood hazard was also evaluated based on review of riverine flood inundation data from WRI-Aqueduct Flood Tool. The tool gives the riverine flood hazard for different return periods using GLOFRIS model. Where, GLOFRIS uses a global hydrological model, PCR-GLOBWB (Sutanudjaja et al. 2018), with a river and floodplain routing scheme to make long-term simulations of discharges and flood levels for several climate conditions.

1.6.2.1 Baseline

As per State Disaster Management Plan of Rajasthan (2014)[12], Jaisalmer district is reported to present *Low* flood hazard based on BMTPC data and secondary information.

As per BMTPC flood hazard maps presented in Figure B-3, no flood hazard was reported in the state of Rajasthan. Therefore no riverine flood hazard in considered for all the study areas.

Similarly, WRI-Aqueduct projections for flood at 100 year return period (Figure B-4) indicated no riverine flooding in any of the study areas. Accordingly, no riverine flood hazard is considered for the entire study area under baseline conditions.

While no riverine flooding is reported in the Study area, media reports indicate instances of flash floods in and around the Jaisalmer[13][14]. Flash floods have also been reported in Pokhran due to high intensity rainfall in the past, resulting in inundation up to 3-4 feet (0.9-1.2 m), submerging and washing away kucha houses[15].

Table 1.10 summarises the baseline hazard for riverine flood for assets in the study area.

[12] http://dmrelief.rajasthan.gov.in/documents/sdmp-eng.pdf

[13] https://timesofindia.indiatimes.com/city/jaipur/three-women-die-in-flash-flood-near-jaisalmer/articleshow/65450020.cms

[14] https://www.hindustantimes.com/india/rajasthan-s-flood-its-worst-in-200-years-300-dead/story-am6SI1UNvOAyocEcCA1MVN.html

[15] https://www.telegraphindia.com/india/rain-rain-sms-comes-again-flash-floods-sink-rajasthan-districts-parties-fight-mobile-war/cid/486967

Table 1.11 Baseline Riverine Flood Hazard

Study Area	Baseline Hazard		Overall Baseline Hazard
	BMTPC	WRI-Aqueduct	
390 MW	None	None	None
600 MW	None	None	None
700 MW	None	None	None

1.6.2.2 Climate Change Projections

Riverine flood hazard under climate change conditions was evaluated based on the projections from WRI-Aqueduct Flood Tool for a 100-year return period flood as presented in Figure C9 and C10 for RCP4.5 and RCP8.5 for 2030 and 2050, respectively. Accordingly, the no flooding was projected for the entire study area under all climate change scenarios and timeframes. Hence, no hazard due to riverine flood is considered for all study areas.

Climate change is likely to intensify the extreme rainfall events such as one day and five day consecutive rainfall. The study area is likely to anticipate an increase in one day maximum rainfall by up to 10.9% by 2050 under RCP 8.5 scenario, and maximum consecutive five day rainfall by up to 8.1% by 2050 under RCP 8.5 scenario. This may result in increased intensity/ frequency of flash floods in future.

Table 1.12 summarises the future hazard for riverine flood for assets in the study area.

Table 1.12 Future Hazard due to Riverine Floods

Study Area	RCP 4.5		RCP 8.5	
	2030	2050	2030	2050
390 MW	None	None	None	None
600 MW	None	None	None	None
700 MW	None	None	None	None

1.6.2.3 Project Implications

Considering no reported or projected riverine floods at the Study area, no implications of the riverine floods on project are considered.

However, localised flooding can take place due to future changes in land use/ topography and extreme precipitation (short duration high intensity rainfall events). Such flooding in general can occur as a flash flood and have range of implications including damage to assets, environmental liabilities, and safety of workers/ employees. General implications of flooding for a wind and solar power project are given below.

- Flash floods can severely damage the project infrastructure in form of physical damage to components stationed close to ground level, water damage, washing out of loosely anchored component or temporary structure.
- Inundation due to floods may render some of the project areas inaccessible temporarily.
- Moreover, mud and silt brought by the flood water may get deposited within project area damaging the key assets or impeding the accessibility even after the flood water recedes.
- Also, flash floods can erode the top soil and expose the foundation of the PV modules, or wind turbine tower and endanger the stability of structure.
- Flash flood also pose a significant risk to the safety of people/ employees working in the open as they may get stuck or inundated during flash floods.

1.6.3 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)[16]. Extreme heat hazard is further categorised in four categories as presented in Table 1.13.

Table 1.13 Classification Extreme Heat Risk

Wet Bulb Temperature	Risk Classification
>32°C	High
>28°C	Medium
>25°C	Low
<25°C	Very Low

The Wet Bulb 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 shady 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[17,18]. Extreme heat was evaluated based on baseline and projected temperature.

1.6.3.1 Baseline

The extreme heat hazard was evaluated on a regional level using the Think Hazard report for Jaisalmer district (ThinkHazard, 2020) and is shown in Figure B-7. The extreme heat hazard at all

[16] ThinkHazard. 2020. Kota Balikpapan, Indonesia. https://thinkhazard.org/en/report/18130-indonesia-kalimantan-timur-kota-balikpapan/EH

[17] https://www.weather.gov/tsa/wbgt#:~:text=The%20WetBulb%20Globe%20Temperature%20(WBGT,is%20calculated%20for%20shady%20areas.

[18] https://thinkhazard.org/static/documents/thinkhazard-methodology-report_v2_0.pdf

assets in study area is reported to be '**High**'. Media reports indicated that the maximum day time temperature to often exceed 40°C in the region. Table 1.14 presents the maximum temperatures recorded in summer season in Jaisalmer during last five years.

Table 1.14 Daily Maximum Temperatures Recorded in Summer Season in Jaisalmer from 2015-2020

Year	Daily Maximum Temperature (°C)
2015	44.5[19]
2016	46.5[20]/ 49[21]
2017	45.6[22]
2018	42.7[23]
2019	>45[24]
2020	44.7[25]

Accordingly, the extreme heat hazard for all the study is considered to be '**High**' under baseline conditions.

Table 1.15 summarises the baseline heat hazard at all assets in the study area.

Table 1.15 Baseline Extreme Heat hazard

Study Area	Overall Baseline Hazard
390 MW	High
600 MW	High
700 MW	High

[19] https://timesofindia.indiatimes.com/city/jaipur/Heat-wave-conditions-continue-Jaisalmer-hottest-at-44-5-celsius/articleshow/46984411.cms
[20] https://www.indiatoday.in/india/story/heat-wave-continues-as-jaisalmer-hits-a-blistering-52-4-degrees-321119-2016-05-02
[21] https://www.skymetweather.com/content/weather-news-and-analysis/heat-in-rajasthan-shatters-record-worst-not-over-yet/
[22] https://timesofindia.indiatimes.com/city/jaipur/heat-wave-sweeps-parts-of-rajasthan-jaisalmer-hottest-at-45-6-deg-c/articleshow/58184568.cms
[23] https://timesofindia.indiatimes.com/city/jaipur/sizzling-heat-affects-normal-life-in-raj-jaisalmer-hottest-at-42-7-deg-c/articleshow/63559556.cms
[24] https://www.firstpost.com/india/heat-wave-hits-more-than-half-of-india-pune-saw-its-highest-temperature-in-50-years-15-indian-cities-among-worlds-hottest-6738381.html
[25] https://www.outlookindia.com/newsscroll/heat-wave-conditions-prevail-in-rajasthan/1844030

1.6.3.2 Climate Change Projections

In the absence of projections for wet bulb globe temperature the hazard due to extreme heat in future was evaluated based on projections for maximum temperature, extreme temperature, and warm spell duration index (WSDI). Climate change projection indicate increase in maximum daily temperature, and warm spell duration. Climate change projections indicate an increase in average maximum daily temperature by 1.1-2.4°C by 2050 and increase of 26 to more than 68 days in warm spell duration. This indicates an increase in extreme temperatures and its duration which are likely to remain high. Hence, the hazard due to extreme heat for all study areas is considered to remain 'High' in future, under all climate change scenarios.

Table 1.16 summarises the future hazard for extreme heat for assets in the study area.

Table 1.16 Future Hazard due to Extreme Heat at Study Area

Study Area	RCP 4.5		RCP 8.5	
	2030	2050	2030	2050
390 MW	High	High	High	High
600 MW	High	High	High	High
700 MW	High	High	High	High

1.6.3.3 Project Implications

Extreme heat conditions can have range of impacts including reduced efficiency of machines/tools and health impacts on human.

Extreme heat may have following implications on the project components.

- Reduced efficiency of wind turbine generator. Literature review indicated that a standard wind turbine could work at full capacity only till 35°C temperature. Temperatures between 35 and 40°C reduce the power capacity and temperatures exceeding 40°C can completely shut down power generation[26]
- Temperature increase is reported to significantly reduce the efficiency of photovoltaic system. However, the reduced efficiency due to higher temperature is likely to be compensated by the increased solar irradiance[27].
- Increased heat may also result in more energy demand. Literature review indicated that the high temperature also results in increased transmission losses. This may pose a challenge for supplying power in peak summer season when the demand is at peak[28].
- The likelihood of malfunctioning of step up/down transformers, electronic monitoring/ controlling units at high temperature cannot be ruled out.
- Any damage or reduced efficiency of the assets will result in loss of production. Also it will incur additional costs for replacement of damaged asset or asset components.

[26] https://www.ge.com/news/reports/just-deserts-wind-turbine-can-handle-sandstorms-desert-sun

[27] https://www.hindawi.com/journals/amete/2014/264506/

[28] https://iopscience.iop.org/article/10.1088/1748-9326/11/11/114008

- Extreme heat could affect the health & well-being of personnel working outdoors due to heat stress or heat exhaustion. It could also decrease the productivity of workers and reduce the working hours in the outdoor environment.
- Increased energy demand for cooling at on-Site indoor places such as offices cannot be ruled out.
- Increased temperature can also lead to increased water demand for drinking, cooling, and irrigation.

1.6.4 Cyclone

As per American Meteorological Society, cyclones, or hurricanes (as they are popularly known in Americas), a cyclone 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 built and natural environment.

For the purpose of this assessment, cyclone hazard was evaluated based on Cyclone Occurrence Map of India from BMTPC, and historical hurricane tracks data from NOAA.

The Cyclone Occurrence Map of India from BMTPC presents the area likely to be affected by cyclones and corresponding wind speeds (≥ 34kt or 17.5 m/s). The map is reported to be prepared based on the sustained wind speed recorded during 1891-2008.

NOAA hurricane tracks tool provides the information on tracks of over 13000 historical cyclones occurred since 1842.

1.6.4.1 Baseline

As per Cyclone occurrence map of India presented in Figure B-8 no historical cyclones are reported in the state of Rajasthan. Hence, no cyclone hazard at all assets within the study area was considered.

NOAA cyclone tracks data indicated, two cyclones tracks to pass within ~200 km of the study area with intensity of Category 1 in 1999, and tropical storm in 1964. However, as presented in Figure B-9 the cyclones were dissipated to tropical depression soon after entering the 200 km buffer distance. The maximum wind speed during 1999 storm is estimated to be between 55-65 kt (28-33 m/s), and 25-35 kt (13-18 m/s). Accordingly, the baseline hazard due to cyclone is considered to be 'Low' at all assets within the study area.

Table 1.17 summarises the baseline hazard from cyclone for assets in the study area.

Table 1.17 Baseline Cyclone Hazard for Assets in Study Area

Study Area	Overall Baseline Hazard
390 MW	Low
600 MW	Low
700 MW	Low

1.6.4.2 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 geo stationary satellites (1970s). However changes in inter-annual and multi-decadal frequency within individual ocean basin are reported to be substantial.

Literature review indicated that the detection of trends in cyclone or Typhoon 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, and 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

IPCC's special report on 1.5°C scenario[29] 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.

The recent study by Knuston et. al. (2020) indicated following likely changes for occurrences of tropical cyclone over north Indian Ocean basin:

- Overall frequency of tropical cyclone by -35 to 35% with median change of -4%,
- Changes in frequency of category 4-5 cyclone between -30 to 80% with median change of 4%.
- Intensity of cyclone indicated change between -1 to 9% with median of 5% increase under 2°C scenario by end of the century.

However, considering historical cyclone occurrences and inland location of the study areas (~420 km from the coast line), the hazard due to cyclone under climate change scenario is considered to remain 'Low'.

Table 1.18 summarises the future hazard from cyclone for assets in the study area.

Table 1.18 Future Hazard due to Cyclone at Study Area

Study Area	RCP 4.5		RCP 8.5	
	2030	2050	2030	2050
390 MW	Low	Low	Low	Low

[29] https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf

Study Area	RCP 4.5		RCP 8.5	
	2030	2050	2030	2050
600 MW	Low	Low	Low	Low
700 MW	Low	Low	Low	Low

1.6.4.3 Project Implications

- Tropical storms can inflict damage in the form of high wind speeds (destroying buildings and infrastructure), storm surges, and flood. Although, the damage due to high winds and storm surges are limited to the coastal locations, flash floods due to heavy rainfall may occur at far inland locations.
- In general as per NOAA, Category 1 Cyclones can damage the roofs of buildings, topple the shallow rooted tress, or snap the branches. It can inflict extensive damage to power line resulting power outages over several days.
- High wind speed can damage the solar panels and uproot or topple them.
- Further, the damages due to floods resulting from extreme rainfall are likely to be much more than the damages due to high wind speed[30].
- Media reports indicate the occurrence of rainfall in Rajasthan in general during the cyclones of Nivar (2020)[31], Maha (2019)[32], and Nisarg (2020)[33]. Particularly, cyclone Maha was reported to cause 5.4 mm of rainfall in Jaisalmer, although no flooding was reported.
- Considering historical data, cyclones are less likely to have significant impact on the proposed project.
- Impacts of high wind speed are discussed in Section 1.6.5.3

1.6.5 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 wild fires and likes of it.

For the purpose of this assessment, average wind speed data 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, average wind speed data was

30

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC42518/reqno_jrc42518_humanitarian%20impact%20of%20tropical%20cyclones%20%28final%29%5B2%5D.pdf

31 https://timesofindia.indiatimes.com/city/jaipur/cyclone-nivar-brings-rain/articleshow/79436239.cms

32 https://www.deccanherald.com/national/rains-in-rajasthan-as-maha-cyclone-intensifies-772981.html

33 https://navbharattimes.indiatimes.com/state/rajasthan/jaipur/rajasthan-heavy-rains-will-occur-impact-of-nisarg-cyclone/articleshow/76168231.cms

complemented with hourly wind speed data for Balikpapan for the period 1985-2014 (Meteoblue, 2020[34]).

Further, from hazard standpoint maximum/ extreme wind speeds were also evaluated based on Wind Hazard Map of Rajasthan prepared by BMTPC.

1.6.5.1 Baseline

As per State Disaster Management Plan of Rajasthan (2014), Jaisalmer district is reported to present Moderate wind hazard based on BMTPC data and secondary information.

Further, based on the average wind speed map as presented in Figure B-10 the hazard due to average wind speed at all study areas is evaluated to be 'Low'.

As per the wind hazard map of Rajasthan presented in Figure B-11 the wind hazard at all the study areas is reported to under 'High Damage' category (wind speed of 47 m/s). Accordingly, wind hazard at all the study areas is considered to be 'High'.

Hence, from hazard standpoint, overall wind hazard at all study areas is considered to be 'High'. Such high wind speed conditions may occur occasionally during storm events such as cyclones or convective storms. However, for day to day operations, wind hazard may be considered as 'Low'.

Table 1.19 summarises the baseline hazard from average and maximum wind speed for assets in the study area.

Table 1.19 Baseline Wind Hazard in Study Area

Study Area	Baseline Hazard		Overall Baseline Hazard
	Average Wind Speed	Maximum Wind Speed	
390 MW	Low	High	High
600 MW	Low	High	High
700 MW	Low	High	High

1.6.5.2 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 indicated rapid increases in wind speed across the globe since 2010 (Zeng et al., 2019)[35]. Considering the limited information available on wind speed projections and high uncertainty, the wind hazard under a climate change scenario is considered to remain same as the baseline. Table 1.20 presents hazard due to average and extreme wind conditions in future.

[34] Meteoblue, 2020. https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/balikpapan_indonesia_1650527

[35] Zeng, Z., Ziegler, A. D., Searchinger, T., Yang, L., Chen, A., Ju, K., and. Wood, E. F. (2019). A reversal in global terrestrial stilling and its implications for wind energy production. Nature Climate Change, 9, 979-985. doi: https://doi.org/10.1038/s41558-019-0622-6

Table 1.20 Future Hazard due to Wind

Study Area	Future Hazard								Overall Future Hazard			
	Average Wind Speed				Maximum Wind Speed							
	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
390 MW	Low	Low	Low	Low	High	High	High	High	High	High	High	High
600 MW	Low	Low	Low	Low	High	High	High	High	High	High	High	High
700 MW	Low	Low	Low	Low	High	High	High	High	High	High	High	High

1.6.5.3 Project Implications

- High wind speeds can be damaging and pose threat to safety of the human life and infrastructure. Wind speeds of storm category can be easily seen as threating, however wind at much lower speed than storm can pose significant threat to the life and property. As per Beaufort scale wind speeds as low as 13-18 mph can make the dust airborne, and may pose risk to safety of people in the open areas. Wind speeds of more than 40 mph are likely to damage structures such as roofs of the buildings, porches, and pool enclosures.
- Wind speed are particular important for wind power generation as wind turbines are usually designed to operate under particular rage of wind speed. The lower limit of wind speed is governed by the minimum wind energy required to turn the turbine blades and the generator, whereas, the upper limits are set as a safety feature to protect the blades from getting damaged. Therefore, wind speed below are above the design wind speeds will result in loss of production. However, present assessment aims at assessment of physical hazards only. Hence, impacts on operational capacity of the project are not assessed presently.
- High wind speeds can also damage assets, structure, transmission lines and towers. Moreover, high wind speeds may also result in short-circuiting by swinging and bringing transmission cable close to one another.
- High wind speed can lead to threat towards safety of workers working at heights for installation or maintenance of wind turbines, transmission line during high wind conditions. The threat can be in the form of fall or injury to the eyes from the debris (sand/ dust) carried by the winds.
- High winds may damage the PV modules or anchoring. High wind speeds may result in suspension of sand/ dust in the air and settlement on PV modules. This can result in reduced production efficiency and require frequent cleaning.
- Moreover, sand storm are generated when the high winds lift large amount of sand and dust from the dry soil surface. Sand storm are common feature of arid or semi-arid regions. Sand storm can impede the movement of vehicle and men and affect visibility, damage the structures due to additional impact/ erosion from the debris (sand and dust) carried by the storm. Moreover, the airborne dust and sand particles can pose significant health risk.

- A sand storm was experienced recently in Jaisalmer on August 5, 2020[36].
- Any damage, or reduced efficiency of the assets will not only result in loss of production but it will also incur additional costs for replacement of damaged asset or asset components

1.6.6 Thunder Storms and Lightning

As per NOAA thunderstorm or convective storm is a storm when a rain shower is associated with lightning and thunder. Such storms are usually created by heating of ground surface resulting upward atmospheric motion that transport moisture along with air. Thunderstorms may lead to high wind conditions with gust speed exceeding 25 m/s, lightning strikes, extreme rainfall and flash floods, and hail showers[37].

As per National Severe Storm Laboratory (NSSL), lightning is a giant spark of electricity in the atmosphere between clouds, the air, or the ground. The process triggers instant release of energy of the order of 1 Gigajoule. Lightning can be caused in three (3) mechanisms; viz within the same thunder cloud, between two (2) thunderclouds or between a thundercloud and ground.

Lighting can cause damage to natural and built environment. Objects struck by lightning experience heat and magnetic forces of great magnitude. It can affect trees, by vaporizing the sap resulting in bursting of bark, damage to tall buildings and structures and several injuries or loss of life.

For the purpose of present assessment, thunderstorms and lightning were evaluated based on the thunder storm incidence map of India from BMTPC and lightning flash data from NASA.

1.6.6.1 Baseline

Thunderstorm incidence map of India as presented in Figure B-12 indicated historical occurrences of thunderstorm in and around the Study area. Accordingly, the locations around the study were reported historical occurrences of thunderstorm in the range of 9 to 15 during the period of 1981-2010.

Lightning map based on NASA lightning flash data as presented in Figure B-13 indicated average lightning frequency to vary between 0-20 flashes/km^2/year in the study area.

In the absence of standards to categorise the thunderstorm/ lightning hazard, no hazard categorisation is done. However, these hazards are evaluated to present the historical events and provide an understanding on different types of hazards likely to be experienced at the study areas.

1.6.6.2 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 indicate that predicting changes in thunderstorm directly is difficult task, and hence generally changes in frequency of 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 CMIP5. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere.

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[36] https://www.indiatimes.com/trending/environment/jaisalmer-sandstorm-viral-video-519725.html#:~:text=While%20Mumbai%20battles%20with%20floods,in%20a%20state%20of%20panic.

[37] https://www.nssl.noaa.gov/education/svrwx101/thunderstorms/

Figure C-11 indicates the likely increase in number of days per year with conditions favourable for severe thunderstorm due to increased CAPE by end of the century. Hence, increase in thunderstorm and lightning activity can be expected in future under climate change scenario.

1.6.6.3 Project Implications

- In addition to the damage caused by the high wind speeds as discussed in Section 1.6.5.3, thunderstorms pose a threat from lightning strikes.
- Because of the height, wind turbines are likely to be more prone to the lightning strikes, as compared to other infrastructure.
- Lightning strikes can damage the electrical/ electronic components of wind turbine and PV modules and interrupt operation.
- Lightning strikes on grid or substation may interrupt power supply.

1.7 Hazard Summary and Implications

Key		Low		Medium		High/Very High		Not Applicable / Not Required		No Hazard

Table 1.21 presents the summary of hazards and implications on the project components.

Key		Low		Medium		High/Very High		Not Applicable / Not Required		No Hazard	NA	Not Applicable	NR	Not Required

Table 1.21 Hazard-Receptor Matrix

Hazard	Hazard Category (Acute or Chronic)	Hazard Level				Applicable Control Measures	Major Receptors							Recommendations
		RCP 4.5 (< 2ºC scenario)		RCP 8.5 (> 2ºC scenario)										
		2030	2050	2030	2050		PV Modules	Wind Turbine (WTG)	Transmission line and Towers	Sub stations	Other Buildings	Employees	Communities	
Water Availability	Chronic					The ESMP identified the following control measures- ■ Regular inspection for identification of water leakage and preventing water wastage; ■ Optimum use of water during sprinkling on roads for dust settlement, washing of vehicles, concrete mixer; ■ Construction labour deputed onsite to be sensitized about water conservation and encouraged for optimal use of water; ■ Recycle and reuse of water to the extent possible; and ■ Prepare and implement water conservation scheme e.g., rainwater harvesting at the project site.	■ Reduced water availability for panel cleaning. ■ Reduced efficiency	No significant implications during operational Phase.	No significant implications during operational Phase.	No significant implications during operational Phase.	No significant implications during operational Phase.	Reduced availability for domestic usage including sanitation and drinking	Reduced availability for domestic and agricultural use	■ The issues related to availability of water should be assessed in greater detail and not just from an operational point of view. ■ Dry cleaning technology should be available for cleaning solar panels as a backup to cleaning solar panels using water. ■ Detailed assessment for water scarcity and identification of alternate water sources may be conducted. ■ Additionally, flows in the Indira Gandhi Canal can be monitored to record the changes in canal water availability.
Riverine Floods	Acute					The ESMP identified the following control measures- ■ The disaster management cell of the district should be involved in preparedness for emergency situation; ■ Company should ensure it has adequate third party	■ Flash floods can erode the top soil and expose the foundation of the PV modules, or wind turbines and compromise the structural stability.		■ Flash floods can damage loosely anchored structures due to sudden runoff from precipitation. ■ Prolonged inundation could result in electrical hazard or damage the electrical installation due to short circuiting etc.		■ Flash floods can severely damage the project infrastructure in form of physical damage to components stationed	■ Inundation due to floods may render some of the project areas inaccessible temporarily or even after the flood	■ Flash flood may cause damage in the nearby settlements, destroy crops and make inundated areas	■ Undertake an asset level flood risk assessment to identify and quantify the flooding risks. ■ Include flood risk in the general emergency preparedness and response plan.

Hazard	Hazard Category (Acute or Chronic)	Hazard Level				Applicable Control Measures	Major Receptors							Recommendations
		RCP 4.5 (< 2ºC scenario)		RCP 8.5 (> 2ºC scenario)										
		2030	2050	2030	2050		PV Modules	Wind Turbine (WTG)	Transmission line and Towers	Sub stations	Other Buildings	Employees	Communities	
						insurance cover to meet the financial loss to any third party due to such emergencies; ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan.					close to ground level, water damage, washing out of loosely anchored component or temporary structure.	water recedes. These may also compromise the safety and well being of the staff and workers.	inaccessible for staff stationed in the adjoining villages. ■ Also, prolonged inundation may result in propagation of diseases.	
Extreme Heat	Acute					The ESMP identified the following control measures- ■ The disaster management cell of the district should be involved in preparedness for emergency situation; ■ Company should ensure it has adequate third party insurance cover to meet the financial loss to any third party due to such emergencies; ■ The workers (both regular and contractual) on the project will be provided with trainings on the Health and Safety policy in place, and their role in the same and refresher courses will be provided throughout the life of the project;	■ Reduce Efficiency ■ Damage to electronic monitoring/ controlling component ■ Costs for replacement of damaged assets	■ Reduce Efficiency ■ Damage to electronic monitoring/ controlling component ■ Loss of production ■ Costs for replacement of damaged assets	■ Reduced transmission efficiency	■ Overheating of components resulting in damage or reduced efficiency	■ Increase in cooling demand	■ Reduced comfort levels ■ Threat of heat stress/ heat stroke ■ Increased water demand	■ Reduced comfort levels ■ Threat of heat stress/ heat stroke ■ Increased water demand	■ Worker's resting areas, on-site offices, worker's quarters should be constructed with heat resisting material to keep the indoor temperature lower. ■ A heat stress management plan should be prepared as part of standard operations and safety procedures. ■ Consider extreme heat as one of the hazards in emergency preparedness and response plan. ■ Train workers to identify the symptoms of heat stress and first aid. Take necessary measures to counter heat stress impacts to personnel, especially workers.

Hazard	Hazard Category (Acute or Chronic)	Hazard Level				Applicable Control Measures	Major Receptors							Recommendations
		RCP 4.5 (< 2ºC scenario)		RCP 8.5 (> 2ºC scenario)			PV Modules	Wind Turbine (WTG)	Transmission line and Towers	Sub stations	Other Buildings	Employees	Communities	
		2030	2050	2030	2050									
						■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan; and ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan.								■ Make appropriate considerations while designing the cooling systems (if required).
Cyclone	Acute						■ Damage due to high wind speeds ■ Uprooting of solar modules ■ Lost production ■ Cost for replacement of assets	■ Damage due to high wind speed ■ Suspension of power generation if the upper limit for wind speed exceeds ■ Lost production ■ Cost for replacement of assets	■ Damage, uprooting of transmission towers ■ Short-circuiting in transmission lines ■ Cost for replacement of assets	■ Structural damage due to heavy rainfall ■ Cost for replacement of assets	■ Damage/ collapse of non-permanent structures ■ Cost for replacement of assets	■ High wind speed can lead to threat towards safety of workers working at heights for installation or maintenance of wind turbines, transmission line during high wind conditions. The threat can be in the form of fall or injury to the eyes from the debris (sand/ dust) carried by the winds.	Health and Safety	■ Early warning system from national government or international organizations should be monitored. ■ Directions issued by government during the cyclonic storm events should be followed. ■ Recommendations for high wind speed and flooding shall apply in general. ■ Include risk of high wind speed in the general emergency preparedness and response plan.
Wind Speed	Acute and chronic					■ The ESMP identified revegetation of construction boundaries using fast growing local vegetation. This may help to mitigate impact of high wind speeds at low height and reduce impacts of low	■ Damage due to high wind speeds ■ Uprooting of solar modules	■ Damage due to high wind speed ■ Suspension of power generation if the upper	■ Damage, uprooting of transmission towers ■ Short-circuiting in	■ Structural damage ■ Cost for replacement of assets	Damage/ collapse of non-permanent structures	■ High wind speed can lead to threat towards safety of workers working at	■ Health and Safety ■ Sand/ dust carried by the winds may get inhaled	■ The systems for wind and solar farms must be designed while considering the projected wind speed. It should also restrict any lateral movement of the solar panel set-up.

Hazard	Hazard Category (Acute or Chronic)	Hazard Level RCP 4.5 (< 2ºC scenario) 2030	Hazard Level RCP 4.5 (< 2ºC scenario) 2050	Hazard Level RCP 8.5 (> 2ºC scenario) 2030	Hazard Level RCP 8.5 (> 2ºC scenario) 2050	Applicable Control Measures	Major Receptors: PV Modules	Major Receptors: Wind Turbine (WTG)	Major Receptors: Transmission line and Towers	Major Receptors: Sub stations	Major Receptors: Other Buildings	Major Receptors: Employees	Major Receptors: Communities	Recommendations
						lying structures and employees working in the open; ■ The workers (both regular and contractual) on the project will be provided with trainings on the Health and Safety policy in place, and their role in the same and refresher courses will be provided throughout the life of the project; ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan; and ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan.	■ Settlement of dust carried by winds on solar panels resulting in reduced efficiency	limit for wind speed exceeds ■ Lost production	transmission lines ■ Cost for replacement of assets			heights for installation or maintenance of wind turbines, transmission line during high wind conditions. The threat can be in the form of fall or injury to the eyes from the debris (sand/ dust) carried by the winds. ■ Sand/ dust carried by the winds may get inhaled		■ Include risk of high wind speed in the general emergency preparedness and response plan. ■ Evaluate the design life of the cables, connectors, panels and WTG's ■ Use of control sensors can optimize stow angles in relation to wind strength to safely position tracking arrays during storms. ■ Incorporate the impact of flying debris due to high wind speed in the design of panels and WTG's. ■ All structures should be built in accordance with the national and international best practices to withstand wind pressure. ■ Develop an advisory to stop work in the open areas if the wind speed exceeds threshold speed (e.g., 17.8 m/s). ■ Implement dust prevention and emission control measures for surface areas exposed to wind hazard for safety of workers and continuity of mine operations.
Thunderstorm	Acute					■ The workers (both regular and contractual) on the project will be provided with trainings on the	■ Damage to electrical components due to	■ Damage to electrical components due to	■ Grid failure ■ Cost for replacement of assets	■ Damage to electrical components due to	■ Damage to electrical components due to	■ People working in the open during	■ People working in the open during	■ Include lightning protection in form of lightning rods in the design of

Hazard	Hazard Category (Acute or Chronic)	Hazard Level				Applicable Control Measures	Major Receptors							Recommendations
		RCP 4.5 (< 2ºC scenario)		RCP 8.5 (> 2ºC scenario)										
		2030	2050	2030	2050		PV Modules	Wind Turbine (WTG)	Transmission line and Towers	Sub stations	Other Buildings	Employees	Communities	
						Health and Safety policy in place, and their role in the same and refresher courses will be provided throughout the life of the project; ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan; and ■ A safety or emergency management plan should be in place to account for natural disasters, accidents and any emergency situations. The nearest hospital, ambulance, fire station and police station should be identified in the implemented emergency management plan.	lightning strike ■ Lost in energy production ■ Cost for replacement of assets	lightning strike ■ Lost production ■ Cost for replacement of assets		lightning strike ■ Cost for replacement of assets	lightning strike ■ Cost for replacement of damaged good	thunder storm may be considered as most vulnerable ■ Lightning strikes on human being may result in death or serious injuries	thunder storm may be considered as most vulnerable ■ Lightning strikes on human being may result in death or serious injuries	solar power system and WTG's according to national/ international standards. ■ Perform regular inspections right after heavy rain.

In addition to the above control measures identified by the Client, AGEL has various standard procedures/ documents/ manual for Environmental and Social management Systems (ESMS) at corporate level which may act as adaptation or disaster management protocols for risks associated with natural disasters at the study area. Following are some the plans which can be relevant to the disaster management/ emergency response-

- Occupational health and safety;
- Emergency preparedness and response plan;
- Environmental and social monitoring plan;
- SOP 06: Use of personal protective equipment;
- SOP 07: Emergency preparedness plan;
- SOP 10: Recognition and reporting of incidences, illness and safety hazards; and

- SOP 14: Water and wastewater management

1.8 Conclusions

In general, the plans shared by the client for the proposed project indicates adequate provision for control measures against both the scenarios of temperature increase by end of century- < 2ºC and > 2ºC temperature increase. Wherever the plans were evaluated to be inadequate, applicable and relevant recommendations were provided as summarized in section 1.7.

APPENDIX A CLIMATE CHANGE PROJECTIONS

Following climate indices were evaluated based on the multi-model mean of climate models from CMIP-5 data sets for RCP 4.5 and RCP 8.5 over a time frames of 2030, 2050, and 2080.

- Annual Rainfall (mm): Projected average annual rainfall over a periods of 2030 (2025-2035), and 2050 (2045-2055)
- Maximum one day rainfall (mm): Projected maximum one day rainfall over a periods of 2030 (2025-2035), and 2050 (2045-2055)
- Maximum five day consecutive rainfall (mm): Projected maximum rainfall over duration of consecutive five days during 2030 (2025-2035), and 2050 (2045-2055)
- Average Temperature: Projected average daily temperature over a periods of 2030 (2025-2035), and 2050 (2045-2055)
- Average maximum daily temperature: Projected average maximum daily temperature over a periods of 2030 (2025-2035), and 2050 (2045-2055)

Absolute and percentage changes in projected climate indices for temperature and precipitation are presented in Table A-1 to Table A-2.

Table A-1 Absolute Changes in Climate Indices

Climate Index	Baseline	RCP 4.5		RCP 8.5	
		2030	2050	2030	2050
Average Temperature (°C)	24.6-25.3 (25.0)	1.2-1.3 (1.2)	1.9-2.0 (1.9)	1.4-1.5 (1.5)	2.5-2.6 (2.5)
Average Maximum Temperature (°C)	32.0-32.8 (32.5)	1.1-1.2 (1.1)	1.8-1.9 (1.8)	1.3-1.3 (1.3)	2.2-2.4 (2.3)
Warm Spell Duration Index (Days)	10	26-27 (27)	48-51 (49.0)	27-28 (28)	64-68 (65)
Annual Rainfall (mm)	169.3-254.1 (215.6)	9.6-14.4 (12.6)	2.6-9.0 (6.9)	6.7-16.7 (13.5)	17.8-23.5 (22.1)
One Day Maximum Rainfall (mm)	21.1-23.4 (22.4)	0.3-1.3 (0.7)	-2.8--2.2 (-2.5)	0.5-0.9 (0.7)	1.4-2.4 (2.0)
Maximum Consecutive Five Days Rainfall (mm)	43.5-47.4 (45.6)	-3.3--1.9 (-2.8)	-5.6--4.2 (-4.8)	0.9-1.5 (1.3)	-0.1-3.8 (1.6)

Table A-2 Percentage Changes in Climate Indices

Climate Index	Baseline	RCP 4.5		RCP 8.5	
		2030	2050	2030	2050
Average Temperature	NA	4.8-5.1 (4.9)	7.4-8.0 (7.6)	5.7-6.2 (5.9)	9.8-10.6 (10.1)
Average Maximum Temperature	NA	3.4-3.6 (3.5)	5.5-5.9 (5.7)	3.9-4.2 (4.0)	6.8-7.4 (7.1)
Warm Spell Duration Index	NA	265.1-278.5 (270.1)	480.2-520.9 (496.2)	270.2-284.6 (275.6)	628.2-683.0 (652.6)

Climate Index	Baseline	RCP 4.5		RCP 8.5	
		2030	2050	2030	2050
Annual Rainfall	NA	5.6-6.6 (5.9)	1.6-3.8 (3.1)	3.9-7.5 (6.2)	9.3-12.7 (10.4)
One Day Maximum Rainfall	NA	1.1-6.1 (3.3)	-12.5--9.8 (-11.1)	2.1-4.0 (3.2)	6.2-10.9 (8.9)
Maximum Consecutive Five Days Rainfall	NA	-7.0--4.4 (-6.0)	-12.1--9.4 (-10.6)	2.0-3.4 (2.9)	-0.3-8.1 (3.6)

APPENDIX B BASELINE HAZARD MAPS

Figure B-1 Baseline Water Stress

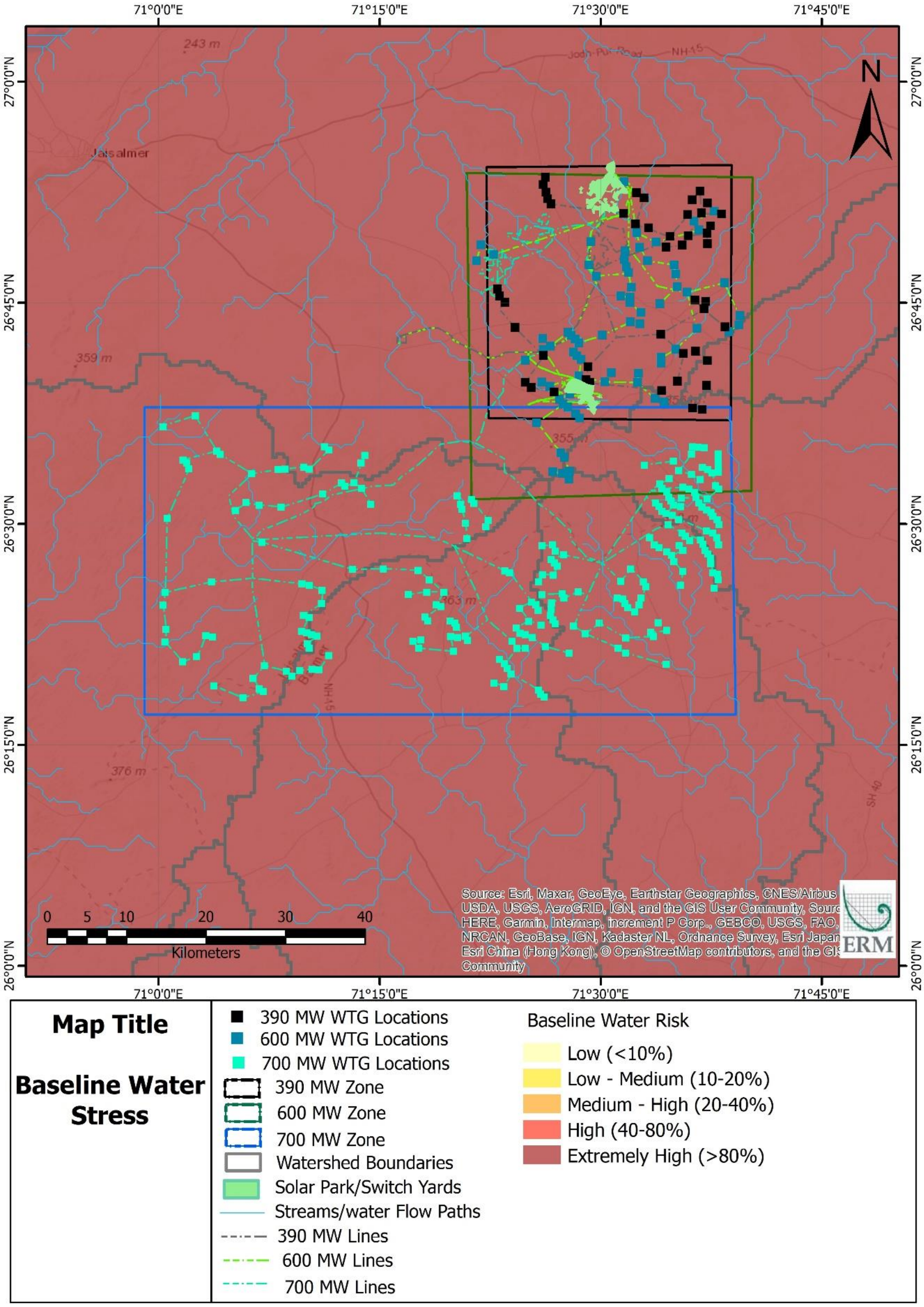


Figure B-2 Seasonal Variability

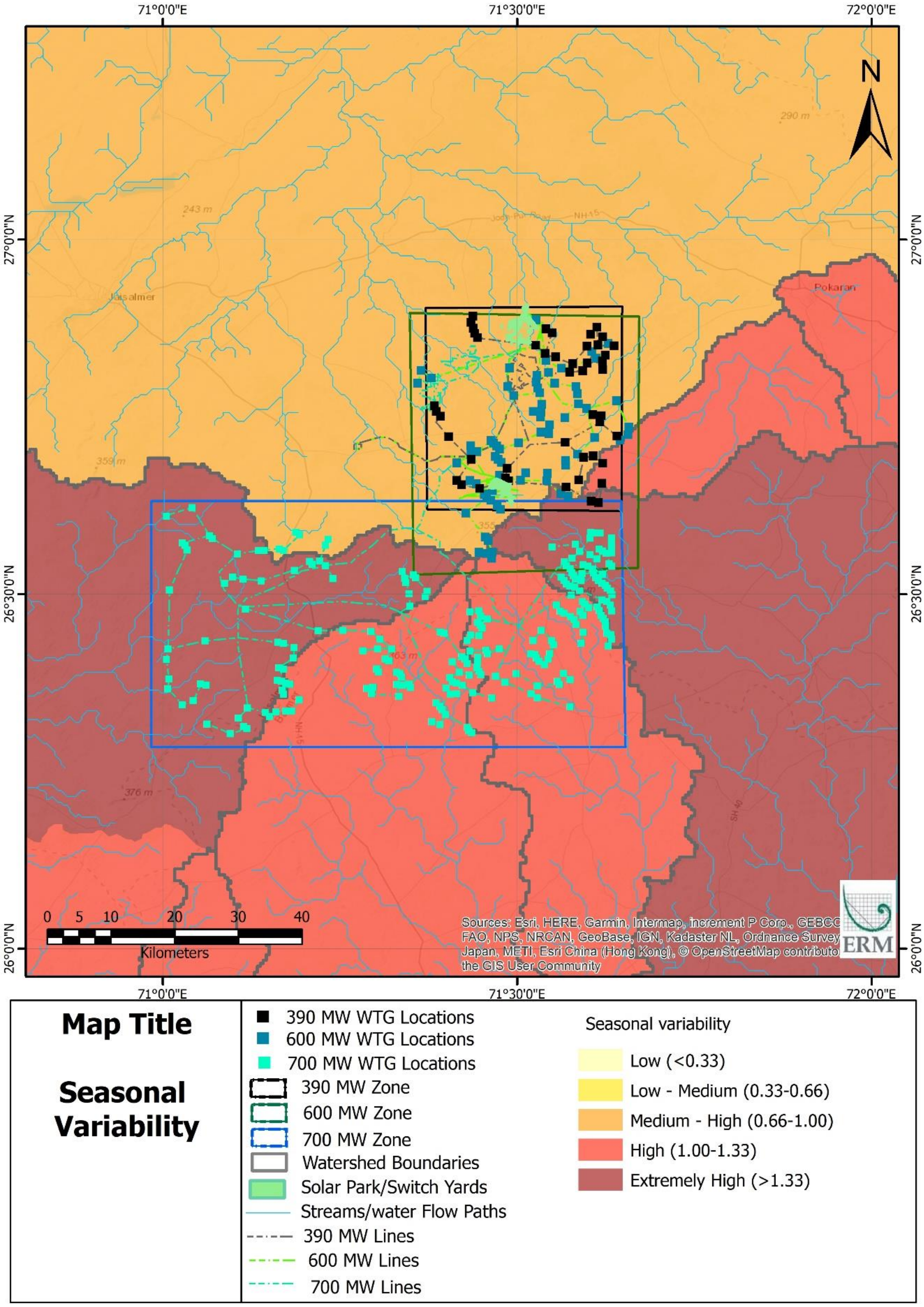
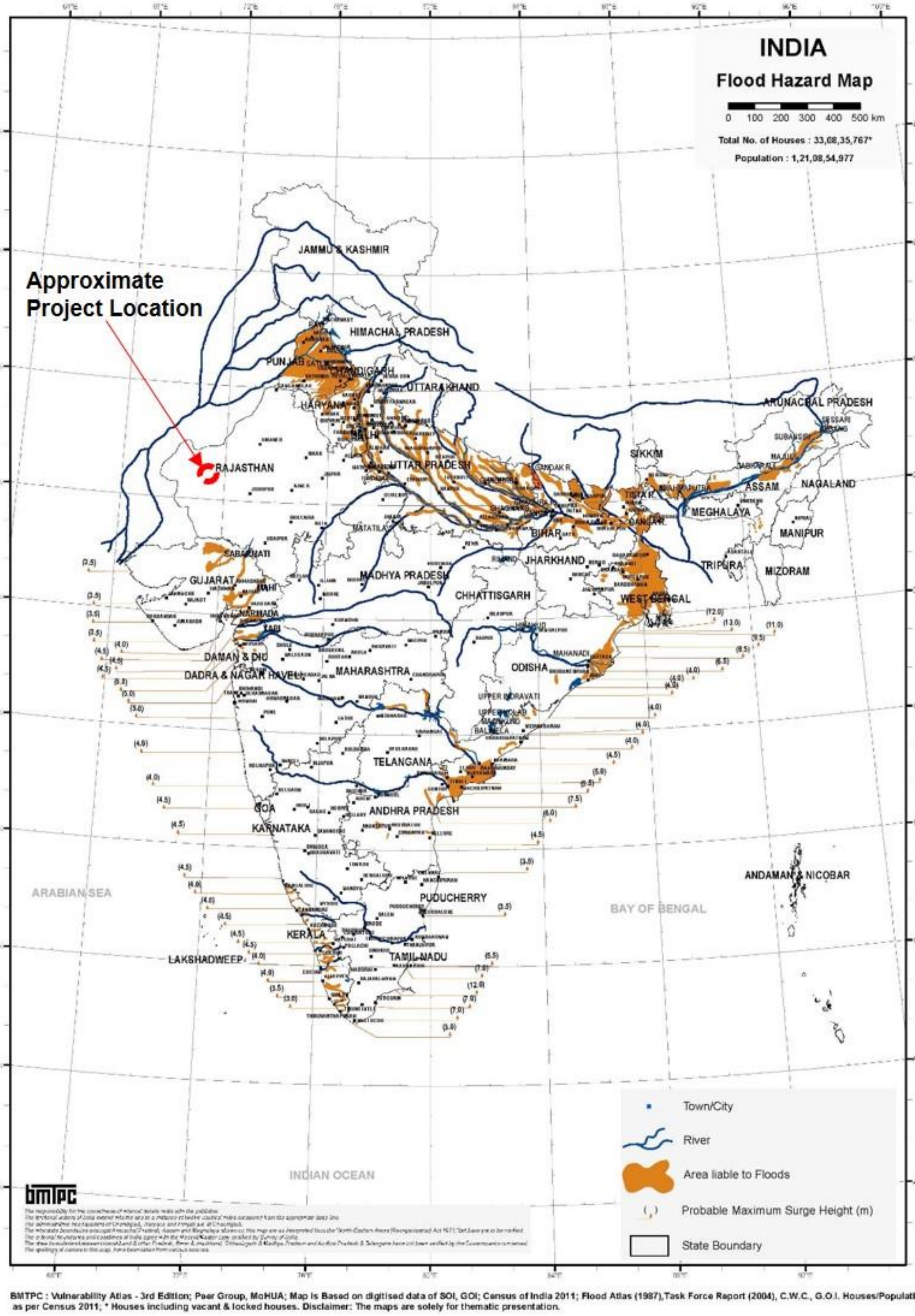


Figure B-3 Flood Hazard Map of India



BMTPC : Vulnerability Atlas - 3rd Edition; Peer Group, MoHUA; Map is Based on digitised data of SOI, GOI; Census of India 2011; Flood Atlas (1987),Task Force Report (2004), C.W.C., G.O.I. Houses/Population as per Census 2011; * Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

Figure B-4 Baseline Riverine Flood Hazard

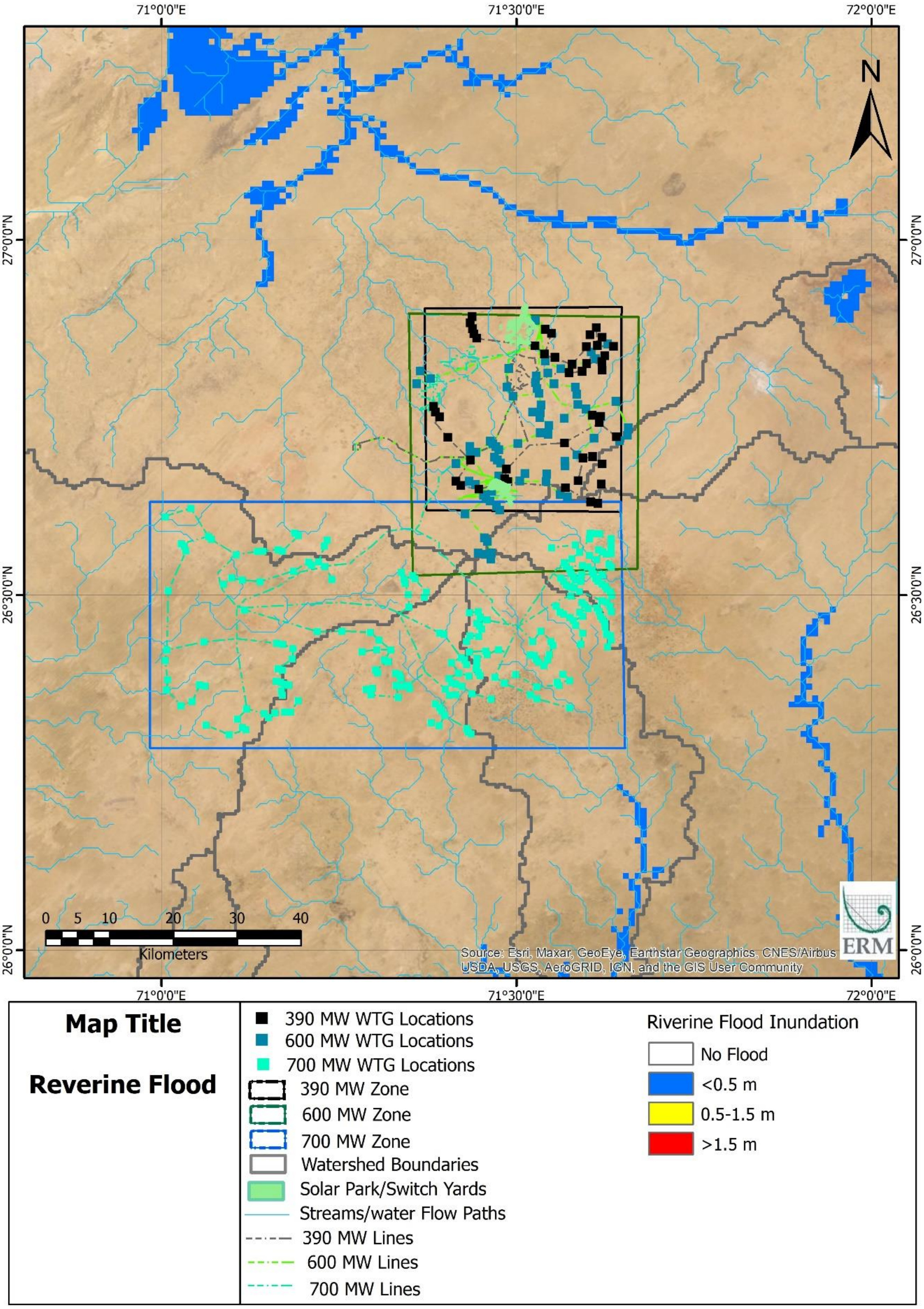
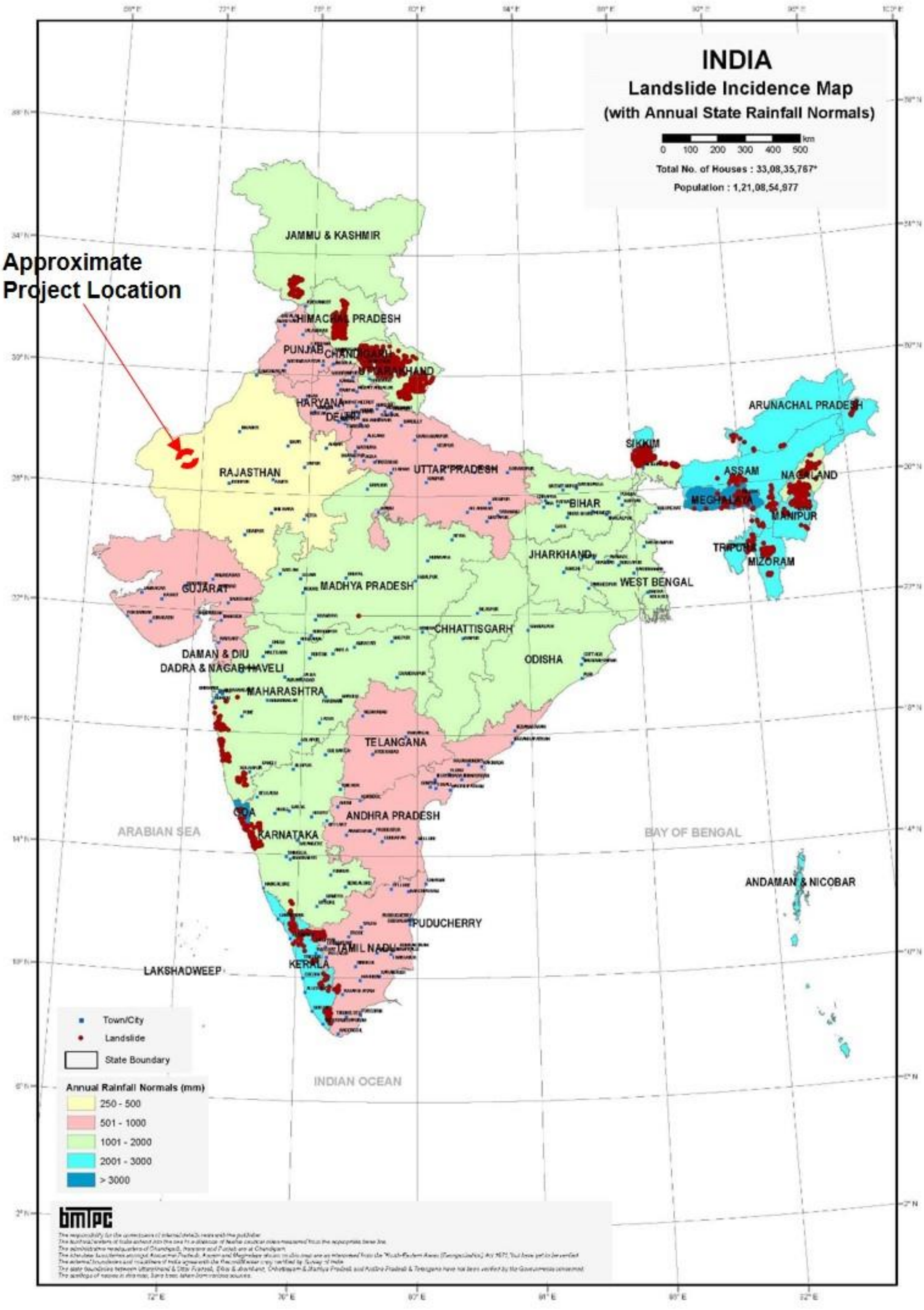


Figure B-5 Landslides Hazard Map of India



BMTPC: Vulnerability Atlas - 3rd Edition: Peer Group, MoHUA,GOI: Map is Based on digitised data of SOI; Landslide Incidence data GSI; Annual Rainfall data IMD. Houses/Population as per Census 2011;
* Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

Figure B-6 Baseline Landslides Due to Precipitation Hazard

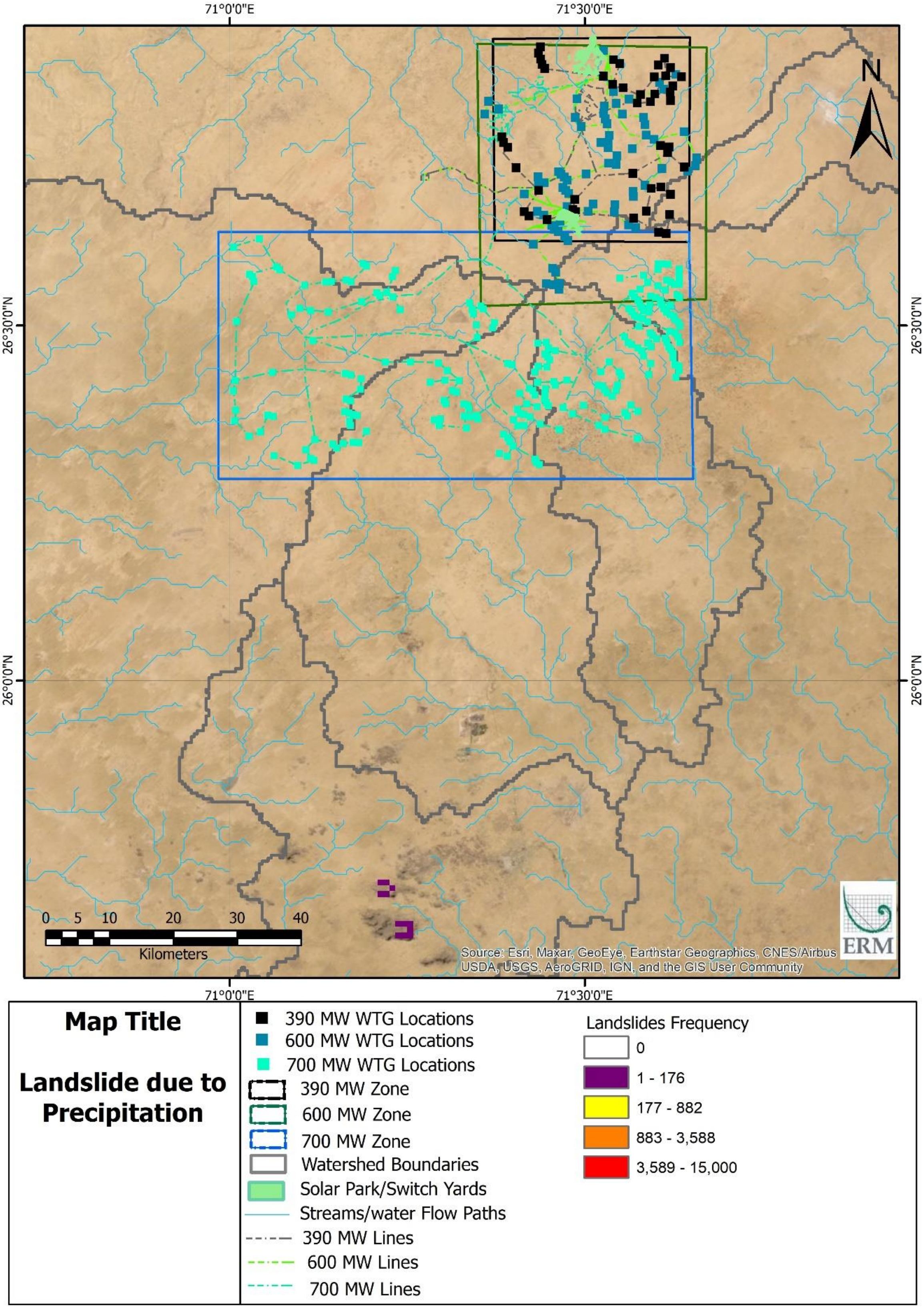


Figure B-7 Baseline Extreme Heat Hazard

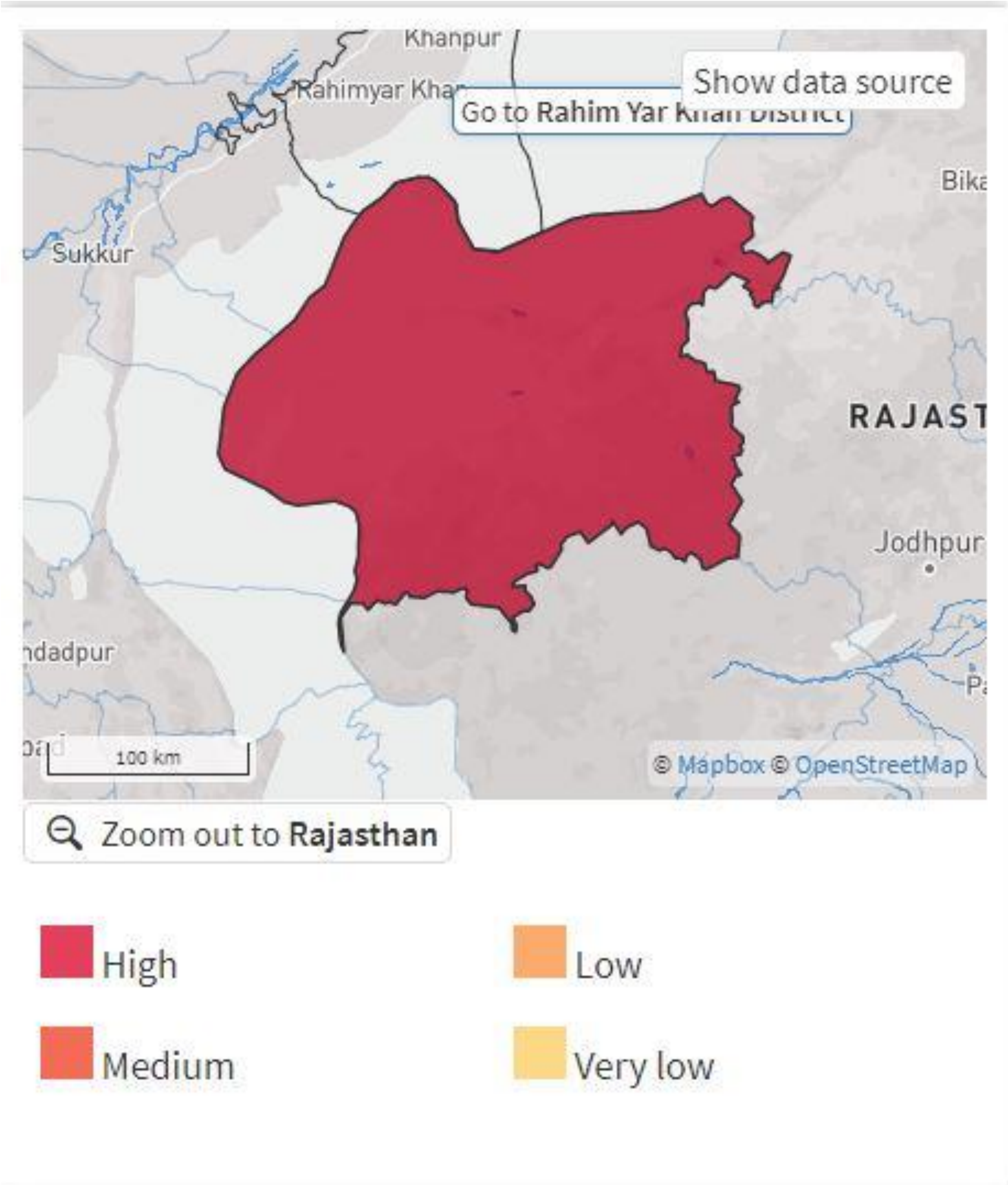


Figure B-8 Baseline Cyclone Hazard

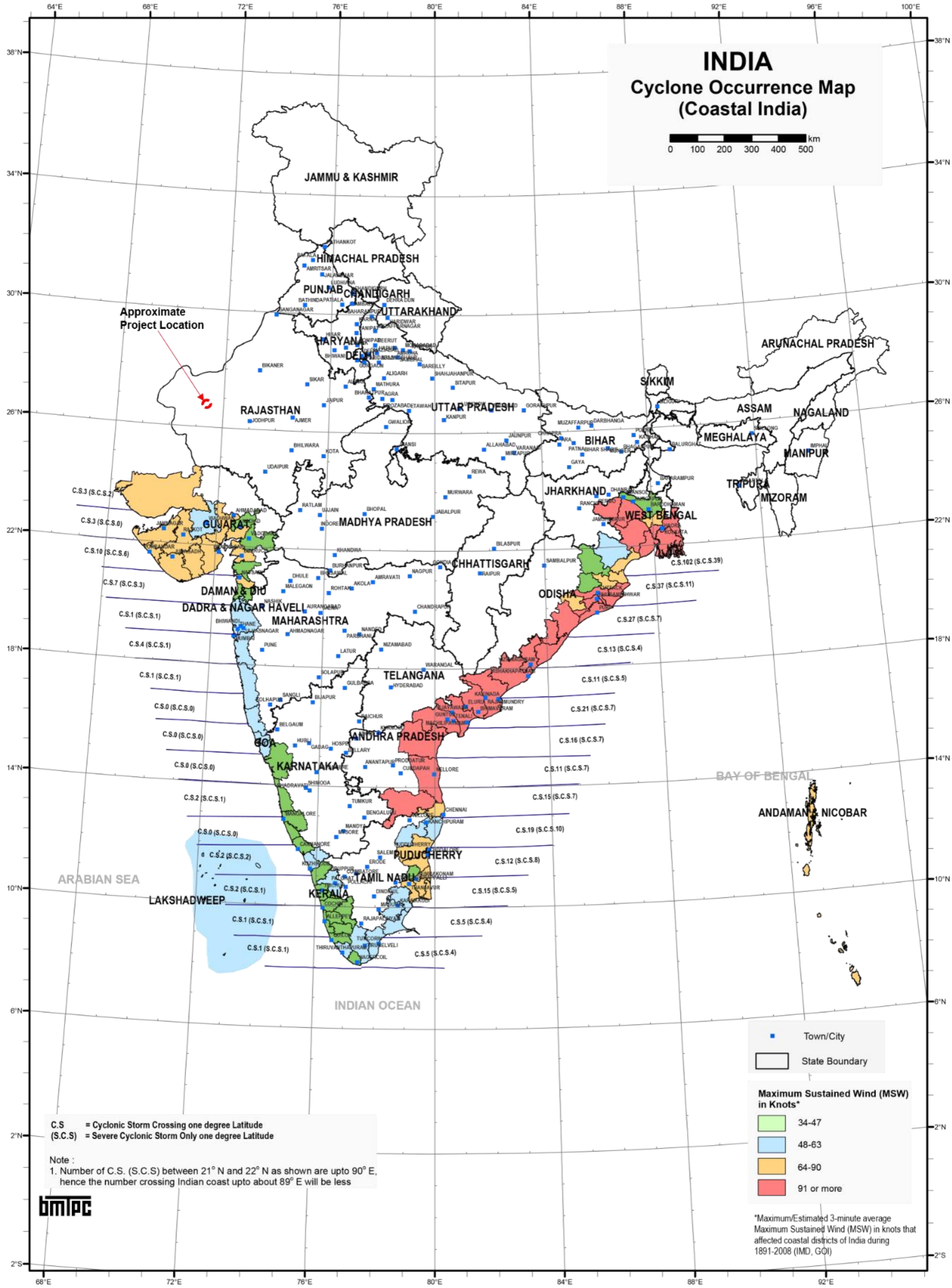


Figure B-9 Historical Cyclone Tracks

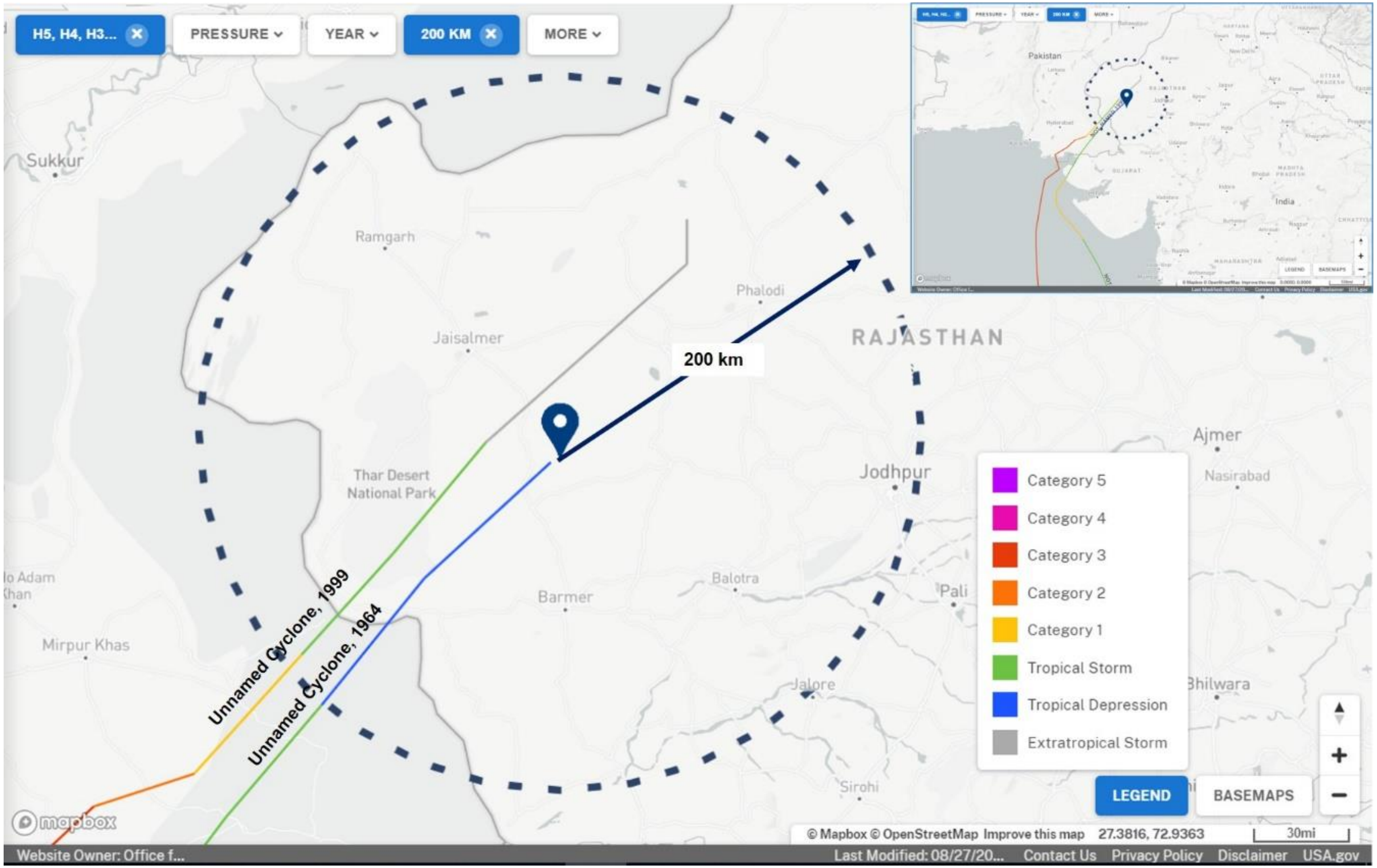


Figure-10 Baseline Average Wind Speed (at 10 m- abgl)

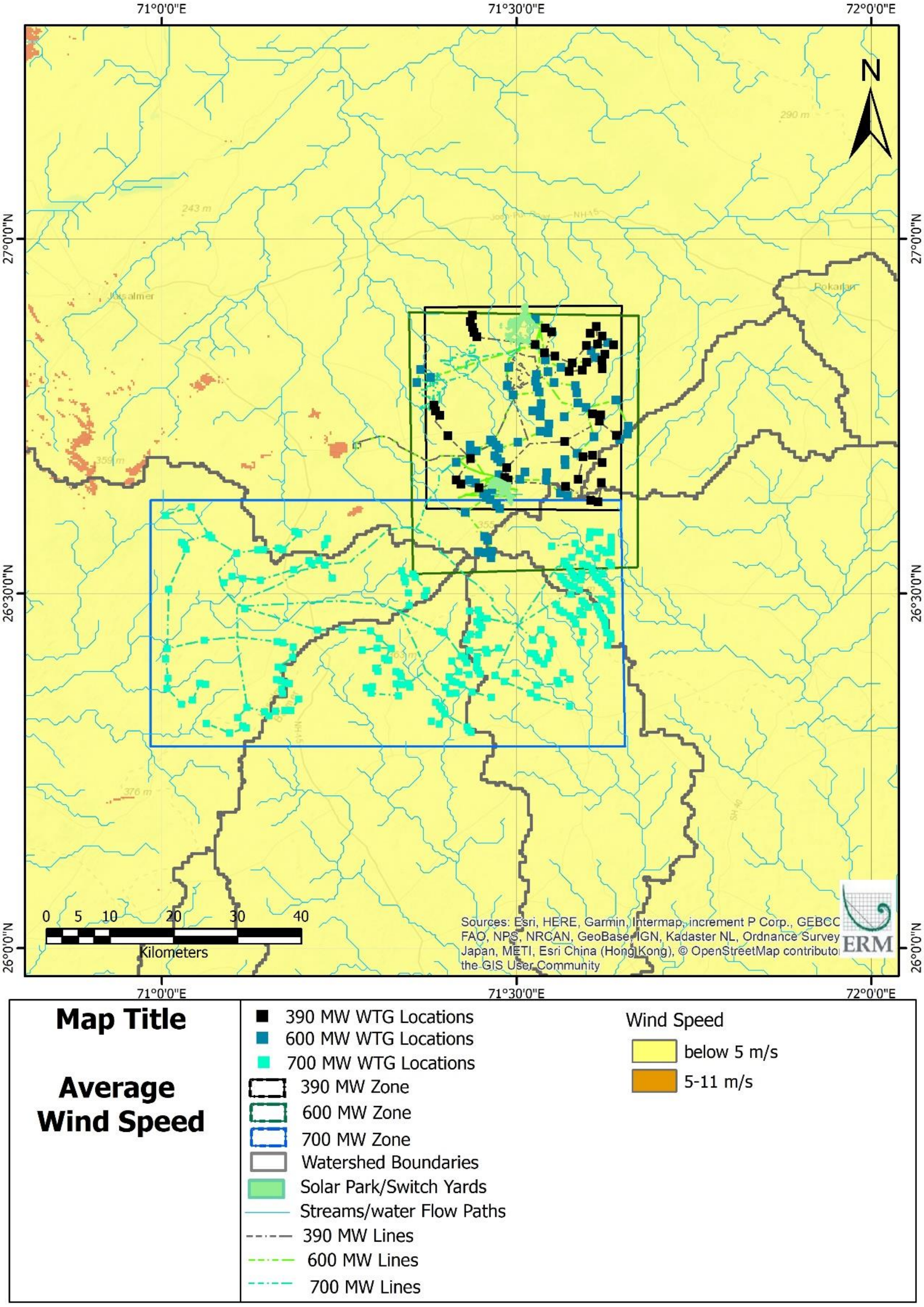


Figure-11 Baseline Extreme Wind Speed

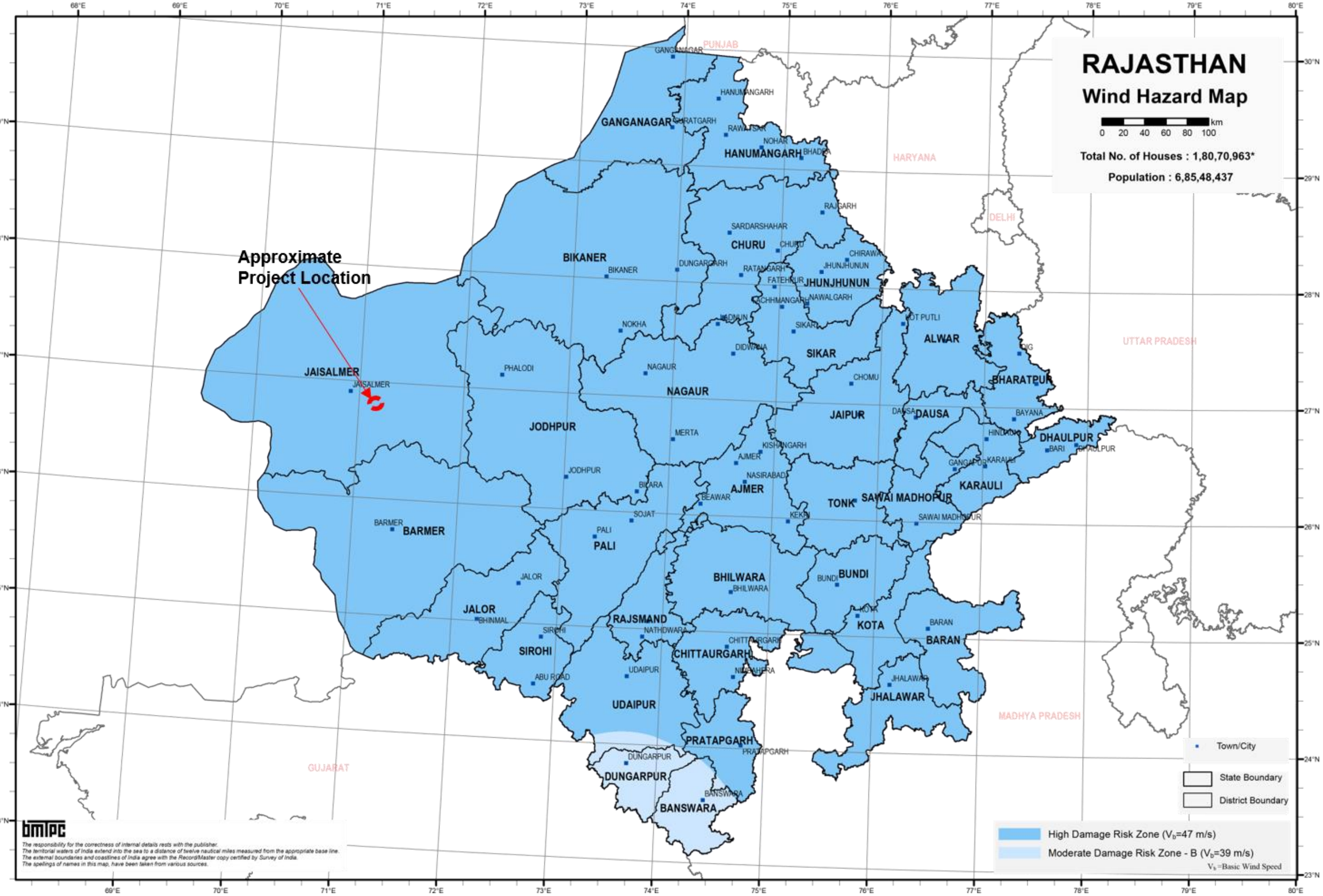


Figure-12 Baseline Occurrence of Thunder Storms

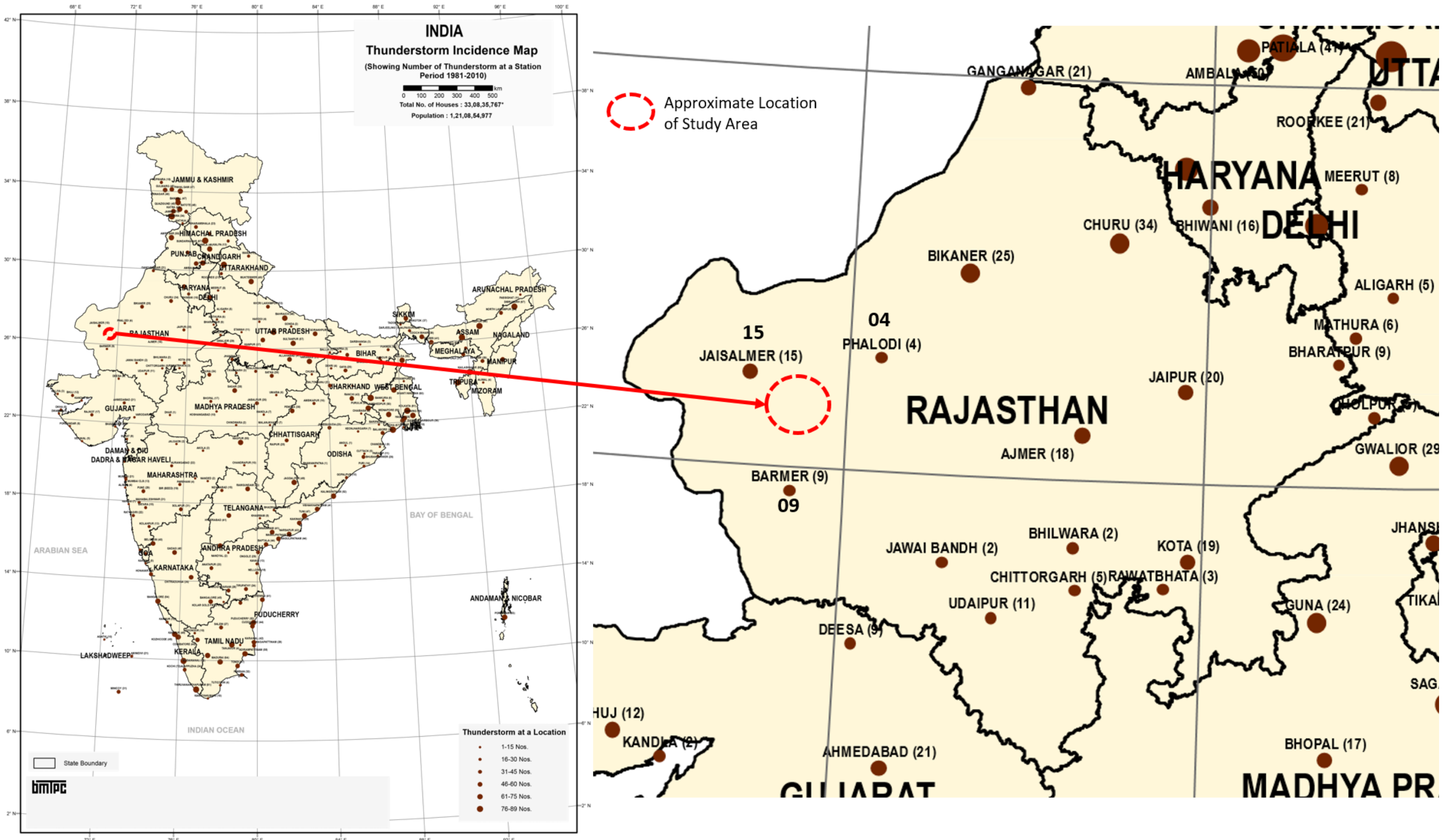
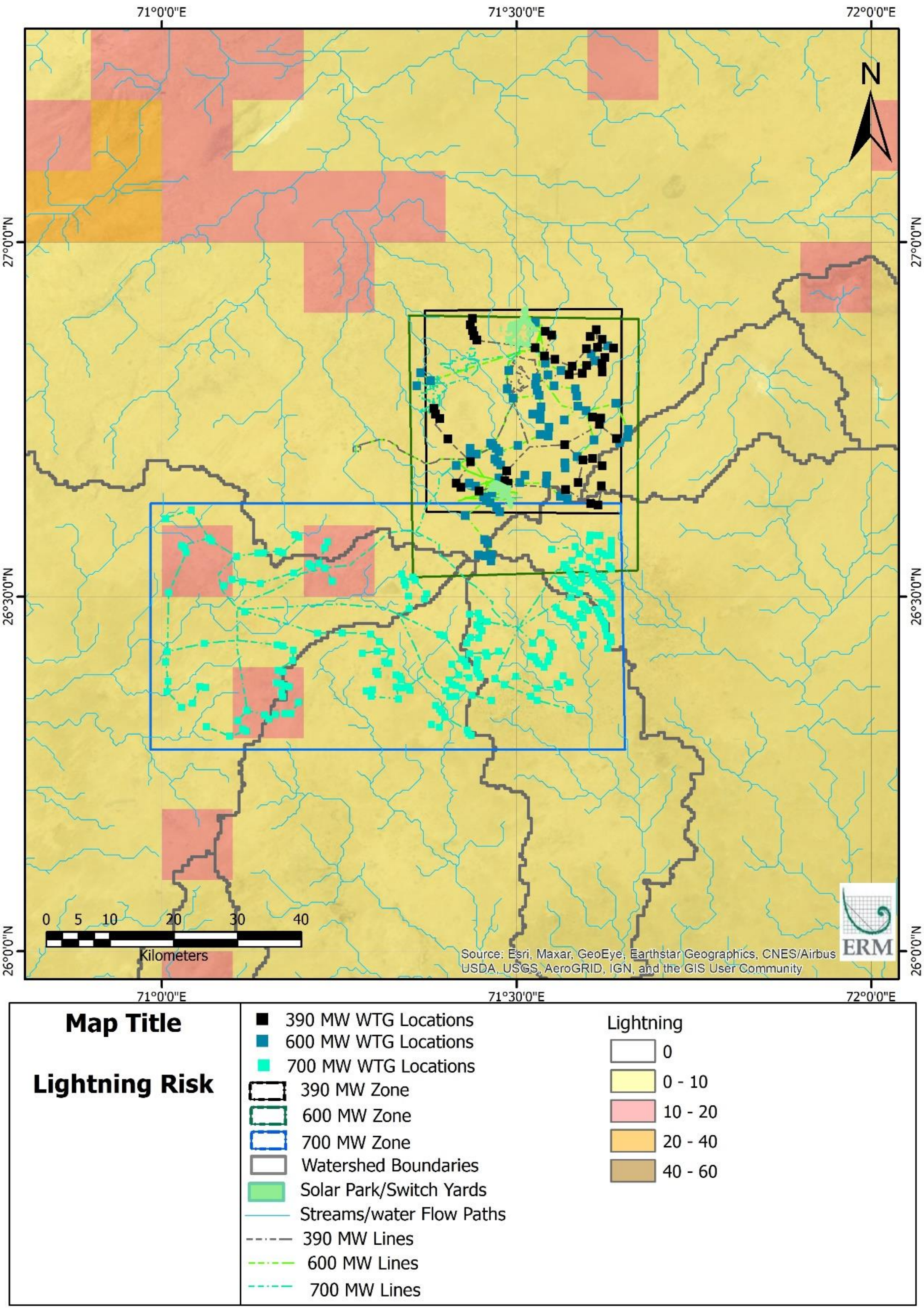


Figure B-13 Baseline Lightning Frequency



APPENDIX C HAZARD MAPS UNDER CLIMATE CHANGE

Figure C-1 Projected Water Stress in 2030 under RCP 4.5

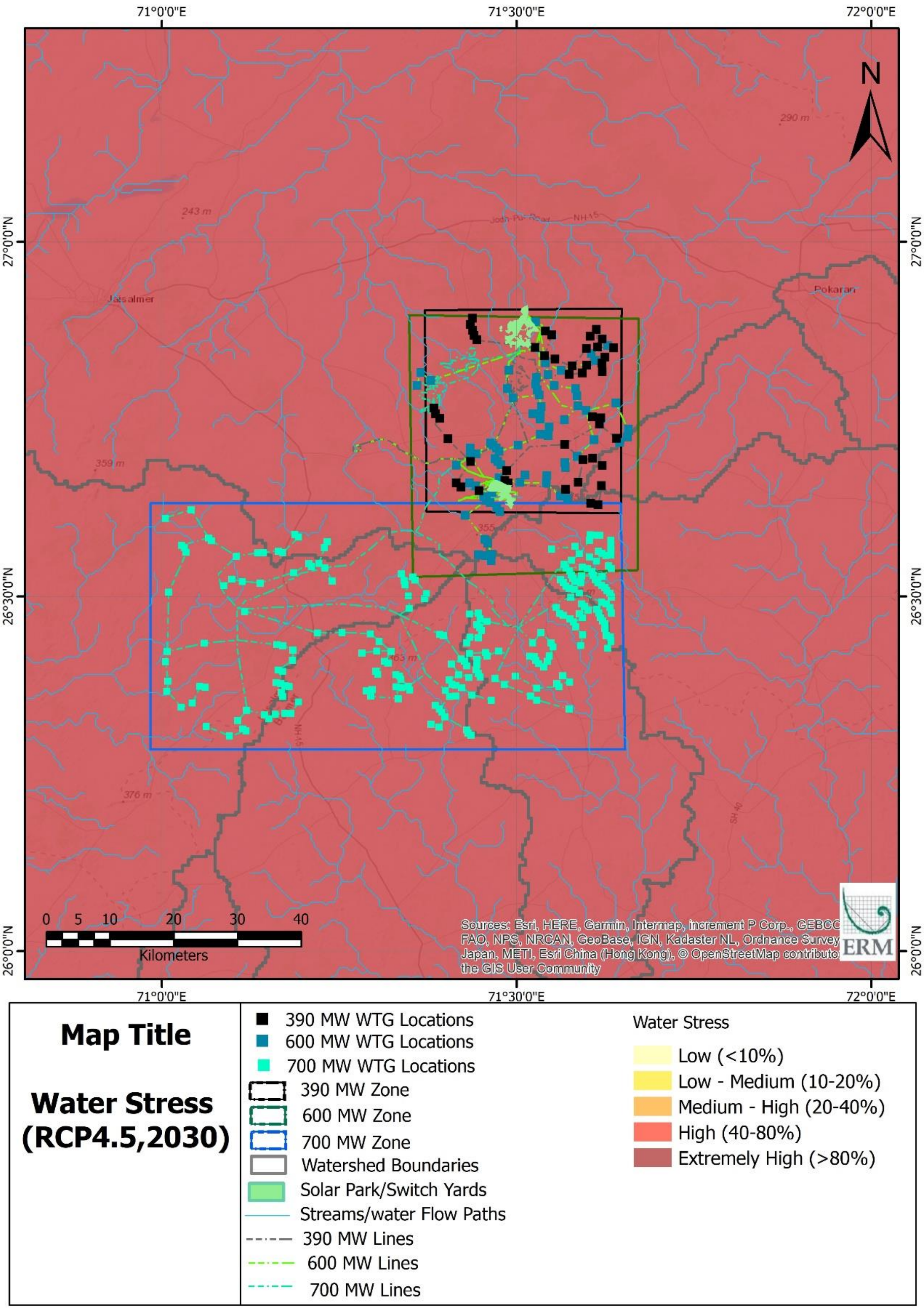


Figure C-2 Projected Water Stress in 2030 under RCP 8.5

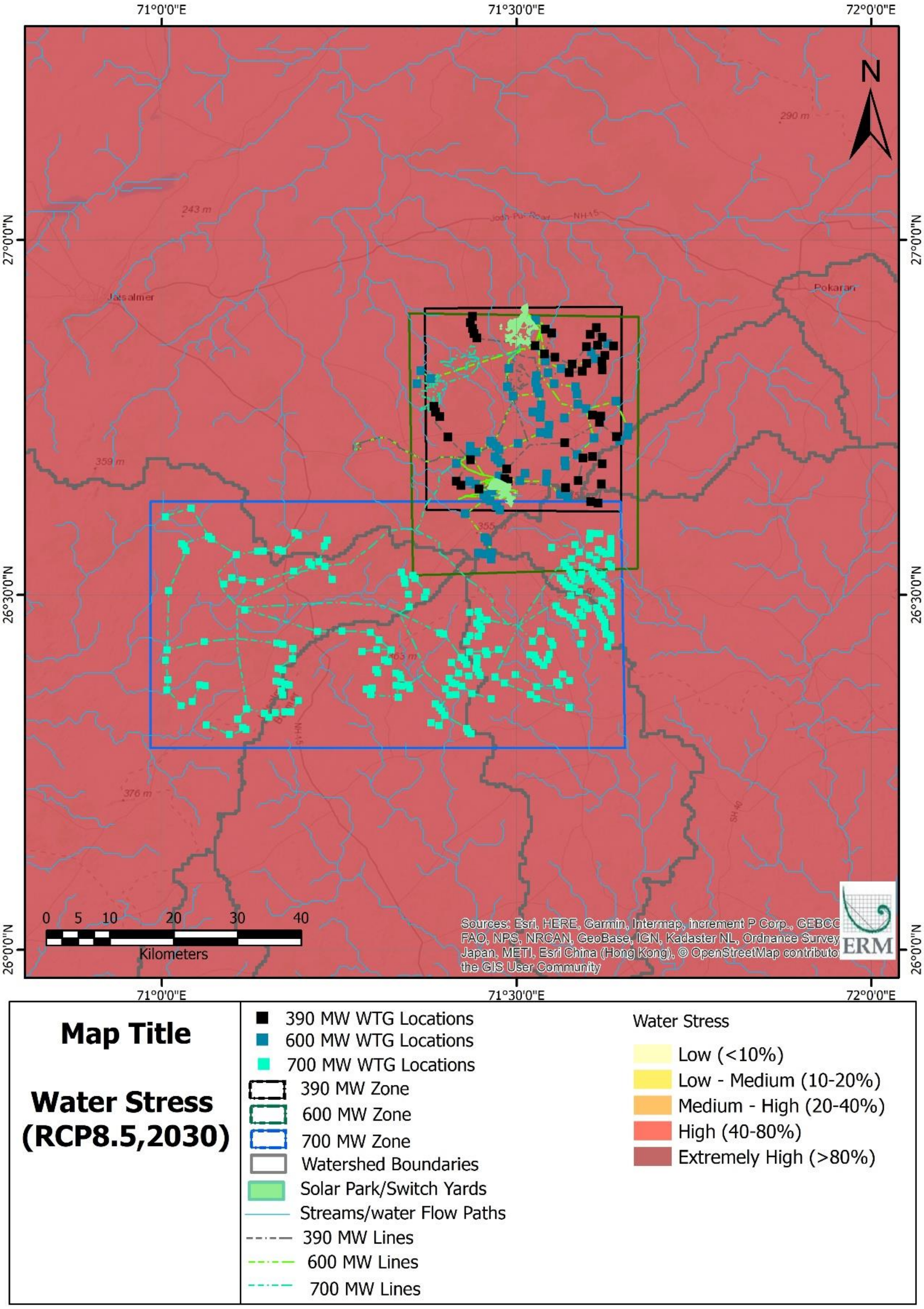
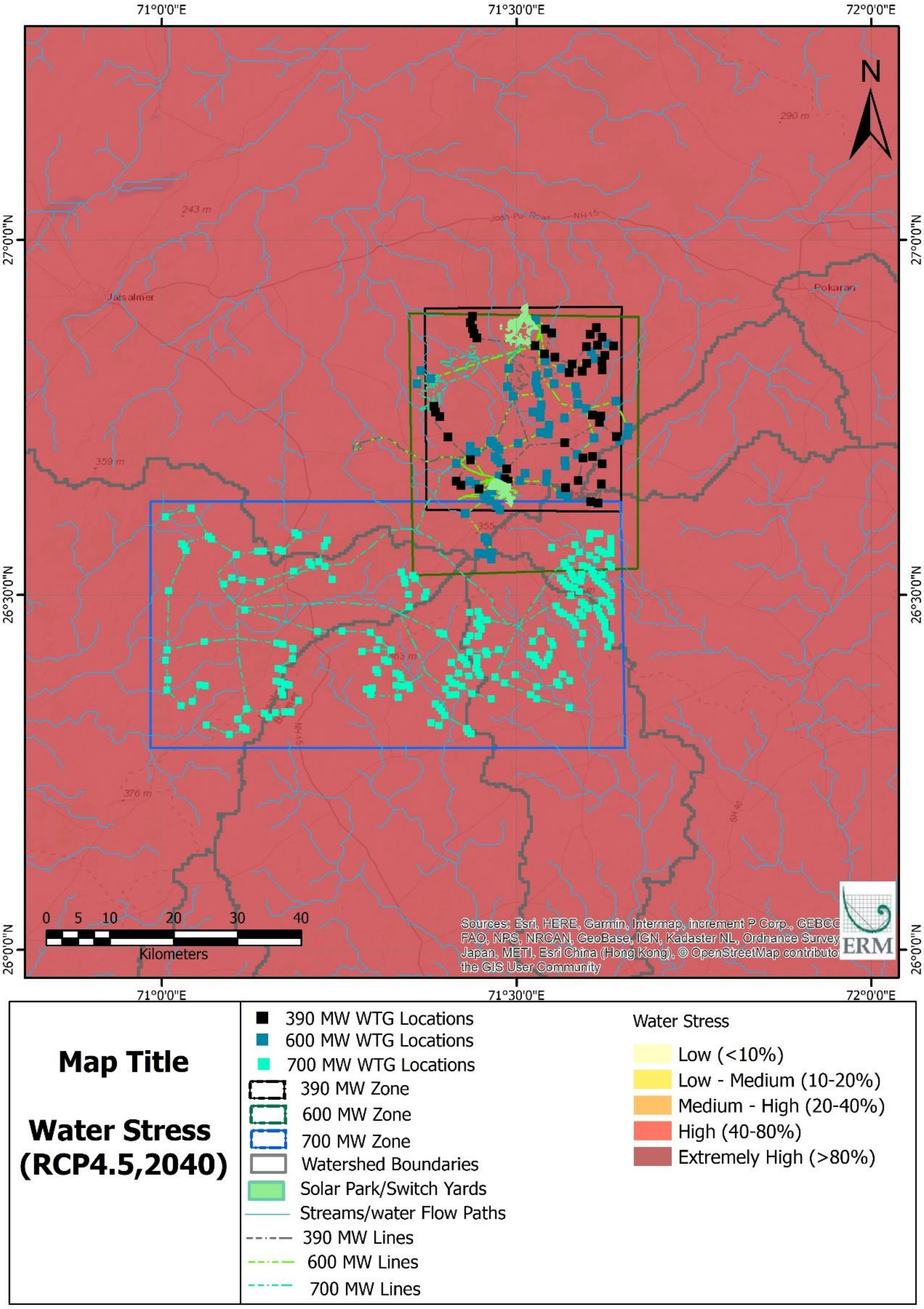
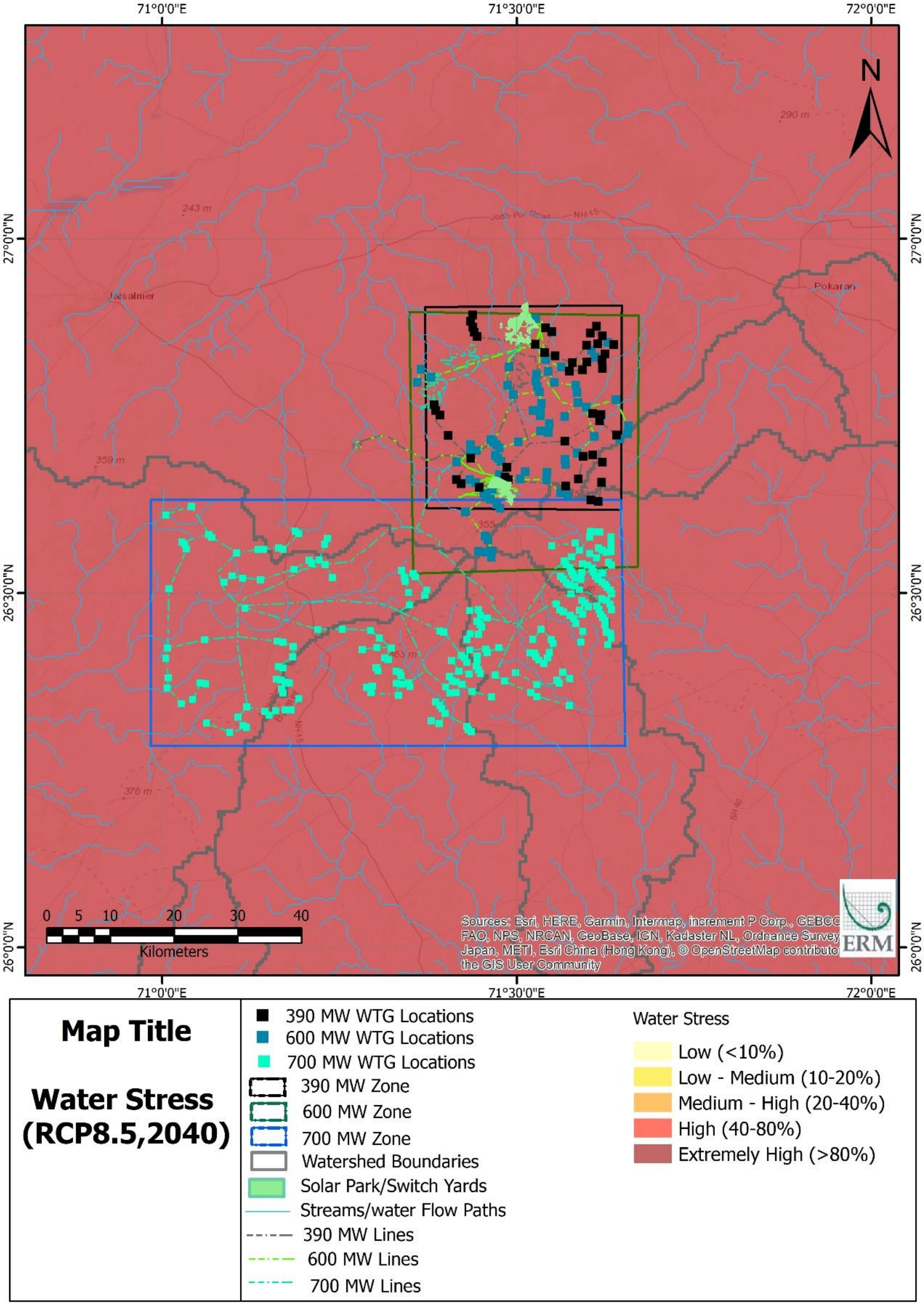


Figure C-3 Projected Water Stress in 2040 under RCP 4.5



(Note: In the absence of data for projection of water stress in 2050, projections for 2040 timeframe are considered for 2050)

Figure C-4 Projected Water Stress in 2040 under RCP 8.5



(Note: In the absence of data for projection of water stress in 2050, projections for 2040 timeframe are considered for 2050)

Figure C-5 Projected Seasonal Variability in 2030 under RCP 4.5

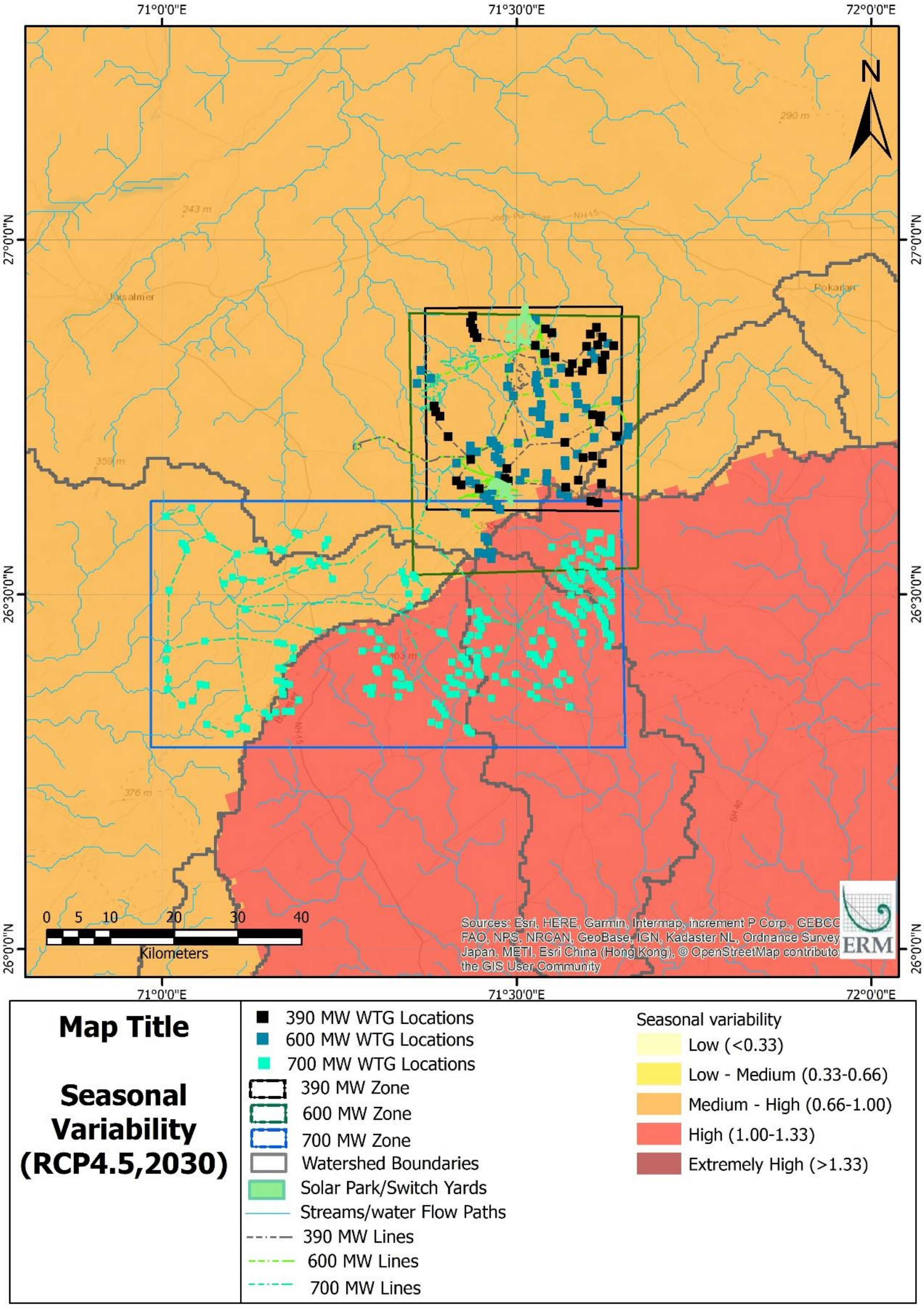


Figure C-6 Projected Seasonal Variability in 2030 under RCP 8.5

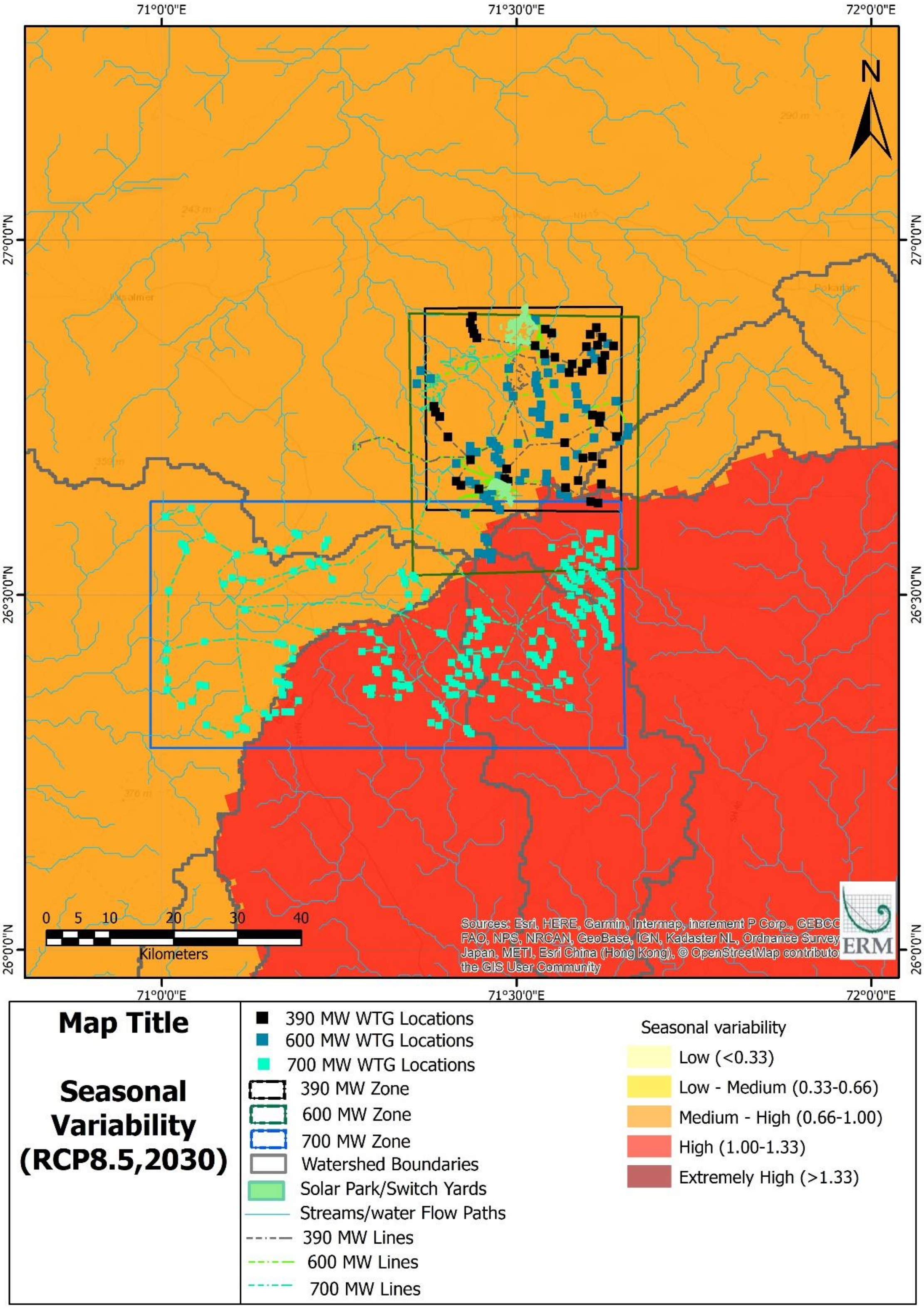
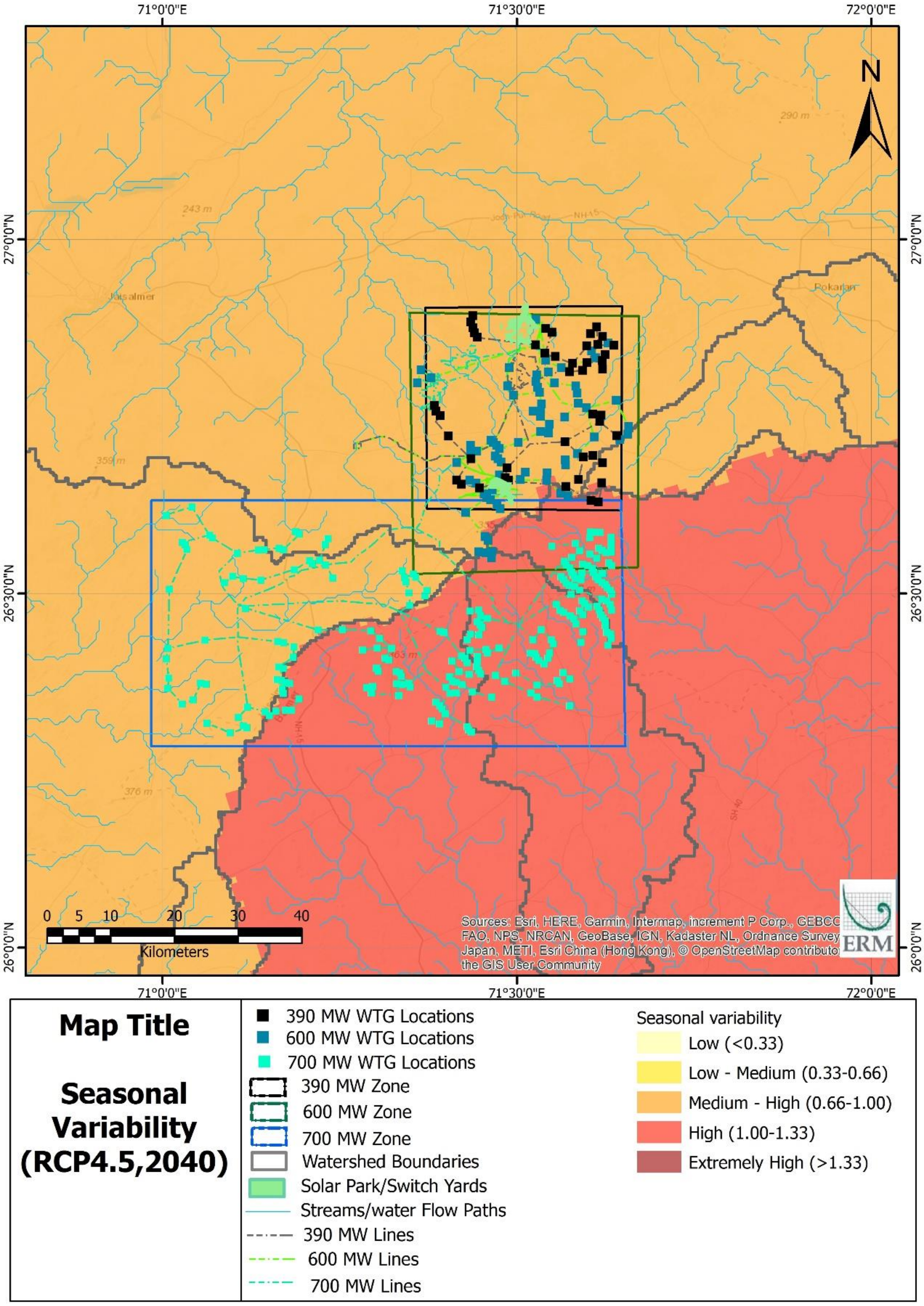
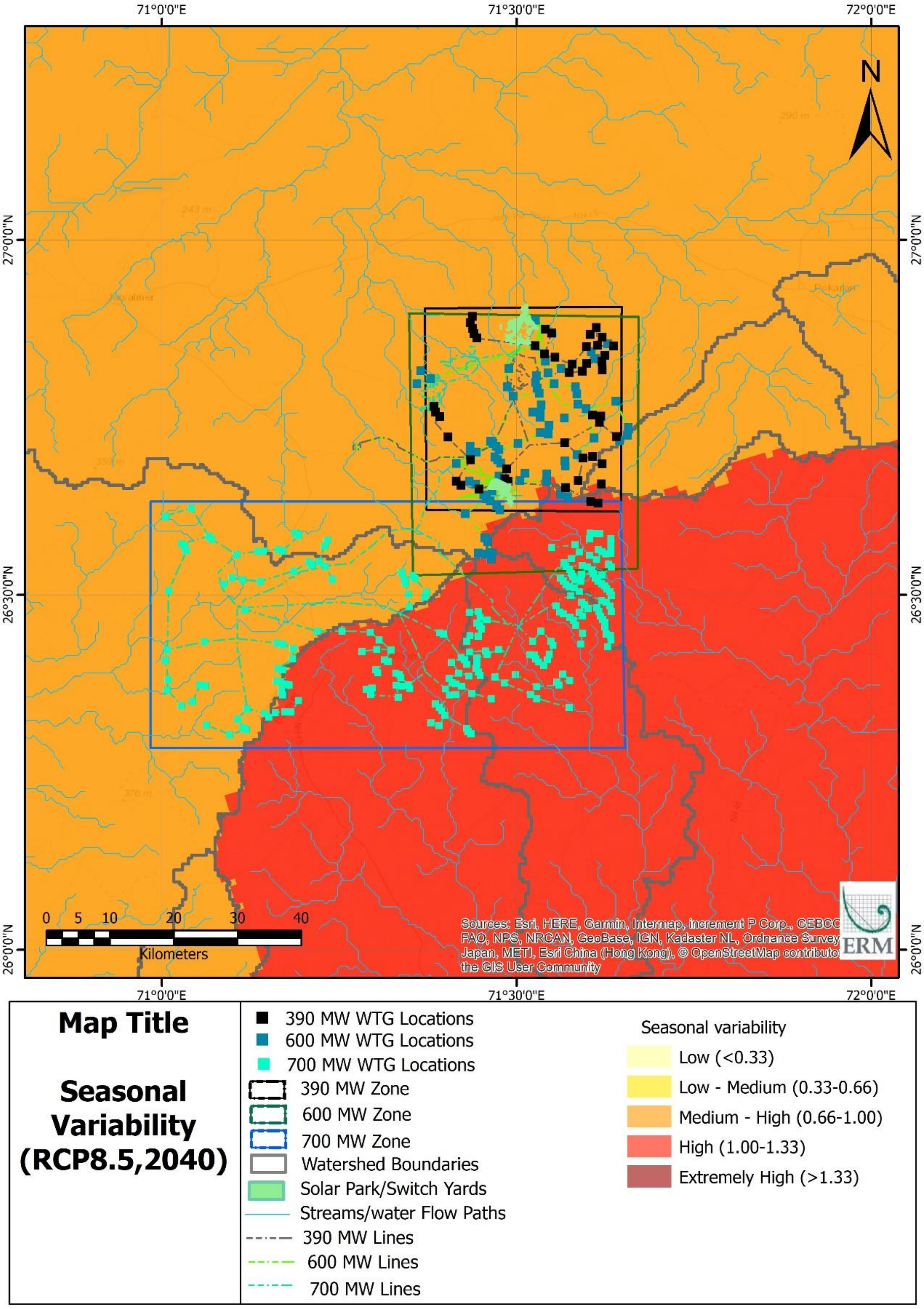


Figure C-7 Projected Seasonal Variability in 2040 under RCP 4.5



(Note: In the absence of data for projection of water stress in 2050, projections for 2040 timeframe are considered for 2050)

Figure C-8 Projected Seasonal Variability in 2040 under RCP 8.5



(Note: In the absence of data for projection of water stress in 2050, projections for 2040 timeframe are considered for 2050)

Figure C-9 Projected Riverine Floods in 2030 and 2050 under RCP 4.5

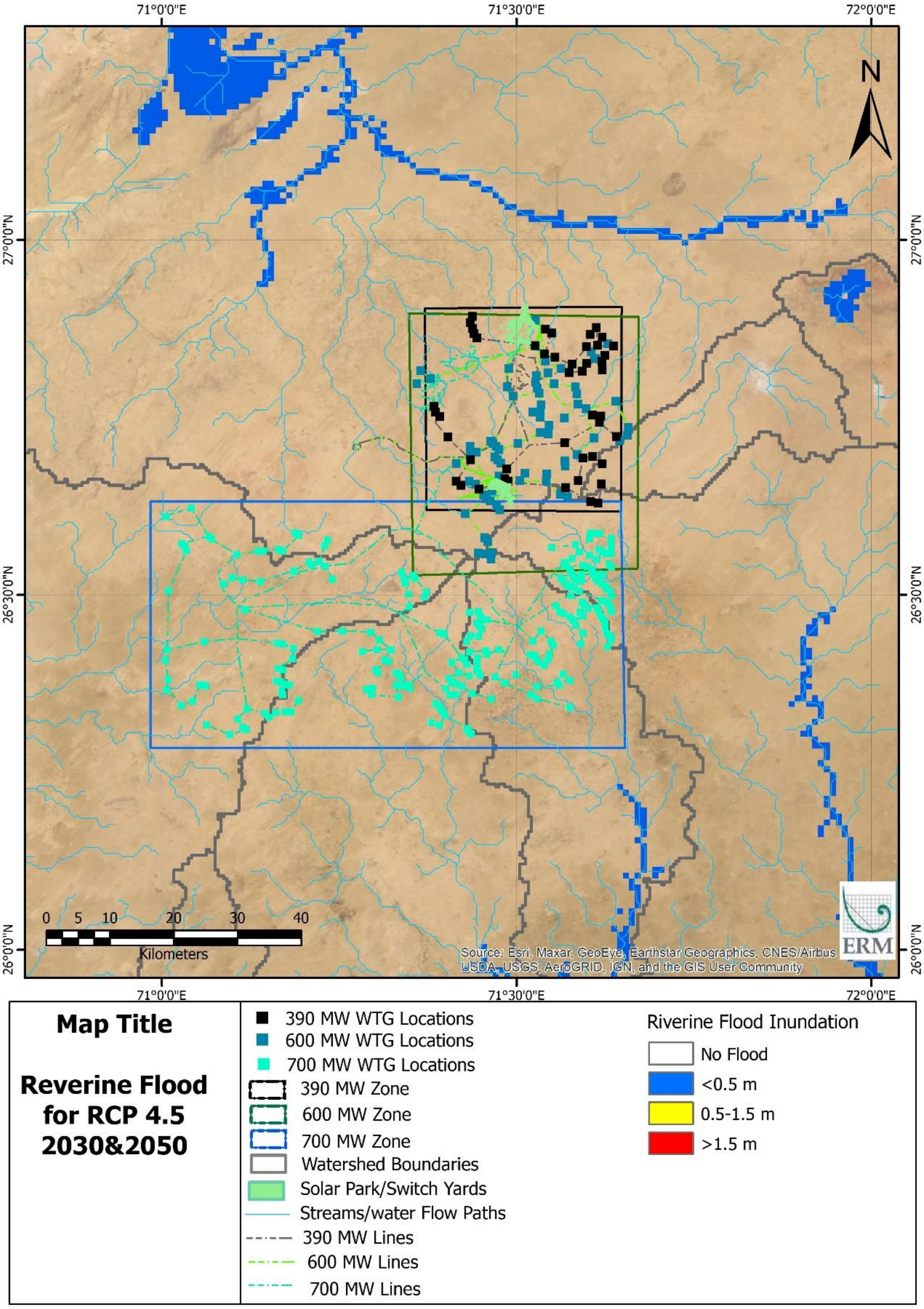


Figure C-10 Projected Riverine Floods in 2030 and 2050 under RCP 8.5

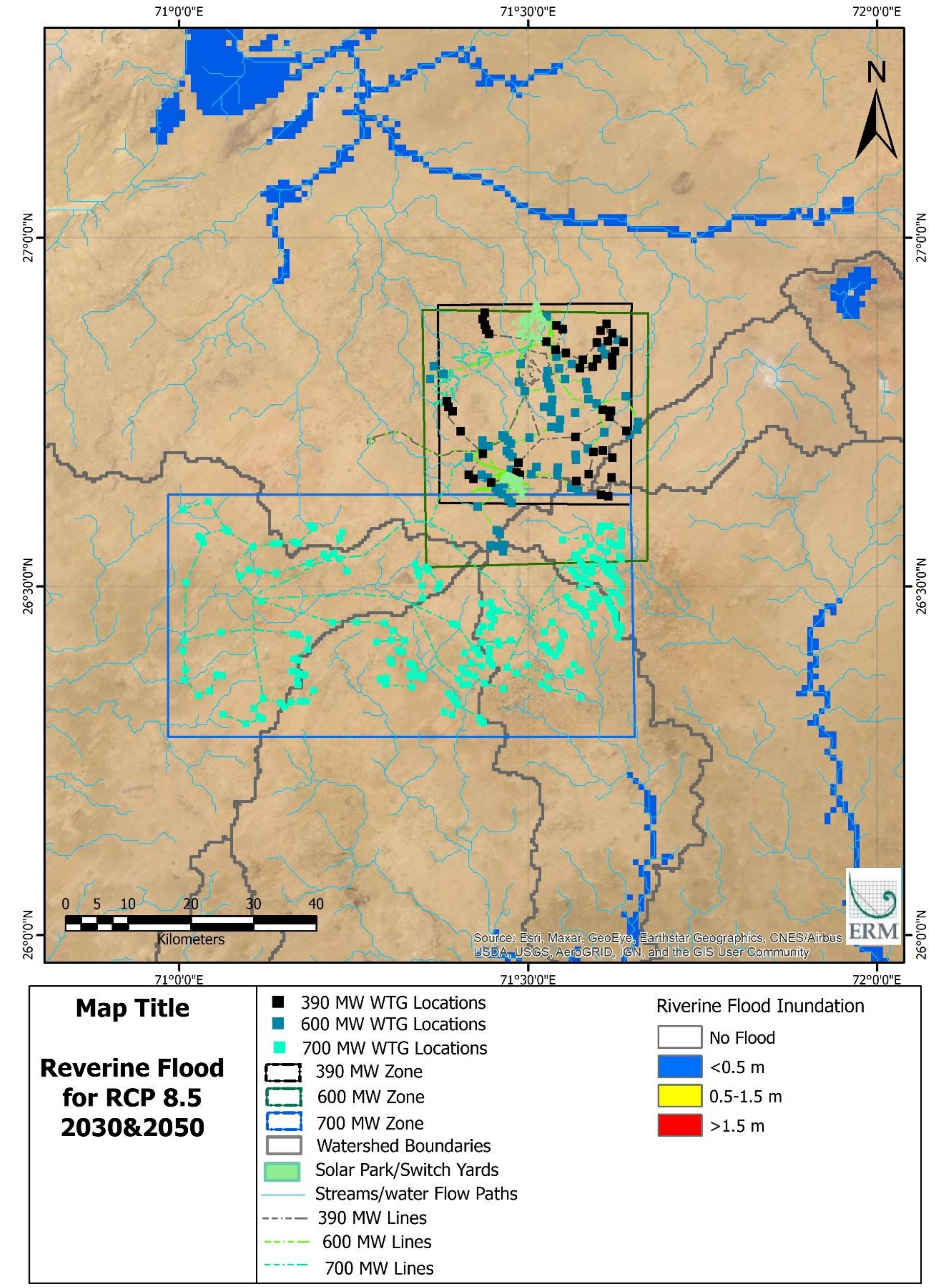
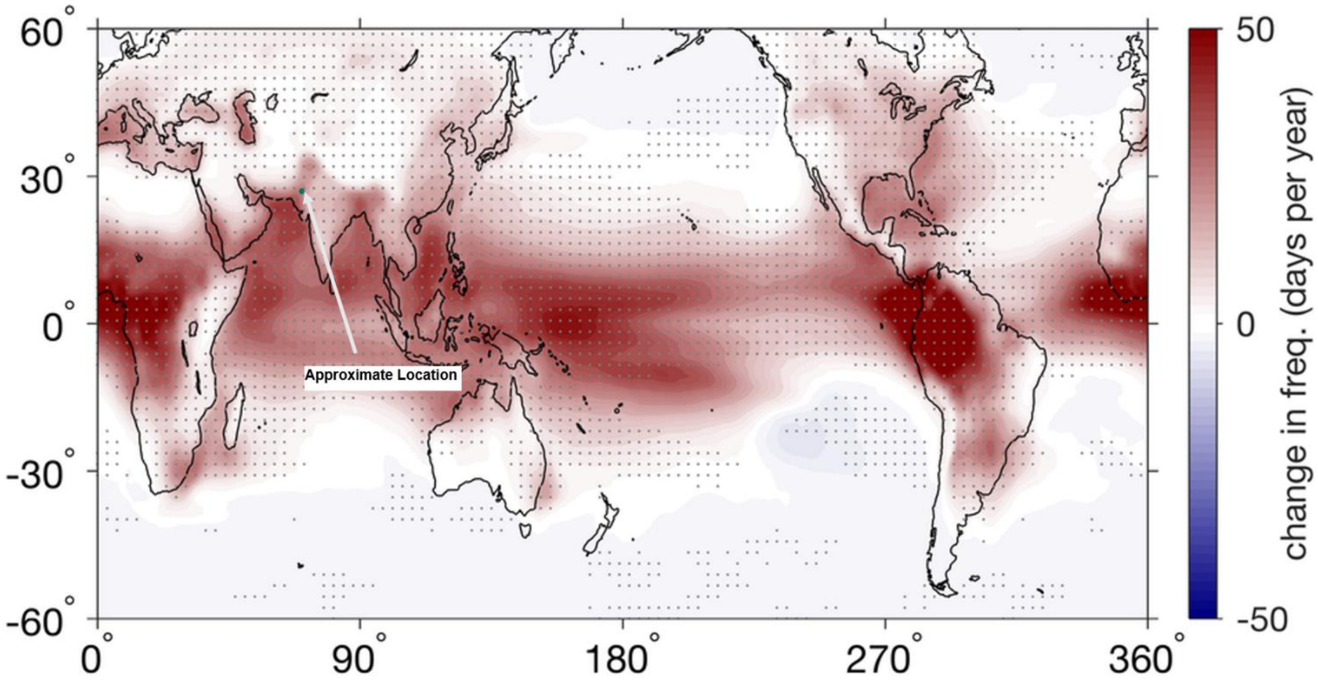


Figure C-11 Projected Increase in Number of Days with Conditions Conducive to Formation of Thunderstorm



Appendix D GLOSSARY

- **Water Stress**: Water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users[38].
- **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[38].
- **Flood**: An overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding, it may last days or weeks[39].
- **Riverine Flood**: A riverine flood occurs when water levels rise over the top of river banks due to excessive rain from tropical systems making landfall, persistent thunderstorms over the same area for extended periods of time, combined rainfall and snowmelt, or an ice jam[40].
- **Land Slide**: A landslide is defined as the movement of a mass of rock, debris, or earth down a slope. Landslides are a type of "mass wasting," which denotes any down-slope movement of soil and rock under the direct influence of gravity. The term "landslide" encompasses five modes of slope movement: falls, topples, slides, spreads, and flows. These are further subdivided by the type of geologic material (bedrock, debris, or earth). Debris flows (commonly referred to as mudflows or mudslides) and rock falls are examples of common landslide types.

  Almost every landslide has multiple causes. Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength. Landslides can be initiated in slopes already on the verge of movement by rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors[41].

---

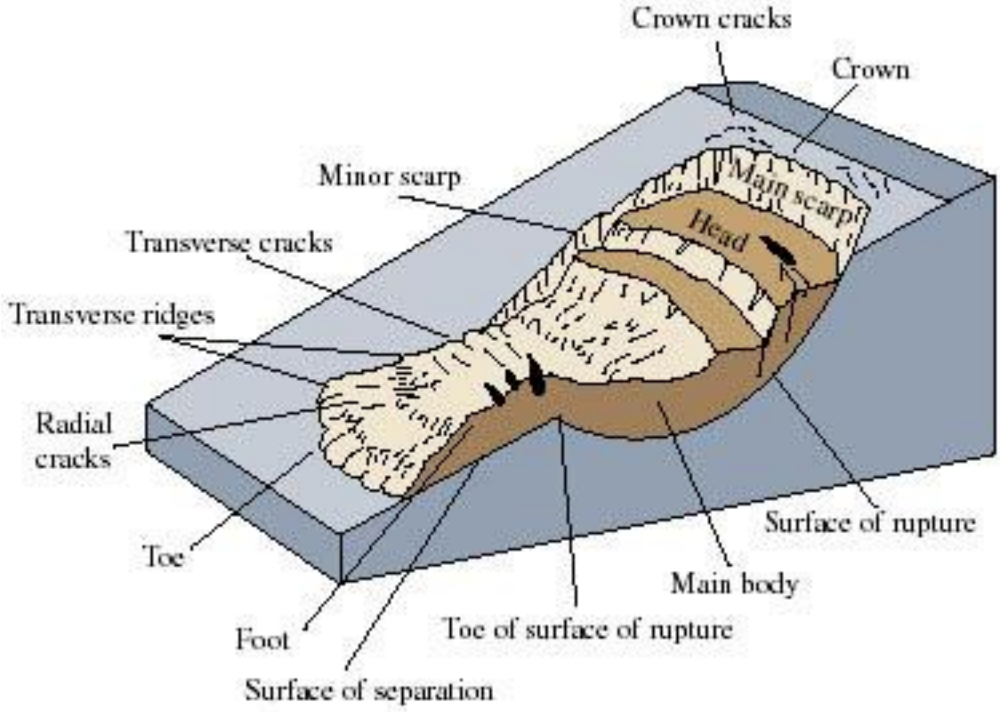
[38] Hofste, R., S. Kuzma, S. Walker, E.H. Sutanudjaja, M.F.P. Bierkens, M.J.M. Kuijper, M. Faneca Sanchez, R. Van Beek, Y. Wada, S.G. Rodríguez and P. Rei. 2019. "Aqueduct 3.0: Updated DecisionRelevant Global Water Risk Indicators." Technical Note.. Available at: https://www.wri.org/publication/aqueduct-30

[39] National Weather Service, https://www.weather.gov/mrx/flood_and_flash

[40] NOAA Severe Weather 101, https://www.nssl.noaa.gov/education/svrwx101/floods/types/#:~:text=A%20coastal%20flood%2C%20or%20the,blowing%20landward%20from%20the%20ocean).

[41] https://www.usgs.gov/faqs/what-a-landslide-and-what-causes-one?qt-news_science_products=0#qt-news_science_products

Figure D-4 Components of Landslides



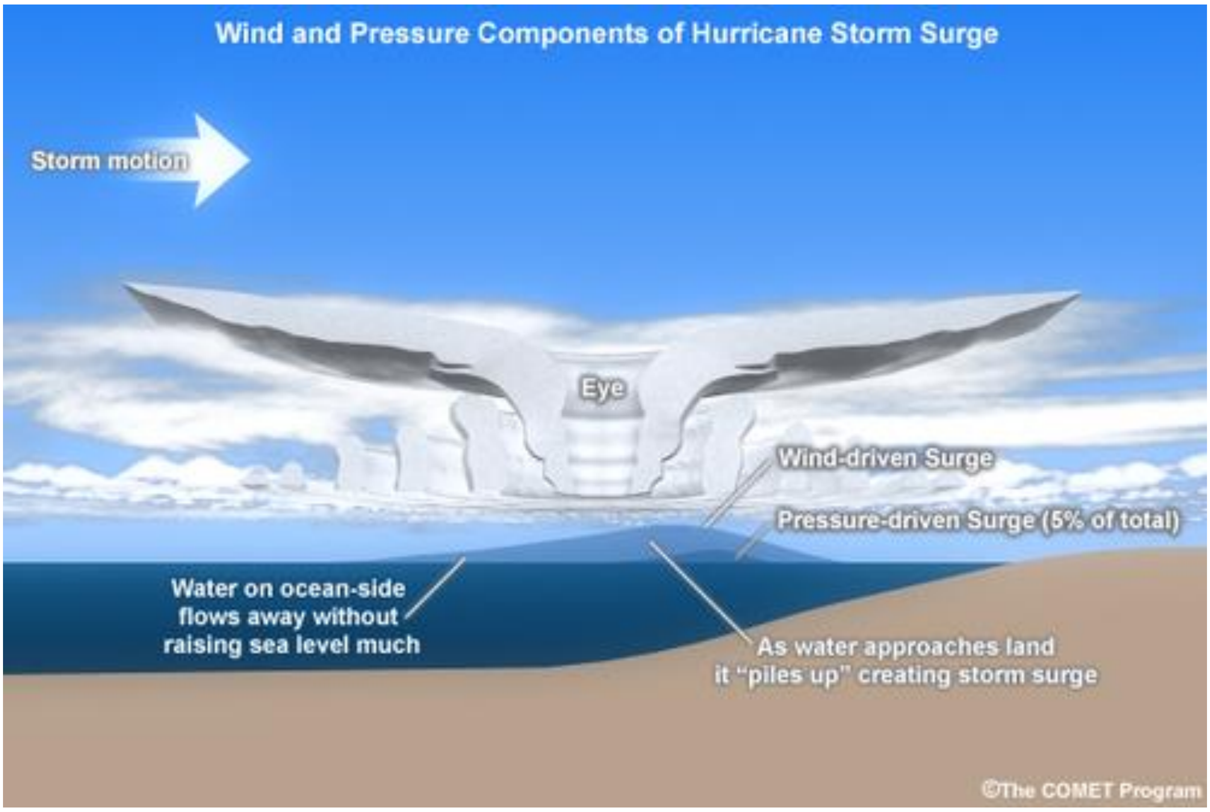
(Source: USGS, https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html)

- **Cyclone and Hurricane**: A warm-core non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined center. Once formed, a tropical cyclone is maintained by the extraction of heat energy from the ocean at high temperature and heat export at the low temperatures of the upper troposphere. In this they differ from extratropical cyclones, which derive their energy from horizontal temperature contrasts in the atmosphere (baroclinic effects)[42]. A tropical cyclone is characterised by a rotting low pressure weather system that has organised thunder storm but no front[43]. The rotations are in anti-clockwise direction in northern hemi-sphere and clockwise in southern-hemisphere. Hurricane is a tropical cyclone with maximum sustained wind speed exceed 119 km/h.

42 NOAA, https://www.nhc.noaa.gov/aboutgloss.shtml

43 NOAA, https://oceanservice.noaa.gov/facts/hurricane.html#:~:text=Transcript,air%20masses%20of%20different%20densities).

Figure D-2 Components of Tropical Cyclone/ Hurricane



(Source: NOAA)

- **Wind**: The horizontal motion of the air past a given point. Winds begin with differences in air pressures. Pressure that's higher at one place than another sets up a force pushing from the high toward the low pressure. The greater the difference in pressures, the stronger the force. The distance between the area of high pressure and the area of low pressure also determines how fast the moving air is accelerated. Meteorologists refer to the force that starts the wind flowing as the "pressure gradient force." High and low pressure are relative. There's no set number that divides high and low pressure. Wind is used to describe the prevailing direction from which the wind is blowing with the speed given usually in miles per hour, knots, meter per second, or kilo-meter per hour[44].
- **Representative Concentration Pathways (RCP)**: RCPs usually refer to the portion of the concentration pathway extending up to 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 emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

  Four RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the Fifth IPCC Assessment as a basis for the climate predictions and projections are as following[45].

[44] NOAA, https://w1.weather.gov/glossary/index.php?letter=w#:~:text=The%20horizontal%20motion%20of%20the%20air%20past%20a%20given%20point.&text=Wind%20is%20used%20to%20describe,miles%20per%20hour%20or%20knots.

[45] IPCC, https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html

1. 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);
2. RCP4.5 and RCP6.0 Two intermediate stabilisation pathways in which radiative forcing is stabilised at approximately 4.5 W m-2 and 6.0 W m-2 after 2100 (the corresponding ECPs assuming constant concentrations after 2150);
3. 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).

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