Developing Climate Strategy and Climate Disclosure Support

Climate Risk Assessment : Physical Risk Hotspot Analysis

BTS Group 2023

27 June 2023

Executive Summary

Executive Summary

Introduction

Key Findings

Based on the risk result, BTS Group has identified the following physical risk items as potentially material for the Bangkok area.

- Water Availability, Floods, Extreme heat and Sea-level rise presented “High” in both RCP 2.6/SSP 1-2.6 and RCP8.5/SSP 5-8.5 scenarios of all timeframes
- Cyclone and wind speed presented “Low” in both RCP 2.6/SSP 1-2.6 and RCP8.5/SSP 5-8.5 scenarios of all timeframes

BTS Group then selected flooding risk to identify the financial impact for each scenarios and timeframes summarized in slide 9.

The key results from the assessment are summarized between p. 5-9. A more detailed review of all physical risk items is then presented between p. 11-68.

Executive Summary

Assessment Approach

The physical risks of the Bangkok have been assessed according to the following approach:

Risk Screening

Screening of risks related to BTS Group using a mix of global and regional climate models.

Risk Review and Analysis

Preparing a set of risk findings. This will include using climate projections to analyse the materiality of future risks.

Financial Estimation

Identify the financial impact from 1 selected risk for both low- and high-end scenarios of all timeframes (2030, 2040 and 2050).

Physical Risk Adaptation

Identify high level adaptation and mitigation measures plan of the relevant physical risks.

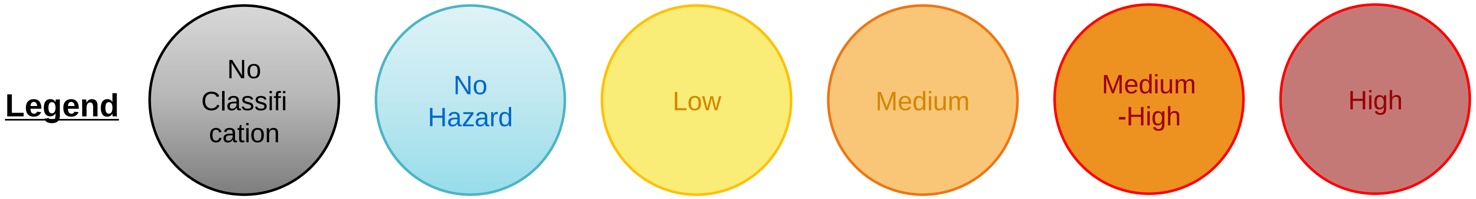
Executive Summary

Future Projections for Key Climate Variables
RCP 2.6 / SSP1-2.6 and RCP 8.5 / SSP5-8.5

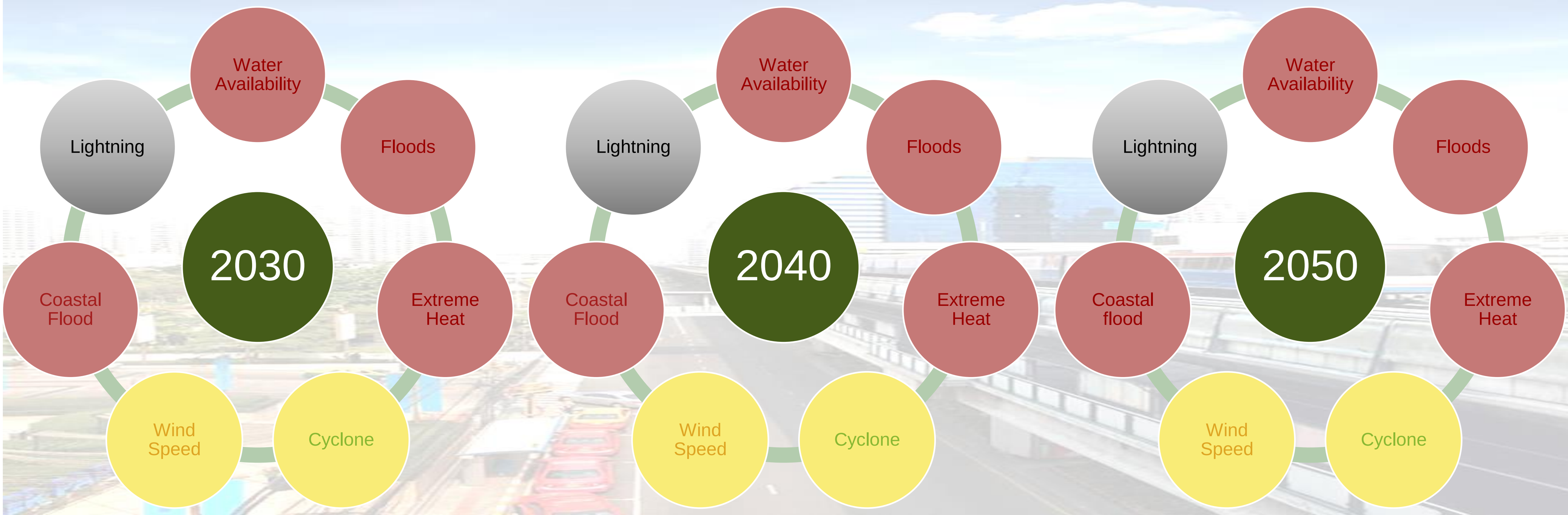
Climate Index	Baseline	RCP2.6/SSP1-2.6 Scenario			RCP8.5/SSP5-8.5 Scenario		
		2030	2040	2050	2030	2040	2050
Water Availability	High	High (-0.04)	High (0.07)	High (0.08)	High (0.03)	High (0.07)	High (0.2)
Floods:	Medium-High	High (236.7mm.)	High (243.2 mm.)	High (249.6 mm.)	High (238.2 mm)	High (253.5 mm)	High (268.9 mm.)
Extreme heat:	High	High (38.7 ° C)	High (39° C)	High (39.3 ° C)	High (38.7 ° C)	High (39.2 ° C)	High (39.8 ° C)
Cyclone	Low	Low	Low	Low	Low	Low	Low
Wind speed	Low	Low (6.85 m/s)	Low (6.83 m/s)	Low (6.82 m/s)	Low (6.90 m/s)	Low (6.70 m/s)	Low (7.18m/s)
Sea-level rise	High	High (0.38 m.)	High (0.55 m.)	High (0.72 m.)	High (0.39 m.)	High (0.58 m.)	High (0.76 m.)
Lightning	No classification (use 2021 information)						

Executive Summary

Qualitative Physical Climate Risks Ratings: Baseline

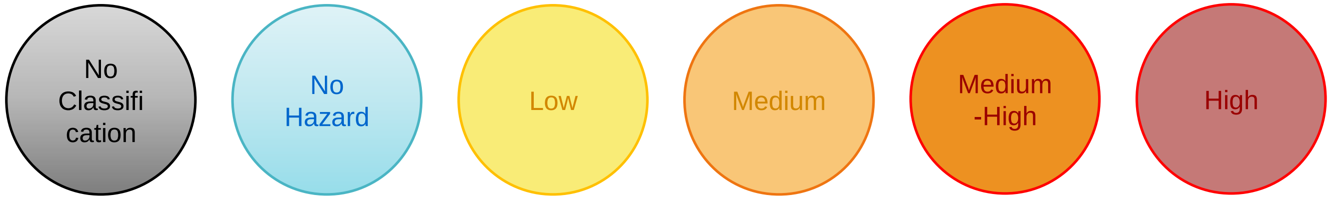


Executive Summary
RCP2.6/SSP1-2.6 and RCP8.5/SSP5-8.5



*There are no significant changes between low- and high-end scenario for quantitative changes see slide 5.

Legend



Executive Summary

Summary Financial Impact from Flooding Risk 2030s, 2040s and 2050s Scenarios

Baseline

Estimated Financial Implications :

- **33,679,452 THB**

Average estimated time frame (in number of years) for financial implications of this risk: 1

- **1 Year**

Estimated cost of these actions:

- **1,038,525 THB**

RCP 2.6

- Financial disruption
  - In 2030: **33,679,452 THB/day x 1.07 days = 36,037,014 THB**
  - In 2040**: 33,679,452 THB/day x 1.10 days = 37,047,397 THB**
  - In 2050: **33,679,452 THB/day x 1.13 days = 38,057,781 THB**

RCP 8.5

- Financial disruption
  - In 2030: **33,679,452 THB/day x 1.08 days = 36,373,808 THB**
  - In 2040**: 33,679,452 THB/day x 1.14 days = 38,394,575 THB**
  - In 2050: **33,679,452 THB/day x 1.21 days = 40,752,137 THB**

Executive Summary

Physical Risks and Adaptation Plans

Time frame = 5 years → 2027*

Physical Risk		
Risk	**Impact for BTS Group**	**Adaptation plan to be completed within 2027**
Water Stress	• Reduced customer and employee water access for drinking, sanitation and maintenance. • Increased cost of water sourcing and treatment.	• Water risk assessment and water auditing. • Explore opportunities for rainwater harvesting. • Water savings fixtures to be installed. • Opportunities for use of recycled water to be explored.
Extreme Heat	• Service disruption due to infrastructure damage: Twisting of tracks and derailment of trains, softening of roads. • Increased power demand for cooling. • Health and safety of staff/ employees due to heat stress / related illness.	• Develop action plan to operate trains under extreme temperature conditions. • Provide training to employees to identify symptoms of heat stress and provide first aid. • Ensure appropriate mix design for construction of asphalt/ bitumen pavements to mitigate the risk of melting/ softening.
Floods & Coastal Floods	• Stations, offices, and depots may become inaccessible. • Debris on road / damage to road surface may disrupt buses. • Damage to supporting infrastructure. • Failure of track circuit or detection of presence/ absence of train on track. • Endanger structural safety of lines.	• Provide regular capacity training to relevant employees in response to flooding which is estimated to be addressed before 2027. • Design and implement suitable mitigation measures such as increasing capacity of storm water drainage or pumping system. • Sufficient drainage system for the viaducts of the Sky Rail to avoid inundation on elevated sections. • Sufficient camber and storm water drainage capacity ensured for the roads carrying bus/BRT transport. • Prepare plan to operate metro rail at lower speed during rainfall intensity.
Wind Speed & Cyclone	• Reduced customer comfort and safety. • Damage/ disruption of assets. • Safety of construction/ maintenance workers.	• Consider wind hazard in emergency response plan and develop action plan identifying steps to be taken if wind speed exceeds certain threshold value. • Install anemometers to monitor wind speeds. • Compliance with national or international best practices for wind load for design and construction of all structures.

Scope of Work

CONTENTS

Scope of Work

This Document Covers Task Gap Closure Climate Strategy Physical Risk

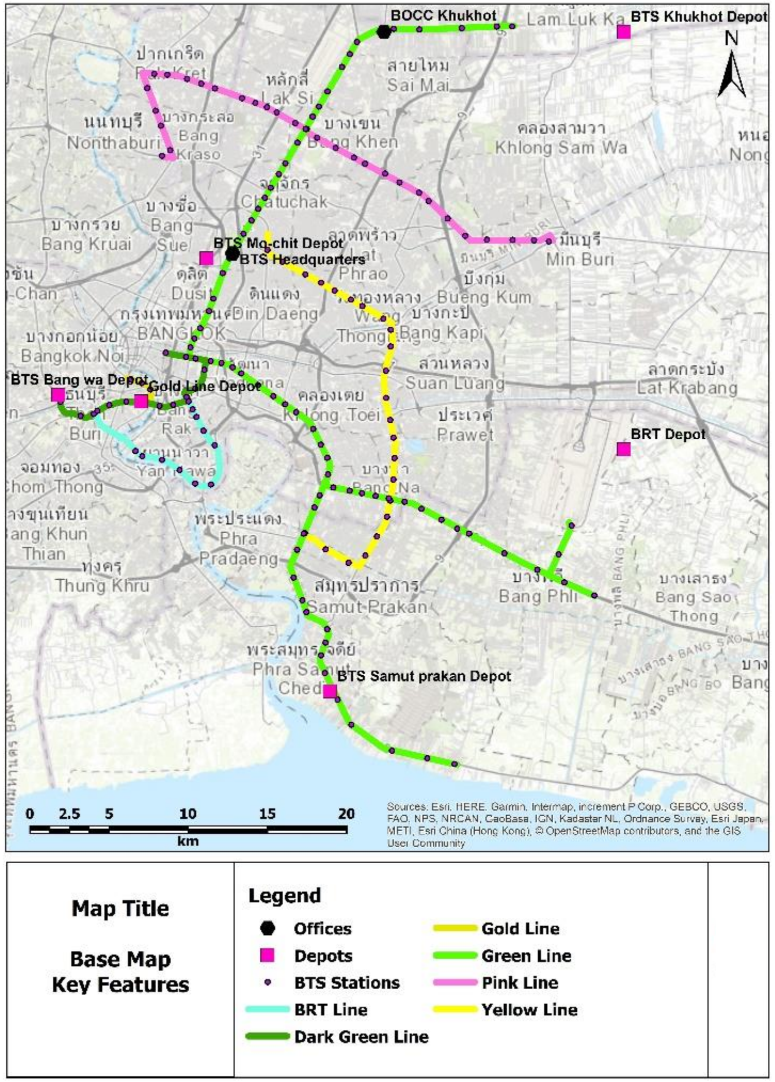
- RCP 2.6/SSP1-2.6 and RCP 8.5/SSP5-8.5 for 2030,2040 and 2050 timeframes in 2023
- Scope of work: Bangkok only

Background

Figure 1: BTS Group Asset Locations Map

- BTS Group commissioned an external consultant to conduct a Screening Level Physical Climate Change Risks Assessment (Physical Risks) for its mass transit transportation assets located in Bangkok as given below and presented on the picture.

Sky Train lines	BRT line	Offices	Depots
Green Line Dark Green Line Pink Line Yellow Line Gold Line	BRT Line	BOCC Khukhot BTS Head Quarters	BTS Khukhot BTS Bang Wa BTS Samut Prakan



TCFD Recommendations on Physical Risk Assessment

- Physical risk are the risks emanating from climate change which can be event driven (acute) such as increased severity of extreme weather events (e.g., **cyclones**, **droughts**, **floods**, and fires). They can also relate to long-term shifts (chronic) in precipitation and temperature and increased variability in weather pattern (e.g., **sea level rise**).[1]

- Organisations can **screen** the outcomes of following variables and hazards using the **multi-model-mean of CMIP5/-CMIP6 data in 2030, 2050**, and beyond[2].

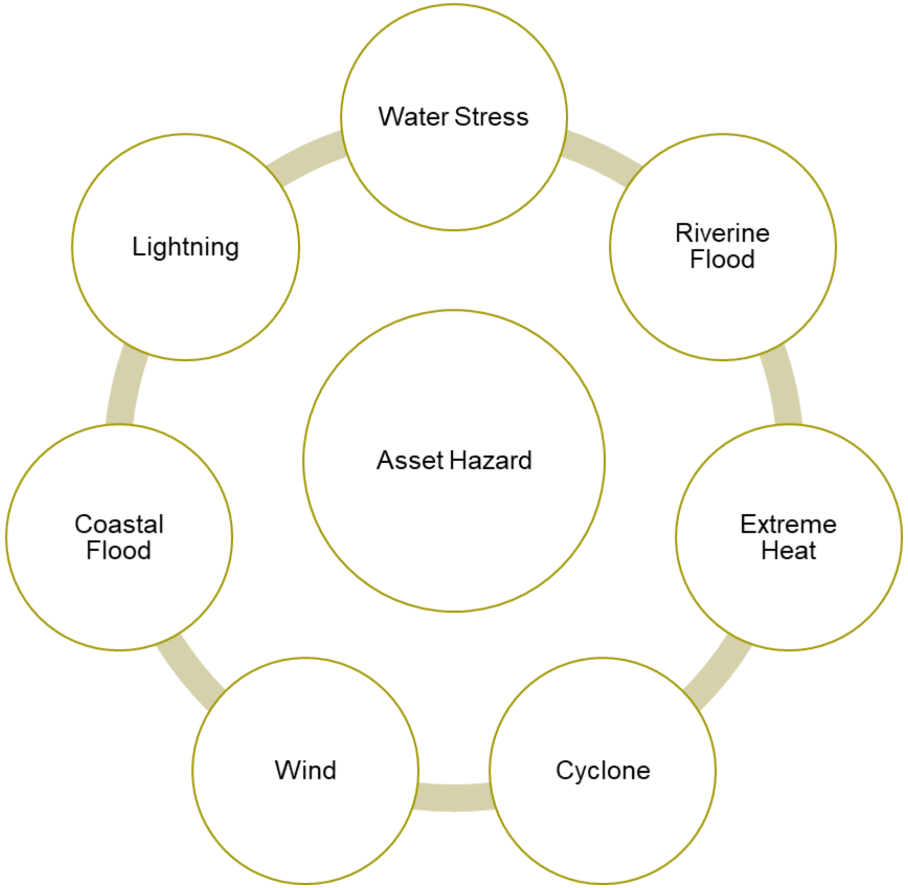
  - Temperature
  - Precipitation
  - Drought
  - Storm Surge
  - Hurricane/Cyclone/Typhoon
  - Floods
  - Water Supply and Demand
  - Sea Level Rise
  - Land Slides

- For organisations wishing to understand their exposure to physical climate change risks **until mid-century**, scenarios consistent **RCP 8.5/SSP5-8.5** scenario is likely to be most helpful (which most closely reflects the pathway consistent with **failure to properly implement NDCs**).[2]

Scope of Physical Risks Assessment

- Screening Physical Climate Change Risks Assessment (Hotspot analysis) for existing and proposed Urban Transportation in **Bangkok, including Sky Rail and BRT.**
- Qualitative assessment of threats from natural hazards and extreme events (see Figure 2) based on the location of the BTS Group assets.
- Assessment using reliable international and national open source data for baseline natural hazards and the "low-end emission case", the "high-end emission case" climate change IPCC scenario of RCP 2.6 or SSP1-2.6 and RCP 8.5 or SSP 5-8.5 that envisaged the highest physical climate risks.
- The hazard assessment was undertaken for timelines including Baseline, 2030, and 2050.
- Considering the ground elevation variation in the range of 1-5 m and no evidence of hilly/mountainous terrain with steep slopes in the project area, landslide hazard was not evaluated even though the region is prone to flooding.

Figure 2: Natural Hazards Selected

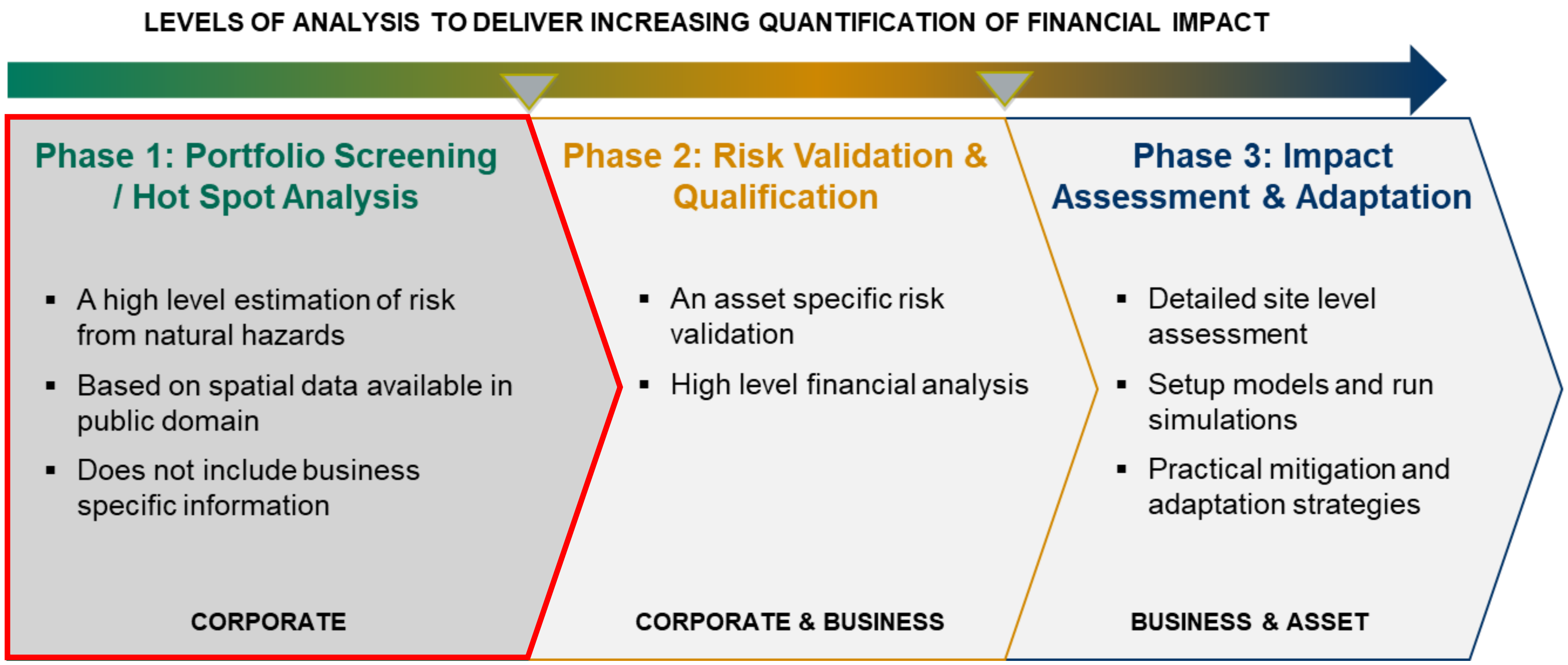


Natural Hazards

Natural Hazard	Scope
Water Stress	Assessment for water availability considers multiple aspects which can affect availability of water such as likelihood of droughts gives the likelihood of occurrence of below normal rainfall, water stress indicates the competition for common water resources presented as a ratio of water demand to available water resource, seasonal variability indicating variations in availability of water resource within a year over different seasons
Floods	Assessment of inland flood considers the likelihood, extents, and intensity of flood in terms of depth of inundation as a result of riverine and urban floods. Riverine flood refers to the floods which typically occur due to excessive rainfall over an extended period of time causing river to exceed its capacity. Whereas, urban flood refers to the floods which occur in the urban areas due to excessive run-off resulting from heavy rainfall, where water does not have anywhere to go.
Extreme Heat	Assessment of extreme heat looks at occurrences of extremely high daily maximum temperature and duration for which the temperature remains high as compared to historical temperatures
Cyclone	Assessment of cyclones looks at whether or not a particular area is prone to cyclones and what category of cyclones (indicting intensity of cyclone) can be experienced at a give location.
Wind Speed	Assessment of wind speed looks at how hazardous wind speeds can be experienced at a given location on day to day basis or during an extreme event such as storm or cyclone
Coastal Floods	Assessment of inland flood considers the likelihood, extents, and intensity of flood in terms of depth of inundation as a result of tides, storm surge, sea level rise, and land subsidence.
Lightning	Assessment of lightning considers at what frequency a particular location experiences lightning flashes.

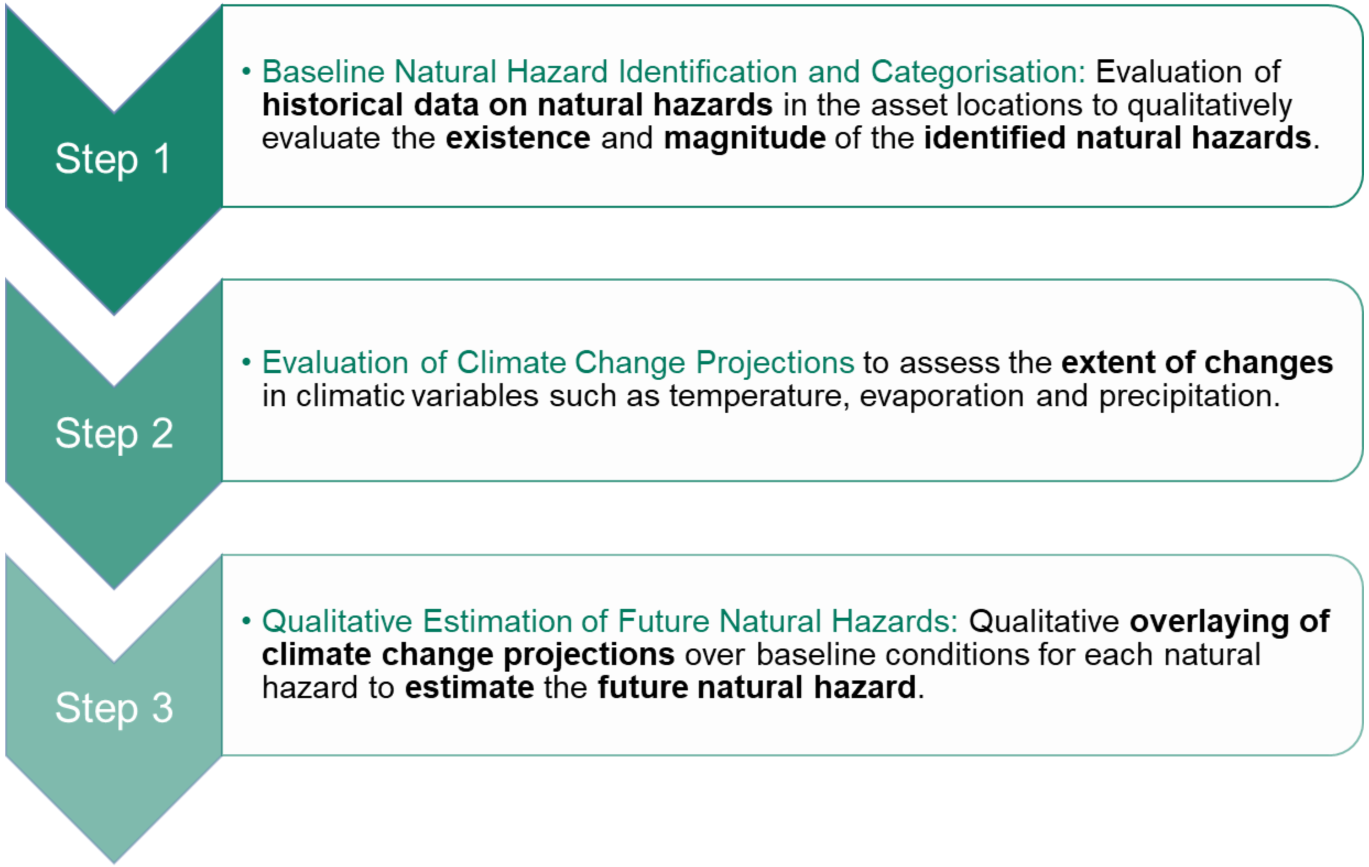
Methodology

Approach for Climate Change Physical Risk Assessment



Methodology

Figure 3: Assessment Methodology



- ✓ Future hazard projections from readily available sources were evaluated and their potential risk in future was categorised.
- ✓ In case the future hazard projections were not readily available, the outputs from climate change projections were overlaid qualitatively on the baseline conditions for each hazards to categorize the climate change risk.

Data sources

Type of Data	Scenario	Factors Assessed for baseline	Data Sources
Water Availability	Baseline and Climate Change	Water Stress Water Scarcity	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 ThinkHazard
Floods	Baseline and Climate Change	Depth of Flood Inundation	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 likelihood	FM Global, 2019. Natural Hazard Toolkit: Global Flood Hazard. https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map
Extreme Heat	Baseline and Climate Change*	Extreme heat hazard level	Climate Change Knowledge Portal, IPCC
Cyclone	Baseline and Climate Change	Cyclone Tracks	Knapp, K. R., M. C. Kruk, D. H. Levinson, H. J. Diamond, and C. J. Neumann, 2010: The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. Bulletin of the American Meteorological Society, 91, 363-376. non-government domain doi:10.1175/2009BAMS2755.1 Knapp, K. R., H. J. Diamond, J. P. Kossin, M. C. Kruk, C. J. Schreck, 2018: International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4. [indicate subset used]. NOAA National Centers for Environmental Information. non-gonvernment domain https://doi.org/10.25921/82ty-9e16

* Conduct climate change projection for this year

Data sources

Type of Data	Scenario (Baseline/Climate Change)	Factors Assessed	Data Sources
Wind Speed	Baseline	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
	Baseline and Climate Change*	Maximum Near-Surface Wind	CMIP6
Coastal Flood (sea-level rise)	Baseline and Climate Change*	Depth of Flood Inundation	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

* Conduct climate change projection for this year

Hazard Categorisation

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	Water Scarcity measures the deficiency of precipitation over an extended period, especially a season or more, resulting in a water shortage for some activity, group, or environmental sector.	Low: <10%	Low:<0.33
		Low-Medium: 10-20%	Medium: 0.33-0.66
		Medium-High: 20-40%	High: 0.66-1
		High: 40-80%	
		Extremely High: >80%	
2	**Riverine Flood and Coastal Flood**		
2.1	WRI-Aqueduct Flood tool *Based on depth of inundation*	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

Hazard Categorisation

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

Summary of Future Projections for Key Climate Variables
RCP 2.6 & SSP1-2.6 and RCP 8.5 & SSP5-8.5

Following climate indices were evaluated based on the multi-model mean of climate models from CMIP-5 and CMIP-6 data sets for RCP 2.6 & SSP1-2.6 over a time frames of 2030, and 2050.

- **Water Availability (SPEI):** Projected the difference between precipitation and the amount of water that evaporates (+ wet area and - is drought area) over a periods of 2030 and 2050
- **Maximum one day rainfall (mm):** Projected maximum one day rainfall over a periods of 2030 and 2050
- **Maximum five-day consecutive rainfall (mm):** Projected maximum rainfall over duration of consecutive five days during 2030, and 2050
- **Average maximum daily temperature:** Projected average maximum daily temperature over a periods of 2030, and 2050
- **Warm spell duration index (WSDI) :** WSDI is defined as annual or seasonal count of days with at least 6 consecutive days when the daily maximum T exceeds the 90th percentile in the calendar 5-day window for the base period 1979-2009
- **Wind speed:** Project daily maximum near-surface wind speed from CMIP6 database to categorize the hazard associated with it
- **Cyclone:** Considered cyclone tracks data for cyclones since 1980 for baseline and the secondary source to indicate a likely changes for occurrences of tropical cyclone over North-West Pacific ocean
- **Sea-level rise:** Project sea-level rise data from IPCC AR6 to view both global and religion sea level projections from 2020 to 2150
- **Lightening**: No classification, used 2021 explanation

Summary of Parameters Using for Baseline and Projection

	Baseline		Projection (Based on the available parameters in CMIP5 and CMIP6 model)	
Hazard Risk	**Baseline Parameter**	**Hazard Categorization used for Baseline**	**Projection Parameter for RCP 2.6/SSP1-2.6 and RCP 8.5/SSP5-8.5**	**Quantitative Figures Used for Projection (except Cyclone)**
Water Availability	Water Stress[1] Water Scarcity[2]	• Low:<10% Medium: 10-20% High: >20% • Low:<0.33 Medium: 0.33-0.66 High: 0.66-1	SPEI for Bangkok using CMIP 5	**Baseline,2030s,2040s and 2050s scenario numbers**: SPEI standardization **Projection result:** Using change in annual draught probability projection trend legend **and compared with water stress from baseline**
Floods	Urban Flood Likelihood Riverine Flood Likelihood Riverine Flood Inundation Depth	• Chance of occurrence of potentially damaging and life-threatening urban flood in coming 10 years • Area to be flooded by a flood of 1 in 100- year return period • Low:<0.5 m. Medium: 0.5-1.5 m. High: >1.5 m.	Change in1-day and 5-days maximum rainfall for Bangkok using CMIP 5	**Baseline,2030s,2040s and 2050s scenario numbers**: Annual Maximum rainfall in Bangkok (mm.) **Projection result:**Using **%**change in annual maximum rainfall trend legend **and compared with baseline**
Extreme Heat	Maximum Daily Temperature in Bangkok and WSDI	Wet Bulb Globe Temperature criteria • Low: less than 28 ^{0}C • Medium: 28<T<32 ^{0}C • High: higher than 32 ^{0}C	Maximum daily temperature and Warm Spell Duration Index (WSDI) for Bangkok using CMIP 6	**Baseline,2030s,2040s and 2050s scenario numbers**: Maximum daily temperature (°C) **Projection result:** Using change in annual average maximum (°C) projection trend legend **and compared with baseline**
Wind Speed	Average Wind Speed Maximum Near Surface Wind	Beaufort's Scale • Low:<11 m/s • Medium: 11-21 m/s • High: >21 m/s	Annual Maximum near-surface wind for Bangkok using CMIP 6	**Baseline,2030s,2040s and 2050s scenario numbers**: Annual Maximum near-surface wind (m/s) **Projection result:** Beaufort's Scale **and compared with baseline**
Cyclone	Historical Cyclone from NOAA-IBTrACS	Saffir-Simpson Scale • Low:Category 1 (119-153 km/h) • Medium: Category 2 (154-177 km/h) • High: ≥ Category 3 (178-208 km/h)	Secondary review from related documents	**Projection result:** Considered with wind speed result and from secondary reviews **and compared with baseline**
Sea-level rise	Coastal Flood Likelihood Map Coastal Flood Inundation Map	• Potentially-damaging waves are expected to flood the coast at least once in the next 10 years • Low:<0.5 m. Medium: 0.5-1.5 m. High: >1.5 m.	Sea-level rise from NASA Sea-level rise model using CMIP 6	**2030s,2040s and 2050s scenario numbers**: Sea-level rise level (cm.) **Projection result:** Using Sea-level rise level (cm.) trend legend **and compared with baseline**

Note: CMIP 5 Coupled Model Intercomparison Project Phase 5, CMIP 6 Coupled Model Intercomparison Project Phase 6
[1]**Water Stress:** Based on ratio of total water withdrawal to available renewable water resources (surface and groundwater)
[2]**Water Scarcity :** measures the deficiency of precipitation over an extended period, especially a season or more, resulting in a water shortage for some activity, group, or environmental sector.

Natural Hazards Evaluation under Baseline and Climate Change Scenarios

Water Availability: Baseline

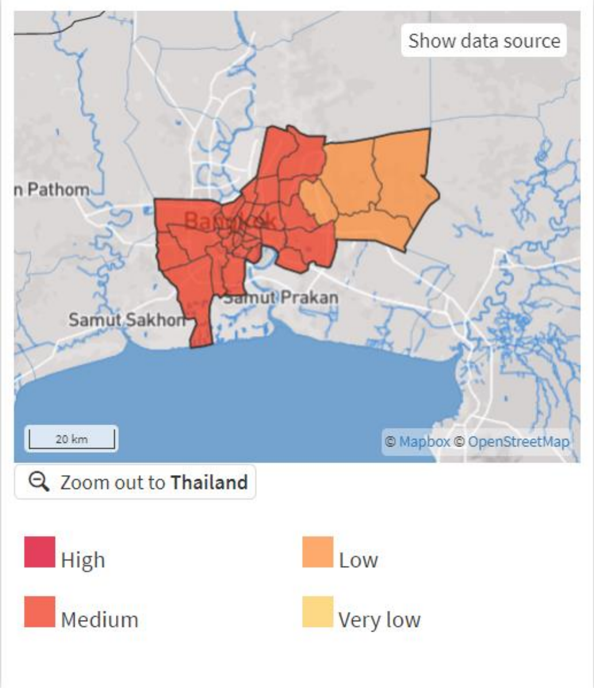
Parameter	Definition/ Methodology/ Data	Source	Hazard Category	Hazard Criteria
Likelihood of Water Scarcity	This is the maximum water scarcity hazard level for the selected area, describing expected frequency of water scarcity. The classification uses simulated water resource availability, and expert guidance.	Think Hazard[1]	Medium	Up to a 20% chance of droughts in the coming 10 years
Water Stress	Baseline water stress is defined as the ratio of the total annual water withdrawals to the total available annual water renewable supply, accounting for upstream consumptive use. Higher value indicate more competition among users.	WRI-Aqueduct Water Risk Atlas[3]	**High**	Water stress 10-40% (Medium-High) (see in the next slide)
Overall Hazard			**High**	Conservative

Water Availability: Baseline

- **Water Scarcity** measures the deficiency of precipitation over an extended period, especially a season or more, resulting in a water shortage for some activity, group, or environmental sector.
- According to the currently available information the **ThinkHazard has, the water scarcity is classified as "Medium" for the baseline**, signifying that there is up to a 20% chance that droughts will occur in the coming 10 years.
- **Water stress** measures the ratio of total water withdrawals to the available renewable surface and groundwater supplies. **The Water Risk Atlas classifies water stress to be "High" for the baseline**.
- Thus, the overall hazard associated with availability of water is considered to be "High" for baseline.

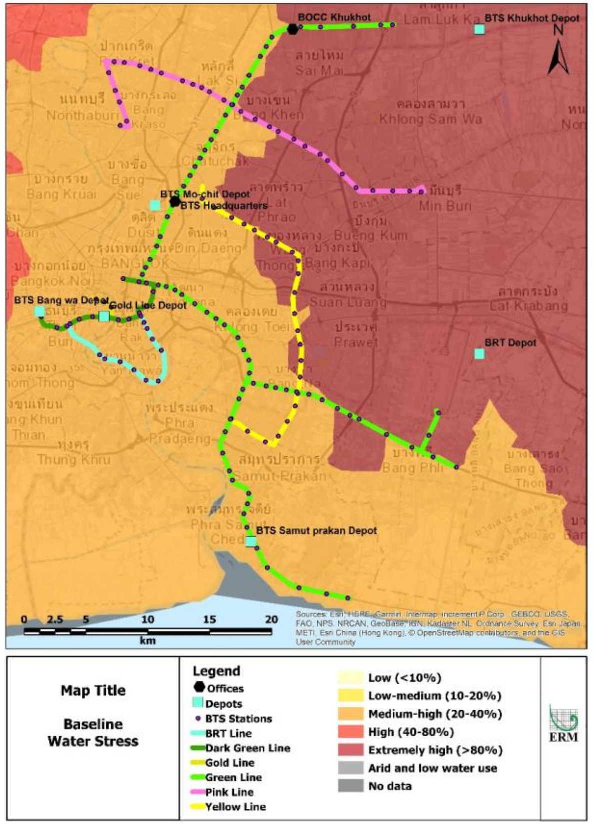
	Water Scarcity	Water Stress	Overall
Baseline	Medium	High	High (Conservative)

Figure 4: Water Scarcity (likelihood) Map



Source: Think Hazard

Figure 5: Water Stress



Source: WRI-Aqueduct Water Risk Atlas

Water Availability: Climate Change RCP 2.6

- WRI-Aqueduct Water Risk Atlas does not provide water-stress related projections for RCP 2.6 scenario.
- Since drought and water scarcity are often interrelated, and droughts can trigger or amplify water scarcity, while water scarcity can aggravate droughts, the Standardized Precipitation Evaporation index (SPEI) which is an indicator of droughts is scrutinized from Climate Change Knowledge Portal for both low-end and high-end emission scenarios.
- SPEI is the difference between precipitation and the amount of water that evaporates (+ve means wet area and –ve means drought area): no unit.
- The SPEI projections lies in near normal range, but compared to baseline, it indicates slightly drought like conditions in the 2030's & 2040's and slightly wet like conditions in 2050's.

Projection: SPEI (RCP 2.6)

Indicator	BSL	2030	2040	2050
SPEI	0.03	-0.04	0.07	0.08
Projection (change compare with BSL)	[redacted]	-0.07	0.04	0.05

Reference: Climate Change Knowledge Portal

Drought/Wet severity	SPEI
Extremely wet	≥2.00
Severely wet	1.50–1.99
Moderately wet	1.00–1.49
Near normal	−0.99–0.99
Moderate drought	−1.00–(−1.49)
Severe drought	−1.50–(−1.99)
Extreme drought	≤−2.00

SPEI Standardization

Category	Drought (Change in annual drought probability
Significant Increase	<-1
Moderate Increase	<-0.5
Slight Increase	<0
No Change	0
Slight Decrease	>0
Moderate Decrease	>0.5
Significant Decrease	>1

Source: Climate projection trend legend

Water Availability: RCP 2.6

- Water stress simply means **the ratio of amount of water we consume (numerator) and the available of water (denominator) e.g. from surface groundwater and precipitation**.
- According to the projection result in slide 20, SPEI index is used to check how the available of water is changing and SPEI projections lies in near normal range, it means the available of water (denominator) is not changing much compared to the available of water from the baseline.
- Since the water stress from the baseline is “High” and the projection of water availability from RCP 2.6 is not much different. Assume that the consumption of water remains the same or increase along with the population of the project area. In that case, the water stress would either be the same or increase because if consumption is increasing at a much higher rate as compared to renewable waters, the water stress would be on the higher side.
- Therefore, the hazard associated with availability of water is considered to be the same as in baseline, “High” under RCP 2.6 scenario for all the time-horizons.

Baseline	2030	2040	2050
High	High	High	High

Water Availability: Climate Change RCP 8.5

- The projected change in water stress from baseline in 2030's and 2040's is near-normal with an increase in eastern and northeastern parts of Bangkok.
- On the other hand, the SPEI projections under RCP8.5 scenario lies in near normal range*, indicating slightly wet like conditions in 2050s.

Projection: SPEI (RCP 8.5)

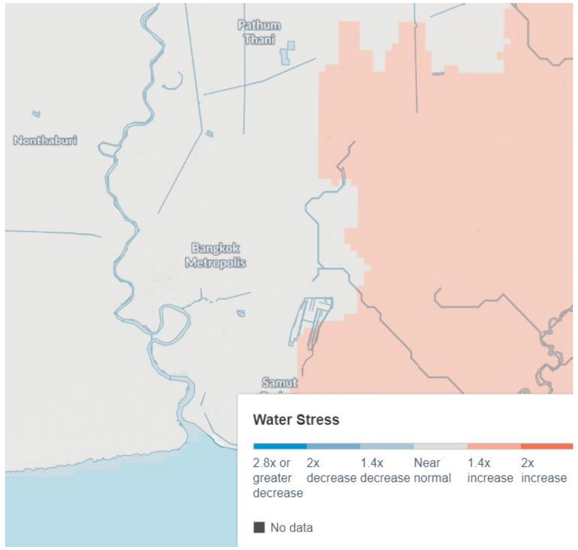
Indicator	BSL	2030	2040	2050
SPEI	0.03	0.03	0.07	0.2
Projection (change compare with BSL)		0.00	0.04	0.17

Reference: Climate Change Knowledge Portal

*Used the same references provided in slide 20

Baseline	2030	2040	2050
High	High	High	High

Figure 6: Projected Change in **Water Stress** 2030's (RCP 8.5)



***Source**: WRI-Aqueduct Water Risk Atlas*

Figure 7: Projected Change in **Water Stress** 2040's (RCP 8.5)

***Source**: WRI-Aqueduct Water Risk Atlas*

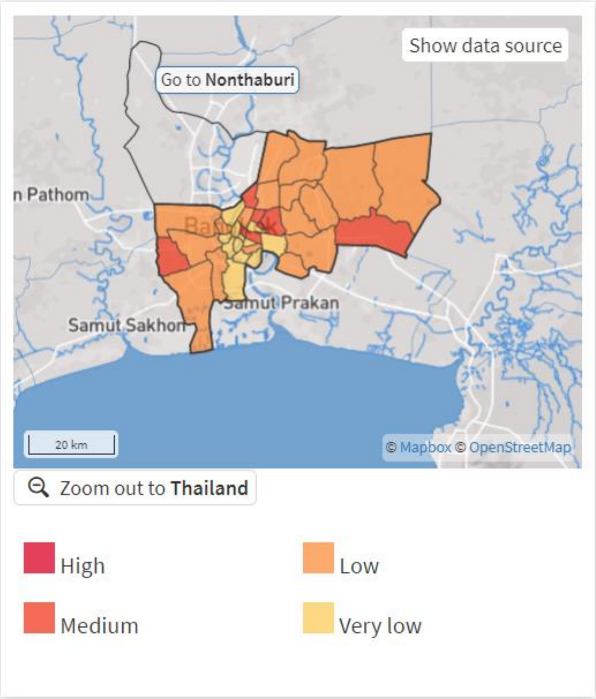
- According to Figure 6 and 7, water stress considers that it lies "near-normal" over certain regions and increase in eastern and north-eastern parts when compared with baseline, along with the fact that the SPEI lies in the "normal range", the associated future hazard is also considered to be same as of baseline, i.e., "High" for all time horizons under RCP 8.5 scenario.

Floods: Baseline

Parameter	Definition/ Methodology/ Data	Source	Hazard Category	Hazard Criteria
Urban Flood Likelihood	describing expected frequency of flood damage. Urban flood describes surface flooding of impermeable urban surfaces and overflow of saturated urban drainage systems and channels, resulting from sustained or intense rainfall	Think Hazard[1]	Medium	Chance of more than 20% for occurrence of potentially damaging and life threatening urban flood in coming 10 years
Riverine Flood Likelihood	describing expected frequency of flood damage. Urban flood describes the water level in a river or stream rises and overflows onto the neighbouring land. The water level rise of the river could be due to excessive rain.	Think Hazard[2]	Medium	Chance of more than 20% for occurrence of potentially damaging and life threatening urban flood in coming 10 years
Riverine Flood Likelihood	Global flood maps presents the areas/zone affected by floods with return periods of 1 in 100 and 1 in 500 year. Flood maps are developed using hydrological models and historical flood data	FM Global Flood Map[3]	High	Area to be flooded by a flood of 1 in 100 year return period
Riverine Flood Inundation depth	The flood hazard map presents the extents and depth of a flood for a given return period. Flood hazard maps are reported to be developed using GLOFRIS model which provides long-term simulations of discharges and flood levels under different climatic conditions.	WRI-Aqueduct Floods[4]	Low	Depth of inundation < 0.15m
Overall Hazard			Medium-High	Conservative

Floods: Baseline

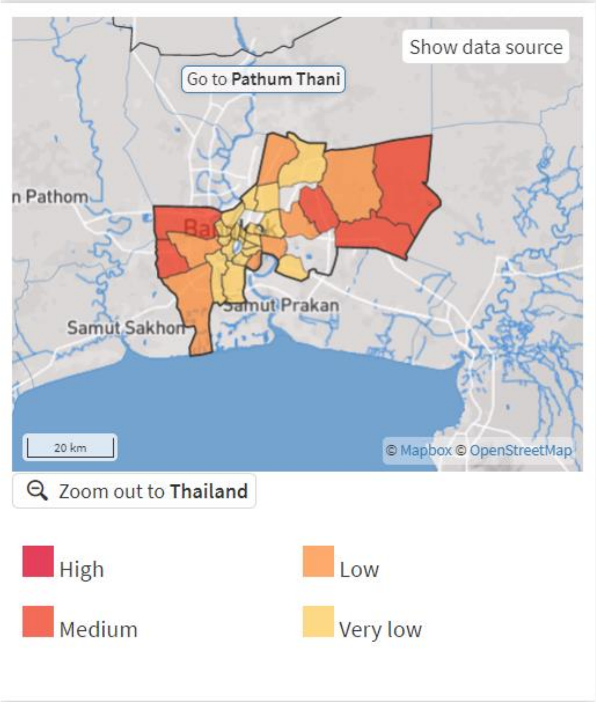
Figure 8: Flood Likelihood Map (Urban)



Source: Think Hazard

High risk area: Bang su, Huai Kwang, Pathumwan, Latkrabang and Nhongkham

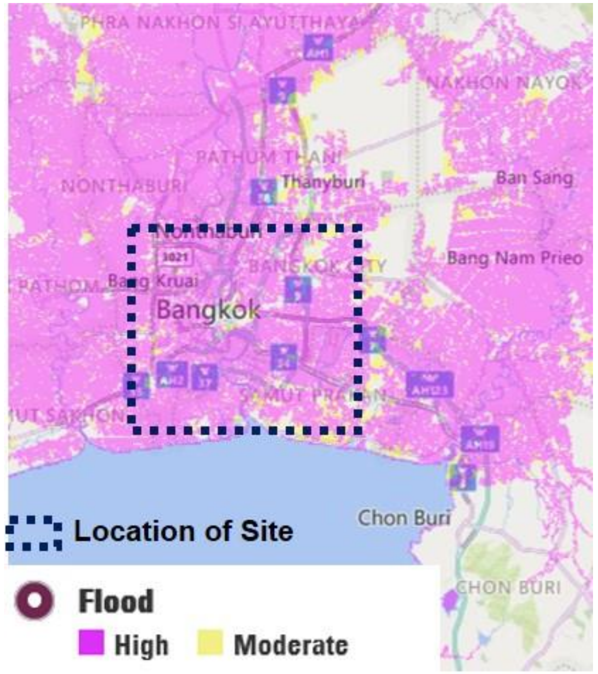
Figure 9: Flood Likelihood Map (Riverine)



Source: Think Hazard

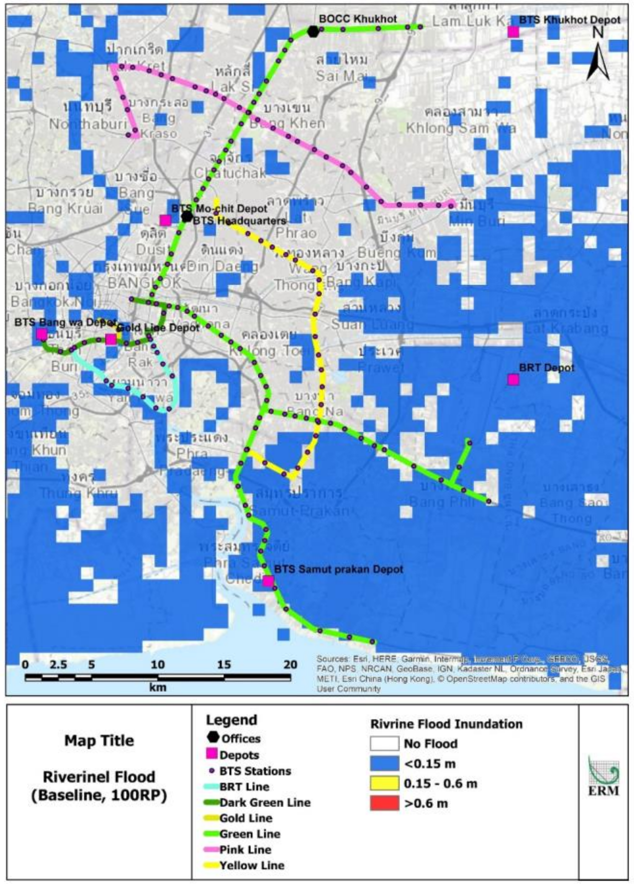
High risk area: Taling Chan, Bungkum, Nong Chok and Latkrabang

Figure 10: Flood Likelihood Map



Source: FM Global Flood Map

Figure 11: Riverine Flood Inundation Map



Source: WRI-Aqueduct Flood

Floods: Baseline Hazard Evaluation

Photo 1: Flooding in the Chatuchak area on Nov. 6, 2011

__Source__: https://www.khaosodenglish.com/news/2018/09/06/2018-wont-be-2011-for-bangkok-flooding-experts/

- The overall risk associated with riverine and urban flooding for baseline is evaluated to be **"Medium-High"** based on following:
  - ThinkHazard classifies risk allied with riverine and urban floods as "Medium" based on the currently available information the tool has.
  - Riverine flood inundation map from WRI-aqueduct indicates inundation as low across project area.
  - Flood likelihood map (FM Global Flood Map) indicates a probability of inundation across most parts of the project area.
  - Past floods caused damages in terms of financial, property, and casualties.

Floods: Climate Change RCP 2.6

- Since WRI-Aqueduct Flood Tool doesn't provide projections for the low-end emission scenario; therefore, the RCP 2.6 scenario analysis is conducted based on CMIP5 from Climate Change Knowledge Portal.
- The indicators used are the "largest 1-day precipitation" and "largest 5-day cumulative precipitation."
- The projected significant (moderate to significant) increase in 1-day (5-day) precipitation, compared to baseline, during the two-time horizons under low-end emission scenario may likely increase the risk associated with flood from **"Medium-high"** in baseline to **"High"** in future time horizons.

Risk Categorization (RCP2.6)

Baseline	2030	2040	2050
Medium-High	High	High	High

Projection: Floods (RCP 2.6)

Indicator	BSL (mm)	2030 (mm)	2040 (mm	2050 (mm)
1- Day Maximum Rainfall (mm)	80.3	93.9	92.8	91.7
Projection (change compare with BSL)		17%	16%	14%
Maximum Consecutive 5 Days Rainfall (mm)	221.5	236.7	243.15	249.6
Projection (change compare with BSL)		7%	10%	13%

Source: Climate Change Knowledge Portal

Category	Chang in maximum rainfall (%)
Significant increase	> 10%
Moderate increase	>5%
Slight Increase	>0%
No Change	0%
Significant decrease	<0%
Moderate decrease	<-5%
Slight decrease	<-10%

Source: Climate projection trend

Floods : Climate Change RCP 8.5

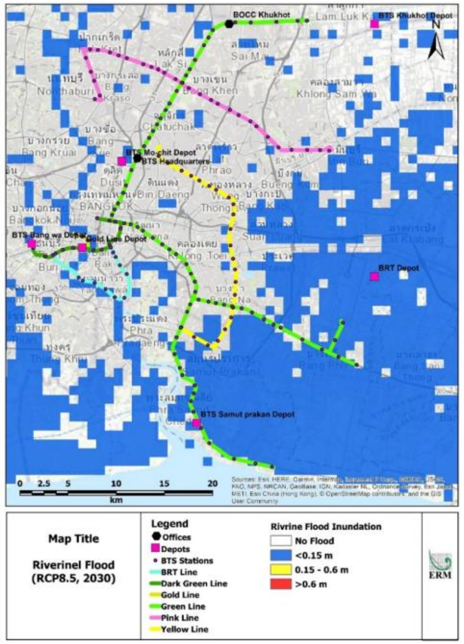
- Bangkok, built on the floodplains of the Chao Phraya River, is expected to be one of the urban areas hit hardest by warming temperatures[1].
- Flood hazard maps from WRI-Aqueduct Flood Tool are evaluated to assess the flood hazard during the 2030s and 2050s under high-end emission scenario for flood with a return period of 1 in 100 year.
- The hazard due to riverine flooding is projected to remain Low with flood inundation depth of less than 0.15 m.
- However, the climate change projections under RCP8.5 scenario for 1-day and 5-day maximum precipitation show a significant and moderate to significant increasing trend, compared to the baseline (see Table below).

Projection: Floods (RCP 8.5)

Indicator	BSL (mm)	2030 (mm)	2040 (mm)	2050 (mm)
1- Day Maximum Rainfall (mm)	80.3	88.4	92.3	96.3
Projection (change compare with BSL)		10%	15%	20%
Maximum Consecutive 5 Days Rainfall (mm)	221.5	238.2	253.5	268.9
Projection (change compare with BSL)		8%	14%	21%

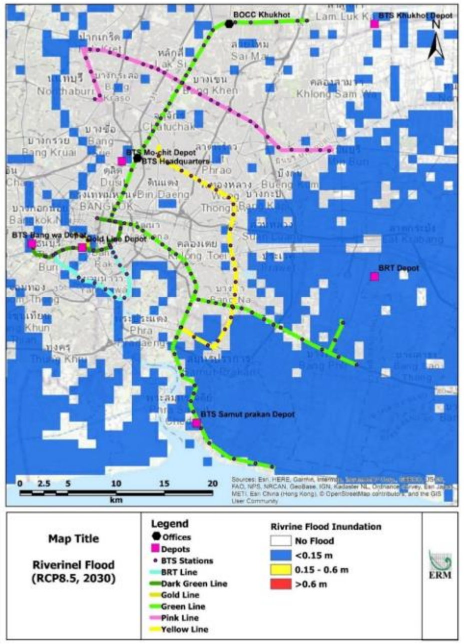
Source: Climate Change Knowledge Portal

Figure 12: Riverine Flood (RCP 8.5, year 2030)



Source: *WRI-Aqueduct Flood*

Figure 13: Riverine Flood (RCP 8.5, year 2050)



Source: *WRI-Aqueduct Flood*

Category	Chang in maximum rainfall (%)
Significant increase	> 10%
Moderate increase	>5%
Slight Increase	>0%
No Change	0%

Source: Climate projection trend legend

Floods: Climate Change RCP 8.5

- Such increase in extreme precipitation may lead to frequent riverine and localised floods.
- Moreover, changes in land use pattern due to rapid urbanisation is likely to aggregate flood risk in future.
- Nearly 40 percent of Bangkok is estimated to be inundated each year as soon as 2030 due to more extreme rainfall, according to the World Bank.[1]
- Accordingly, considering the “Medium-High” baseline flood hazard, and projected increase in an extreme precipitation, flood hazard is evaluated to “High” in all future time-horizons under RCP8.5 climate change scenario.

Risk Categorization (RCP 8.5)

Baseline	2030	2040	2050
Medium-High	High	High	High

Photo 2: Representative Photo of Flooded Street in Bangkok

***Source**: https://www.bangkokpost.com/photo/1342351*

Historical Floods

Date	Reason	Impact	Reference
December 1983	N.D.	Inundation of Sukhumvit Road, Estimated 462 million baht damage of roads, 400 million baht damage in total, 55 deaths	Bangkok Post, October 21, 2011: https://www.bangkokpost.com/photo/262533/splash-from-the-past
October, 1995	N.D.	Worst flood ever experienced then, Flood lasted over October to November 2.27 m of flood inundation in some areas, 2.6 million population impacted, 26 major roads were damaged, 70 rai of farmlands were affected, Damages were estimated to be billions of THB	
October, 2011	More than normal rainfall	680 people killed 13 million affected people Estimated restoration cost of 1.5 trillion baht	Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning, http://documents1.worldbank.org/curated/en/677841468335414861/pdf/698220WP0v10P106011020120Box370022B.pdf
June 21, 2016	141.5 mm of rainfall over a period of 24 hours (highest over 25 years) due to low pressure over Vietnam	Flooding in 36 areas, Traffic disruption, Inundation of ~60 cm in some areas	Flood List, June 22, 2016: http://floodlist.com/asia/thailand-bangkok-flood-june-2016

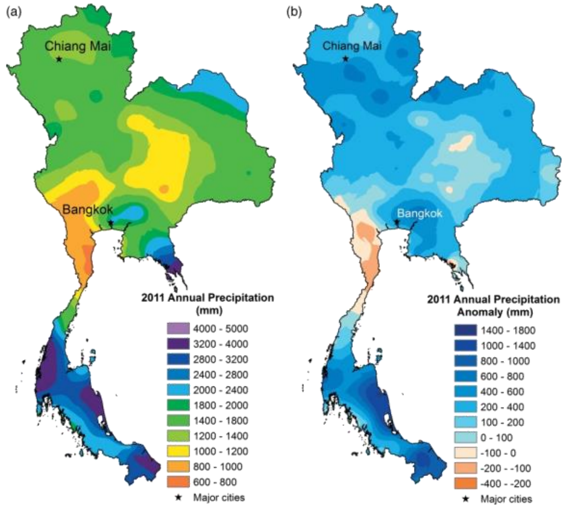
Special Case: Floods of 2011

- The flood in 2011 was ranked as world's fourth costliest disaster over the period of 1995-2011, after the two earthquakes in Japan (2011 and 1995) and hurricane Katrina in USA (August 2005)[1].
- The floods of 2011 were accounted to heavy precipitation (1439 mm) exceeding (143%) the average seasonal rainfall over two decades[1].
- The literature review suggests that the flood in 2011 accounted for heavy precipitation received during four cyclonic activities (1 in August and 3 in October), resulting in the filling and overtopping of reservoirs. Consequently, large amounts of water were released resulting in the inundation of downstream areas.[1, 2]
- Further, due to relatively flat topography, the floodwater drains out very slowly in the Chao Phraya River basin.[3]
- Additionally, **due to rapid urbanisation in Bangkok** (i.e., turning traditional paddy fields into developed lands) had made the situation even worse as the developed lands are unable to accommodate flood waters as it does in the past.

Figure 14:Locations of Dams Overtopped in 2011

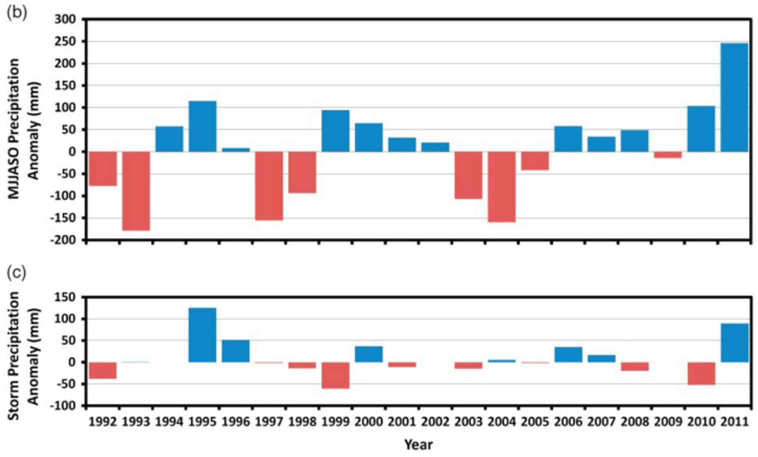
Special Case: Floods of 2011

Figure 15: Precipitation Anomaly in 2011



- Using Thai Meteorological Department data, Emma et al. (2013) reported that the Northern Thailand received a precipitation between 1400mm and 1800mm in year 2011, which is ~23% above normal at country level.
- Bangkok also received surplus rainfall annual rainfall of 2073mm (i.e., 530mm or ~25.5% higher than the normal) in 2011.

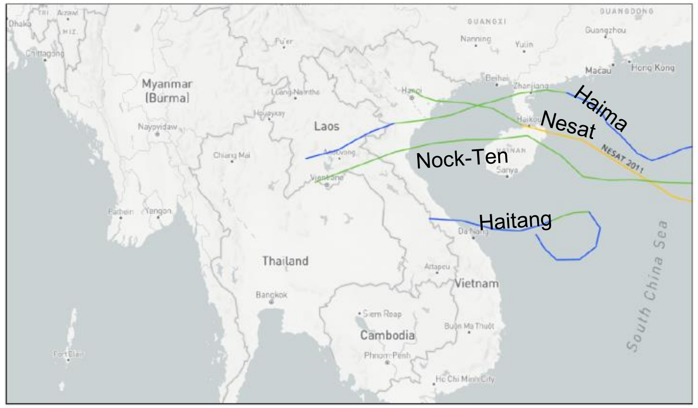
Figure 16: Monsoon vs Tropical Storm Precipitation



Red Bar: negative precipitation anomaly
Blue Bar: positive precipitation anomaly

- The monsoon rainfall anomaly of +246.1 mm was reported to be highest in last 20 year.
- During 1992 to 2011, 52 tropical cyclones (or their remnants) were reported to cross Thailand, with an average of 2.6 storms per year.
- At country level, in 2011 the remnants of four Tropical storms caused +89.3 mm anomaly of rainfall, with a contribution of ~33% in anomalously high rainfall in Thailand.

Figure 17: Tropical Storms around Thailand in 2011



Storm Name	Date Range	Storm Type
Nesat	Sep 23-30, 2011	Typhoon
Haitang	Sep 23-27, 2011	Pacific Typhoon
Nock-Ten	Jul 24-31, 2011	Tropical Storm
Haima	Jun 16-25, 2011	Tropical Storm

***Source**: NOAA Hurricane Tracks*

Special Case: Floods of 2011

Figure 18: Return Period of 2011 Rainfall

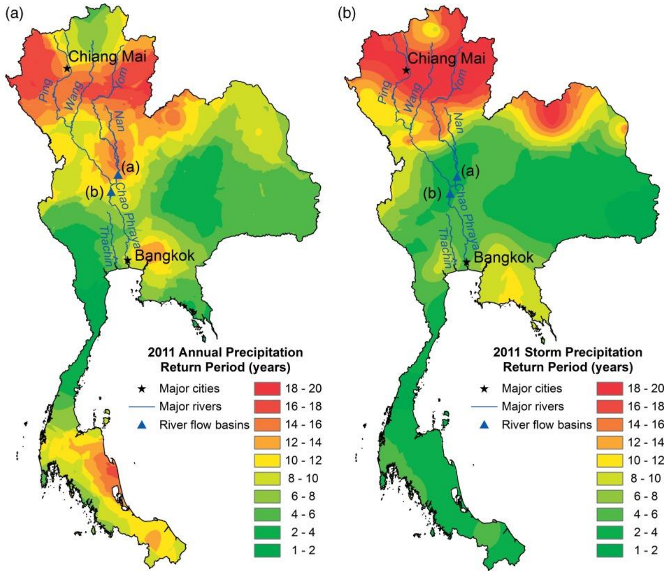
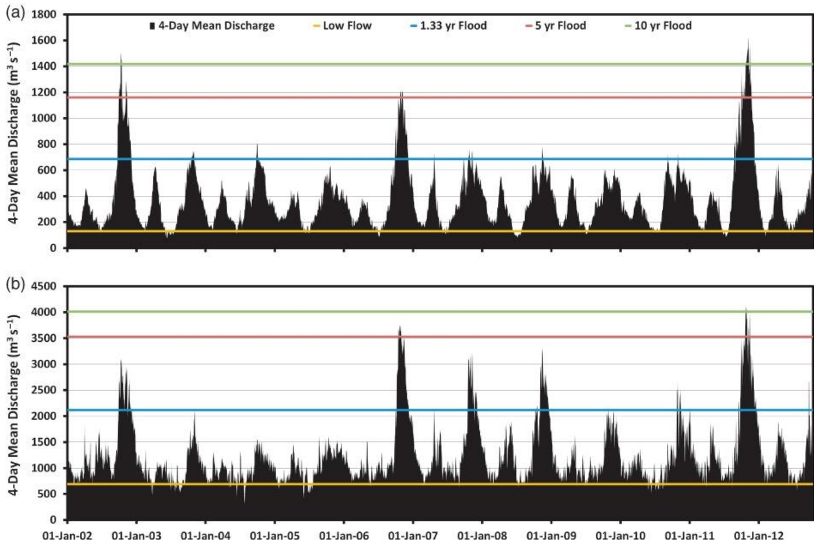


Figure 19: River Flow Return Period



- *The rainfall return-period analysis employed rain gauge data for the 20-year period 1992–2011. The return periods for 2011 annual total rainfall and annual tropical storm rainfall were computed for each of the 100 weather stations in Thailand using the standard method*
- *This method divides the number of years with complete rainfall data by the number of years where the annual (or storm) rainfall total is greater than or equal to the observed total in 2011*
- *In this study historical data was available only for 20 years, hence longest return period calculated was limited to 20 years, which may be an under estimation of the return period.*
- *Accordingly, the rainfall received in year 2011 in Bangkok was estimated to be corresponding to return period of 10 years.*
- *Whereas, central and northern areas of Thailand indicated rainfall return periods to be in the range of 2-20 year return period.*

- *Satellite-derived river flows in the Chao Phraya River basin – the Thai region most heavily flooded in 2011 - were obtained from the Dartmouth Flood Observatory online repository of global river discharge data*
- *Riverflows are computed from satellite passive microwave observations and calibrated using global hydrological modelling*
- *Riverflows obtained with this satellite method agree well with flow estimates from ground-based discharge gauges*
- *The peak discharge in 2011 was the highest since January 2002 at both sites with the northern site showing a flood return period of 10–20 years and the southern site a flood return period of about 10 years.*
- ***A consensus of three different estimates suggests a return period for the 2011 Thailand flood of 10–20 years. However, these estimates may be biased low due to the limited 20–30 years extent of the historical data used for model building**.*

Extreme Heat: Baseline

Baseline

- To categorise the hazard associated with Extreme Heat, **the Maximum of Daily Max-Temp** and **Warm Spell Duration Index (WSDI)** from the Climate Change Knowledge portal are analysed.
- **For Bangkok, the Maximum of Daily Max-Temp is 38.1°C during baseline, having an aggregate of 12 days annually contributing to unusually warm events.**
- Thus, based on the criteria presented in the Table, the hazard associated with **Extreme Heat is categorised to be "High" for the baseline.**
- Most of the regions in Thailand reported temperature greater than 40°C in April 2016 (a 65 year record heat wave)[1].
- Bangkok recorded average peak temperature of 40°C, with a peak temperature of 44.2°C in April 2016[2].

Wet Bulb Globe Temperature	Hazard Category
>32^{0}C	High
>28^{0}C	Medium
>25^{0}C	Low
<25^{0}C	Very Low

Baseline Hazard
High

Extreme Heat: Climate Change SSP1-2.6

- SSP1-2.6 scenario is conducted based on CMIP6 from Climate Change Knowledge Portal.
- The indicators used are the **"Warm Spell Duration Index (WSDI)"** and **"Maximum of Daily Max-Temperature**"
- Even though under SSP1-2.6, a scenario aiming to limit the increase of global mean temperature to 2 °C , the model projected that the
  - Warm Spell Duration Index (WSDI) is likely to be increase by 20 days in 2030s, 31 days in 2040s and 42 days in 2050s indicating a significant increase compared to the baseline value of 12 days.
  - Maximum of daily Max-Temp also likely to be increase by 0.6°C by 2030s, 0.9 °C by 2040a and 1.2°C by 2050s from the baseline value of 38.1°C.
- Hence, the hazard associated with extreme heat is considered to be "High" in all time-horizons under the SSP1-2.6 scenario.

Baseline	2030	2040	2050
High	High	High	High

Projection: Extreme heat (SSP1-2.6)

Indicator	BSL	2030	2040	2050
Warm Spell Duration Index (day)	12	32	43	54
Maximum Daily Temperature (°C)	38.1	38.7	39.0	39.3
Projection (change compare with BSL)		0.6	0.9	1.2

Source: Climate Change Knowledge Portal

Category	Change in annual average maximum (°C)
Significant increase	> 2°C
Moderate increase	>1°C
Slight Increase	> 0°C
No Change	0%

Source: Climate projection trend legend

Note: There is no available legend for WSDI, we used the same trend for WSDI and Change in Max temperature.

Extreme Heat: Climate Change SSP5-8.5

- SSP5-8.5 scenario is also conducted based on CMIP6 from Climate Change Knowledge Portal.
- The indicators used are the **“Warm Spell Duration Index (WSDI)” and “Maximum of Daily Max-Temperature”**
- Under SSP5-8.5 scenario, a scenario representing the highest emissions no-policy baseline scenario, the model projected that the
  - Warm Spell Duration Index (WSDI) is likely to be increase up to 35 days, 64 days and 94 days in the 2030s, 2040s and 2050s, respectively, compared to baseline value of 12 days.
  - Maximum of daily Max-Temp also likely to be increase up to 38.7°C, 39.2 °C and 39.8°C in the year 2030s, 2040s and 2050s, respectively, indicating an upsurge by 0.6°C, 1.2°C and 1.7°C from the baseline.
- Hence, under SSP5-8.5 scenario also, the extreme heat hazard is considered to be “High” for all time-horizons.
- The projected rise in temperatures under all scenarios considered may trigger the increased risk to heat stress-related conditions like heat strokes.

Baseline	2030	2040	2050
High	High	High	High

Projection: Extreme heat (SSP5-8.5)

Indicator	BSL	2030	2040	2050
Warm Spell Duration Index (day)	12	35	64	94
Maximum Daily Temperature (°C)	38.1	38.7	39.2	39.8
Projection (change compare with BSL)		0.6	1.2	1.7

Source: Climate Change Knowledge Portal

Category	Change in annual average maximum (°C)
Significant increase	> 2°C
Moderate increase	>1°C
Slight Increase	> 0°C
No Change	0%

Source: Climate projection trend legend

Note: There is no available legend for WSDI, we used the same trend for WSDI and Change in Max temperature.

Cyclones: Baseline

Parameter	Source
Cyclones Tracks Cyclone tracks data for cyclones since 1980 (modern era of satellite observations) till present.	NOAA-IBTrACS[1]

- During the period 1980 to 2020, **only one tropical storm (i.e., BulBul-Matmo, 2019)** made landfall in central Vietnam and crossed within the vicinity of 100km from Bangkok. While moving westwards, it weakened into a tropical depression, having a maximum wind speed of 15 knots (7.7 m/sec).
- However, as indicated by a case study of the 2011 floods, the project area is likely to have some indirect impacts from such tropical storms.
- Moreover, during the analysis period, approx. 62 such types of Tropical disturbances occurred within the vicinity of 100km from Thailand (see Fig. 24).
- But considering very less occurrences of such Tropical Storms near the 100km vicinity of Bangkok in the past, the hazard associated with it is considered to be **"Low" for baseline.**

Baseline	Low

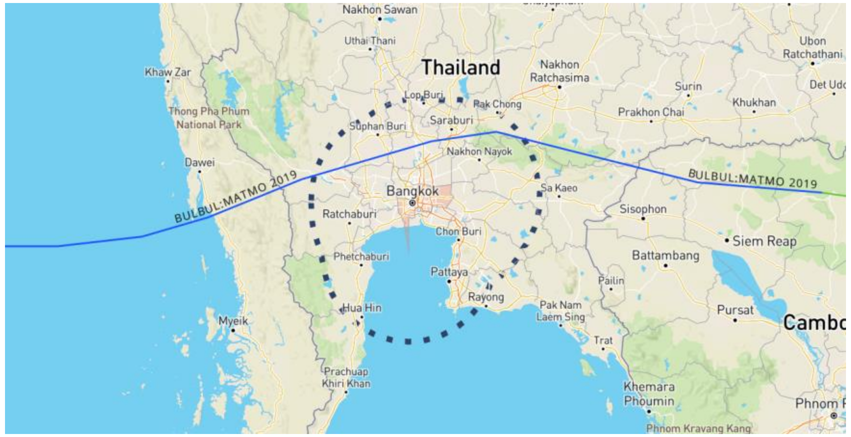


Figure 20: Historical Tropical Storms within 100km vicinity of Bangkok during 1980-2020 (NOAA IBTrACS)

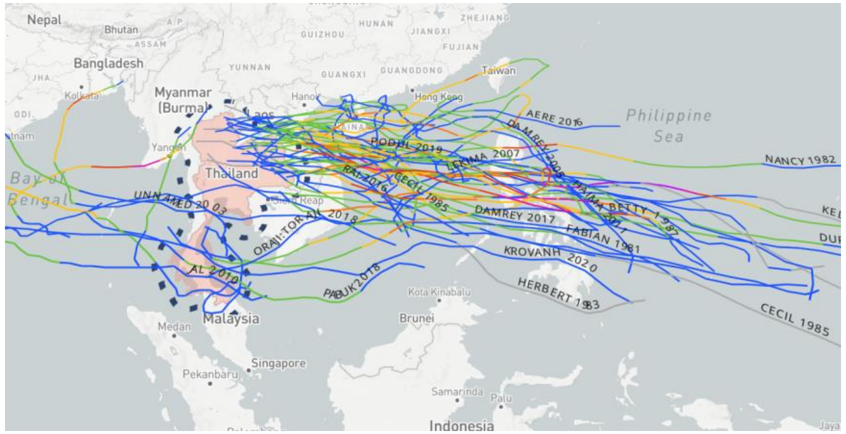


Figure 21: Occurrences of Tropical disturbances within 100km vicinity of Thailand (NOAA IBTrACS)

Cyclones: Baseline

Historical storms within 100 km from Bangkok

Storm	Storm Category	Areas that has been affected
Vae (1952)	Tropical Depression	Bangkok, Chonburi, Chantaburi and Samut Prakarn (Central part, Thailand)
ELSIE (1972)	Tropical Depression	Bangkok and Central part, Thailand
BulBul:Matmo (2019)	Tropical Depression	Bangkok and Lop Buri ,along with little rain (Central part, Thailand)

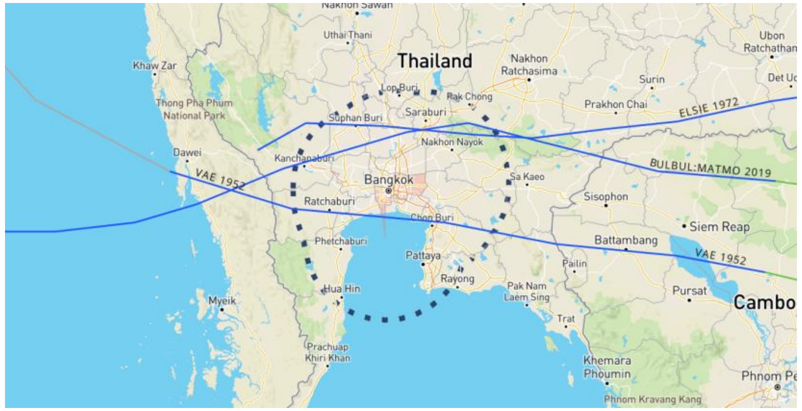


Figure 22: Past Tropical storms that crossed within the vicinity of 100km from Bangkok (NOAA IBTrACS)

Cyclones: Climate Change

Historical Occurrences of Cyclone or Typhoons[1]

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.

Observed Changes[1]

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

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

Hence, no hazard due to cyclone is considered for the project area.

Projected Changes[1]

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.

Observations in IPCC 1.5°C scenario report[2]

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

Cyclones: Climate Change

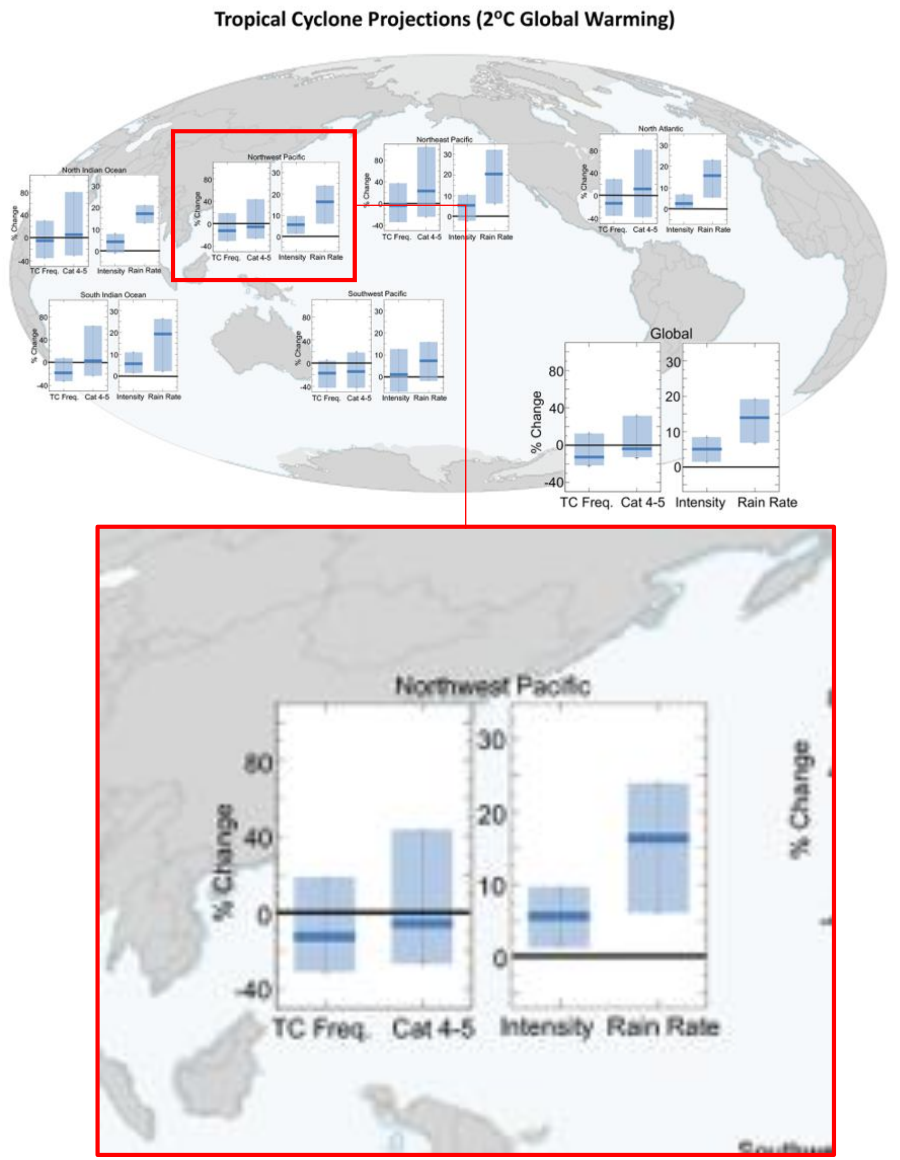
Projected Changes at Site

The recent study by Knuston et. al. (2020)[1] indicated a likely changes for occurrences of tropical cyclone over north-west Pacific ocean as following

- Overall frequency of tropical cyclone by -30 to 20% with median change of -12%
- Changes in frequency of category 4-5 cyclone between -25 to 40% with median change of -5%
- However, intensity of cyclone indicated likely increase of 1 to 9% with median of 5% increase
- Increase in precipitation is likely to be in the range of 5-25% with a median of 15% under 2°C scenario by end of century
- Although, the climate change projections for cyclones indicate a likely increase in frequency and intensity, considering no direct impacts at the Project Site, the hazard associated with it is considered to be '**Low**'.

Baseline	2030	2050
Low	Low	Low

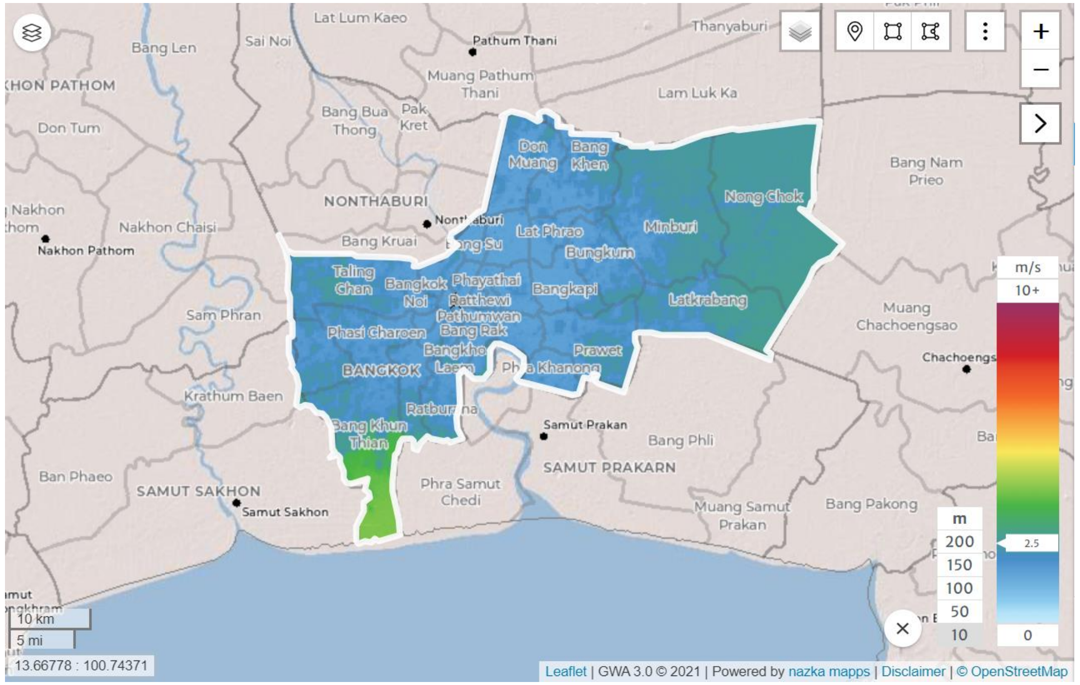
Figure 23: Historical Cyclone Tracks



***Source**: Knuston et al (2020)*

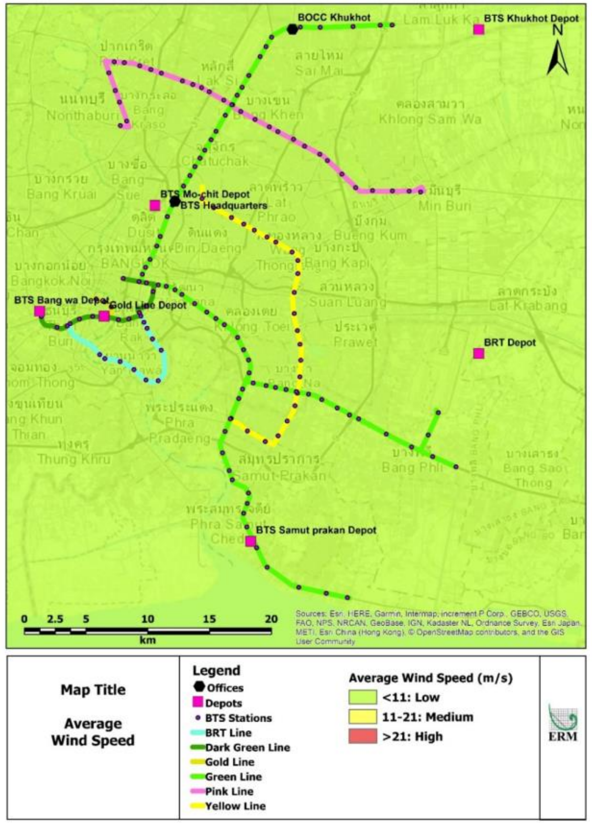
Wind Speed: Baseline

Figure 24: Average Wind Speed



***Source**: Global Wind Atlas*

Figure 25: Risk Categorization



Wind Speed: Baseline

Parameter	Definition/ Methodology/ Data	Source	Hazard Category	Hazard Criteria
Average Wind Speed	Average wind speed data from Global Wind Atlas 2.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU) in partnership with the World Bank Group	Global Wind Atlas[1]	Low	Wind Speed < 11m/s
Maximum Near-Surface Wind	Wind variability has a key impact on water cycles, wind energy, and natural hazards such as hurricanes and typhoons. Thus, it is crucial for many socioeconomic and environmental issues, and can cause damage to buildings, infrastructure, and frequency of dust storms. Here daily maximum near-surface wind speed from CMIP6 database is analysed to categorize the hazard associated with it.	CMIP6	Low	Wind Speed < 11m/s
Overall Hazard			Low	Conservative

Wind Speed: Climate Change

- To categorize the hazard associated with wind, the daily Max. near-surface wind from CMIP6 is analysed.
- **Figure 26** shows the change in the annual maximum of near-surface wind speed during the 2030s and 2050s, compared to Baseline, under the Low- and High-end emission scenarios for Thailand.

Figure 26:Projected Change in the near-surface wind

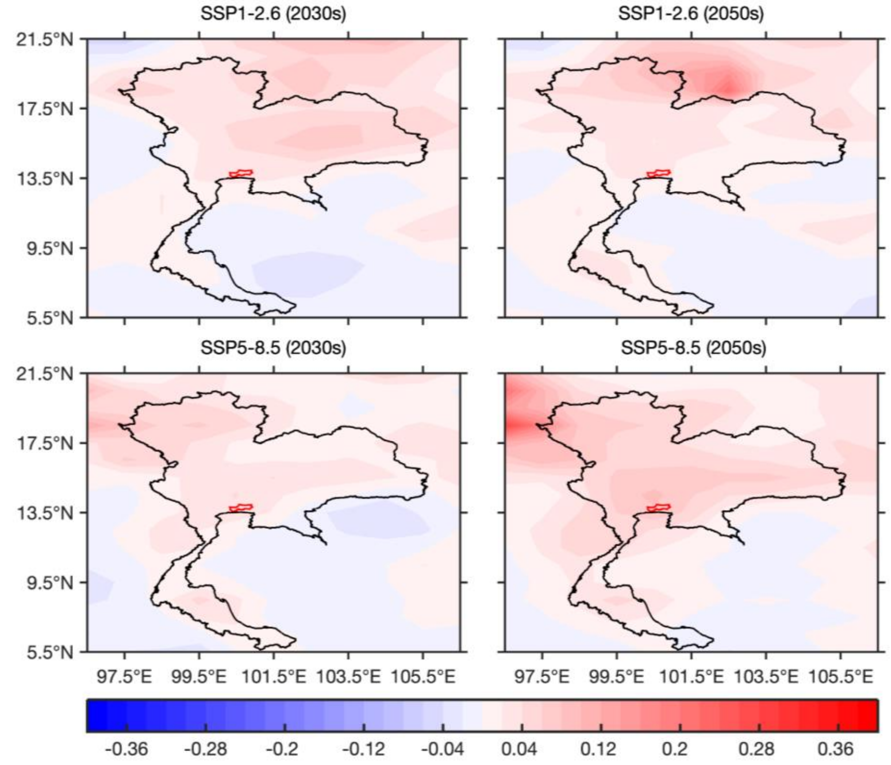
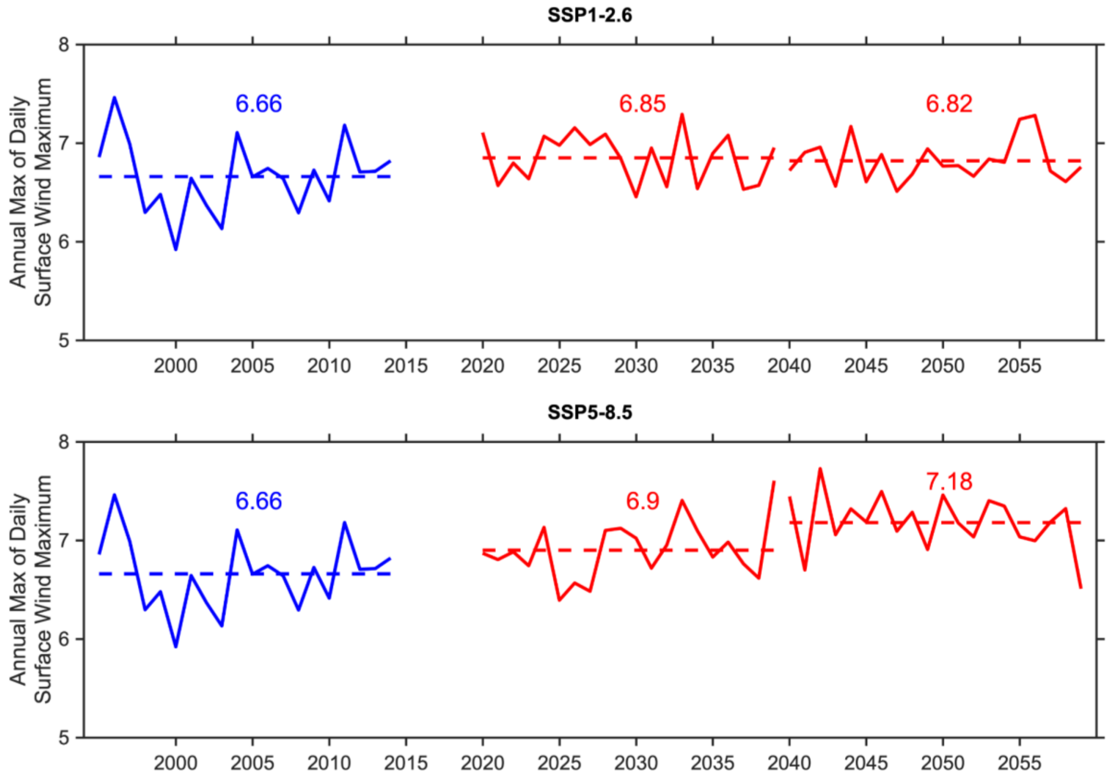


Figure 27: Temporal Variation of Annual Maximum near-surface wind for Bangkok (m/s)



- To get further insights into how the annual maximum of near-surface wind speed over Bangkok will change, the time series is plotted for the baseline and future time horizons.

Wind Speed: Climate Change

- Annual maximum of near-surface wind speed under:
    - **SSP1-2.6 scenario** shows a moderate/sight increase in the 2030s/2050s, i.e., reaching values of 6.85/6.82 m/sec, respectively, compared to the baseline value of 6.6 m/sec.
    - **SSP5-8.5 scenario** illustrates a moderate/significant increase in the 2030s/2050s, i.e., attaining values of 6.9/7.18 m/sec, respectively, compared to the baseline.
- Even though, the annual maximum of near-surface wind shows moderate to significant increase in the 2030s and 2050s, under the scenarios considered, the wind hazard in future time-horizons is still considered to be same as in the baseline, i.e., ‘Low’ as the mean of maximum near-surface wind is well below the threshold value of 11m/s.

Baseline	2030	2050
Low	Low	Low

Projection: Annual Maximum of near-surface wind

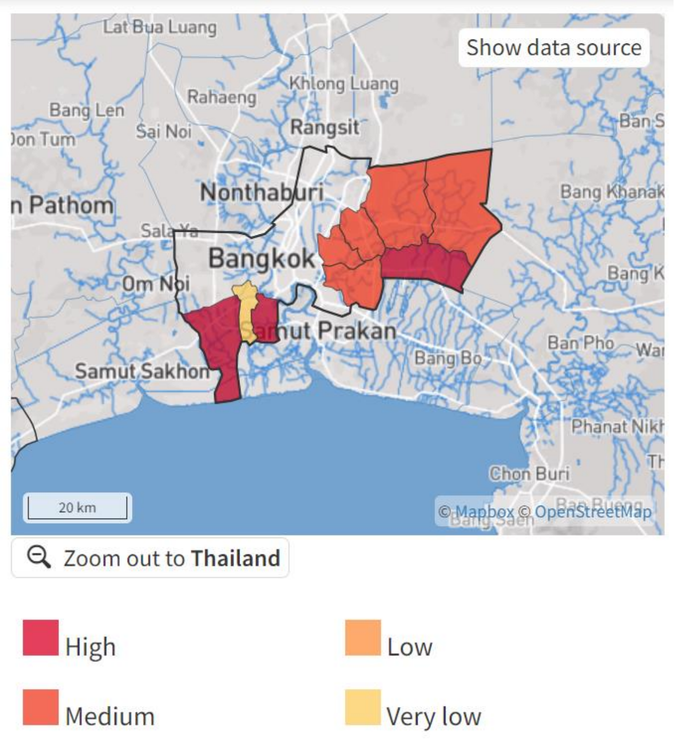
Scenario	BSL (m/s)	2030 (m/s)	2040 (m/s)	2050 (m/s)
SSP1-2.6	6.66	6.85	6.83	6.82
SSP5-8.5	6.66	6.90	6.70	7.18

Coastal Flood: Baseline

Parameter	Definition/ Methodology/ Data	Source	Hazard Category	Hazard Criteria
Flood likelihood	Describes expected frequency of flood damage. The classification uses simulated flood depth data and expert guidance. Coastal flood describes onshore flooding due to high tides, storm surge (due to high winds and low pressure), and wave set-up (energy transfer from offshore waves to the coast).	Think Hazard[1]	Medium-High	Potentially-damaging waves are expected to flood the coast at least once in the next 10 years
Flood Inundation Depth	To estimate coastal hazard, the Global Tide and Surge Reanalysis (GTSR) dataset (Muis et al. 2016) is used as a database of extreme water levels. GTSR is a global dataset of daily sea levels (due to tide and storm surge) for 1979–2014, based on the hydrodynamic Global Tide and Surge Model (GTSM).	WRI-Aqueduct Floods[2]	Medium	Depth of inundation 0.15-0.6 m
Overall Hazard			High	Conservative

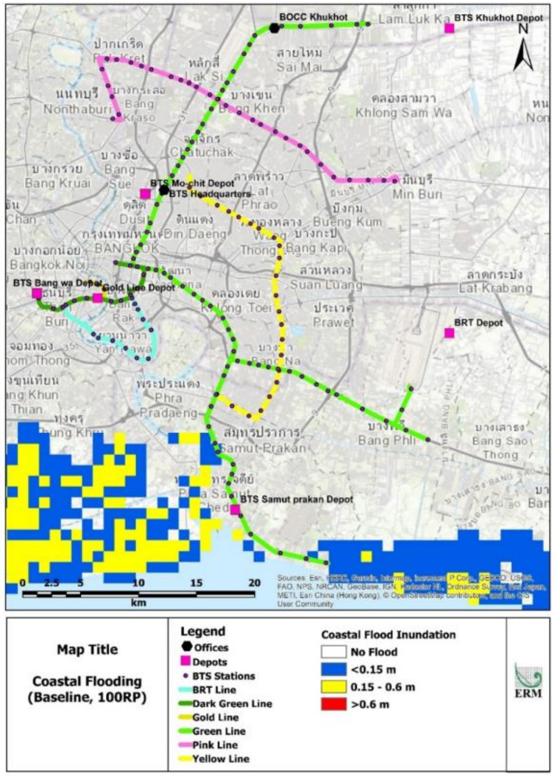
Coastal Flood: Baseline

Figure 28: Coastal Flood Likelihood Map



__Source__: ThinkHazard

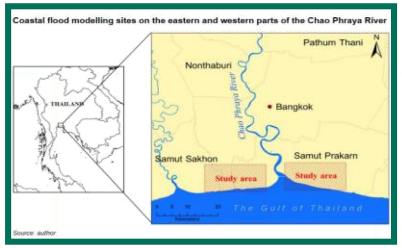
Figure 29: Coastal Flood Inundation Map

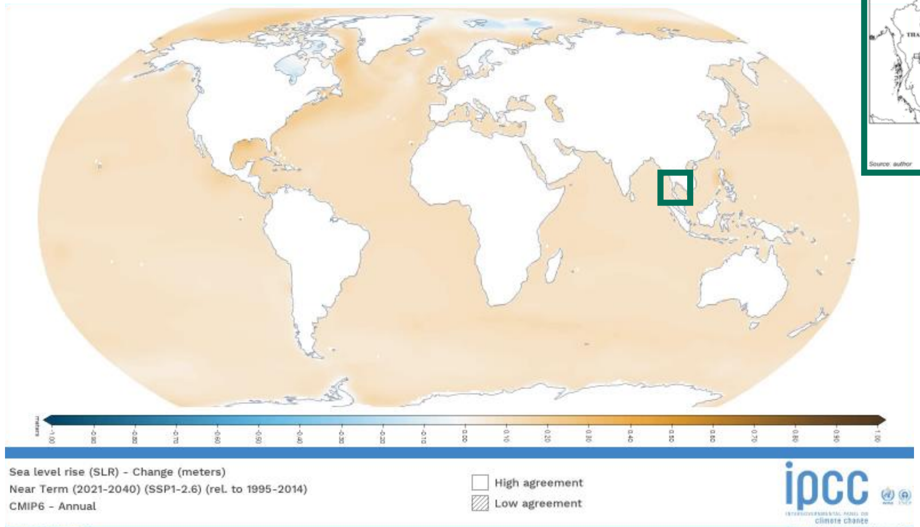


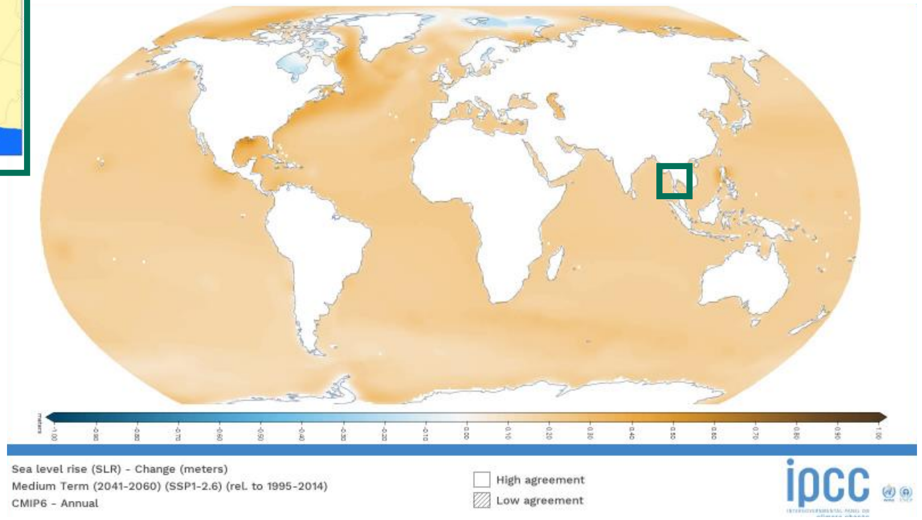
__Source__: WRI-Aqueduct Flood

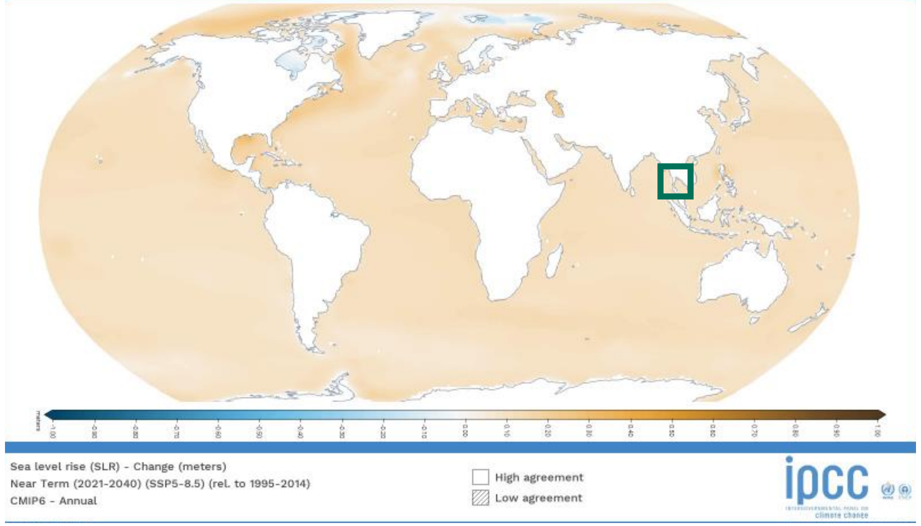
	ThinkHazard	WRI-Aqueduct	Overall
Baseline	Medium-High	Medium	High

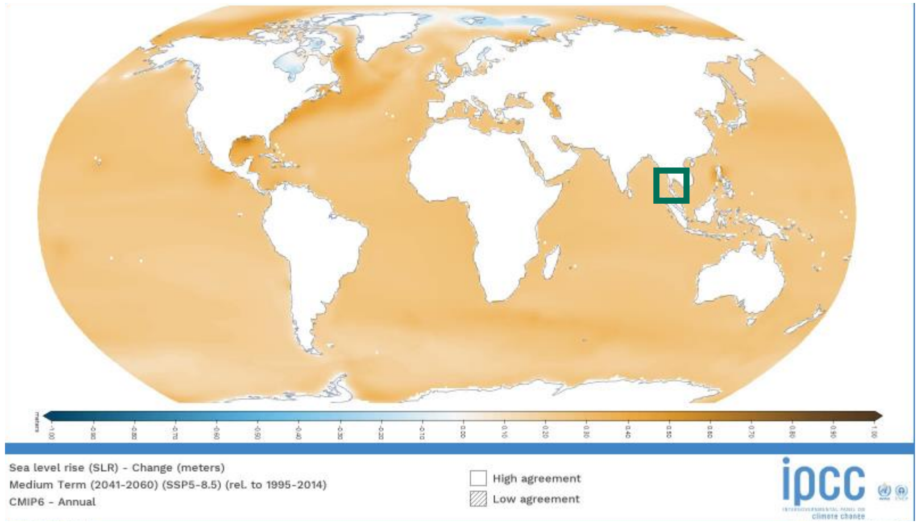
Figure 30: Sea Level Rise under SSP1-2.6 & SSP5-8.5



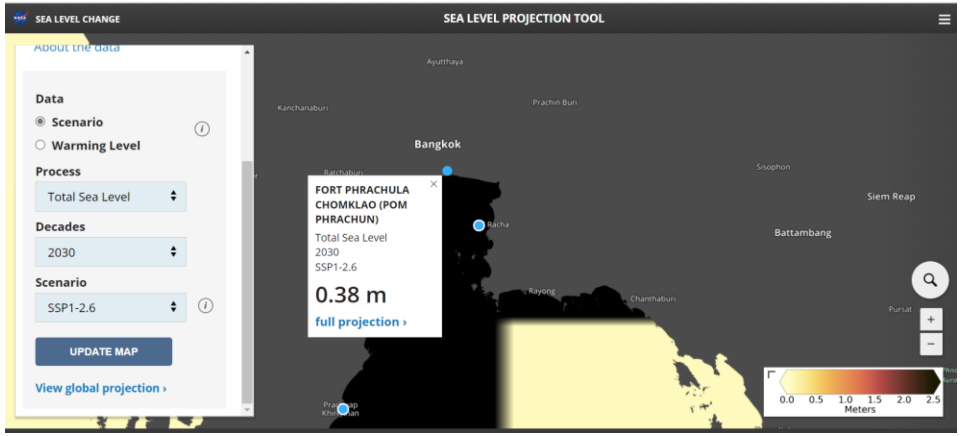


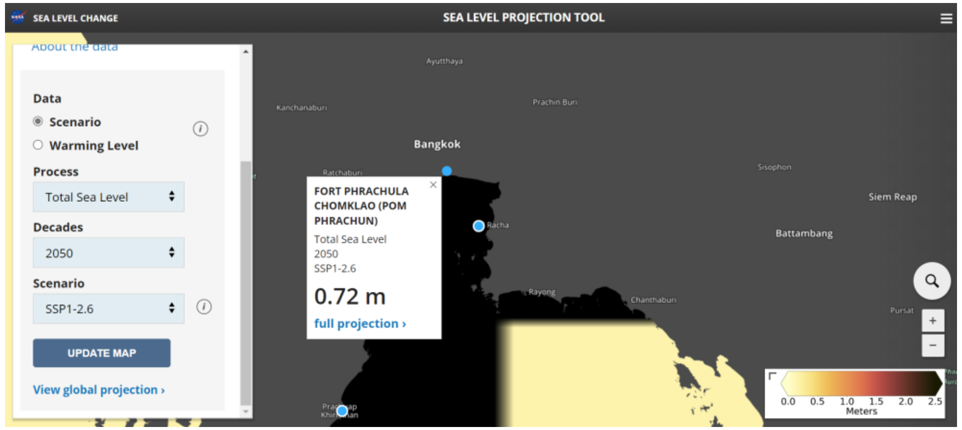






Coastal Flood: Climate Change SSP1-2.6





Source: IPCC 2021: https://sealevel.nasa.gov/data_tools/17

Projection: Coastal Flood (SSP 1-2.6)

Indicator	2030 (cm)	2040 (cm)	2050 (cm)
Sea-level Rise	38	55	72

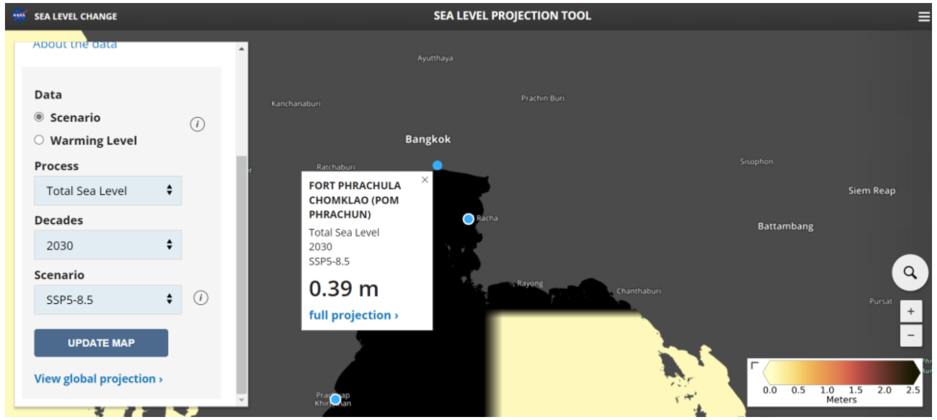
- The low-end emission scenario reveals a slight increase in sea level rise in the 2030s, 2040s and 2050s compared to the baseline. Hence the coastal flood risk is likely to be projected as **'High'** for both time horizons.

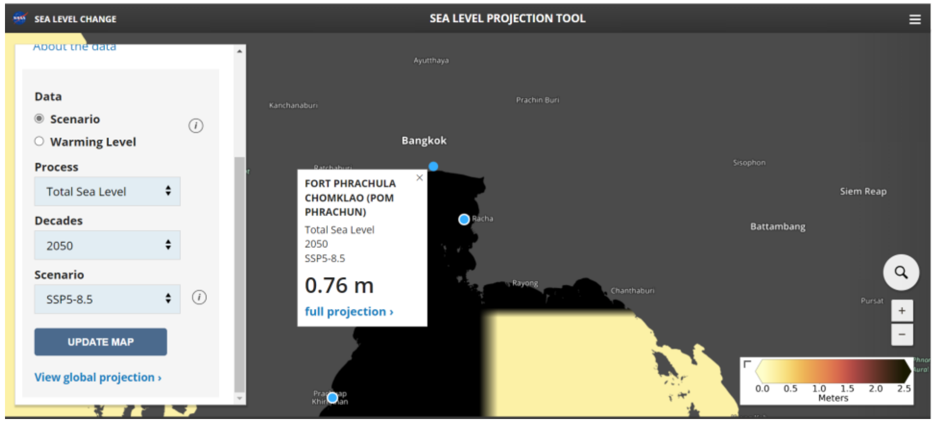
Category	Sea-level rise (cm.)
Significant increase	> 50 cm.
Moderate increase	> 25 cm.
Slight Increase	>0 cm.
No Change	0%

Source: Climate projection trend legend

Baseline	2030	2040	2050
High	High	High	High

Coastal Flood: Climate Change SSP5-8.5





Source: IPCC 2021: https://sealevel.nasa.gov/data_tools/17

Projection: Coastal Flood (SSP 5-8.5)

Indicator	2030 (cm)	2040 (cm)	2050 (cm)
Sea-level Rise	39	58	76

- The high-end emission scenario reveals a significant increase in sea level rise in the 2030s, 2040s and 2050s compared to the baseline. Hence the coastal flood risk is likely to be projected as **'High'** for both time horizons.

Category	Sea-level rise (cm.)
Significant increase	> 50 cm.
Moderate increase	> 25 cm.
Slight Increase	>0 cm.
No Change	0%

Source: Climate projection trend legend

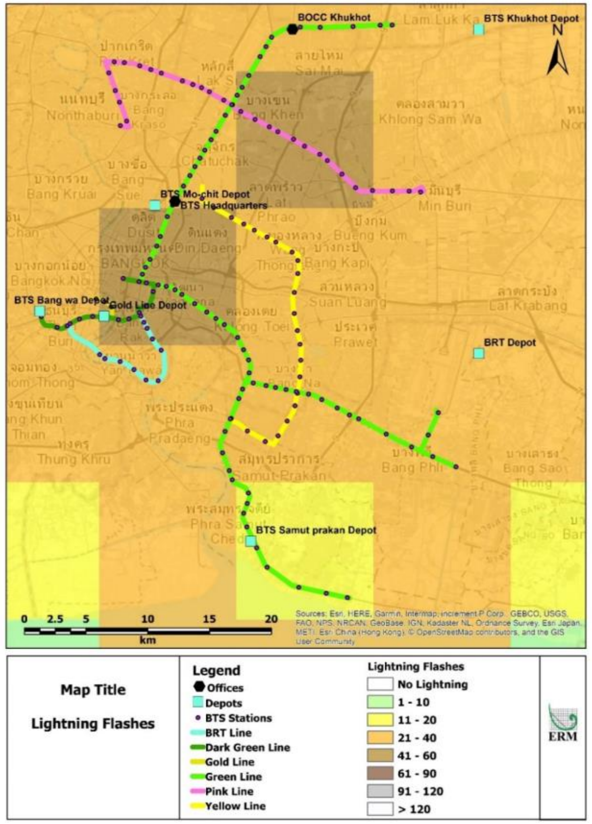
Baseline	2030	2040	2050
High	High	High	High

Lightning: Baseline

Parameter	Definition	Source
Lightning Flash Density	Average number of lightning flashes per year per km^2 recorded during 1998-2013	NASA- Global Hydrology Resource Centre

- Lightning flash density map indicates the density of lightning flashes to be between 20-60 flashes/km^2/year during the period 1998-2013 in the region.

Figure 31: Historical Lightning Flashes

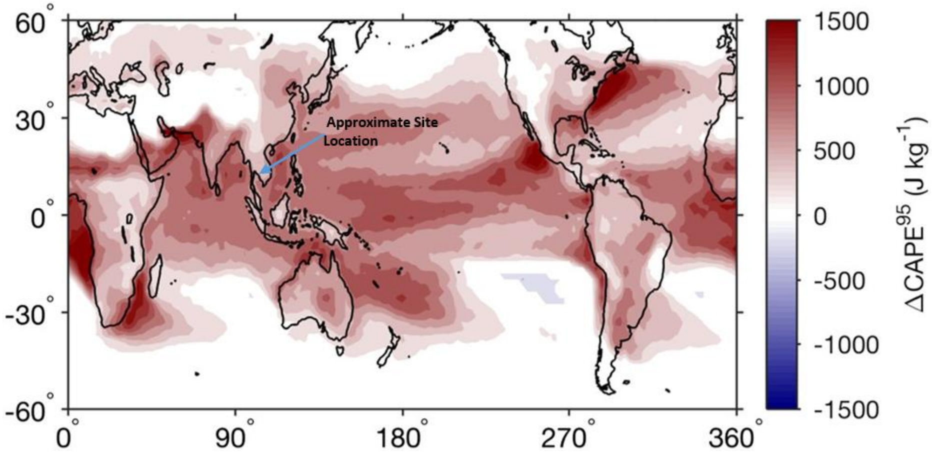


***Source**: NASA-GHRC*

Lightning: Climate Change

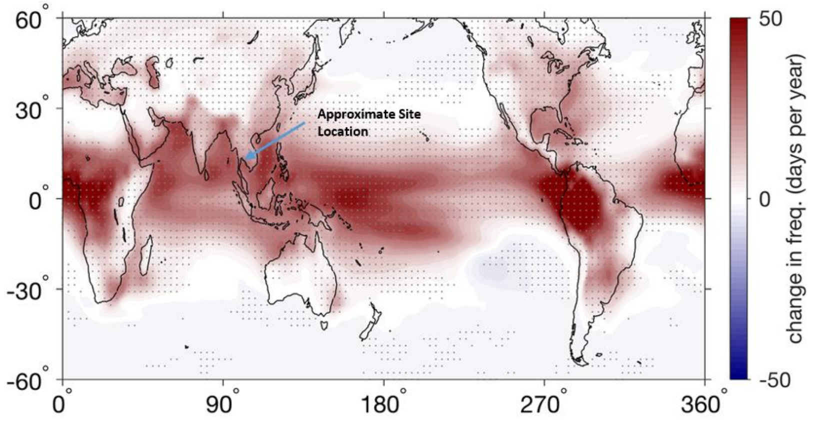
- **There are no direct projections available for lightning**. However, as lightning usually occurs during thunder storms, any changes in occurrences of thunder storm are considered as measure for changes in lightning in future.
- Literature review indicate that predicting changes in thunderstorm directly 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 thunder storms in warming atmosphere.
- Accordingly, the increase in number of favourable days (frequency) at Site are likely to be 0-10 days/year. Assuming the linear change in the increase the change in **2030** and 2050 is likely to be 0-5 more days.

Figure 32: Projected Change in CAPE



Source: Kulp, S.A., and Strauss, B.H (2019)

Figure 33: Projected Change in Number of Days with Conditions Conducive to Thunder Storms



Source: martin Singh (2017)

Summary of Future Projections for Key Climate Variables
RCP 2.6 / SSP1-2.6 and RCP 8.5 / SSP5-8.5

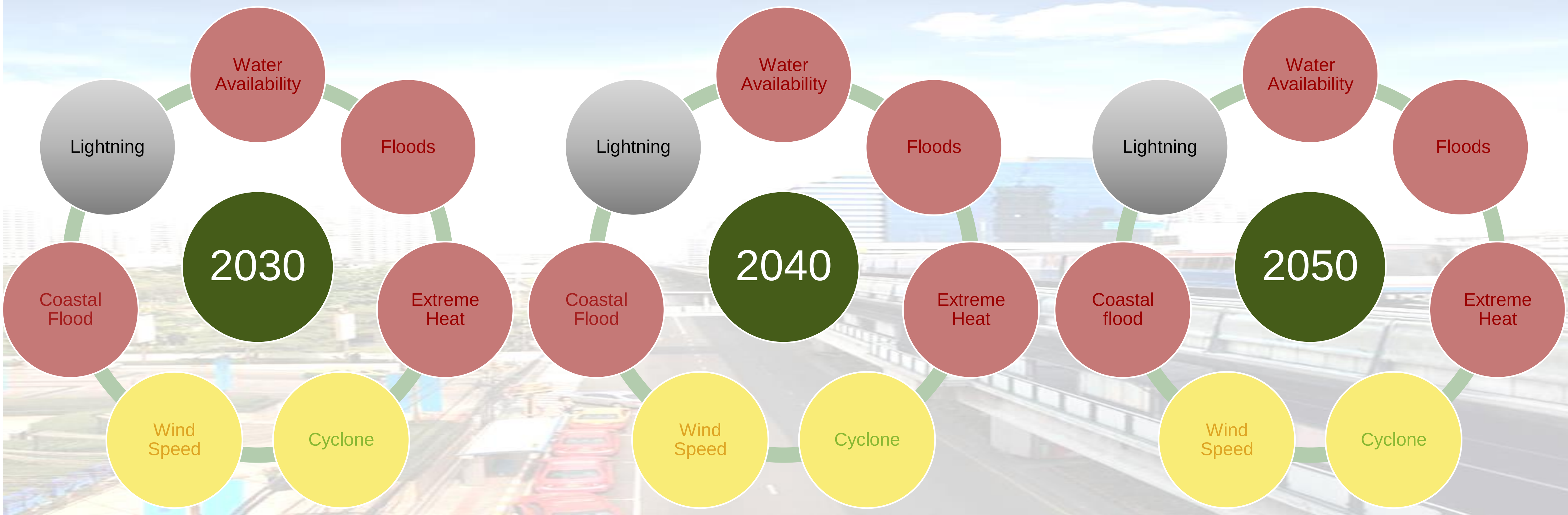
Climate Index	Baseline	RCP2.6/SSP1-2.6 Scenario			RCP8.5/SSP5-8.5 Scenario		
		2030	2040	2050	2030	2040	2050
Water Availability	High	High (-0.04)	High (0.07)	High (0.08)	High (0.03)	High (0.07)	High (0.2)
Floods:	Medium-High	High (236.7mm.)	High (243.2 mm.)	High (249.6 mm.)	High (238.2 mm)	High (253.5 mm)	High (268.9 mm.)
Extreme heat:	High	High (38.7 ° C)	High (39° C)	High (39.3 ° C)	High (38.7 ° C)	High (39.2 ° C)	High (39.8 ° C)
Cyclone	Low	Low	Low	Low	Low	Low	Low
Wind speed	Low	Low (6.85 m/s)	Low (6.83 m/s)	Low (6.82 m/s)	Low (6.90 m/s)	Low (6.70 m/s)	Low (7.18m/s)
Sea-level rise	High	High (0.38 m.)	High (0.55 m.)	High (0.72 m.)	High (0.39 m.)	High (0.58 m.)	High (0.76 m.)
Lightning	No classification (use 2021 information)						

Qualitative Physical Climate Risks Ratings
Baseline

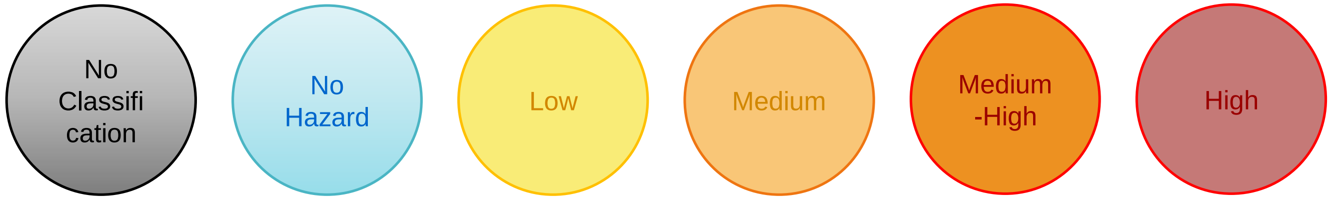
Legend

No Classification | No Hazard | Low | Medium | Medium-High | High

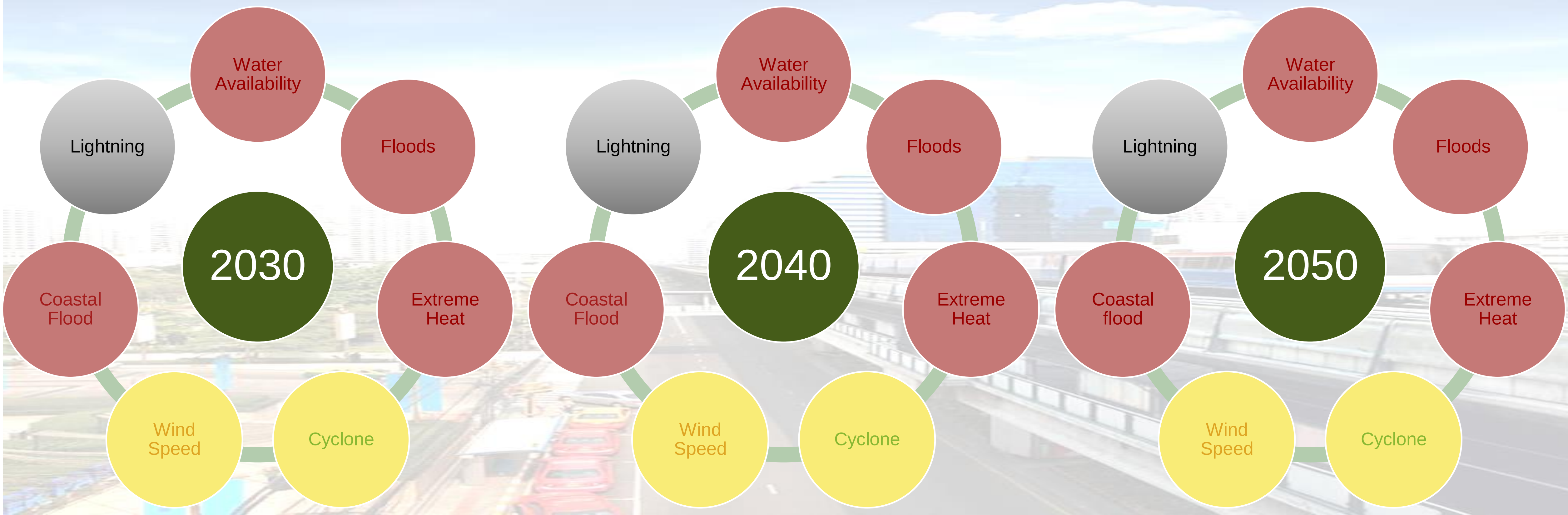
Qualitative Physical Climate Risks Ratings
RCP2.6/SSP1-2.6



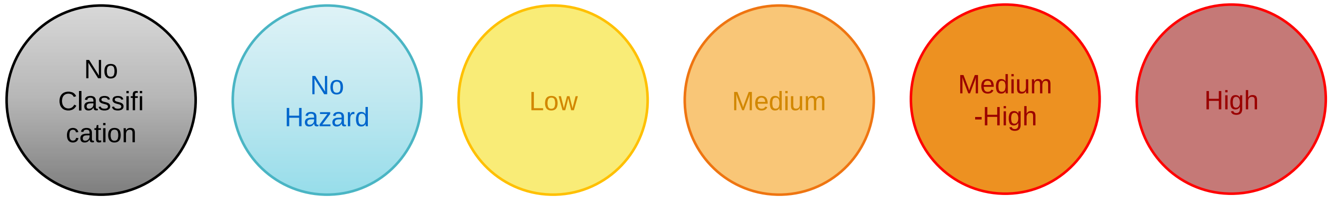
Legend



Qualitative Physical Climate Risks Ratings
RCP8.5/SSP5-8.5



Legend



Physical Risks and Adaptation Plans

Time frame = 5 years 2027*

Physical Risk		
Risk	**Impact for BTS Group**	**Adaptation plan to be completed within 2027**
Water Stress	• Reduced customer and employee water access for drinking, sanitation and maintenance. • Increased cost of water sourcing and treatment.	• Water risk assessment and water auditing. • Explore opportunities for rainwater harvesting. • Water savings fixtures to be installed. • Opportunities for use of recycled water to be explored.
Extreme Heat	• Service disruption due to infrastructure damage: Twisting of tracks and derailment of trains, softening of roads. • Increased power demand for cooling. • Health and safety of staff/ employees due to heat stress / related illness	• Develop action plan to operate trains under extreme temperature conditions. • Provide training to employees to identify symptoms of heat stress and provide first aid. • Ensure appropriate mix design for construction of asphalt/ bitumen pavements to mitigate the risk of melting/ softening.
Floods & Coastal Floods	• Stations, offices, and depots may become inaccessible. • Debris on road / damage to road surface may disrupt buses. • Damage to supporting infrastructure. • Failure of track circuit or detection of presence/ absence of train on track. • Endanger structural safety of lines.	• Provide regular capacity training to relevant employees in response to flooding which is estimated to be addressed before 2027. • Design and implement suitable mitigation measures such as increasing capacity of storm water drainage or pumping system. • Sufficient drainage system for the viaducts of the Sky Rail to avoid inundation on elevated sections. • Sufficient camber and storm water drainage capacity ensured for the roads carrying bus/BRT transport. • Prepare plan to operate metro rail at lower speed during rainfall intensity.
Wind Speed & Cyclone	• Reduced customer comfort and safety. • Damage/ disruption of assets. • Safety of construction/ maintenance workers.	• Consider wind hazard in emergency response plan and develop action plan identifying steps to be taken if wind speed exceeds certain threshold value. • Install anemometers to monitor wind speeds. • Compliance with national or international best practices for wind load for design and construction of all structures.

Financial Impact

Identify Financial Impact from Flooding Risk

The most significant risk and methods used to manage:

- **Flooding Risk**: High Level flooding which causes water breaching inside the workshop in the depot halting all maintenance of trains. Trains will not be able to undergo maintenance in the case of train malfunction or engine failure etc. therefore concrete walls must be set up as well as stop log distributed at important locations.
- We have evaluated financial risks related to climate-related physical risks around our rail systems (sky train) that operates in Thailand. The risks from delay service and service disruption was estimated to be around 33,679,452 THB. We assumed disruption from climate-related physical impacts would be around 1 days per year. As of 31 March 2023, end of the FY, **total revenue of MOVE business is 12,293,000,000 THB/year** which equal to 33,679,452 THB/day financial implications for cost of disruption is approximately **33,679,452 THB**.

- Determined %change of rainfall intensity of RCP 2.6 in 2030, 2040 and 2050 from climate change projection
  - 7% in 2030
  - 1.10% in 2040
  - 13% in 2050
- Estimated the disruption days by using the assumption

"The disruption days in 2030 and 2050 are assumed based on the %change of rainfall intensity of RCP 2.6 with the 1-day disruption baseline in 2022"

  - 7% of 1 day disruption = 1.07 days
  - 1.10% of 1 day disruption = 1.10 days
  - 13% of 1 day disruption = 1.13 days

- Determined %change of rainfall intensity of RCP 8.5 in 2030, 2040 and 2050 from climate change projection
  - 8% in 2030
  - 1.14% in 2040
  - 21% in 2050
- Estimated the disruption days by using the assumption

"The disruption days in 2030 and 2050 are assumed based on the %change of rainfall intensity of RCP 8.5 with the 1-day disruption baseline in 2022"

  - 8% of 1 day disruption = 1.08 days
  - 1.14% of 1 day disruption = 1.14 days
  - 21% of 1 day disruption = 1.21 days

Summary Financial Impact from Flooding Risk
2030s, 2040s and 2050s Scenarios

Baseline

Estimated Financial Implications :
- **33,679,452 THB**

Average estimated time frame (in number of years) for financial implications of this risk: 1
- **1 Year**

Estimated cost of these actions:
- **1,038,525 THB**

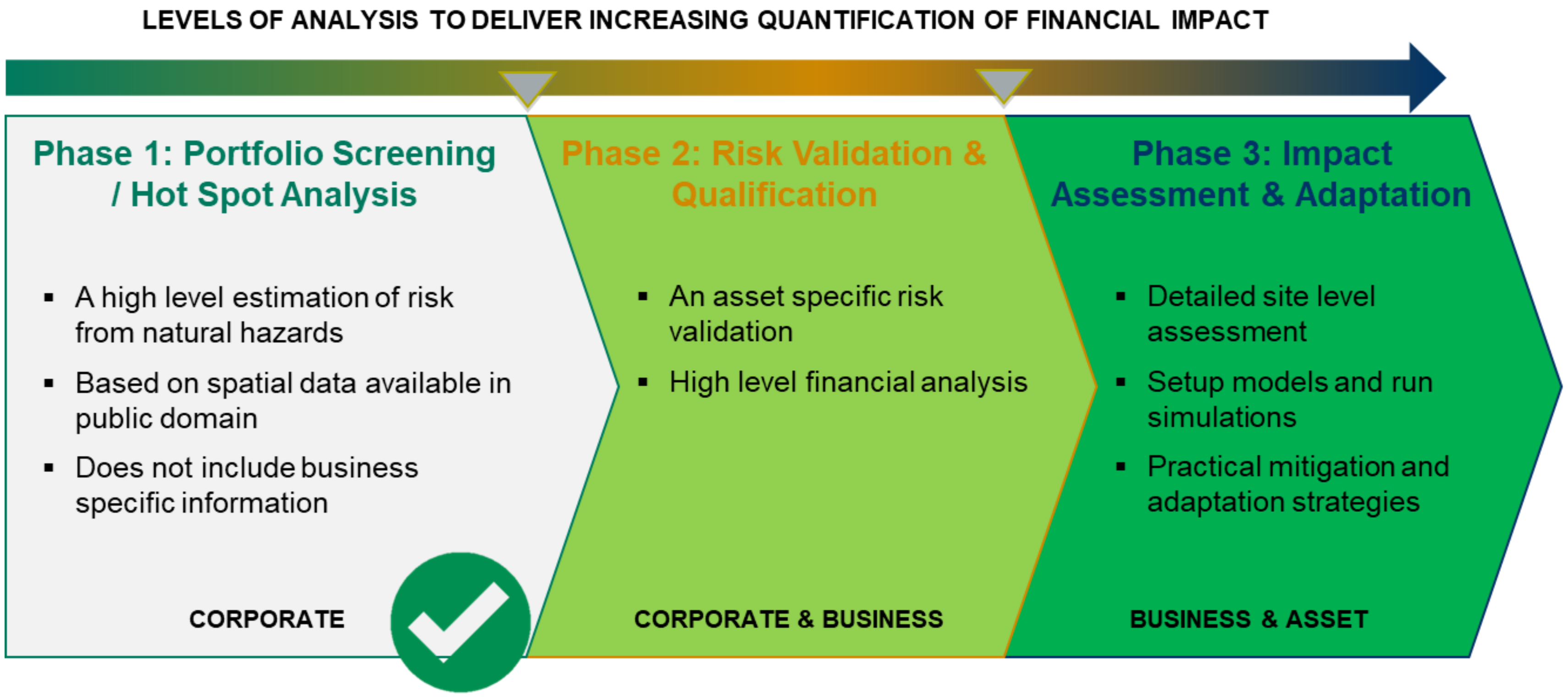
RCP 2.6

- Financial disruption
  - In 2030: **33,679,452 THB/day x 1.07 days = 36,037,014 THB**
  - In 2040**: 33,679,452 THB/day x 1.10 days = 37,047,397 THB**
  - In 2050: **33,679,452 THB/day x 1.13 days = 38,057,781 THB**

RCP 8.5

- Financial disruption
  - In 2030: **33,679,452 THB/day x 1.08 days = 36,373,808 THB**
  - In 2040**: 33,679,452 THB/day x 1.14 days = 38,394,575 THB**
  - In 2050: **33,679,452 THB/day x 1.21 days = 40,752,137 THB**

Way forward


LEVELS OF ANALYSIS TO DELIVER INCREASING QUANTIFICATION OF FINANCIAL IMPACT
Phase 1: Portfolio Screening / Hot Spot Analysis
A high level estimation of risk from natural hazards
Based on spatial data available in public domain
Does not include business specific information
CORPORATE
Phase 2: Risk Validation & Qualification
An asset specific risk validation
High level financial analysis
CORPORATE & BUSINESS
Phase 3: Impact Assessment & Adaptation
Detailed site level assessment
Setup models and run simulations
Practical mitigation and adaptation strategies
BUSINESS & ASSET

Thank You!