FINAL REPORT

Physical Climate Risk Assessment, Quantification and Climate Disclosure

REFERENCE: 0802982

PREPARED FOR: WESTPORTS MALAYSIA SDN BHD

PREPARED BY: ENVIRONMENTAL RESOURCES MANAGEMENT (M) SDN BHD

DATE: 25 MARCH 2026

Sustainability is our business

Document details	
Document title	Physical Climate Risk Assessment, Quantification and Climate Disclosure
Document subtitle	Final Report
Project No.	0802982
Date	25 March 2026
Version	1.0
Author/s	Senthil Gurusamy, Sharifah Nurul Akmal, Xiao Feng Gan, Hoffman Cheung, Pramon Karnchanapimonkul
Client	WESTPORTS MALAYSIA SDN BHD

Document history

					ERM approval to issue		
Version	Revision	Phases	Author/s	Reviewed by	Name	Date	Comments
1.0	0.0	1	Senthil Gurusamy, Sharifah Nurul Akmal	Venkat Kolluru	Jye Yng Voon	13 February 2026	Submitted as Draft Report
		2	Xiao Feng Gan, Hoffman Cheung, Senthil Gurusamy	Venkat Kolluru		13 February 2026	
		3	Xiao Feng Gan, Pramon Karnchanapimonkul	Yulia Dobrolyubova		30 December 2025	
	1.0	1	Senthil Gurusamy	Edmund Ang, Venkat Kolluru	Jye Yng Voon	25 March 2026	Submitted as Final Report
		2	Hoffman Cheung, Senthil Gurusamy	Edmund Ang, Venkat Kolluru		25 March 2026	
		3	Xiao Feng Gan, Pramon Karnchanapimonkul	Edmund Ang, Yulia Dobrolyubova		04 March 2026	

SIGNATURE PAGE

Physical Climate Risk Assessment, Quantification and Climate Disclosure

Final Report
0802982

Voon Jye Yng
Partner In Charge

Environmental Resources Management (M) Sdn Bhd
Suite 8-5, Level 8, Menara Milenium,
No. 8, Jalan Damanlela,
Damansara Heights,
50490, Kuala Lumpur,
Malaysia.

T: +603 2706 0010

Glossary

Acronyms and Abbreviations	Description
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
BBT	Break Bulk Terminal
CT	Container Terminal
DBT	Dry Bulk Terminal
ENSO	El Niño–Southern Oscillation
ETWL	Extreme Total Water Level (ETWL) (metres)
GCD	ERM's Global Climate Database
HVAC	Heating, Ventilation and Air Conditioning
IFRS	International Financial Reporting Standards
IFRS S2	International Financial Reporting Standards: Climate-Related Disclosures
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
LBT	Liquid Bulk Terminal
NSRF	National Sustainability Reporting Framework
PIANC	Permanent International Association of Navigation Congresses-The World Association for Waterborne Transport Infrastructure
QC	Quay Cranes
RTG	Rubber-Tyred Gantry Crane
SLR	Sea Level Rise (metres)
SSP	Shared Socioeconomic Pathway
TCFD	Tasked Force on Climate-Related Financial Disclosures
TEUs	Twenty-foot Equivalent Unit
WSDI	Warm Spell Duration Index (days)

Content

Executive Summary

Executive Summary – Port Assets and Operations – Site Visit Observation

ERM conducted a 2-day site visit on 6th and 7th August 2025 to look at how climate hazards may impact the processes, infrastructure, and/or equipment within the asset. The site visit highlighted several operational, environmental, and infrastructure-related factors that directly influence the materiality of physical climate risks for the port. These observations were essential in validating the assumptions, exposure ratings, and vulnerability pathways used in the physical risk assessment for the eight hazards.

Operational Sensitivities Confirm Exposure to Climate-Driven Interruptions

- **Swell >3 m** → Pilot boarding delays (8–12 hrs).
- **Winds >30m/s**→ Quayside operations halted (cranes, container handling).
- **Reduced visibility (haze)** → Safety concerns, slower operations.

Related hazards: **Winds & Storms, Waves, Currents, and Extreme Total Water Level (ETWL)**

Infrastructure Dependence Highlights Materiality of Flooding & Sea-Level-Related Risks

- **Drainage system performance** is critical during intense rainfall events.
- **Site elevation (~8.0 m)** provides baseline protection but requires assessment against future SLR.
- **Low-lying electrical substations** increase vulnerability to coastal flooding and ETWL.

Related hazards: **Coastal Flooding, ETWL, and Rainfall Flooding**

Equipment & Crane Operations Reinforce Sensitivity to Wind and Heat Hazards

- **QCs (quay cranes) auto-shutdown at wind >30 m/s**, confirming vulnerability to high-wind conditions.
- **RTGs (dependent on operator skill** under adverse weather.
- **Enclosed cabins reduce heat exposure**, but heat still drives:

Related hazards: **Extreme Heat**

Maintenance Practices Indicate Long-Term Vulnerability of Marine Assets

- **Dredging cycles** reflect ongoing influence of sedimentation and currents.
- **Corrosion control intervals** highlight exposure to humidity and salt spray.
- **Drainage maintenance** underscores vulnerability during heavy rainfall events.

Related hazards: **Currents and Waves**

Electrical Power Systems Identified as Critical Nodes with Cascading Risk Potential

- **Dual power feeds and backup generators** improve resilience.
- **Substations near the waterfront** remain exposed to flood pathways.

Related hazards: **Flooding , ETWL and Winds & Storms**

High Vessel Throughput Increases Consequence of Disruptions

With ~50 vessel movements daily, operational delays rapidly create congestion and financial impacts.

Related hazards: **Winds & Storms, Waves, Rainfall Flooding and Extreme Heat**

Executive Summary – Climate Hazard Risk Evaluation for Westports

This assessment evaluated **36 Asset Group Types** (**199 assets)** for baseline and projected risk scores for **eight climate-related hazards** under **SSP5-8.5 scenarios for 2050 and 2085**. The analysis covered critical infrastructure categories including buildings, operational facilities, equipment, utilities, warehouses, and nearshore assets.

Key Findings by Hazard

- **Extreme Heat**
  - **Trend:** A pronounced upward trend.
  - **High-Risk Assets:** Data centers, chemical manufacturing, and fuel warehouses
- **Extreme Winds & Storms**
  - **Trend:** Minimal increase.
  - **High-Risk Assets:** All assets remain in the **Minimal to Low-risk range**.
- **Rainfall Flooding**
  - **Trend:** Negligible change.
  - **High-Risk Assets:** All assets remain in **the minimal risk range**.
- **Riverine Flooding**
  - **Trend:** No measurable change
  - **High-Risk Assets:** All assets remain in **the minimal risk range**.
- **Coastal Flooding**
  - **Trend:** Minimal increase.
  - **High-Risk Assets:** Sewerage systems, nearshore operational buildings, uncovered warehouses and maintenance buildings.
- **Extreme Total Water Level**
  - **Trend:** A clear upward trend
  - **High-Risk Assets:** Berths, nearshore equipment, operational buildings, and power substations.
- **Waves**
  - **Trend: No projected increase.**
  - **High-Risk Assets: Revetment onshore, Buildings (data centers, operational nearshore), power substations Nearshore, warehouses (covered nearshore) and telecommunication services nearshore.**
- **Currents**
  - **Trend: Slight decline**
  - **High-Risk Assets: Openwater nearshore and transport waterways.**

Heat Map of Westports Assets**

Physical Hazard*	Baseline	SSP5-8.5: 2050	SSP5-8.5: 2085
Extreme Heat	1.56	5.54	6.41
Extreme Winds & Storms	0.81	0.95	1.03
Rainfall Flooding	0.01	0.01	0.01
Riverine Flooding	0.00	0.00	0.00
Coastal Flooding	0.24	0.34	0.66
Extreme Total Water level	3.48	4.51	5.12
Waves	2.32	2.32	2.32
Currents	1.92	1.95	1.85

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

** Definitions of physical hazards are included on slides in Appendix A.*

*** Risk level in each cell refers to the aggregated risk score (arithmetic mean) across all 199 assets.*

Overall Risk Outlook

- **Potential Hazards:** Extreme Heat and Extreme Total Water Level show the highest escalation and pose severe risks to nearshore and operational assets.
- Waves and Currents remain largely unchanged, while Riverine, Rainfall and Coastal Flooding pose minimal risk.
- **Strategic Priority:** Prioritise investment in **heat adaptation strategies, coastal flood defenses**, and **water-level resilience measures** to safeguard critical infrastructure.
- The heat-map assessment (detailed risk register table is shown in the following slide) shows a clear and progressive escalation of physical climate hazards across the port's asset group types from the baseline to 2050 and further to 2085 under the SSP5-8.5 scenario, with the most significant increases occurring in Extreme Heat, Extreme Total Water Level (ETWL), Waves, Currents and Coastal Flooding.

Executive Summary – Climate Hazard Heatmaps for Asset Group Types Across Time Horizons

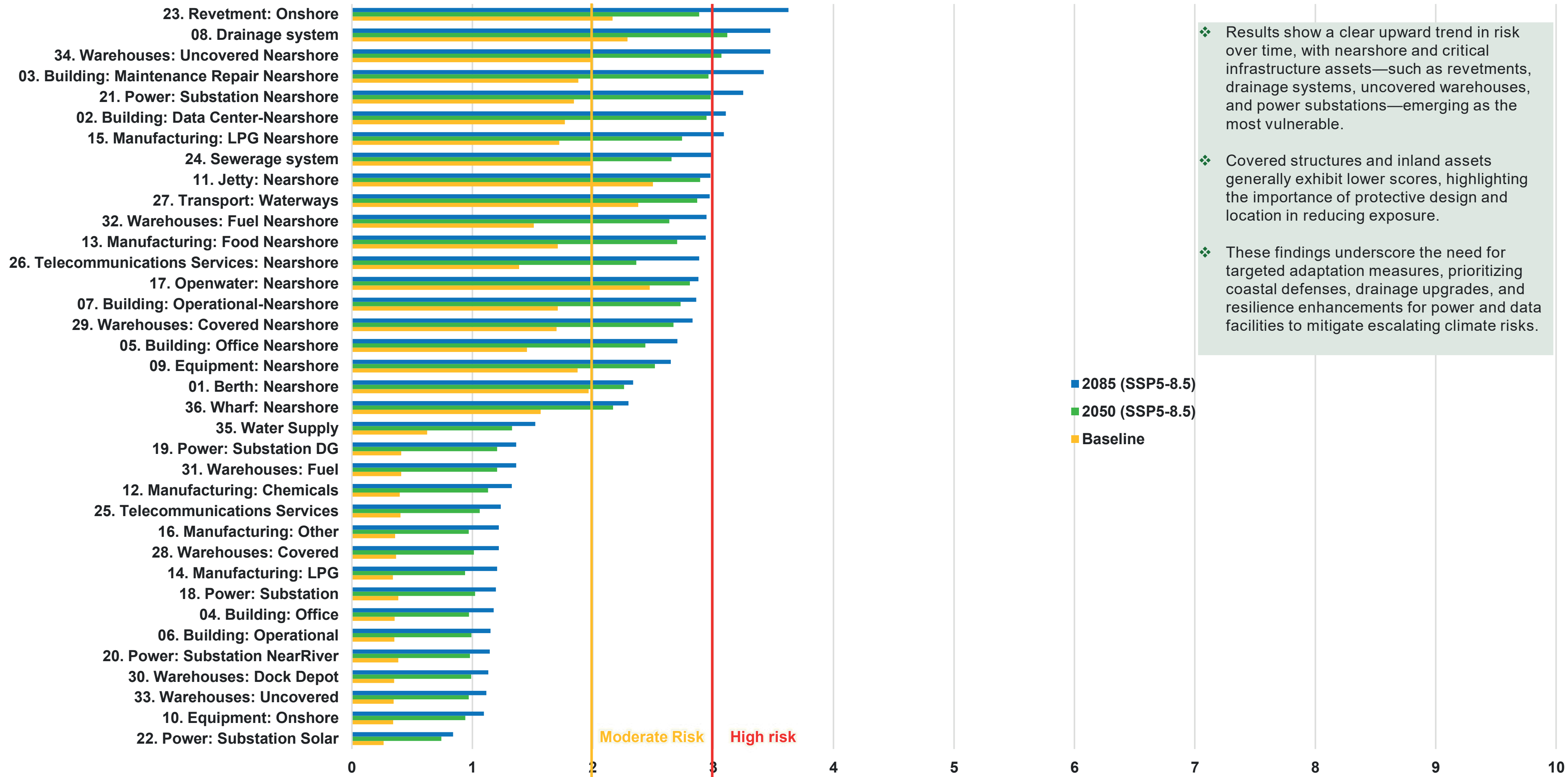
Heat maps of physical climate hazards for asset group types– baseline period as well as 2050 and 2085 timeframes under SSP5-8.5 scenarios

Asset Group Types	Extreme Heat			Extreme Winds & Storms			Rainfall Flooding			Riverine Flooding			Coastal Flooding			Extreme Total Water level			Waves			Currents		
	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085	Baseline	2050	2085
01. Berth: Nearshore	0.95	3.36	3.88	0.66	0.78	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	1.20	1.20	1.20	4.92	4.74	4.76
02. Building: Data Center-Nearshore	2.40	8.60	9.80	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
03. Building: Maintenance Repair Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	1.45	2.33	4.73	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
04. Building: Office	1.86	6.52	7.66	0.88	1.04	1.12	0.01	0.02	0.02	0.00	0.00	0.00	0.08	0.20	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05. Building: Office Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.96	4.96	8.00	8.00	3.94	3.94	3.94	0.00	0.00	0.00
06. Building: Operational	1.92	6.88	7.84	0.88	1.04	1.12	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07. Building: Operational-Nearshore	1.92	6.88	7.84	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
08. Drainage system	1.44	5.16	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	2.96	5.86	8.00	5.92	5.92	5.92	0.00	0.00	0.00
09. Equipment: Nearshore	1.92	6.88	7.84	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	1.20	1.20	1.20	3.00	3.02	3.03
10. Equipment: Onshore	1.86	6.50	7.65	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11. Jetty: Nearshore	0.92	3.20	3.80	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.69	8.00	8.00	1.50	1.50	1.50	10.00	9.40	9.39
12. Manufacturing: Chemicals	2.30	8.00	9.50	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.24	0.87	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
14. Manufacturing: LPG	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.58	2.07	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
16. Manufacturing: Other	1.84	6.40	7.60	0.88	1.04	1.12	0.07	0.08	0.08	0.00	0.00	0.00	0.07	0.24	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17. Openwater: Nearshore	0.96	3.44	3.92	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	1.20	1.20	1.20	8.75	8.77	8.79
18. Power: Substation	1.90	6.73	7.77	0.88	1.04	1.12	0.01	0.01	0.01	0.00	0.00	0.00	0.30	0.40	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19. Power: Substation DG	2.40	8.60	9.80	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20. Power: Substation NearRiver	1.84	6.40	7.60	0.88	1.04	1.12	0.36	0.41	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21. Power: Substation Nearshore	1.90	6.76	7.78	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.43	1.18	5.83	9.68	10.00	5.92	5.92	5.92	0.00	0.00	0.00
22. Power: Substation Solar	1.44	5.16	5.88	0.66	0.78	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23. Revetment: Onshore	1.42	5.06	5.83	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.45	1.19	2.30	4.35	8.65	9.86	9.86	9.86	2.63	2.32	2.36
24. Sewerage system	0.96	3.44	3.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	2.96	5.86	8.00	3.94	3.94	3.94	0.00	0.00	0.00
25. Telecommunications Services	1.91	6.84	7.82	0.88	1.04	1.12	0.01	0.01	0.01	0.00	0.00	0.00	0.43	0.61	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26. Telecommunications Services: Nearshore	1.92	6.88	7.84	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.20	2.39	5.04	8.00	5.92	5.92	5.92	0.00	0.00	0.00
27. Transport: Waterways	1.44	5.16	5.88	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	8.00	8.00	1.20	1.20	1.20	7.50	7.54	7.58
28. Warehouses: Covered	1.90	6.74	7.77	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.32	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
30. Warehouses: Dock Depot	1.92	6.88	7.84	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31. Warehouses: Fuel	2.40	8.60	9.80	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	2.30	8.00	9.50	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.00	4.96	8.00	8.00	3.94	3.94	3.94	0.00	0.00	0.00
33. Warehouses: Uncovered	1.89	6.72	7.76	0.88	1.04	1.12	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34. Warehouses: Uncovered Nearshore	1.84	6.40	7.60	0.88	1.04	1.12	0.09	0.10	0.10	0.00	0.00	0.00	2.16	3.08	5.05	4.96	8.00	8.00	5.92	5.92	5.92	0.00	0.00	0.00
35. Water Supply	1.86	6.52	7.66	0.88	1.04	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.42	1.24	2.00	2.00	0.99	0.99	0.99	0.00	0.00	0.00
36. Wharf: Nearshore	0.95	3.38	3.89	0.66	0.78	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.83	7.27	7.71	1.20	1.20	1.20	4.89	4.72	4.74
Asset Averaged Risk Score	1.56	5.54	6.41	0.81	0.95	1.03	0.01	0.01	0.01	0.00	0.00	0.00	0.24	0.34	0.66	3.53	4.59	5.12	2.32	2.32	2.32	1.92	1.84	1.85

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Executive Summary – Asset Aggregated Risk Score for Asset Group Types

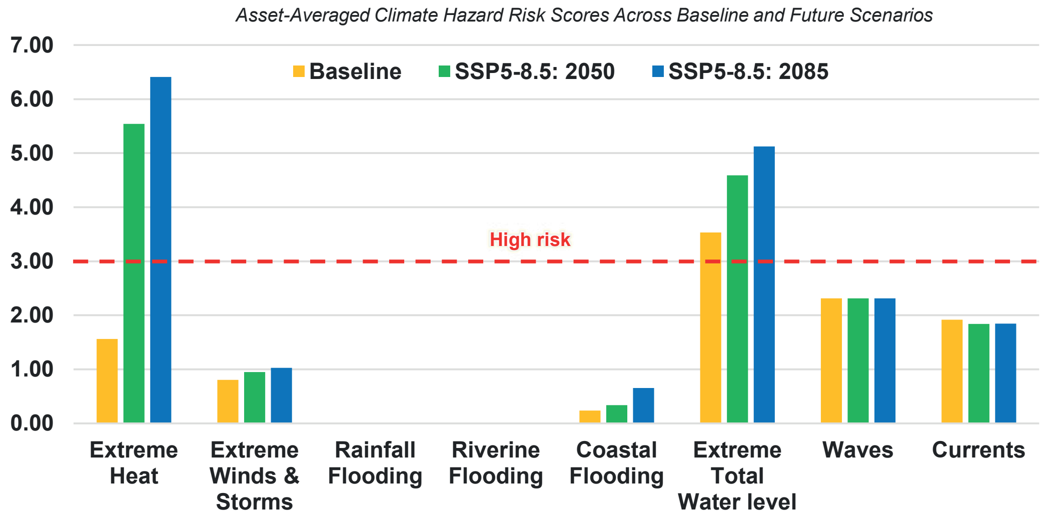
The chart illustrates aggregated climate risk scores for various asset group types under baseline conditions and future scenarios (SSP5-8.5-2050 & 2085).



- Results show a clear upward trend in risk over time, with nearshore and critical infrastructure assets—such as revetments, drainage systems, uncovered warehouses, and power substations—emerging as the most vulnerable.
- Covered structures and inland assets generally exhibit lower scores, highlighting the importance of protective design and location in reducing exposure.
- These findings underscore the need for targeted adaptation measures, prioritizing coastal defenses, drainage upgrades, and resilience enhancements for power and data facilities to mitigate escalating climate risks.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Summary of High-Risk Assets by Key Physical Hazard Categories



Number of assets at high risk (risk score ≥ 3) *

High Risk	Baseline	SSP5-8.5	
		2050s	2085s
Extreme Heat	0	36	36
Extreme Winds & Storms	0	0	0
Rainfall Flooding	0	0	0
Riverine Flooding	0	0	0
Coastal Flooding	2	3	4
Extreme Total Water level	16	20	20
Waves	14	14	14
Currents	6	6	6

*Numbers with more than 18 (50% of assets) are shaded.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Key Findings

- **Extreme Heat** is projected to become the most critical hazard, with high-risk assets increasing from **0 at baseline** to **36 assets (100%)** by both **2050s and 2085s** under SSP5-8.5 scenario. This indicates that all assessed assets will face severe heat-related risks in future timeframes.
- **Extreme Total Water Level** remains a major concern, starting with **16 assets (44%)** at high risk in the baseline period and increasing to **20 assets (56%)** by 2050, maintaining the same level through 2085. This highlights persistent vulnerability to elevated water levels.
- **Coastal Flooding** shows a gradual rise in high-risk exposure, from **2 assets (6%)** at baseline to **3 assets (8%)** by 2050 and **4 assets (11%)** by 2085, indicating incremental but notable risk growth.
- **Waves** maintain consistent high-risk exposure across all timeframes, with **14 assets (39%)** identified as high risk from baseline through 2085. Similarly, **Currents** remain unchanged at **6 assets (17%)**, reflecting stable but significant operational challenges.
- Other hazards, including **Extreme Winds & Storms**, **Rainfall Flooding**, and **Riverine Flooding**, show **0 assets** at high risk across all timeframes, suggesting comparatively lower exposure under SSP5-8.5 scenario.

Executive Summary – Physical impacts and High-Level Recommendations (1/2)

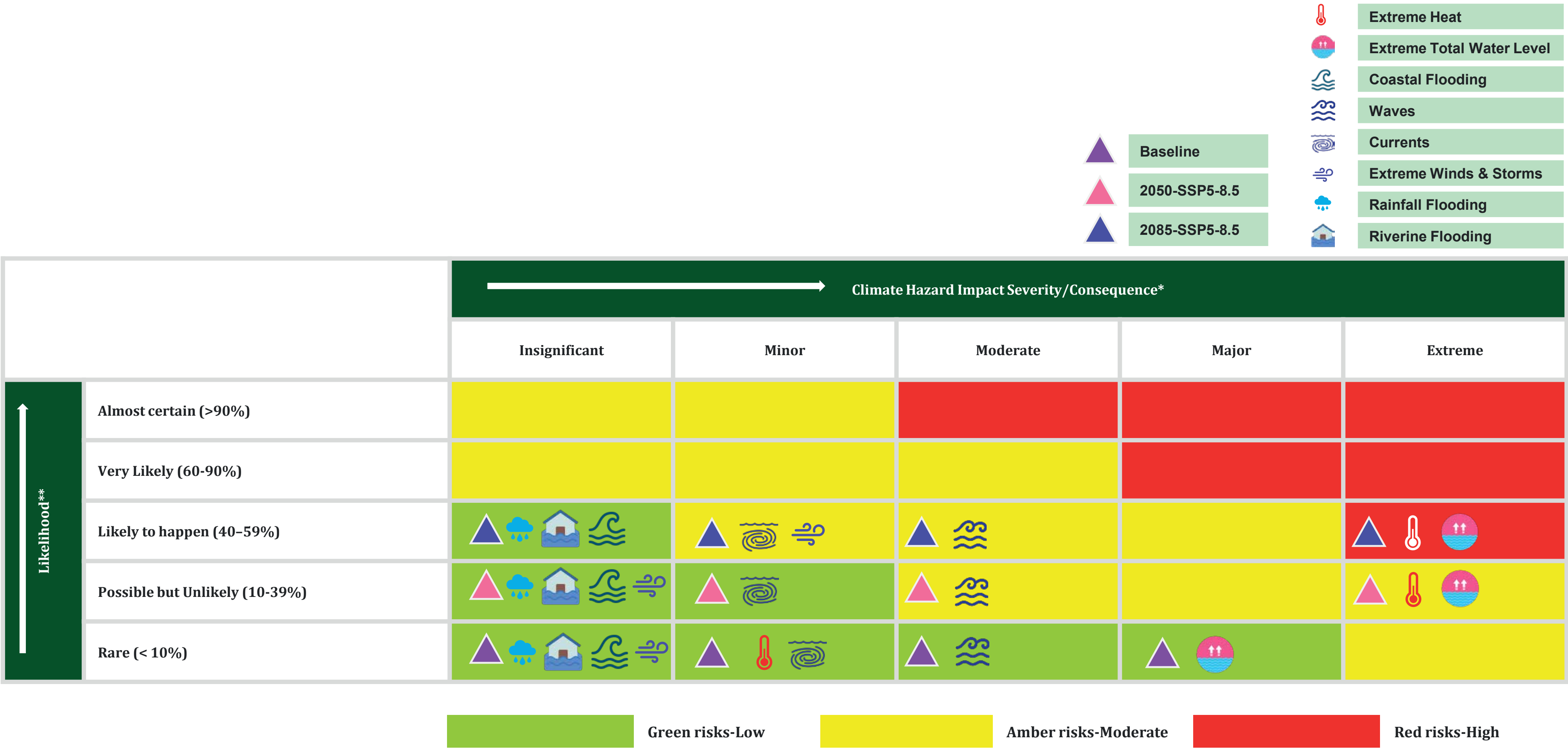
The overall physical risk level is projected to increase from baseline to 2050s and 2085s with higher increase under the high emissions scenario (SSP5-8.5). Five major climate hazards are identified from this assessment across different timeframes:

Hazard	Affected Assets	Potential Physical and Financial Impacts	High-level Recommendations
Extreme heat	Extreme heat risk shows a pronounced upward trend. 02. Building: Data Center-Nearshore, 19. Power: Substation DG, 31. Warehouses: Fuel, 32. Warehouses: Fuel Nearshore, 12. Manufacturing: Chemicals, 26. Telecommunications Services: Nearshore, 09. Equipment: Nearshore, 30. Warehouses: Dock Depot, 06. Building: Operational, 07. Building: Operational-Nearshore, 25. Telecommunications Services, 21. Power: Substation Nearshore, 28. Warehouses: Covered, 18. Power: Substation, 33. Warehouses: Uncovered	**Physical Impacts:** ❖ Increased cooling demand for indoor areas, leading to higher energy consumption. ❖ Accelerated wear and tear on building materials and equipment. ❖ Elevated risk of equipment failure in data centers, telecom systems and sensitive electronics due to overheating. ❖ Greater likelihood of electricity shortages, fires, and explosions, causing operational disruptions. ❖ Health and safety risks for site personnel (e.g., heat stroke), reducing workforce efficiency. **Financial Impacts:** ❖ Operating Costs: Higher energy bills for cooling and increased maintenance expenses. ❖ Capital Expenditure: Investment in advanced cooling systems and heat-resistant materials. ❖ Business Interruption: Revenue loss from downtime and reduced productivity. ❖ Insurance Premiums: Increased coverage costs due to elevated fire and equipment failure risks.	❖ Implement advanced cooling systems for data centers and critical indoor areas. ❖ Upgrade building materials to heat-resistant specifications. ❖ Enhance energy efficiency through insulation and smart cooling technologies. ❖ Develop workforce safety protocols (heat stress management, shaded rest areas). ❖ Install backup power systems to prevent outages during peak demand.
Extreme Total Water level	Extreme Total Water Level risk shows a clear upward trend under the SSP5-8.5 scenario. 21. Power: Substation Nearshore, 23. Revetment: Onshore, 08. Drainage system, 01. Berth: Nearshore, 32. Warehouses: Fuel Nearshore, 11. Jetty: Nearshore, 29. Warehouses: Covered Nearshore, 27. Transport: Waterways, 26. Telecommunications Services: Nearshore, 09. Equipment: Nearshore, 34. Warehouses: Uncovered Nearshore, 05. Building: Office Nearshore, 03. Building: Maintenance Repair Nearshore, 13. Manufacturing: Food Nearshore, 07. Building: Operational-Nearshore	**Physical Impacts:** ❖ Inundation of nearshore assets such as berths, wharves, warehouses, and operational buildings. ❖ Structural instability and accelerated deterioration of foundations due to prolonged water exposure. ❖ Corrosion of metal components and electrical systems, reducing asset lifespan. ❖ Increased risk of damage to power substations and telecommunication infrastructure. ❖ Disruption of cargo handling and vessel operations, leading to operational delays. **Financial Impacts:** ❖ Operating Costs: Higher maintenance expenses for corrosion control and structural repairs. ❖ Capital Expenditure: Significant investment in flood barriers, elevation works, and reinforcement of critical infrastructure. ❖ Business Interruption: Revenue loss from downtime during extreme water-level events and recovery periods. ❖ Insurance Premiums: Increased coverage costs due to elevated flood and structural failure risks.	❖ Construct robust flood barriers and storm surge protection systems. ❖ Elevate critical infrastructure (power substations, control rooms, warehouses). ❖ Reinforce foundations and structural components to withstand prolonged water exposure. ❖ Develop emergency response and continuity plans for operational downtime. ❖ Integrate real-time water-level monitoring systems for early warning.

Executive Summary – Physical impacts and High-Level Recommendations (2/2)

Hazard	Affected Assets	Potential Physical and Financial Impacts	High-level Recommendations
Waves	Wave risk remains stable across all timeframes, showing no projected change under the SSP5-8.5 scenario. 23. Revetment: Onshore, 15. Manufacturing: LPG Nearshore, 13. Manufacturing: Food Nearshore, 34. Warehouses: Uncovered Nearshore, 03. Building: Maintenance Repair Nearshore, 07. Building: Operational-Nearshore, 29. Warehouses: Covered Nearshore, 02. Building: Data Center-Nearshore, 08. Drainage system, 26. Telecommunications Services: Nearshore	**Physical Impacts:** ❖ Continuous wave action causing erosion of revetments and nearshore structures. ❖ Structural stress on berths, wharves, and mooring systems. ❖ Damage to protective barriers and coastal infrastructure over time. ❖ Increased risk of operational delays during high wave conditions. **Financial Impacts:** ❖ Operating Costs: Ongoing maintenance for revetments and breakwaters. ❖ Capital Expenditure: Periodic reinforcement or replacement of coastal defenses. ❖ Business Interruption: Potential delays in vessel berthing and cargo handling during severe wave events.	❖ Maintain and reinforce revetments and breakwaters to reduce erosion. ❖ Design berths and mooring systems to withstand wave-induced stress. ❖ Schedule vessel operations based on wave forecasts to minimize delays. ❖ Periodic inspection and maintenance of coastal structures.
Currents	Currents risk remains unchanged across all timeframes under the SSP5-8.5 scenario. 11. Jetty: Nearshore, 17. Openwater: Nearshore, 27. Transport: Waterways, 01. Berth: Nearshore, 36. Wharf: Nearshore, 09. Equipment: Nearshore, 23. Revetment: Onshore	**Physical Impacts:** ❖ Strong currents affecting navigation safety and vessel maneuverability. ❖ Increased strain on mooring systems and berthing infrastructure. ❖ Higher risk of vessel collisions and operational accidents. ❖ Potential damage to underwater structures and pipelines. **Financial Impacts:** ❖ Operating Costs: Investment in current monitoring systems and enhanced mooring equipment. ❖ Capital Expenditure: Reinforcement of berthing and mooring infrastructure. ❖ Business Interruption: Losses from shipping delays and potential accidents. ❖ Insurance Premiums: Increased coverage costs for navigation-related risks.	❖ Install current monitoring and alert systems for navigation safety. ❖ Upgrade mooring and berthing infrastructure to handle strong currents. ❖ Develop operational protocols for vessel movement during high-current conditions. ❖ Train personnel on emergency maneuvers and contingency planning.
Coastal Flooding	Coastal flooding risk shows a slight upward trend under the SSP5-8.5 scenario. 08. Drainage system, 24. Sewerage system, 34. Warehouses: Uncovered Nearshore, 03. Building: Maintenance Repair Nearshore, 15. Manufacturing: LPG Nearshore, 23. Revetment: Onshore, 21. Power: Substation Nearshore	**Physical Impacts:** ❖ Inundation of nearshore operational buildings, warehouses, and sewerage systems. ❖ Corrosion and structural degradation of exposed metal and concrete components. ❖ Damage to electrical systems and utilities located at or below ground level. ❖ Increased vulnerability of uncovered storage areas and maintenance facilities. ❖ Disruption of port operations and cargo handling during flood events. **Financial Impacts:** ❖ Operating Costs: Higher maintenance and repair expenses for flood-damaged assets. ❖ Capital Expenditure: Significant investment in coastal defenses, elevation works, and waterproofing measures. ❖ Business Interruption: Revenue loss from operational downtime and recovery delays. ❖ Insurance Premiums: Increased coverage costs due to elevated flood risk and structural failure exposure.	❖ Implement coastal defense structures (revetments, seawalls, breakwaters). ❖ Relocate or elevate vulnerable nearshore assets where feasible. ❖ Waterproof electrical systems and install submersible pumps for rapid drainage. ❖ Plan for temporary relocation of operations during severe flood events.

Executive Summary – Climate Change Risk Criteria Assessment Matrix



*Climate Hazard Impact Severity / Consequence, indicates the extent of material impact likely to happen under 8 hazard conditions. This is adapted from Westports Enterprise Risk Register Map.

**Indicates the probability of occurrence at any given year (e.g., 1-in-100 year = 1%). It will be assumed the during the indicated time periods, each separate return period events represent a discrete event that happen at least once. Using this basis, cumulative probability (or likelihood) of 100-year return period over the time periods (or time horizons) can be estimated.

Executive Summary – Quantify Financial Impact of Physical Risks

The following two physical risks have been quantified based on Phase 1 results:

- **Impact of Extreme Heat on Electricity Cooling Cost (OPEX).**
- **Impact of Extreme Total Water Level on Revenue.**

Comparatively, the **anticipated financial impact*** of extreme total water level is significantly larger than that of extreme heat. This is related to the potential of business interruption caused by higher projected water level.

Anticipated Financial Impacts due to Extreme Heat and Extreme Total Water Level (RM)*

Time Horizon	Extreme Heat	Extreme Total Water Level
2050	RM 1,710,000	RM 29,240,000 to 34,750,000 (1.50 to 1.78% of FY2024 revenue)
2085	RM 4,201,000	RM 87,280,000 to 96,790,000 (4.48 to 4.96% of FY2024 revenue)

Hence, it is crucial to enhance the climate resilience against future projected extreme water levels.

Note: **All financial data provided by Westports were from FY2024. Therefore, the anticipated financial impacts represent additional financial impacts compared to FY2024 figures.* ***Note that business growth and inflation are not considered in the quantification. In other words, the results here reflect the financial impacts on the current operation under future climate conditions.***

Project Background and Objectives

Preparing a science-based context for climate disclosure through four key steps, with stakeholder (ranging from operations/facilities managers to management functions in risk, finance, and management) validation at each stage.

1 Comprehensive Physical Risks Assessment using IPCC AR6

- Site visit and asset exposure validation
- Detailed assessment of physical risks using IPCC AR6 projections
- Scenario analysis across relevant climate futures

Phase 1 Task

- ✓ Site visit
- ✓ Reassessment of Physical Risk with AR6
- ✓ Scenario analysis of physical risks

2 Quantify Financial Impact of Physical Risks

- Financial quantification of potential climate impacts
- Identification of relevant adaptation and resilience measures
- Evaluation of adaptation measures/ planning

Phase 2 Task

- ✓ Financial Quantification of Physical Climate Risks
- ✓ Identification of Relevant Adaptation and Resilience Measures
- ✓ Evaluation of adaptation measures/ planning

3 Develop Climate Disclosure Reporting

- Preparation of climate disclosure, covering report aligned with stakeholder expectations and global frameworks

Phase 3 Task

- ✓ Climate disclosure report development

- To better understand how climate hazards may impact the processes within Westports' asset, ERM conducted a site visit to look at how climate hazards may impact the processes, infrastructure, and/or equipment within the asset.
- ERM reviewed past climate risk assessments, which include Environmental Impact Assessments (EIAs), latest CCRA reports, risk matrix defining materiality, and any TCFD/NSRF/IFRS S2-aligned reports.
- Physical risk reassessment with IPCC AR6 have been undertaken to assess the physical risks and hazard types that are relevant to the assets/infrastructures, which include extreme heat, extreme rainfall and flooding, extreme winds (including wind direction and speed), ocean waves (including wave height and wind current), sea level rise, thunderstorms, and visibility.
- Key processes, infrastructure, and/or equipment that will be impacted by agreed-upon key climate hazards will also be identified. These are chosen based on their importance towards Westports' underlying financial performance and their exposure to the agreed-upon key climate hazards.

- ERM has developed two financial models focusing on extreme heat and extreme total water levels to quantify the potential impacts of the climate hazards shortlisted in Phase 1 on Westports' critical processes, infrastructure, and equipment. The financial models assess impacts across two future time horizons (2050 and 2085) under the IPCC SSP5-8.5 scenario.
- Based on the results of the site-specific physical risks assessment, ERM assessed and identified pertinent and effective response measures specific to Westports' assets.
- ERM conducted a desktop review to develop a long list of up to three adaptation options per prioritized climate hazard. The provisional longlist of adaptation options will be reviewed by Westport, and a final list of items will be agreed upon to carry through to appraisal.
- ERM has compiled the site-specific physical risk assessment results, identified adaptation measures, and overall recommendations for Westports' management in a PPT slide deck.
- ERM has provided high-level cost estimates on the adaptation measures.
- ERM developed the key KPIs to be tracked for identified adaptation and mitigation plans to provide the Company with the ability to measure the effectiveness of the actions proposed.

- ERM drafted climate disclosure in line with TCFD/NSRF/IFRS S2 requirements to be included in the Company's Sustainability / Integrated Report or to be published as a standalone climate disclosure.

Review of 2022 Westports Climate Change Assessment*

Westports Climate Change Assessment – Review and Future Recommendations

- The 2022 DHI's Climate Change Assessment evaluated how projected climatic and metocean changes may affect Westports' existing and planned infrastructure and operations over a **60-year horizon (to ~2080)**.
- The study followed PIANC (2020) Climate Change Adaptation Planning Guidelines and focused on **winds, waves, water levels/sea-level rise, currents, rainfall, and temperature**, followed by an initial vulnerability and risk screening.

Key Findings by Hazard

- **Sea Level Rise (SLR): Primary Long-Term Risk**
  - Projected SLR of **~0.47–0.65 m by 2080** (central (median) to 83% confidence).
  - 100-year extreme water levels increase to **~6.48–6.66 mCD**, significantly reducing berth freeboard over time.
  - SLR is the **dominant driver of long-term structural and operational risk** for quay structures.
- **Winds & Waves: Generally Minor Changes with Uncertainty in Extremes**
  - Mean wind and wave changes are **small under low–medium scenarios**.
  - Under high-emission scenarios, **seasonal increases in peak wind and wave heights** (especially during the NE monsoon) are possible.
  - **Squall-related extremes remain highly uncertain** due to modelling limitations but cannot be dismissed operationally.
- **Rainfall: Higher Extremes, Longer Dry Spells**
  - No clear trend in annual rainfall totals.
  - **Intensity of extreme rainfall increases** (higher 1-day maxima; higher contribution from very wet days).
  - **Longer dry spells** increase operational stress on drainage, utilities, and maintenance regimes.
- **Temperature: Clear and Consistent Increase**
  - Mean temperature increase of **~1.6–2.6°C by 2080**, depending on scenario.
  - **Heatwaves are more frequent, longer, and more intense**, with potential compounding from urban heat effects.
  - Implications for **workforce safety, equipment reliability, and energy demand**.
- **Currents: Negligible Change**
  - Future changes in tidal and residual currents are **minor** and not expected to materially affect port operations.

Forward-Looking Recommendations

1. Move from Screening to Asset-Level Adaptation Planning

2. Climate-Proof New Developments

- Design all new berths and coastal structures for **future water levels (≥2080 conditions)**, potentially requiring **higher deck levels and enhanced wave protection**.

3. Strengthen Drainage and Flood Resilience

- Implement targeted upgrades to **low-lying drainage nodes and critical electrical infrastructure**.

4. Establish a Permanent Metocean Monitoring Program

- Use data for **early warning, operational decision-making, and periodic risk reassessment**.

5. Update the Climate Risk Assessment Regularly

- Refresh the assessment **every 5 years**, or earlier when **high-resolution AR6 downscaled data for Malaysia becomes available**.
- Align future updates with **ESG reporting, capital investment planning, and insurance risk reviews**.

Source: * Westports Climate Change Assessment Report 2022.pdf
Climate Change Adaptation Planning for Ports and Inland Waterways – PIANC (2020)

Climate Change Physical Risk Re-assessment – Key Deliverables

A Climate Change Physical Risk Re-assessment has been undertaken following the recommendations of the previous assessment and subsequent site visit findings. The study utilises **IPCC AR6 high-resolution downscaled climate data for Malaysia** to robustly evaluate future physical climate risks relevant to Westports' assets and infrastructure.

Key Climate Hazards

- The assessment covers a comprehensive range of **key climate hazards** that potentially affect Westports assets, including:
  - **Extreme Heat**
  - **Extreme Winds & Storms**
  - **Rainfall Flooding**
  - **Riverine Flooding**
  - **Coastal Flooding**
  - **Extreme Total Water Level**
  - **Waves**
  - **Currents**
- **Detailed studies** have been carried out to address additional hazards and operational stressors that are critical to port performance and asset resilience, including:
  - **Swells and wave amplification**
  - **TEU (Twenty-foot Equivalent Unit)- related operational disruptions**
  - **Sedimentation and maintenance dredging implications**
  - **Localised flooding within operational and hinterland areas**
  - **Squall events and short-duration high-intensity wind systems**
  - Other site-specific hazards with the potential to affect the port's **structural integrity and operational continuity**
- **Financial impact models** have been developed for each of the key climate hazards to quantify potential impacts on **Westports' core processes, infrastructure assets, and critical equipment**, supporting risk-informed decision-making and long-term investment planning.
- A **comprehensive climate-related disclosure package**, aligned with **IFRS S2 and the Malaysian National Sustainability Reporting Framework (NSRF)**, has been prepared, capturing:
  - **Identified climate hazards and physical risks**
  - **Asset-level and operational exposure**
  - **Financial implications and risk pathways**
  - **Alignment with regulatory and best-practice disclosure expectations**

Chapter 1

COMPREHENSIVE PHYSICAL RISKS ASSESSMENT USING IPCC AR6

Site Visit – Asset Condition and Vulnerability Assessment

PORT ASSETS AND OPERATIONS

Port Assets and Operations

ERM conducted a 2-day site visit on 6th and 7th August 2025 to look at how climate hazards may impact the operations, infrastructure, and/or equipment within the asset.

Key Assets and Operational Processes

- **Berthing & Unberthing:** Main operations involve berthing/unberthing cargo ships.
- **Berths:** 24 total (4 conventional cargo, 20 container).
- **Support Assets:**
    - 9 tugboats (45–70 tons pulling capacity).
    - 5 pilot boats for pilot transfer.
- **Mooring:** Manual mooring gangs secure vessels during loading/unloading.

Operational Challenges

- **Berthing Requirements:**
    - Tugboat needs vary by vessel size (1–4 tugs per guidelines).
    - Additional support during adverse weather or technical issues.
- **Weather-Related Disruptions:**
    - Swell events (>3m) cause pilot boarding delays (8–12 hrs).
    - High winds (>15 knots) or poor visibility halt operations; past incidents linked to container instability.
- **Climate Factors:**
    - Haze historically caused rare disruptions; minimal recent impact.

Facility Management & Maintenance

- **Dredging:** Every 18 months to maintain depth.
- **Sedimentation Surveys:** Monthly; quarterly reports to authorities.
- **Crane Operations:** Halted at wind >15 knots or poor visibility; incidents of empty containers falling in strong winds.
- **Corrosion Control:** Special coatings applied; repainting every ~10 years.

Port Assets and Operations (Cont'd)

Operational & Personnel Risks

- **Traffic:** ~50 vessel movements/day (~8,000 ships/year).
- **Heat:** No stoppages due to extreme heat; operators have air-conditioned cabins.
- **Flooding:** Highest tide (5.6m) has never flooded deck.
- **Environmental Risks:** Oil spills, waste dumping, tsunami/earthquake risks minimal but monitored.

Equipment & Maintenance

- **Cranes:**
  - Quay Cranes (**QCs**) auto-shutdown at wind >30 m/s; Rubber-Tyred Gantry Crane **(RTGs)** more stable.
  - RTGs equipped with anti-sway systems; QCs rely on operator skill.
- **Maintenance:** Weatherproof coatings; repaint every 10 years.

Drainage System

- **Liquid Bulk Terminal:** ~1-1.5m deep drainage.
- **Container Yard:** Slotted drainage integrated into pavement; flooding usually due to blockages.

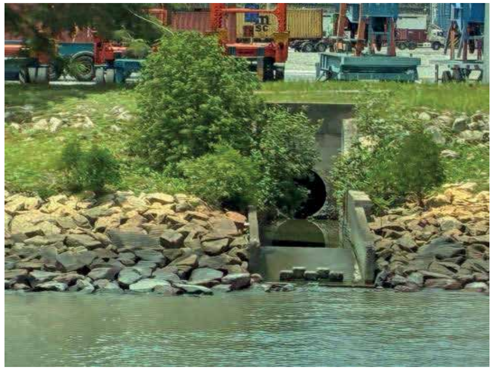
Electrical Operations & Power Supply

- **Redundancy:** Dual power feeds; substations critical for cranes and reefers.
- **Backup:** Mobile generators (3–4 hrs); some reefers last up to 12 hrs.
- **Solar Panels:** On warehouse roofs; supply ~5% of total power.

Climate & Flood Resilience

- **Site Levels:** Current and future reclamation aim for ~8.2m elevation.
- **Drainage Capacity:** Designed for rainwater and treated wastewater; historical reliability high.
- **Critical Assets:** Substations near sea require flood protection assessment.



Port Assets and Operations (Cont'd)

Take-Away Message: Materiality of Risks

Although day-to-day operations at the port are generally stable and resilient, the materiality of risks lies in their potential to cause high-impact operational, financial, or safety disruptions, even if such events are infrequent. Several risk categories remain operationally significant due to their system-critical nature and the compounding effects of climate and operational stressors:

Critical Infrastructure = High Consequence

Assets such as **substations, quay cranes, RTGs, power feeds, and tugboats** form the backbone of port operations. Even a single point of failure—particularly in power supply or marine assets—can halt ship movements or container handling, triggering:

- Large vessel delays
- Berth congestion
- Revenue loss and penalty exposure
- Safety risks for workers and marine operations

Thus, risks related to these assets remain **material** even if incidents are rare.

Weather-Driven Operational Thresholds Are Increasingly Tested

Wind, swell, and visibility thresholds directly govern safe operating conditions. While shutdowns are not frequent, the consequences of exceeding limits (e.g., 15-knot wind thresholds for crane operations, >3m swell for pilot transfer) can result in:

- Multi-hour to multi-day operational losses
- Safety incidents such as container sway or equipment instability
- Increased insurance claims and vessel diversion risks

Swell-driven pilot delays and past crane damage highlight that **climate-sensitive risks are real and potentially escalating**.

Compounding Hazards Can Overwhelm Historically Sufficient Systems

Flooding has not historically disrupted port operations, but the combination of:

- Higher rainfall intensities
- Blocked or capacity-limited drainage
- Higher tide levels
- More climate volatility may expose vulnerabilities not previously observed.

This does not indicate current failure but demonstrates **material future exposure** that requires anticipatory planning.

Operational Dependencies Increase Risk Amplification

Many systems are interdependent:

- If **power** is lost, cranes stop.
- If cranes stop, **RTG and yard movements** are disrupted.
- If pilots cannot board, **vessels cannot enter**, regardless of berth availability.

These interdependencies make even unlikely events **material** because their cascading impacts can be large.

Financial Exposure Is Driven by Low-Likelihood but High-Impact Events

Historical incidents—e.g., the 2019 vessel collision damaging cranes—show that:

- Financial losses can involve major repair costs
- Business interruption claims can be significant
- Downtime carries high opportunity cost

While probabilities remain low, the **cost severity** elevates the materiality of operational and climate risks.


Container Yard

Westports Asset Grouping Framework for Climate Risk Screening

- The **199 individual assets** were consolidated into **36 asset group types** based on a combination of **asset location (e.g., nearshore, onshore, offshore)** and **functional role in day-to-day port operations** (e.g., berthing, power supply, drainage, warehouses, telecommunications).
- Assets performing **similar operational functions** and experiencing **comparable physical climate exposure** were grouped together to ensure consistency in climate-risk screening and to reflect how risks are experienced in practice rather than at an individual-asset level.
- This grouping approach enables a **manageable, exposure-based assessment framework**, allowing climate hazards to be evaluated efficiently across asset types while preserving operational relevance for port activities.

No.	Asset Group Types	Total Assets
1	Berth: Nearshore	39
2	Building: Data Center-Nearshore	1
3	Building: Maintenance Repair Nearshore	2
4	Building: Office	4
5	Building: Office Nearshore	1
6	Building: Operational	3
7	Building: Operational-Nearshore	1
8	Drainage system	1
9	Equipment: Nearshore	5
10	Equipment: Onshore	10
11	Jetty: Nearshore	2
12	Manufacturing: Chemicals	1
13	Manufacturing: Food Nearshore	4
14	Manufacturing: LPG	1
15	Manufacturing: LPG Nearshore	1
16	Manufacturing: Other	2
17	Openwater: Nearshore	2
18	Power: Substation	13
19	Power: Substation DG	1
20	Power: Substation NearRiver	1
21	Power: Substation Nearshore	12
22	Power: Substation Solar	1
23	Revetment: Onshore	14
24	Sewerage system	1
25	Telecommunications Services	11
26	Telecommunications Services: Nearshore	10
27	Transport: Waterways	1
28	Warehouses: Covered	14
29	Warehouses: Covered Nearshore	1
30	Warehouses: Dock Depot	6
31	Warehouses: Fuel	1
32	Warehouses: Fuel Nearshore	1
33	Warehouses: Uncovered	3
34	Warehouses: Uncovered Nearshore	5
35	Water Supply	4
36	Wharf: Nearshore	19
	Total	199

Overview – Climate Scenarios and Physical Hazards

ERM has undertaken a high-level physical risk screening of 36 Asset Group Types (199 assets) across the Westports area using ERM's proprietary Global Climate Database (GCD). The assessment covers:

One (1) shared socioeconomic (**SSP**) scenarios* from the sixth assessment report (**AR6**) of the **Intergovernmental Panel on Climate Change (IPCC)** to account for the uncertainty of future climate change:

SSP5-8.5# – a high emissions (business-as-usual / stress-test) scenario;

Three (3) timeframes representing 30-year climatic conditions from present-day to different periods in the 21st century:

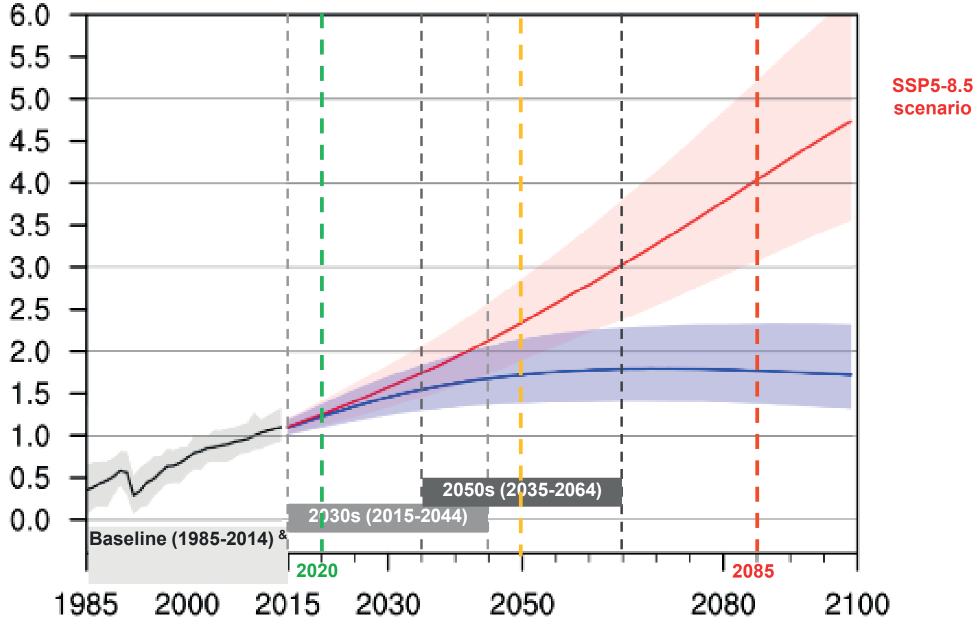
Baseline*** present-day climatic condition and a reference period of future climate.

2050s and **2085s** – short-to-medium term and medium-to-long-term climate change.

Eight (8) physical hazard types that potentially affect Westports assets:

- **Extreme Heat**
- **Extreme Winds & Storms**
- **Rainfall Flooding**
- **Riverine Flooding**
- **Coastal Flooding**
- **Extreme Total Water Level**
- **Waves**
- **Currents**

Global Warming above 1850-1900 Level (unit: °C)



Observed and Projected Global Warming Trajectories Under SSP5-8.5 (Baseline to 2100)

Time series of global surface air temperature above 1850-1900 level under IPCC SSP5-8.5 scenarios. The solid line and shading indicate the median and the 5% to 95% likelihood based on IPCC AR6 climate models. The three (3) time horizons considered in this assessment are labeled at bottom.

#The high-emissions scenario (SSP5-8.5), representing a business-as-usual trajectory, was selected for the assessment based on guidance from Westports' management.

**The climate scenarios in IPCC AR6 report are shared socioeconomic pathways (SSPs) in IPCC AR6 report incorporate socioeconomic conditions and greenhouse gas emissions.*

***Redrawn from Figure SPM. 8 in IPCC AR6 Summary for Policymakers (https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf), where the data are available at Centre for Environmental Data Analysis Archive (https://data.ceda.ac.uk/badc/ar6_wg1/data/spm/spm_08/v20210809/panel_a)*

****1985-2014 is the standard baseline period that refers to the last 30 years of the historical run in IPCC AR6 models, but the baseline period is different for some of the climate indicators.*

Overview – Risk Score Calculations

Asset-level **risk scores** will be used to determine the risk level of individual **physical hazard types** as well as the overall risk level of **an asset** across different timeframes and climate scenarios. The risk scores are calculated through the following four stages*:

1. **Collection of asset coordinates/addresses and asset type;**
2. **Extraction of physical hazard data** for each of **8 hazard types** during **baseline period** and **2050** and **2085;** timeframes from ERM's Global Climate Database (GCD) or publicly available datasets based on asset coordinates (location dependent); then the data are **normalized** to a 0 to 1 range;
3. **Determination of unmitigated exposure rating multiplier** (0 to 10 range) for each hazard type based on asset type (location independent)
4. **Calculation of hazard type risk scores** by combining normalised data and exposure rating multiplier (0 to 10 range).

The **hazard type risk scores** will be used to identify key physical risks at individual assets. The risk scores of 8 climate hazard types will also be **aggregated** to deduce the assets with higher overall physical climate risk. Five (5) risk levels categorise all risk scores – minimal (0 to 1), low (1 to 2), moderate (2 to 3), high (3 to 4), and very high (4 to 10).

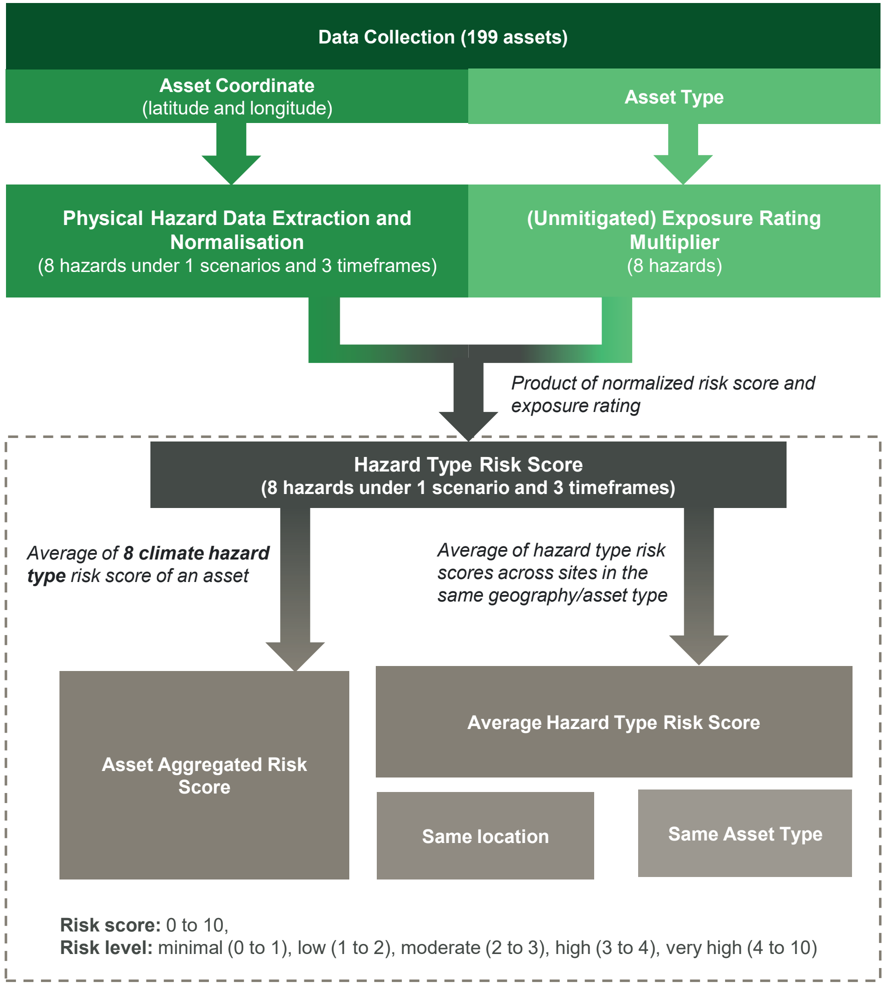
Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

The procedures of risk score calculation are illustrated by a schematic diagram on the right.

Note that this approach assumes no mitigation measures are in place.

**Details of methodology are presented in Appendix A, and the rationale of exposure ratings is provided in Appendix B .*

Schematic Diagram of Risk Score Calculation



Physical Risk Methodology

For each asset, risk scores are calculated for **eight (8) hazards (Hazard Type Risk Score)** for the **baseline period**, **2050** and **2085** timeframe under **SSP5-8.5** scenarios. The hazard type risk score is aggregated to a risk score representing the overall physical hazard experienced by the asset (Asset Aggregated Risk Score).

Hazard Type Risk Score at an asset = **Normalized Indicator** at asset location × **Exposure Rating Multiplier** of asset type for specific hazard

$$\textbf{Asset Aggregated Risk Score} = \frac{\textbf{Sum of Hazard type Risk Score}}{\textbf{Number of Hazards}}$$

Similarly, the hazard type risk scores would be aggregated over all assets.

$$\textbf{Hazard Aggregated Risk Score for all assets} = \frac{\textbf{Sum of Hazard type Risk Score}}{\textbf{Number of Assets}}$$

Risk scores are categorized into five categories (minimal/low/moderate/high/very high) for a **qualitative assessment of physical hazard level**:

Categorization	Normalized Risk Score	Mid-Point of Exposure Rating Multiplier	Hazard Type/Aggregated Risk Score
Minimal	0 to 0.2	× 5 =	0 to 1
Low	0.2 to 0.4		1 to 2
Moderate	0.4 to 0.6		2 to 3
High	0.6 to 0.8		3 to 4
Very High	0.8 to 1		4 to 10*

**Threshold of 'very high' risk score is determined by the multiplication of normalized indicator x mid-point of exposure rating (4 = 0.8 x 5), and the upper-limit is determined by multiplication of maximum normalized risk score and maximum exposure rating (10 = 1 x 10).*

To analyse how much hazard type/asset aggregated risk score changes from the baseline period to a future timeframe, a difference is calculated between the future timeframes (2050 and 2085) and the baseline period, which is categorized into seven (7) categories representing the direction and magnitude of change.

Categorization	Hazard Type Risk Score	Asset Aggregated Risk Score
Significant Decrease	-10 to -2	-10 to -1
Moderate Decrease	-2 to -1	-1 to -0.5
Minimal Decrease	-1 to -0.25	-0.5 to -0.125
No/Limited Change	-0.25 to +0.25	-0.125 to +0.125
Minimal Increase	+0.25 to +1	+0.125 to +0.5
Moderate Increase	+1 to +2	+0.5 to +1
Significant Increase	+2 to +10	+1 to +10

Major Climate Hazards on Asset Group Types

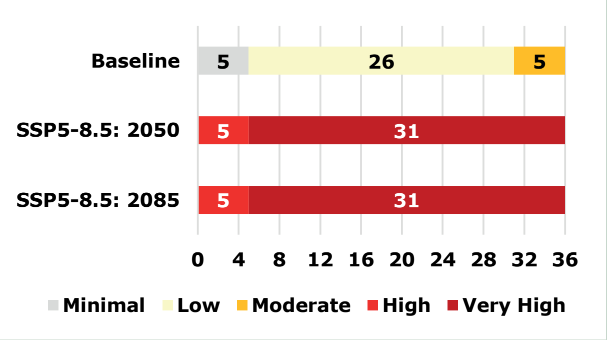
FIVE KEY HAZARDS

Major Physical Hazards – Extreme Heat

Understand the trend and potential impact of major hazards

Trends

- Extreme heat risk shows a pronounced upward trend. During the baseline period, all 36 asset group types were classified under minimal, low, or moderate risk. However, projections indicate a substantial escalation, with all 36 assets by 2050 and 2085 under the SSP5-8.5 scenario.



Warm Spell Duration Index

- The risk of extreme heat is measured by the warm spell duration index. Under climate change, temperature is projected to increase and corresponds to increase in unusually warm days as well as increased severity of extreme heat conditions.

The assets most vulnerable to extreme heat in **2050 and 2085 timeframes under SSP5-8.5 scenario**, ranked in descending order of risk score are:

Rank	Asset Group Type
1	02. Building: Data Center-Nearshore
2	19. Power: Substation DG
3	31. Warehouses: Fuel
4	32. Warehouses: Fuel Nearshore
5	12. Manufacturing: Chemicals
6	26. Telecommunications Services: Nearshore
7	09. Equipment: Nearshore
8	30. Warehouses: Dock Depot
9	06. Building: Operational
10	07. Building: Operational-Nearshore
11	25. Telecommunications Services
12	21. Power: Substation Nearshore
13	28. Warehouses: Covered
14	18. Power: Substation
15	33. Warehouses: Uncovered
16	04. Building: Office
17	35. Water Supply
18	10. Equipment: Onshore
19	20. Power: Substation NearRiver
20	16. Manufacturing: Other
21	29. Warehouses: Covered Nearshore
22	15. Manufacturing: LPG Nearshore
23	34. Warehouses: Uncovered Nearshore
24	14. Manufacturing: LPG
25	05. Building: Office Nearshore
26	13. Manufacturing: Food Nearshore
27	03. Building: Maintenance Repair Nearshore
28	27. Transport: Waterways
29	08. Drainage system
30	22. Power: Substation Solar
31	23. Revetment: Onshore
32	24. Sewerage system
33	17. Openwater: Nearshore
34	36. Wharf: Nearshore
35	01. Berth: Nearshore
36	11. Jetty: Nearshore

Potential Physical and Financial Impacts

Physical Impacts:

- Increased cooling demand for indoor areas, leading to higher energy consumption.
- Accelerated wear and tear on building materials and equipment.
- Elevated risk of equipment failure in data centers, telecom systems and sensitive electronics due to overheating.
- Greater likelihood of electricity shortages, fires, and explosions, causing operational disruptions.
- Health and safety risks for site personnel (e.g., heat stroke), reducing workforce efficiency.

Financial Impacts:

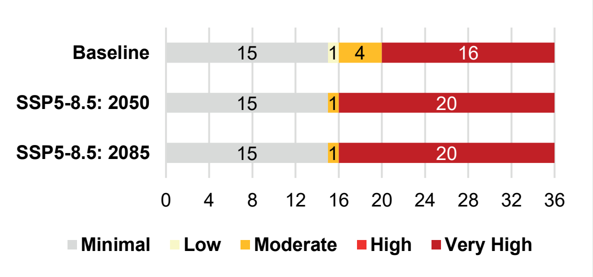
- **Operating Costs:** Higher energy bills for cooling and increased maintenance expenses.
- **Capital Expenditure:** Investment in advanced cooling systems and heat-resistant materials.
- **Business Interruption:** Revenue loss from downtime and reduced productivity.
- **Insurance Premiums:** Increased coverage costs due to elevated fire and equipment failure risks.

Major Physical Hazards – Extreme Total Water Level

Extreme Total Water Level- Combined Ocean Forcing

Trends

- **Extreme Total Water Level risk shows a clear upward trend under the SSP5-8.5 scenario. At baseline, 15 assets (42%) are classified as minimal risk, 1 asset (3%) as low risk, 4 assets (11%) as moderate risk, and 16 assets (44%) as very high risk. By 2050 and 2085, the number of assets at very high risk increases to 20 (56%), while moderate risk decreases to 1 asset (3%) and low risk is eliminated. This indicates a significant escalation in exposure for assets currently at higher risk levels.**



The assets most vulnerable to extreme total water level in **2050 and 2085 timeframes under SSP5-8.5 scenario**, ranked in descending order of risk score are:

Rank	Asset Group Type
1	21. Power: Substation Nearshore
2	23. Revetment: Onshore
3	08. Drainage system
4	01. Berth: Nearshore
5	32. Warehouses: Fuel Nearshore
6	11. Jetty: Nearshore
7	29. Warehouses: Covered Nearshore
8	27. Transport: Waterways
9	26. Telecommunications Services: Nearshore
10	09. Equipment: Nearshore
11	34. Warehouses: Uncovered Nearshore
12	05. Building: Office Nearshore
13	03. Building: Maintenance Repair Nearshore
14	13. Manufacturing: Food Nearshore
15	07. Building: Operational-Nearshore
16	15. Manufacturing: LPG Nearshore
17	02. Building: Data Center-Nearshore
18	24. Sewerage system
19	17. Openwater: Nearshore
20	36. Wharf: Nearshore

Potential Physical and Financial Impacts

Physical Impacts:

- Inundation of nearshore assets such as berths, wharves, warehouses, and operational buildings.
- Structural instability and accelerated deterioration of foundations due to prolonged water exposure.
- Corrosion of metal components and electrical systems, reducing asset lifespan.
- Increased risk of damage to power substations and telecommunication infrastructure.
- Disruption of cargo handling and vessel operations, leading to operational delays.

Financial Impacts:

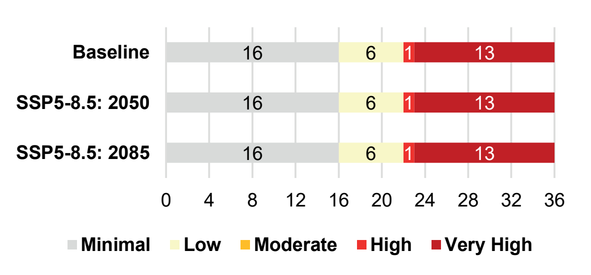
- **Operating Costs:** Higher maintenance expenses for corrosion control and structural repairs.
- **Capital Expenditure:** Significant investment in flood barriers, elevation works, and reinforcement of critical infrastructure.
- **Business Interruption:** Revenue loss from downtime during extreme water-level events and recovery periods.
- **Insurance Premiums:** Increased coverage costs due to elevated flood and structural failure risks.

Major Physical Hazards – Waves

Waves

Trends

- **Wave risk remains stable across all timeframes, showing no projected change under the SSP5-8.5 scenario. During the baseline period, 16 assets (44%) are classified as minimal risk, 6 assets (17%) as low risk, 1 asset (3%) as high risk, and 13 assets (36%) as very high risk. These proportions remain unchanged through 2050 and 2085, indicating persistent exposure for assets currently at high and very high-risk levels.**



Waves

- Waves are assessed using significant wave height projections. Under SSP5-8.5, stronger storms and changing wind patterns increase wave heights, posing risks to marine operations and coastal defenses.

The assets most vulnerable to waves in **2050 and 2085 timeframes under SSP5-8.5 scenario**, ranked in descending order of risk score are:

Rank	Asset Group Type
1	23. Revetment: Onshore
2	15. Manufacturing: LPG Nearshore
3	13. Manufacturing: Food Nearshore
4	34. Warehouses: Uncovered Nearshore
5	03. Building: Maintenance Repair Nearshore
6	07. Building: Operational-Nearshore
7	29. Warehouses: Covered Nearshore
8	02. Building: Data Center-Nearshore
9	08. Drainage system
10	26. Telecommunications Services: Nearshore
11	21. Power: Substation Nearshore
12	32. Warehouses: Fuel Nearshore
13	24. Sewerage system
14	05. Building: Office Nearshore

Potential Physical and Financial Impacts

Physical Impacts:

- Continuous wave action causing erosion of revetments and nearshore structures.
- Structural stress on berths, wharves, and mooring systems.
- Damage to protective barriers and coastal infrastructure over time.
- Increased risk of operational delays during high wave conditions.

Financial Impacts:

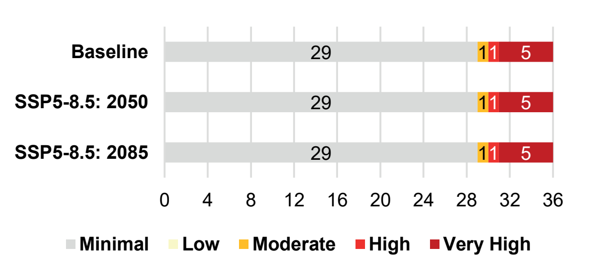
- **Operating Costs:** Ongoing maintenance for revetments and breakwaters.
- **Capital Expenditure:** Periodic reinforcement or replacement of coastal defenses.
- **Business Interruption:** Potential delays in vessel berthing and cargo handling during severe wave events.

Major Physical Hazards – Currents

Currents

Trends

- **Currents risk remains unchanged across all timeframes under the SSP5-8.5 scenario. At baseline, 29 assets (81%) are classified as minimal risk, 1 asset (3%) as moderate risk, 1 asset (3%) as high risk, and 5 assets (14%) as very high risk. These proportions remain consistent through 2050 and 2085, indicating stable exposure with no projected escalation in risk levels.**



Currents

- Ocean current risk relates to changes in nearshore current speeds, which can affect navigation and port operations. Under SSP5-8.5, altered wind and wave dynamics may strengthen currents, increasing operational challenges.

The assets most vulnerable to currents in **2050 and 2085 timeframes under SSP5-8.5 scenario**, ranked in descending order of risk score are:

Rank	Asset Group Type
1	11. Jetty: Nearshore
2	17. Openwater: Nearshore
3	27. Transport: Waterways
4	01. Berth: Nearshore
5	36. Wharf: Nearshore
6	09. Equipment: Nearshore
7	23. Revetment: Onshore

Potential Physical and Financial Impacts

Physical Impacts:

- Strong currents affecting navigation safety and vessel maneuverability.
- Increased strain on mooring systems and berthing infrastructure.
- Higher risk of vessel collisions and operational accidents.
- Potential damage to underwater structures and pipelines.

Financial Impacts:

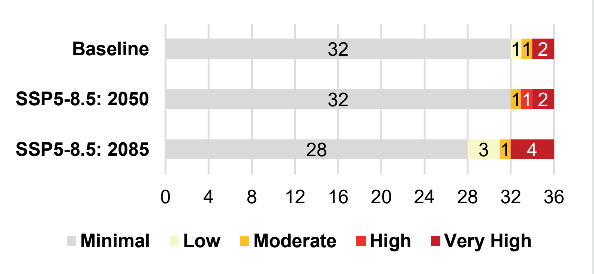
- **Operating Costs:** Investment in current monitoring systems and enhanced mooring equipment.
- **Capital Expenditure:** Reinforcement of berthing and mooring infrastructure.
- **Business Interruption:** Losses from shipping delays and potential accidents.
- **Insurance Premiums:** Increased coverage costs for navigation-related risks.

Major Physical Hazards – Coastal Flooding

Coastal Flooding

Trends

- **Coastal flooding risk shows a slight upward trend under the SSP5-8.5 scenario. At baseline, 32 assets (89%) are classified as minimal risk, 1 asset (3%) as low risk, 1 asset (3%) as moderate risk, and 2 assets (6%) as very high risk. By 2050, the distribution remains largely unchanged, with only a minor shift—low risk is eliminated, and 1 asset moves to high risk. By 2085, minimal risk decreases to 28 assets (78%), low risk increases to 3 assets (8%), and very high-risk doubles to 4 assets (11%). This indicates a gradual increase in exposure for**



Coastal Flooding

- Coastal flooding risk is driven by rising mean sea level combined with storm surge and tidal effects. Under SSP5-8.5, accelerated ice melt and thermal expansion cause significant sea level rise, increasing inundation risk for ports and coastal infrastructure.

The assets most vulnerable to coastal flooding in **2050 and 2085 timeframes under SSP5-8.5 scenario**, ranked in descending order of risk score are:

Rank	Asset Group Type
1	08. Drainage system
2	24. Sewerage system
3	34. Warehouses: Uncovered Nearshore
4	03. Building: Maintenance Repair Nearshore
5	15. Manufacturing: LPG Nearshore
6	23. Revetment: Onshore
7	21. Power: Substation Nearshore

Potential Physical and Financial Impacts

Physical Impacts:

- Inundation of nearshore operational buildings, warehouses, and sewerage systems.
- Corrosion and structural degradation of exposed metal and concrete components.
- Damage to electrical systems and utilities located at or below ground level.
- Increased vulnerability of uncovered storage areas and maintenance facilities.
- Disruption of port operations and cargo handling during flood events.

Financial Impacts:

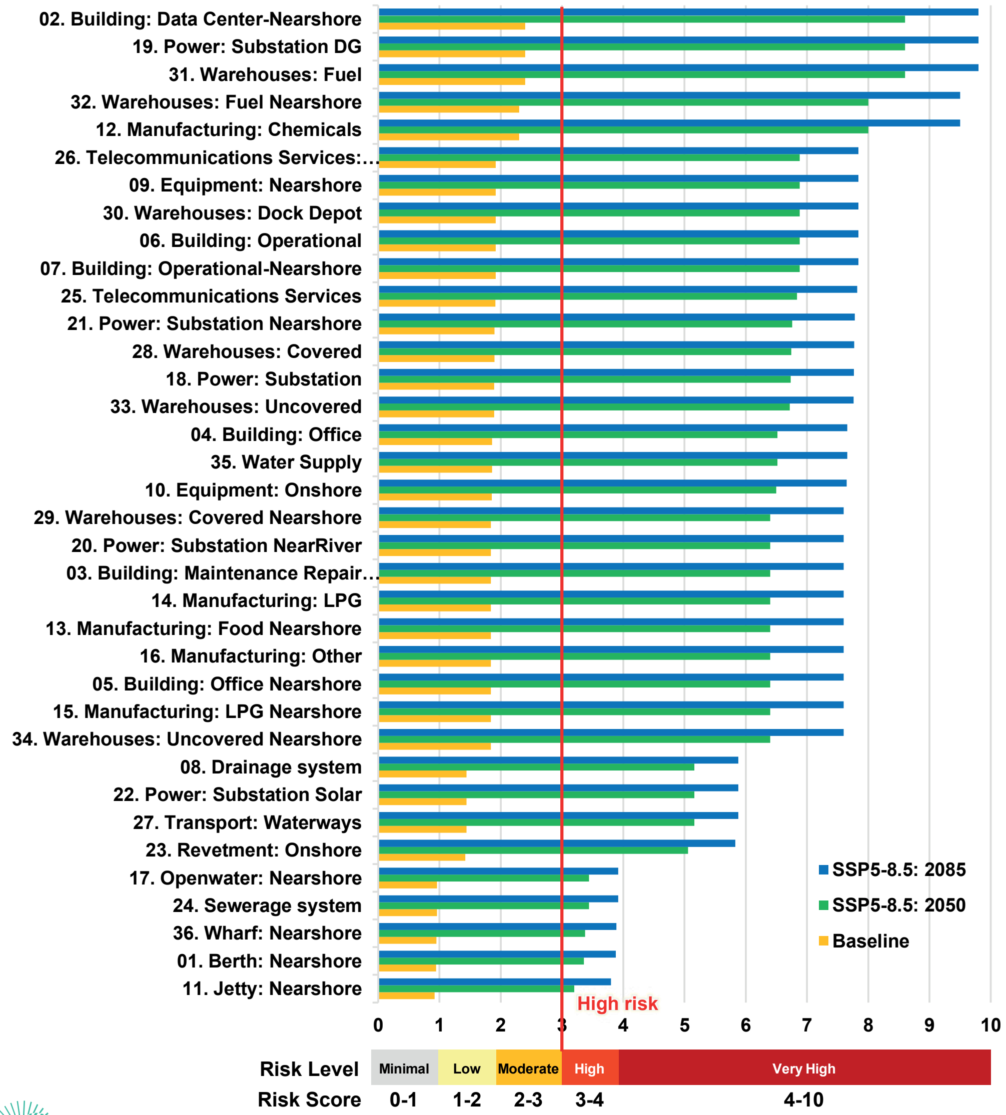
- **Operating Costs:** Higher maintenance and repair expenses for flood-damaged assets.
- **Capital Expenditure:** Significant investment in coastal defenses, elevation works, and waterproofing measures.
- **Business Interruption:** Revenue loss from operational downtime and recovery delays.
- **Insurance Premiums:** Increased coverage costs due to elevated flood risk and structural failure exposure.

Hazard Risk Score

BASELINE AND PROJECTED RISK SCORES BY ASSET GROUP TYPES- FIVE KEY HAZARDS

Extreme Heat: Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table presents the progression of asset-averaged risk scores for **Extreme Heat** across multiple asset types under **baseline** conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score increases sharply from **1.56** at baseline to **5.54** in 2050 and **6.41** in 2085, representing a **72% rise by 2050** and **76% by 2085**. This indicates a significant escalation in heat-related risks over time, moving most assets into the **High** or **Very High risk** categories.

High-Risk Assets

Assets with the greatest projected vulnerability include:

- **Data Centers (Nearshore)** – Risk score surges from **2.40** to **9.80** by 2085.
- **Chemical Manufacturing Facilities** – Increase from **2.30** to **9.50**.
- **Fuel Warehouses** – Jump from **2.30** to **9.80**.

These assets exhibit **Very High** risk levels by 2085, reflecting extreme sensitivity to prolonged heat exposure and operational disruptions.

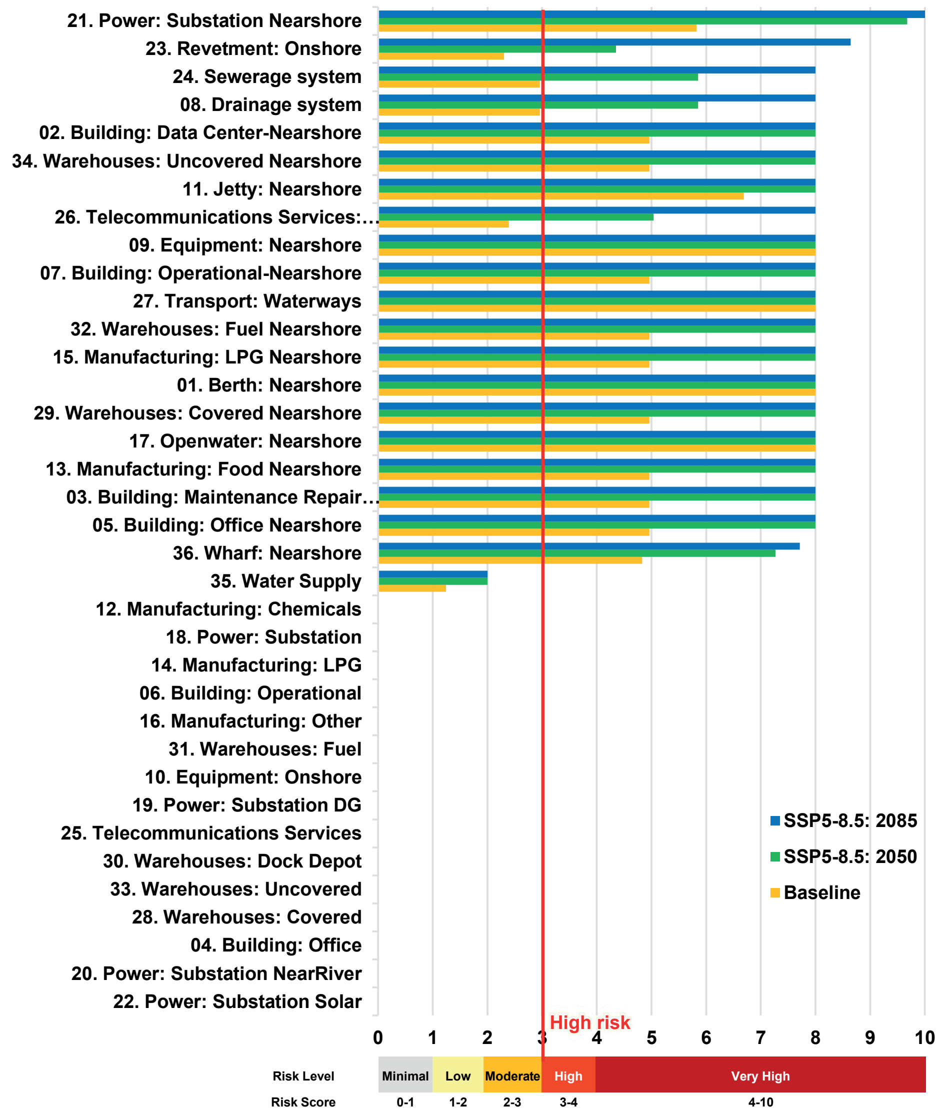
Other Vulnerable Assets

- **Nearshore Buildings**, **Power Substations**, and **Operational Facilities** show substantial increases, reaching scores between **7.0–8.0** by 2085.
- **Telecommunication Services** and **Drainage Systems** also trend upward, signaling potential infrastructure stress.
- Conversely, **Sewerage Systems** and **Open Water Areas** remain relatively lower risk, with scores below **4.0**, though still higher than baseline.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	1.56	5.54	6.41
% Change from Baseline		72%	76%

Extreme Total Water Level : Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table shows the aggregated risk scores for **Extreme Total Water Level** across various asset types under **baseline** conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score increases from **3.53** at baseline to **4.59** in 2050 and **5.12** in 2085, representing a **23% rise by 2050** and **31% by 2085**. This indicates a significant escalation in water-level-related hazards, pushing many assets into the **Very High risk category (≥4)**.

High-Risk Assets

- **Nearshore Berths and Equipment** remain at **8.00** across all periods, indicating persistent **Very High risk**.
- **Operational and Nearshore Buildings** surge from **4.96** to **8.00**, reflecting extreme vulnerability.
- **Warehouses (Fuel Nearshore and Uncovered Nearshore)** also climb to **8.00**, signaling severe exposure.
- **Power Substations Nearshore** increase sharply from **5.83** to **10.00**, becoming one of the most critical assets at risk.

Other Vulnerable Assets

- **Telecommunication Services Nearshore** rise from **2.39** to **8.00**, moving from **Moderate** to **Very High risk**.
- **Water Supply** shows a slight increase from **1.24** to **2.00**, remaining in the **Moderate risk range**.
- **Manufacturing Facilities** (Chemicals, LPG, Food Nearshore) also reach **8.00**, indicating severe exposure.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	3.53	4.59	5.12
% Change from Baseline		23%	31%

Waves : Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types

Key Trends & Risks

The table presents the aggregated risk scores for **Waves** across various asset types under baseline conditions and projected climate scenarios (SSP5-8.5 for **2050** and **2085**).

Overall Trend

The average risk score remains unchanged at **2.32** across all timeframes, indicating **no measurable increase** in wave-related risk for the assessed assets under the projected scenarios. This suggests that wave hazards are **static and not expected to intensify significantly** for these asset types.

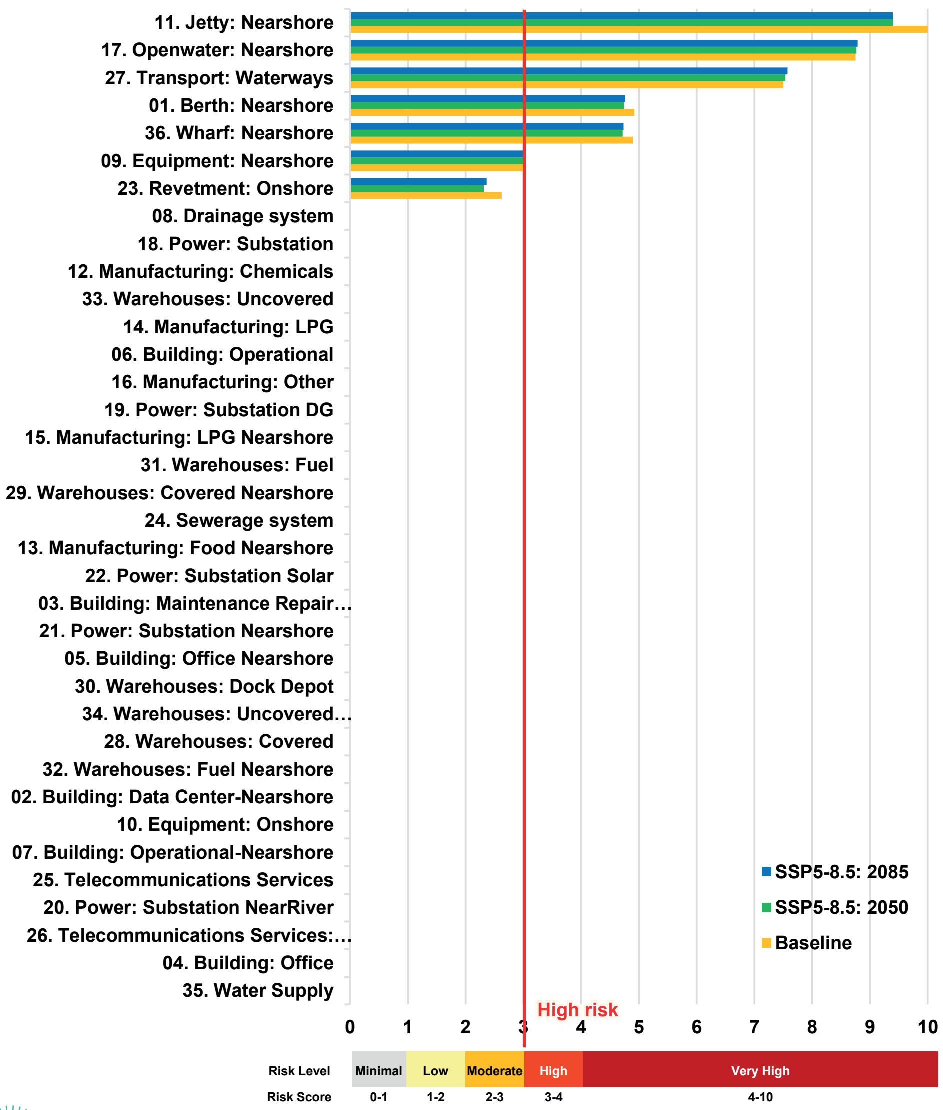
Risk Level

- Several assets already fall within the **Very High risk category (≥4)** at baseline and remain unchanged through 2085:
  - **Buildings (Data Centers, Operational Nearshore)** – consistently at **5.92**.
  - **Power Substations Nearshore – 5.92**.
  - **Warehouses (Covered Nearshore) – 5.92**.
  - **Telecommunication Services Nearshore – 5.92**.
- **Revetment Onshore** remains at **9.86**, indicating extreme vulnerability.
- Other assets, such as **Berths Nearshore** and **Equipment Nearshore**, stay within **Low to Moderate risk ranges (1.20–1.50)**.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	2.32	2.32	2.32
% Change from Baseline		0%	0%

Currents : Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table presents the aggregated risk scores for **Currents** across various asset types under **baseline** conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score decreases slightly from **1.92** at baseline to **1.84** in 2050 and **1.85** in 2085, representing a **4% decline by 2050** and **2085** respectively. This indicates that current-related hazards are expected to remain stable or slightly reduce over time.

Risk Level

- **Openwater Nearshore** remains the highest-risk asset, with scores around **8.75–8.79**, indicating persistent **Very High risk**.
- **Transport Waterways** also stays elevated at **7.50–7.58**, reflecting strong exposure to current-related hazards.
- **Berths Nearshore** and **Wharfs Nearshore** slightly decreases from **4.92** to **4.76**, within the **Very High risk category**.
- **Equipment Nearshore** remains moderate at **3.00–3.03**, while **Revetment Onshore** slightly decreases from **2.63** to **2.36**.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	1.92	1.84	1.85
% Change from Baseline		-4%	-4%

Coastal Flooding : Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Coastal Flooding** across various asset types under **baseline** conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score rises from **0.24** at baseline to **0.34** in 2050 and **0.66** in 2085, representing a **30% increase by 2050** and a substantial **64% increase by 2085**. This indicates a growing vulnerability to coastal flooding over time, particularly for assets located nearshore.

High-Risk Assets

- **Drainage and Sewerage Systems** remain at **8.00** across all periods, indicating persistent **Very High risk**.

Other Vulnerable Assets

- **Maintenance Repair Buildings Nearshore** increase from **1.45** to **4.73** by 2085, moving from **Moderate** to **Very High risk**.
- **Warehouses (Uncovered Nearshore)** rise sharply from **3.08** to **5.05**, indicating growing susceptibility.
- **Manufacturing LPG Nearshore** climbs from **0.58** to **2.07**, shifting from **Minimal** to **Moderate risk**.
- **Power Substations Nearshore** and **Telecommunication Services Nearshore** show incremental increases, though remaining below **2.0**.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	0.00	0.34	0.66
% Change from Baseline		30%	64%

Details regarding the others hazards are given in Appendix C

Hazard Risk Score

CHANGE FROM BASELINE RISK SCORE- FIVE KEY HAZARDS

Extreme Heat: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	0.95	2.41	2.93
02. Building: Data Center-Nearshore	2.40	6.20	7.40
03. Building: Maintenance Repair Nearshore	1.84	4.56	5.76
04. Building: Office	1.86	4.66	5.80
05. Building: Office Nearshore	1.84	4.56	5.76
06. Building: Operational	1.92	4.96	5.92
07. Building: Operational-Nearshore	1.92	4.96	5.92
08. Drainage system	1.44	3.72	4.44
09. Equipment: Nearshore	1.92	4.96	5.92
10. Equipment: Onshore	1.86	4.64	5.79
11. Jetty: Nearshore	0.92	2.28	2.88
12. Manufacturing: Chemicals	2.30	5.70	7.20
13. Manufacturing: Food Nearshore	1.84	4.56	5.76
14. Manufacturing: LPG	1.84	4.56	5.76
15. Manufacturing: LPG Nearshore	1.84	4.56	5.76
16. Manufacturing: Other	1.84	4.56	5.76
17. Openwater: Nearshore	0.96	2.48	2.96
18. Power: Substation	1.90	4.84	5.87
19. Power: Substation DG	2.40	6.20	7.40
20. Power: Substation NearRiver	1.84	4.56	5.76
21. Power: Substation Nearshore	1.90	4.86	5.88
22. Power: Substation Solar	1.44	3.72	4.44
23. Revetment: Onshore	1.42	3.63	4.41
24. Sewerage system	0.96	2.48	2.96
25. Telecommunications Services	1.91	4.92	5.91
26. Telecommunications Services: Nearshore	1.92	4.96	5.92
27. Transport: Waterways	1.44	3.72	4.44
28. Warehouses: Covered	1.90	4.85	5.87
29. Warehouses: Covered Nearshore	1.84	4.56	5.76
30. Warehouses: Dock Depot	1.92	4.96	5.92
31. Warehouses: Fuel	2.40	6.20	7.40
32. Warehouses: Fuel Nearshore	2.30	5.70	7.20
33. Warehouses: Uncovered	1.89	4.83	5.87
34. Warehouses: Uncovered Nearshore	1.84	4.56	5.76
35. Water Supply	1.86	4.66	5.80
36. Wharf: Nearshore	0.95	2.43	2.94
Asset Averaged Risk Score	1.56	3.98	4.85

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Extreme Heat** across various asset types from the baseline to future climate scenarios **(SSP5-8.5 for 2050 and 2085)**.

Overall Trend:

The average risk score **increases significantly** from the baseline to 3.98 in 2050 and 4.85 in 2085, indicating a substantial escalation in heat-related risks over time.

High-Risk Assets:

Critical assets such as data centers, chemical manufacturing facilities, and fuel warehouses exhibit the highest projected increases, with scores exceeding 7.0 by 2085, reflecting their high sensitivity to temperature extremes.

Other Vulnerable Assets:

Nearshore buildings, power substations, and operational facilities also show marked vulnerability, while assets such as sewerage systems and open water remain relatively lower risk.

These trends underscore the urgent need for proactive heat adaptation strategies, including advanced cooling systems, material upgrades, and operational resilience planning for high-risk assets.

Projected Risk Change and Potential Operational Impacts

Extreme Heat – projected to **increase significantly** from baseline **to 'very high' risk level** by **2050 and 2085** under **SSP5-8.5** scenario. This escalation leads to potential risks including:

Operational Costs:

- Substantial increase in cooling demand for indoor areas, driving up energy consumption and operating expenses.

System Reliability:

- Greater likelihood of electricity shortages, equipment failures, fires, and explosions, resulting in business interruption, revenue loss, and higher capital expenditure, repair costs, and insurance premiums.

Health & Safety:

- Elevated health risks for site personnel, with potential reductions in working hours or downtime during extreme heat events, leading to productivity loss and decreased revenue.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Extreme Total Water Level: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	8.00	0.00	0.00
02. Building: Data Center-Nearshore	4.96	3.04	3.04
03. Building: Maintenance Repair Nearshore	4.96	3.04	3.04
04. Building: Office	0.00	0.00	0.00
05. Building: Office Nearshore	4.96	3.04	3.04
06. Building: Operational	0.00	0.00	0.00
07. Building: Operational-Nearshore	4.96	3.04	3.04
08. Drainage system	2.96	2.90	5.04
09. Equipment: Nearshore	8.00	0.00	0.00
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	6.69	1.31	1.31
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	4.96	3.04	3.04
14. Manufacturing: LPG	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	4.96	3.04	3.04
16. Manufacturing: Other	0.00	0.00	0.00
17. Openwater: Nearshore	8.00	0.00	0.00
18. Power: Substation	0.00	0.00	0.00
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.00	0.00	0.00
21. Power: Substation Nearshore	5.83	3.85	4.18
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	2.30	2.05	6.34
24. Sewerage system	2.96	2.90	5.04
25. Telecommunications Services	0.00	0.00	0.00
26. Telecommunications Services: Nearshore	2.39	2.65	5.61
27. Transport: Waterways	8.00	0.00	0.00
28. Warehouses: Covered	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	4.96	3.04	3.04
30. Warehouses: Dock Depot	0.00	0.00	0.00
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	4.96	3.04	3.04
33. Warehouses: Uncovered	0.00	0.00	0.00
34. Warehouses: Uncovered Nearshore	4.96	3.04	3.04
35. Water Supply	1.24	0.76	0.76
36. Wharf: Nearshore	4.83	2.44	2.89
Asset Averaged Risk Score	3.53	1.06	1.59

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Extreme Total Water Level** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:
The average risk score rises sharply from **baseline** to **1.06 in 2050** and **1.59 by 2085**, indicating a **significant increase** in risk associated with extreme water levels over time.

Asset-Level Observations:
High-Risk Assets:
Multiple nearshore assets—including **data centers, maintenance repair buildings, operational buildings, LPG manufacturing facilities, and warehouses**—reach **3.04 by 2050**, remaining high through 2085.
Power Substation Nearshore increases from **3.85 (2050)** to **4.18 (2085)**, representing one of the highest risk scores.
Telecommunications Services Nearshore rises from **2.65 (2050)** to **5.61 (2085)**, indicating severe vulnerability.
Drainage and Sewerage Systems escalate from **2.90 (2050)** to **5.04 (2085)**, highlighting critical exposure.

Moderate Risk:
Wharf Nearshore climbs to **2.44 (2050)** and **2.89 (2085)**, impacting port operations.
Water Supply reaches **0.76**, suggesting moderate exposure.

Minimal Risk: Inland assets remain near **0.00**, reflecting negligible exposure.
These findings indicate that **Extreme Total Water Level** poses a **major threat to port facilities and nearshore infrastructure**, requiring urgent adaptation measures.

Projected Risk Escalation and Potential Operational Impacts

Extreme Total Water Level – projected to **increase significantly** from baseline **to 'very high' risk level** by **2050 and 2085** under **SSP5-8.5** scenario. As extreme water levels intensify, potential impacts on port facilities and operations include:

Severe Flooding and Inundation:

High exposure of nearshore warehouses, power substations, and telecommunications systems to storm surge and tidal extremes.

Operational Disruptions:

Prolonged downtime for cargo handling, vessel berthing, and critical services during extreme water level events.

Asset Integrity and Safety:

Structural damage to wharves, drainage systems, and electrical infrastructure, leading to costly repairs and increased insurance premiums.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Waves: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	1.20	0.00	0.00
02. Building: Data Center-Nearshore	5.92	0.00	0.00
03. Building: Maintenance Repair Nearshore	5.92	0.00	0.00
04. Building: Office	0.00	0.00	0.00
05. Building: Office Nearshore	3.94	0.00	0.00
06. Building: Operational	0.00	0.00	0.00
07. Building: Operational-Nearshore	5.92	0.00	0.00
08. Drainage system	5.92	0.00	0.00
09. Equipment: Nearshore	1.20	0.00	0.00
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	1.50	0.00	0.00
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	5.92	0.00	0.00
14. Manufacturing: LPG	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	5.92	0.00	0.00
16. Manufacturing: Other	0.00	0.00	0.00
17. Openwater: Nearshore	1.20	0.00	0.00
18. Power: Substation	0.00	0.00	0.00
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.00	0.00	0.00
21. Power: Substation Nearshore	5.92	0.00	0.00
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	9.86	0.00	0.00
24. Sewerage system	3.94	0.00	0.00
25. Telecommunications Services	0.00	0.00	0.00
26. Telecommunications Services: Nearshore	5.92	0.00	0.00
27. Transport: Waterways	1.20	0.00	0.00
28. Warehouses: Covered	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	5.92	0.00	0.00
30. Warehouses: Dock Depot	0.00	0.00	0.00
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	3.94	0.00	0.00
33. Warehouses: Uncovered	0.00	0.00	0.00
34. Warehouses: Uncovered Nearshore	5.92	0.00	0.00
35. Water Supply	0.99	0.00	0.00
36. Wharf: Nearshore	1.20	0.00	0.00
Asset Averaged Risk Score	2.32	0.00	0.00

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Waves** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:

The average risk score remains 0.00 across all timeframes (baseline, 2050, and 2085), indicating **no significant change** in **wave-related risk** under the assessed climate scenario.

All assets—including **buildings(data centers, operational nearshore), power substations nearshore, warehouses (covered nearshore), telecommunication services nearshore, revetment Onshore**—remain at a high-risk, though no measurable increase projected for 2050 or 2085 under the SSP5-8.5 scenario.

Drainage systems and sewerage systems remain at a high-risk level because the baseline assessment already indicated a high risk. Although the risk score does not change by 2050 or 2085 under the SSP5-8.5 scenario, the overall risk remains elevated.

Berths, wharves, nearshore warehouses, and manufacturing facilities—remain at a low-risk, though no measurable increase projected for 2050 or 2085 under the SSP5-8.5 scenario.

These findings confirm that Waves pose no material risk to the assessed infrastructure under SSP5-8.5, though ongoing monitoring is recommended to address potential changes in wave dynamics due to sea-level rise or extreme storm events.

Projected Risk Escalation and Potential Operational Impacts

Waves– projected to **increase minimally** from baseline by **2050 and 2085** under **SSP5-8.5** scenario. Given the negligible risk scores, wave activity is not expected to cause significant operational or structural impacts. However, potential considerations include:

Localized Splash and Spray:

Minor effects on nearshore structures during extreme storm conditions.

Operational Delays:

Temporary restrictions on cargo handling or vessel berthing during high-energy wave events.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Currents: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	4.92	-0.18	-0.16
02. Building: Data Center-Nearshore	0.00	0.00	0.00
03. Building: Maintenance Repair Nearshore	0.00	0.00	0.00
04. Building: Office	0.00	0.00	0.00
05. Building: Office Nearshore	0.00	0.00	0.00
06. Building: Operational	0.00	0.00	0.00
07. Building: Operational-Nearshore	0.00	0.00	0.00
08. Drainage system	0.00	0.00	0.00
09. Equipment: Nearshore	3.00	0.02	0.03
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	10.00	-0.60	-0.61
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	0.00	0.00	0.00
14. Manufacturing: LPG	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	0.00	0.00	0.00
16. Manufacturing: Other	0.00	0.00	0.00
17. Openwater: Nearshore	8.75	0.02	0.04
18. Power: Substation	0.00	0.00	0.00
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.00	0.00	0.00
21. Power: Substation Nearshore	0.00	0.00	0.00
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	2.63	-0.31	-0.26
24. Sewerage system	0.00	0.00	0.00
25. Telecommunications Services	0.00	0.00	0.00
26. Telecommunications Services: Nearshore	0.00	0.00	0.00
27. Transport: Waterways	7.50	0.04	0.08
28. Warehouses: Covered	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	0.00	0.00	0.00
30. Warehouses: Dock Depot	0.00	0.00	0.00
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	0.00	0.00	0.00
33. Warehouses: Uncovered	0.00	0.00	0.00
34. Warehouses: Uncovered Nearshore	0.00	0.00	0.00
35. Water Supply	0.00	0.00	0.00
36. Wharf: Nearshore	4.89	-0.17	-0.16
Asset Averaged Risk Score	1.92	-0.08	-0.07

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Currents** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:

The average risk score shifts slightly from baseline to **-0.08 in 2050** and **-0.07 by 2085**, indicating a **minimal decrease** in current-related risk over time. This suggests that currents are not expected to pose significant hazards under the assessed scenario.

Asset-Level Observations:

Minor Negative Changes:

- **Jetty Nearshore, Transport: Waterways, Berth Nearshore** and **Wharf Nearshore** remain at a very high-risk level because the baseline assessment already indicated a very high risk, though the risk score does have a minimal decrease by 2050 or 2085 under the SSP5-8.5 scenario.
- **Equipment Nearshore** remain at a high-risk level.
- **Revetment Onshore** remain at a moderate-risk level though there is a minimal decreases to **-0.31 (2050) and -0.26 (2085).**

Minimal Positive Changes:

Some inland assets (e.g., **Manufacturing Other**) show negligible increases (up to 0.04), but these remain insignificant.

These findings indicate that **Currents** pose **no material risk** to port facilities and operations under SSP5-8.5, with slight reductions in exposure for nearshore structures.

Projected Risk Escalation and Potential Operational Impacts

Currents– projected to have **no significant change** by **2050 and 2085** under **SSP5-8.5** scenario. Given the negligible and slightly decreasing risk scores, currents are unlikely to cause significant operational or structural impacts. However, potential considerations include:

Localized Flow Variations:

Minor changes in current patterns could affect berthing maneuvers or mooring stability during extreme conditions.

Operational Adjustments:

Occasional need for tug assistance or revised docking protocols in areas with altered current flow.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Coastal Flooding: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	0.00	0.00	0.00
02. Building: Data Center-Nearshore	0.00	0.00	0.00
03. Building: Maintenance Repair Nearshore	1.45	0.88	3.28
04. Building: Office	0.08	0.12	0.55
05. Building: Office Nearshore	0.00	0.10	0.96
06. Building: Operational	0.00	0.01	0.22
07. Building: Operational-Nearshore	0.00	0.00	0.00
08. Drainage system	8.00	0.00	0.00
09. Equipment: Nearshore	0.00	0.00	0.00
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	0.00	0.00	0.00
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	0.08	0.16	0.79
14. Manufacturing: LPG	0.00	0.08	0.92
15. Manufacturing: LPG Nearshore	0.18	0.40	1.90
16. Manufacturing: Other	0.07	0.17	0.89
17. Openwater: Nearshore	0.00	0.00	0.00
18. Power: Substation	0.30	0.10	0.36
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.00	0.00	0.00
21. Power: Substation Nearshore	0.23	0.20	0.95
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	0.23	0.22	0.96
24. Sewerage system	8.00	0.00	0.00
25. Telecommunications Services	0.43	0.18	0.51
26. Telecommunications Services: Nearshore	0.00	0.01	0.20
27. Transport: Waterways	0.00	0.00	0.00
28. Warehouses: Covered	0.16	0.17	0.70
29. Warehouses: Covered Nearshore	0.00	0.00	0.00
30. Warehouses: Dock Depot	0.00	0.00	0.10
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	0.00	0.10	1.00
33. Warehouses: Uncovered	0.00	0.00	0.04
34. Warehouses: Uncovered Nearshore	2.16	0.92	2.89
35. Water Supply	0.03	0.07	0.39
36. Wharf: Nearshore	0.00	0.00	0.00
Asset Averaged Risk Score	0.24	0.10	0.42

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for Coastal Flooding across various asset types from the baseline to future climate scenarios (SSP5-8.5 for 2050 and 2085).

Overall Trend:

The average risk score increases from **baseline** to **0.10 in 2050** and **0.42 by 2085**, indicating a **progressive escalation** in coastal flooding risk over time, particularly for nearshore and exposed assets.

Asset-Level Observations:

High-Risk Assets by 2085:

Building: Maintenance Repair Nearshore rises sharply from baseline to **3.28 (2085).**

Warehouses: Uncovered Nearshore increases from baseline to **2.89 (2085).**

Warehouses: Fuel Nearshore reaches **1.00 by 2085**.

Drainage systems and sewerage systems remain at a very high-risk level because the baseline assessment already indicated a very high risk. Although the risk score does not change by 2050 or 2085 under the SSP5-8.5 scenario, the overall risk remains elevated.

Moderate Risk Growth:

Nearshore manufacturing facilities (LPG, food) and power substations show incremental increases, reaching **0.79–1.90 by 2085**.

Minimal Risk: Inland assets remain near 0.00, reflecting negligible exposure.

These findings indicate that **Coastal Flooding** poses a growing threat **to nearshore operational facilities**, **warehouses, drainage systems and sewerage systems and maintenance buildings**, requiring targeted adaptation measures.

Projected Risk Escalation and Potential Operational Impacts

Coastal Flooding – projected to **increase minimally** by **2085** under **SSP5-8.5** scenario. As coastal flooding risk intensifies, potential impacts on port facilities and operations include:

Structural Damage:

Increased exposure of nearshore warehouses and maintenance facilities to inundation and saltwater corrosion.

Operational Disruptions:

Delays in cargo handling and vessel berthing during high tide or storm surge events.

Asset Integrity:

Accelerated deterioration of critical infrastructure, leading to higher maintenance and repair costs.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Details regarding the others hazards are given in Appendix D

Key Climate Hazard Insights and Operational Implications

This report presents a comprehensive physical risk assessment of **eight (8)** climate hazard types across **199 assets** located in Westports, utilizing **ERM's Global Climate Database** for the baseline period, as well as projections for **2050** and **2085** under the **SSP5-8.5 (high emissions) scenario**. The assessment encompasses:

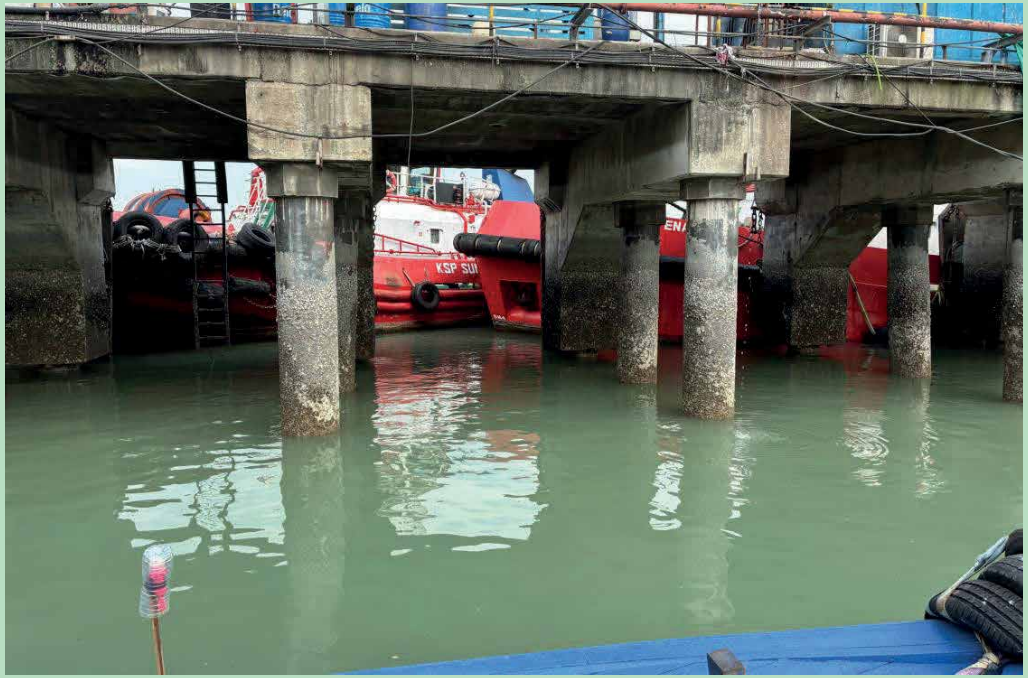
- Identification of major hazards affecting all **36 asset group types**; and
- A detailed analysis of the most at-risk assets, baseline and projected risk scores and change from the baseline risk score

From the asset group evaluations, five (5) key climate hazards were identified as critical to infrastructure resilience. These hazards impact essential categories including buildings, operational facilities, equipment, utilities, warehouses, and nearshore assets.

<table>
<tr><th rowspan="2">Major Hazard</th><th colspan="2">Number of 'High' or 'Very High' Risk Assets (risk score ≥ 3)</th><th rowspan="2">Affected Asset Group Type</th><th rowspan="2">Potential Physical and Financial Impacts</th></tr>
<tr><th>Baseline</th><th>2085s under SSP5-8.5</th></tr>
<tr><td>Extreme heat</td><td>0 (0%)</td><td>36 (100%)</td><td>02. Building: Data Center-Nearshore, 19. Power: Substation DG, 31. Warehouses: Fuel, 32. Warehouses: Fuel Nearshore, 12. Manufacturing: Chemicals, 26. Telecommunications Services: Nearshore, 09. Equipment: Nearshore, 30. Warehouses: Dock Depot, 06. Building: Operational, 07. Building: Operational-Nearshore, 25. Telecommunications Services, 21. Power: Substation Nearshore, 28. Warehouses: Covered, 18. Power: Substation, 33. Warehouses: Uncovered</td><td rowspan="5">❖ Power outage (extreme heat, flooding, extreme winds & storms)
❖ Increase in operating cost (extreme heat)
❖ Increase in capital expenditure, repairing cost and insurance premium (extreme heat, flooding, extreme winds & storms, extreme total water level)
❖ Decrease in revenue (all eight hazards)
❖ Health and safety risk to site personnel (all eight hazards)</td></tr>
<tr><td>Extreme Total Water level</td><td>16 (44%)</td><td>20 (56%)</td><td>21. Power: Substation Nearshore, 23. Revetment: Onshore, 08. Drainage system, 01. Berth: Nearshore, 32. Warehouses: Fuel Nearshore, 11. Jetty: Nearshore, 29. Warehouses: Covered Nearshore, 27. Transport: Waterways, 26. Telecommunications Services: Nearshore, 09. Equipment: Nearshore, 34. Warehouses: Uncovered Nearshore, 05. Building: Office Nearshore, 03. Building: Maintenance Repair Nearshore, 13. Manufacturing: Food Nearshore, 07. Building: Operational-Nearshore</td></tr>
<tr><td>Waves</td><td>14 (39%)</td><td>14 (39%)</td><td>23. Revetment: Onshore, 15. Manufacturing: LPG Nearshore, 13. Manufacturing: Food Nearshore, 34. Warehouses: Uncovered Nearshore, 03. Building: Maintenance Repair Nearshore, 07. Building: Operational-Nearshore, 29. Warehouses: Covered Nearshore, 02. Building: Data Center-Nearshore, 08. Drainage system, 26. Telecommunications Services: Nearshore</td></tr>
<tr><td>Currents</td><td>6 (17%)</td><td>6 (17%)</td><td>11. Jetty: Nearshore, 17. Openwater: Nearshore, 27. Transport: Waterways, 01. Berth: Nearshore, 36. Wharf: Nearshore, 09. Equipment: Nearshore, 23. Revetment: Onshore</td></tr>
<tr><td>Coastal Flooding</td><td>2 (6%)</td><td>4 (11%)</td><td>08. Drainage system, 24. Sewerage system, 34. Warehouses: Uncovered Nearshore, 03. Building: Maintenance Repair Nearshore, 15. Manufacturing: LPG Nearshore, 23. Revetment: Onshore, 21. Power: Substation Nearshore</td></tr>
</table>

- **Extreme Heat** → Most critical hazard by 2050 & 2085; impacts indoor assets, electronics, cooling demand, and workforce safety.
- **Extreme Total Water Level (ETWL)** → Continues to escalate; drives inundation, corrosion, structural weakening, and berthing/cargo disruptions.
- **Coastal Flooding** → Minimal in current dataset but understated due to missing sea-level-rise inputs; ETWL is the more realistic indicator of future coastal risk.
- **Waves & Currents** → No projected change, but swell remains operationally material (vessel delays, TEUs/meter lost).
- **Sedimentation** → Recurring monsoon-linked issue; increases dredging needs, reduces depth, affects deeper-draft vessel operations.
- **Other Hazards** (**Extreme Winds & Storms, Rainfall Flooding, Riverine Flooding**) → Remain comparatively low-risk across all scenarios.

Extreme Water Level Analysis



Extreme Water Level Analysis

Wharf Ground Elevation (mCD) Represents the wharf structural ground elevation, measured in meters, Chart Datum (mCD).

Revetment (mCD) Indicates the crest height of the revetment or coastal protection structure, showing how high the revetment stands relative to chart datum.

All Yard Ground Level (mCD) Shows the general ground elevation across the port yard. Used to assess flooding or overtopping risk to operational areas.

Highest Astronomical Tide (HAT) (mCD) represents the highest tidal level predicted to occur under average meteorological conditions (new/full moon + lunar perigee + sun declination). (**5.82 mCD**)

Tide (mCD) Represents the predicted tide level relative to the chart datum. This is the total High-Water level for a 100-year RP without sea-level rise or storm effects. This is the normal water level without sea-level rise or storm effects.

Sea Level Rise (m) The assessment relies on actual observed sea-level records collected from Permanent Service for Mean Sea Level (PSMSL)/Department of Survey and Mapping Malaysia (JUPEM)/ tide-gauge station (1993–2018) and satellite altimetry datasets from AVISO/DUACS. These real measurements of sea-surface height form the basis of the historical trend analysis, which shows an average rise of **3.8 mm/yr** from tide gauges and **4.4 mm/yr** from satellite altimetry over the same period. In the Westports assessment, sea-level rise was estimated and projected using NAHRIM's Sea Level Rise Projection and Adaptations for Malaysia Based on IPCC AR6 (2023). This dataset is considered more reliable for Malaysia because it provides location-specific projections grounded in the latest IPCC assessment. In contrast, Seeger and Minderhoud (2026), "Sea level much higher than assumed in most coastal hazard assessments," focuses primarily on the global challenge of incorrect or inconsistent use of vertical datums. While their work highlights an important methodological issue, it is less suited for site-specific projection needs in Malaysia compared to NAHRIM's locally calibrated analysis.

Tide + Sea Level Rise (mCD) Shows the future elevated tide level after accounting for projected sea-level rise. Indicates long-term baseline water height.

Tide + Sea Level Rise + Storm Surge (mCD) Represents extreme water levels during severe storm conditions, combining tide, sea-level rise, and 100-year storm surge

Tide + Sea Level Rise + Storm Surge + Wave Height (mCD)
Shows the total extreme water level, adding the 100-year extreme wave height to the storm surge on top of sea-level rise. This line represents the maximum potential water elevation impacting port structures such as revetments and wharves. At Westports, a semidiurnal tide produces 5.5–6.5-hour intervals between successive high and low tides, meaning any tide-driven overtopping typically aligns with this **~6-hour** high-water window. During storm conditions, peak surge and wave forcing—the period when overtopping is most likely—usually lasts **3–12 hours**, but can extend to **12–24 hours** for slow-moving systems, or shorten to **1–3 hours** for fast-moving storms.

SSP5-8.5 represents the highest emissions pathway under CMIP6, reflecting a fossil-fuel–intensive global development trajectory with limited climate mitigation. Under this scenario, greenhouse gas concentrations continue to rise substantially throughout the century, driving the system toward a radiative forcing level of 8.5 W/m² by 2100. It is widely used as a "worst-case" or high-end stress-test scenario in climate impact studies. Global mean temperature increase in **2085** under **SSP5-8.5** is projected to be approximately **4.4°C above pre-industrial levels.**

The **'100-year event'** is a modelled projection(forecast), not an observed past event, so there is no actual record of when it last occurred.

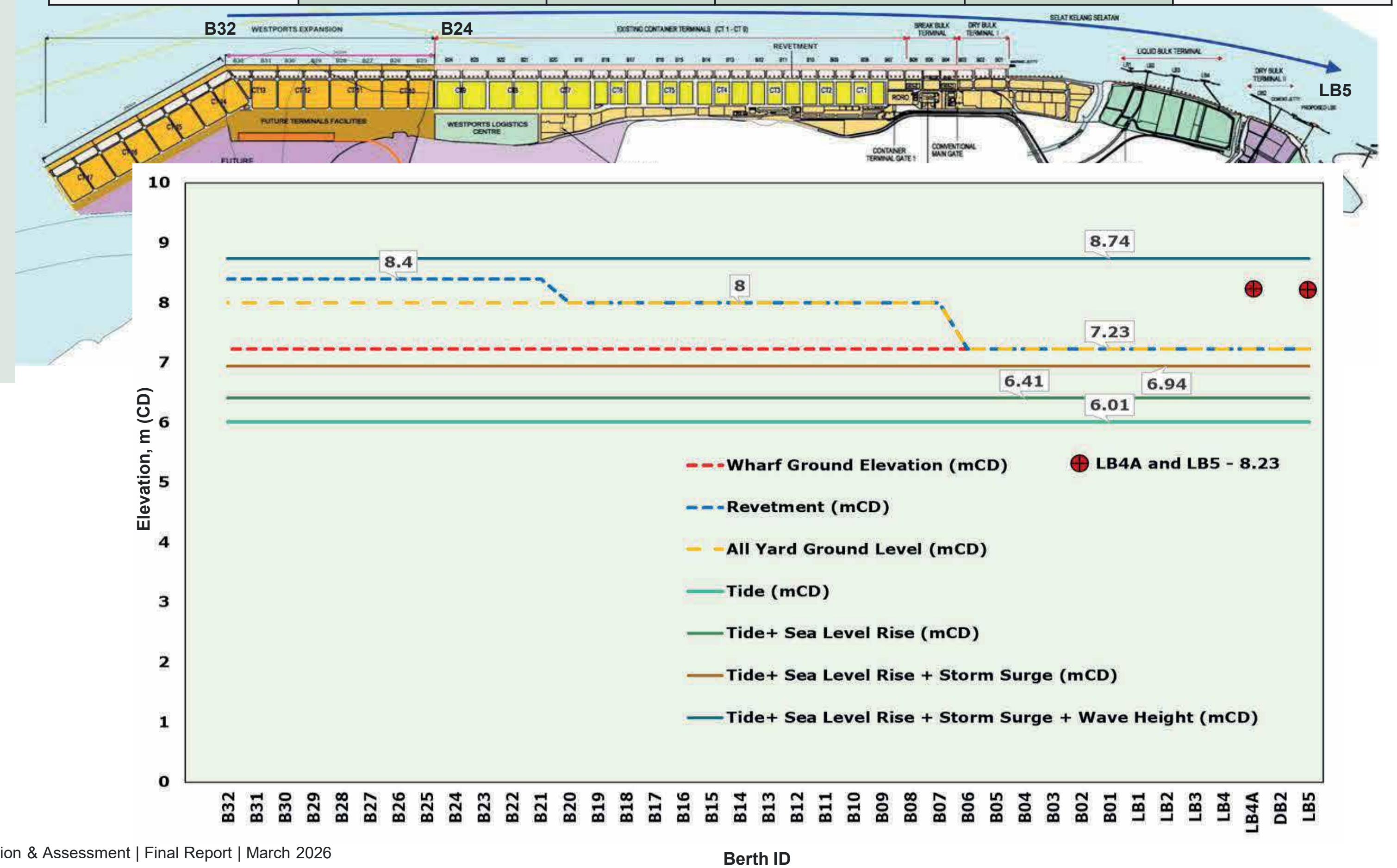
References: NAHRIM-https://digital.nahrim.gov.my/portal-main/publication-details?id=804
Sea level much higher than assumed in most coastal hazard assessments | Nature

Extreme Water Level Analysis- 2050

The section compares port ground and coastal protection elevations against progressively more extreme water-level conditions. Under normal conditions, existing **wharf, yard, and revetment levels** remain well above the **present 100-year tide level**. When **sea-level rise** is included, baseline water levels rise closer to yard and wharf elevations, reducing freeboard. During **100-year storm surge conditions**, water levels does not approach the revetment crest, indicating lowered risk of overtopping. Under the combined **tide + sea-level rise + storm surge + extreme wave height**, the total water level reaches or exceeds **revetment and wharf ground elevations** (notably around LB4A–LB5 at ~8.23 mCD), highlighting a **high risk of overtopping and wave impact on wharves and behind-wharf yards** by **2050**, unless adaptation measures (crest raising, wave walls, or drainage upgrades) are implemented.

*Joint probability of all events occurring together

Scenario: SSP5-8.5 Time frame: 2050	High-Water Level 100-year Return Period	Sea Level Rise	Storm Surge 100-year Return Period	Wave Height	Total Water Level
Projected/estimated /observed value	6.01 mCD	0.4 m	0.53 m	1.8 m	8.74 mCD
% Probability	26%	26%	26%	26%	0.5%*
Likelihood					Rare
Impact Severity/Consequence					Extreme



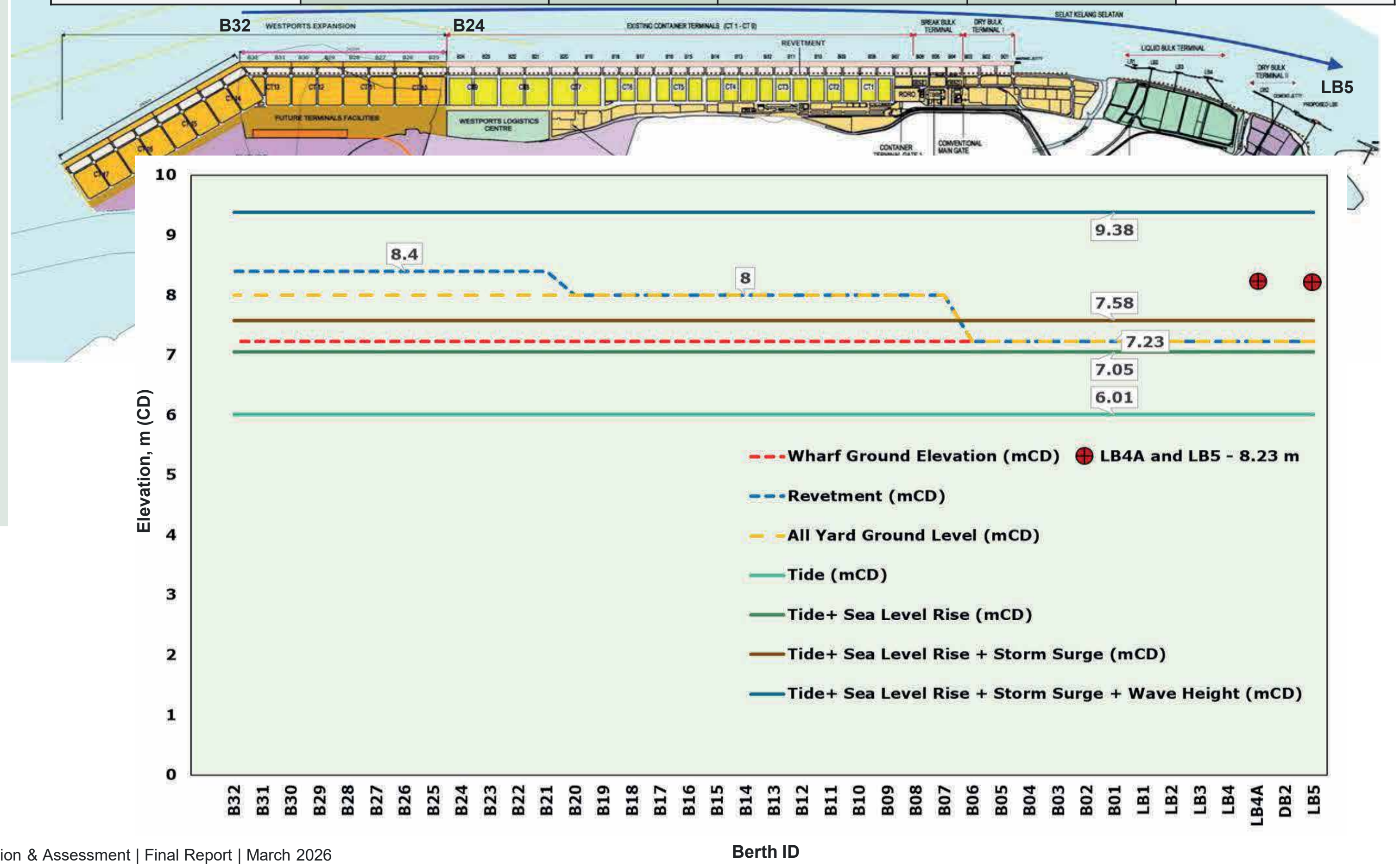
Extreme Water Level Analysis- 2085

Global mean temperature increase in **2085** under **SSP5-8.5** is projected to be approximately **4.4°C above pre-industrial levels.**

The section compares port ground and coastal protection elevations against progressively more extreme water-level conditions. Under normal conditions, existing **wharf, yard, and revetment levels** remain well above the **present 100-year tide level**. When **sea-level rise** is included, baseline water levels rise closer to yard and wharf elevations, reducing freeboard. During **100-year storm surge conditions**, water levels approach the revetment crest at several locations, indicating increased risk of overtopping. Under the combined **tide + sea-level rise + storm surge + extreme wave height**, the total water level reaches or exceeds **revetment and wharf ground elevations** (notably around LB4A–LB5 at ~8.23 mCD), highlighting a **high risk of overtopping and wave impact on wharves and behind-wharf yards** by **2085**, unless adaptation measures (crest raising, wave walls, or drainage upgrades) are implemented.

*Joint probability of all events occurring together

Scenario: SSP5-8.5 Time frame: 2085	High-Water Level 100-year Return Period	Sea Level Rise	Storm Surge 100-year Return Period	Wave Height	Total Water Level
Projected/estimated /observed value	6.01 mCD	1.04 m	0.53 m	1.8 m	9.38 mCD
% Probability	48%	48%	48%	48%	5.3%*
Likelihood					Rare
Impact Severity/Consequence					Extreme



Swells and TEUs Analysis

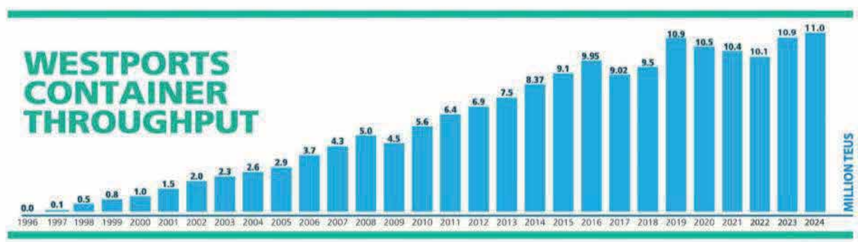
Swells and TEUs Analysis

- An **ocean swell** is a series of long, rolling surface waves that travel across the ocean, often generated by distant storms or strong winds.
- Unlike local wind waves, which are short and choppy and caused by winds blowing directly over the water, swells:
  - **Originate far away** from where they are observed.
  - **Travel long distances** across the ocean with little loss of energy.
  - Have **longer wavelengths** (the distance between wave crests) and **smoother, more uniform shapes**.
- Can arrive at coastlines even when the local weather is calm, since the energy that formed them may have come from a storm thousands of kilometers away.
- Swell waves are important in **navigation, coastal erosion, surfing, and wave energy studies**, since they carry large amounts of energy and can strongly impact shorelines.
- Swells in ports can be a **serious problem** because they bring ocean wave energy into areas that are supposed to be relatively calm for safe mooring, loading, and unloading of ships.
- **Effects of swells in ports**

  - **Ship movement at berth** → moored vessels move excessively (surging, swaying, yawing), making cargo handling dangerous or impossible.
  - **Mooring line stress** → ropes and fenders can break under constant tension.
  - **Damage risk** → to ships, piers, and port infrastructure.
  - **Delays** → loading/unloading operations may stop, and ships may have to wait offshore, increasing costs.

- A **TEU**, short for **Twenty-foot Equivalent Unit**, is a standard unit of measurement derived from the size of a standard 20' shipping container, which is 20 feet in length.

- The TEU became the standard unit to help calculate the capacity of container vessels and the volume of cargo they can carry. This standardization has allowed for greater efficiency in the loading and unloading of ships, as well as the stacking and transportation of containers via multi-modal transport.

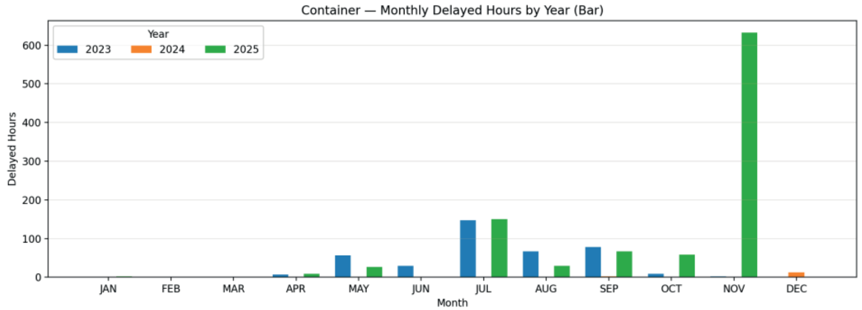


Source: Westports

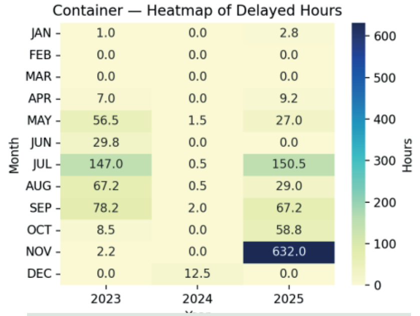
Climate Change Projections

- In summary, even under a high-emissions future (SSP5-8.5, year ~2085), the Malacca Strait's wave climate is projected to remain very much like today's: calm on average with small monsoonal waves and occasional squall waves up to ~1 m, but no emerging trend toward larger waves.
- The consensus of high-resolution modeling and multi-model ensembles is that seasonal mean SWH (Significant wave heights) and extreme wave events will not significantly change in this region, making sea-level rise (and associated coastal flooding) a far greater concern than wave height increases.

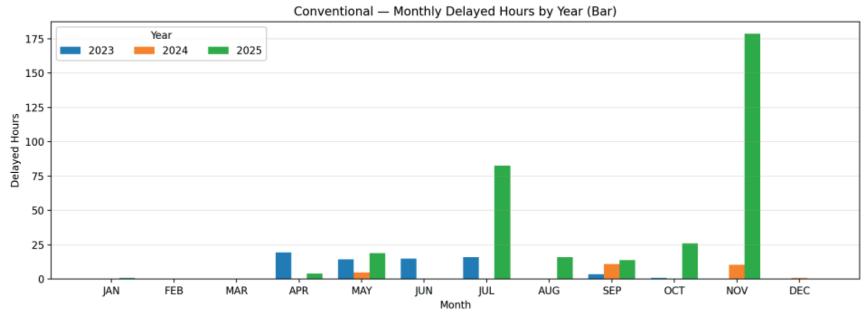
Swells and TEUs Analysis



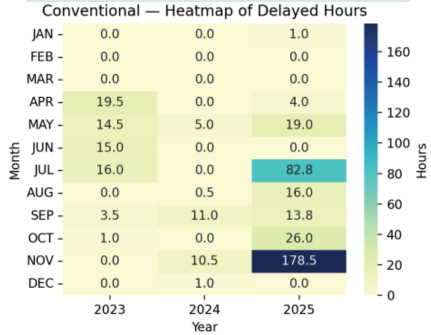
The plot shows container monthly delayed hours for all the years,



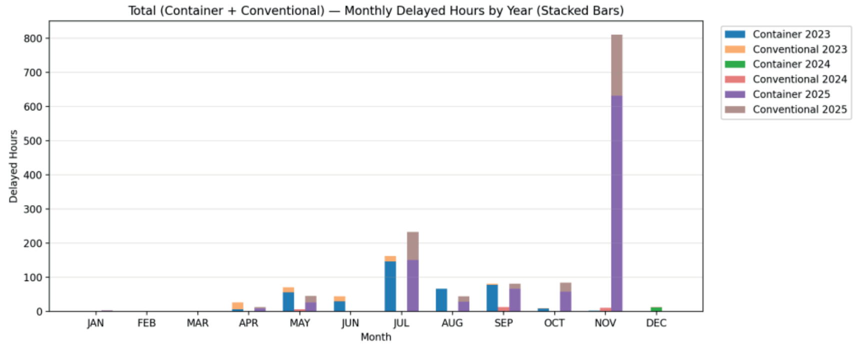
Container- Heatmap of Delayed Hours



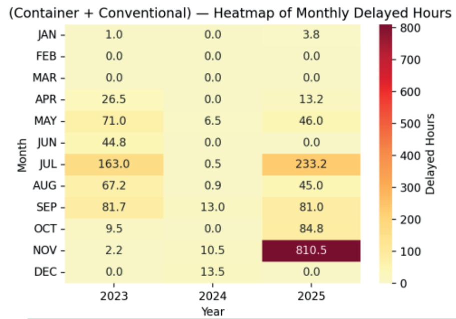
The plot shows conventional monthly delayed hours for all the years,



Conventional — Heatmap of Delayed Hours



The plot shows both container and conventional monthly delayed hours for all the years,



Heatmap- Container and Conventional combined

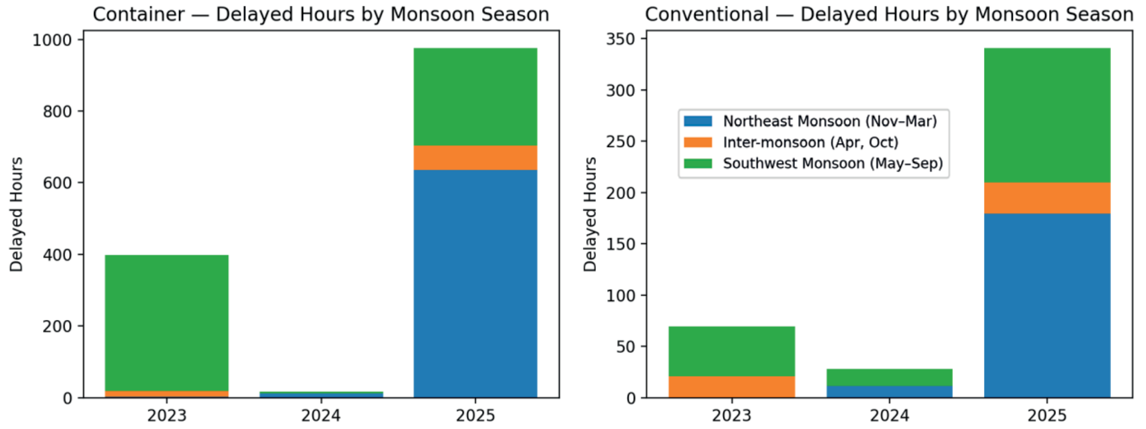
Key Trends

- **Containers — Monthly Delayed Hours by Year:**
  Peak in **Nov-2025 (~632 hr)** with a clear secondary ridge in **Jul-2025**; **2024** remains low across months.
- **Conventional — Monthly Delayed Hours by Year:**
  Sharp spike in **Nov-2025 (~178.5 hr)** and elevated **Jul-2025**; other months are comparatively modest.
- **Containers — Heatmap:**
  Hot cells cluster at **Jul-2023, Sep-2023, Jul-2025**, and especially **Nov-2025.**
- **Conventional — Heatmap:**
  Intensity concentrates in **Nov-2025** and **Jul-2025**; moderate activity in **Apr/Jun-2023** and **Sep/Nov-2024**.

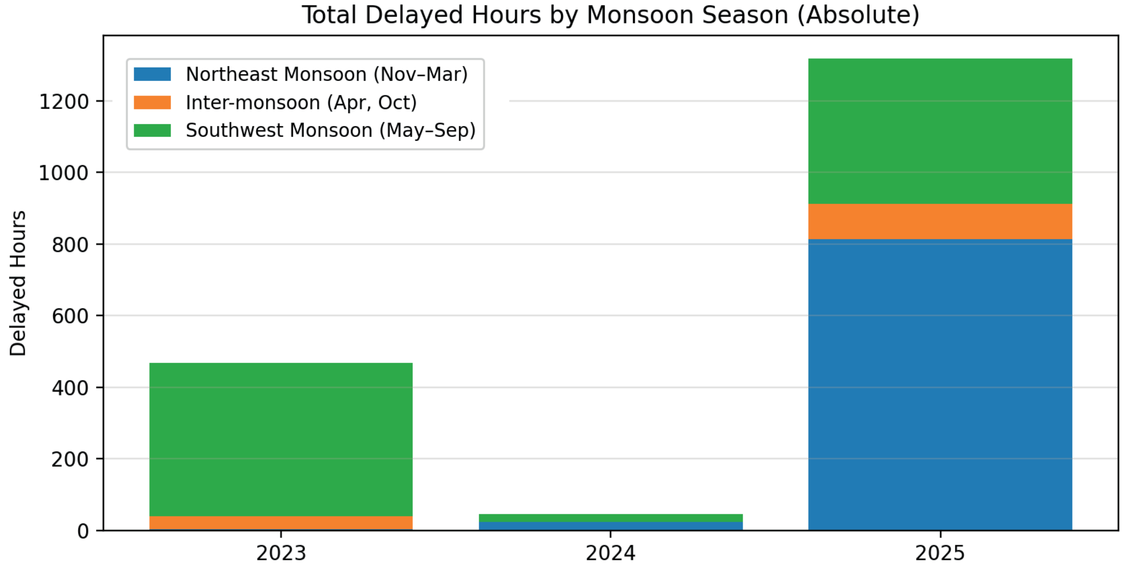
Key points

- **2025** shows a sharp resurgence in weather-related schedule impacts across both segments, dominated by the **Container** trade. In 2025, containers account for **~74.1%** of all delayed hours (976.5 of 1,317.5 hours).
- **November 2025** stands out as the largest spike across both trades (Containers >> Conventional). Secondary hotspot appears in **July 2025** (Southwest Monsoon), visible in both the plots and heatmaps.
- Secondary hotspot appears in **July 2025** (Southwest Monsoon), visible in both the lines and heatmaps.

Swells and TEUs Analysis



The heatmap shows container and conventional delayed hours during monsoon seasons for all the years,



The heatmap shows total delayed hours during monsoon seasons for all the years,

- **Northeast Monsoon-NEM (Nov–Mar)**
- **Inter-monsoon (Apr & Oct)**
- **Southwest Monsoon-SWM (May–Sep)**

- **2023:** Seasonality is **strongly SWM-centric** (>90% of total delays).
- **2024:** Low activity overall; **NEM ≈ SWM** split (no Inter-monsoon signal).
- **2025: NEM becomes the dominant driver** (≈62% of total), with **SWM** still material (~31%). Containers account for **~74%** of all 2025 delayed hours.

Operational implications

1. Plan around July- November risk

- Pre-position pilots/tugs and allocate buffer windows in **Jul–Nov**; build contingency berth plans for “swell-exposed” berths to reduce cascading delays in peak weeks.

2. Container-centric mitigations

- Because containers yield **~74%** of 2025 delay hours, prioritize container services for dynamic berth reassignment to more sheltered berths when forecast thresholds are exceeded.

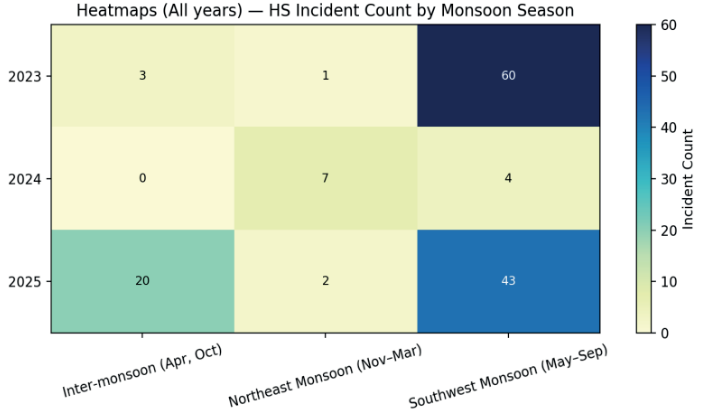
3. Seasonal rostering & cut-off policies

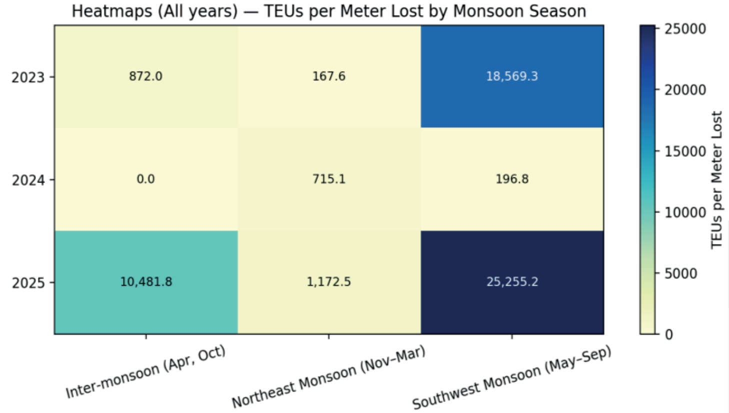
- Implement stricter cut-off/ETA control and proactive rescheduling in **Northeast Monsoon** months; escalate pilotage/weather hold criteria in **July** as a secondary hotspot.

4. KPIs to track going forward

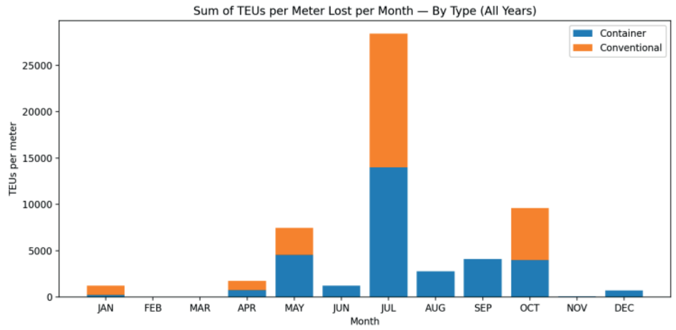
- (i) **Delay hours per call** by service string,
- (ii) **% of calls affected** by month/monsoon,
- (iii) **Mean delay vs forecasted swell/wind categories** to improve trigger thresholds for holds and berth swaps.

Swells and TEUs Analysis

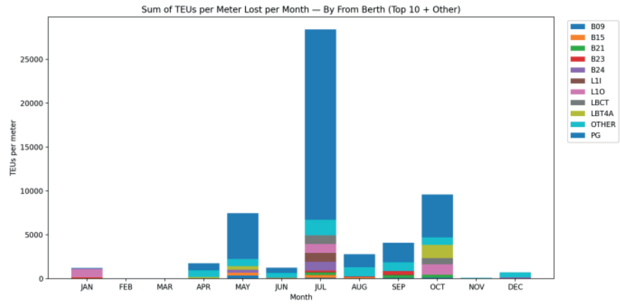




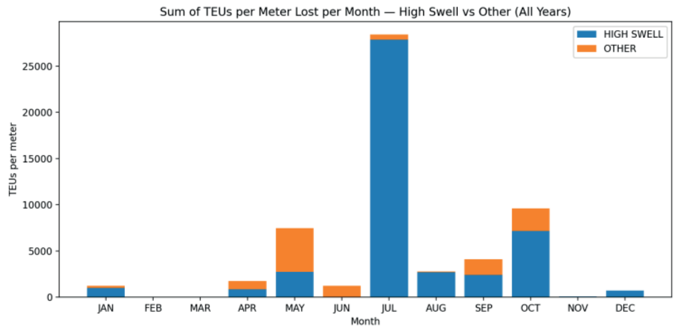
The heatmap shows High Swell incident counts during monsoon seasons, while TEUs/m lost heatmap illustrates the severity of operational impact attributed to each re-defined monsoon season.



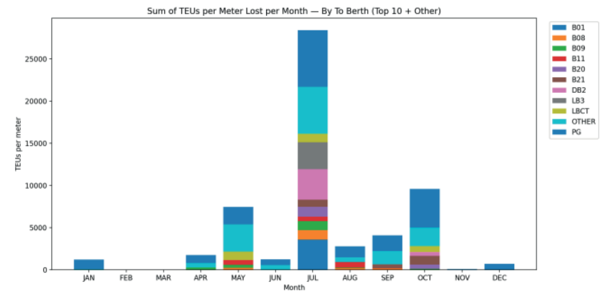
This visualisation compares TEUs per meter lost by vessel type.



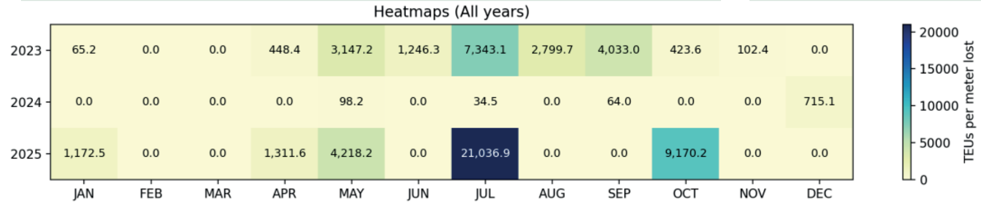
This plot shows "from berth" cumulative TEUs per meter lost across years, stacked per month.



This plot shows sum of TEUs per meter lost due to High Swell and all other delayed reasons for all years.



This plot shows "to berth" cumulative TEUs/m lost across years, stacked per month.



The heatmap shows monthly TEUs per meter lost across 2023, 2024, and 2025 (upto Oct).

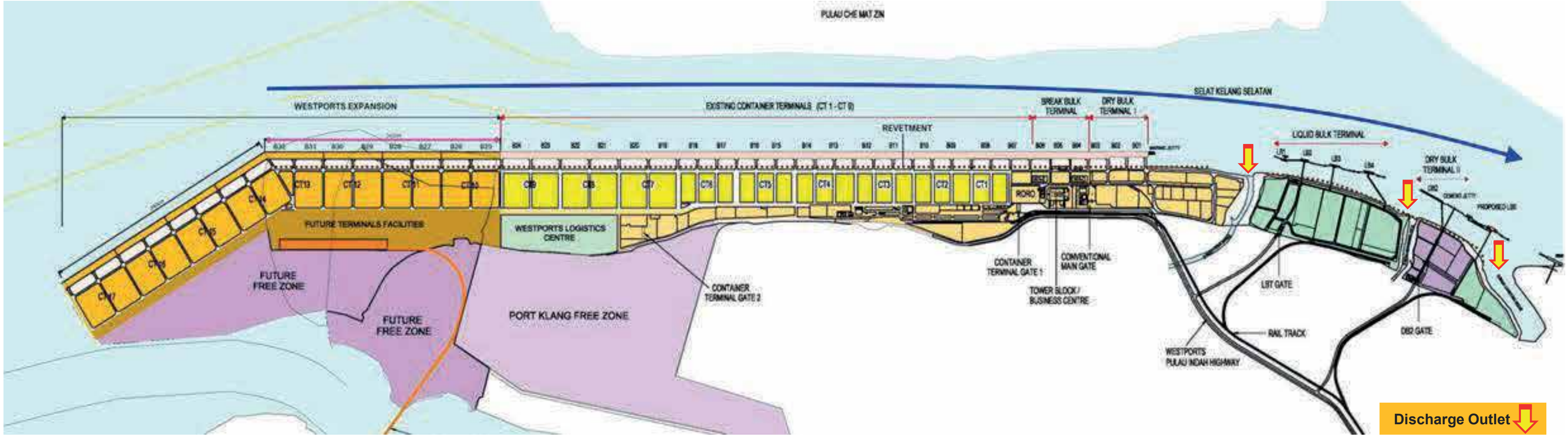
In summary, there is no change in the baseline trend in future years due to climate projections.

Sedimentation in Port Klang Channel

Port layout in the Klang Channel

Westports Layout

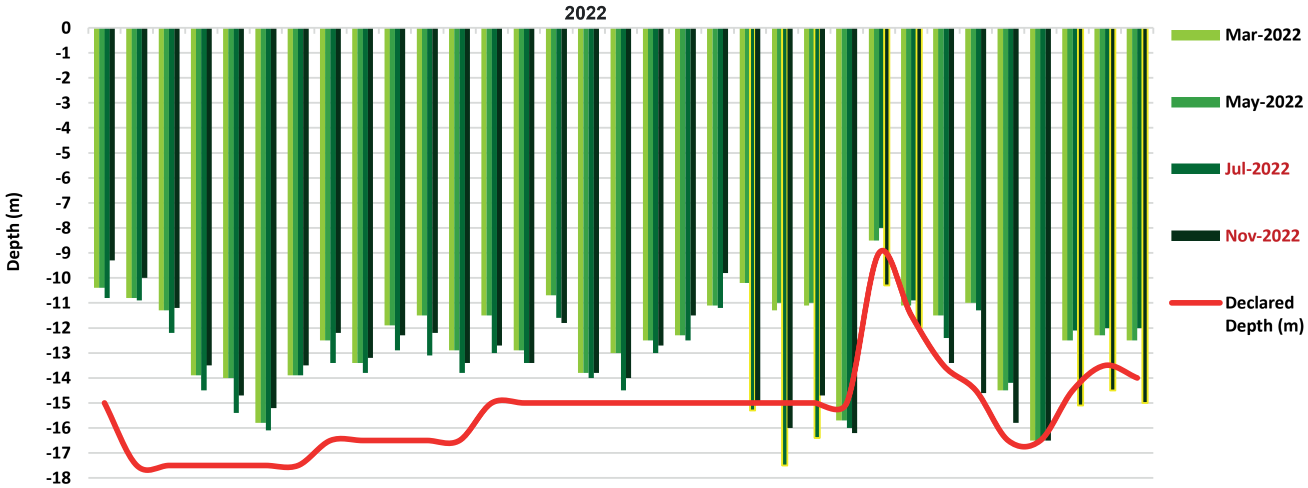
- The figure shows the overall layout of Westports' full development, including existing container terminals (CT1 to CT9), planned expansion berths to the southwest, logistics and future free zone areas inland, and specialised terminals (break bulk, dry bulk, liquid bulk) on the eastern side, all connected through multiple gates, highways, and rail access.



Sedimentation in Ports

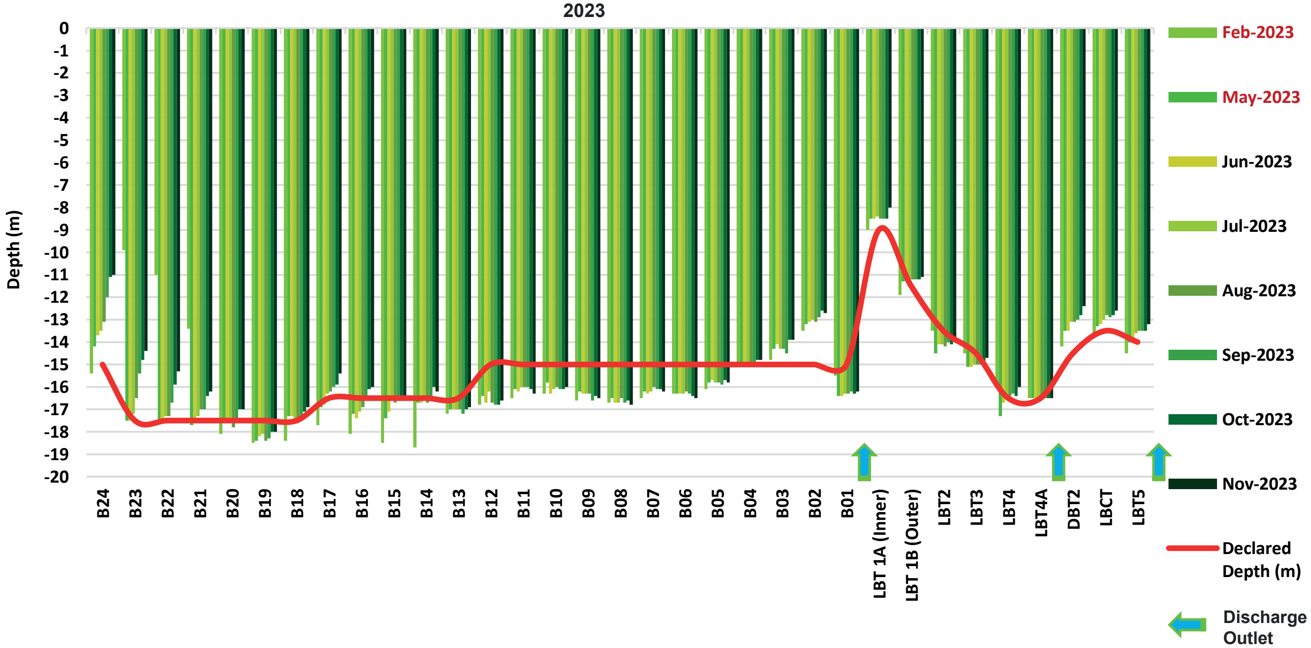
- Sedimentation in ports is the process where natural and human-induced factors cause suspended sediment to settle and accumulate in navigation channels, berthing areas, and other port infrastructure, reducing water depth and hindering port operations.
- This process is driven by factors like **river discharge**, tidal currents, wind, waves, and ship movements, which transport and deposit sediments, requiring regular **dredging** for maintenance and posing significant economic challenges.

Bathymetry along the Berths



The plot shows measured seabed depths along a continuous sequence of berths (B24 → B01 → LBT berths → OBT berths → LCT berths) for four different survey periods in 2022 (Mar, May, Jul, Nov), compared against the Declared Depth (red line).

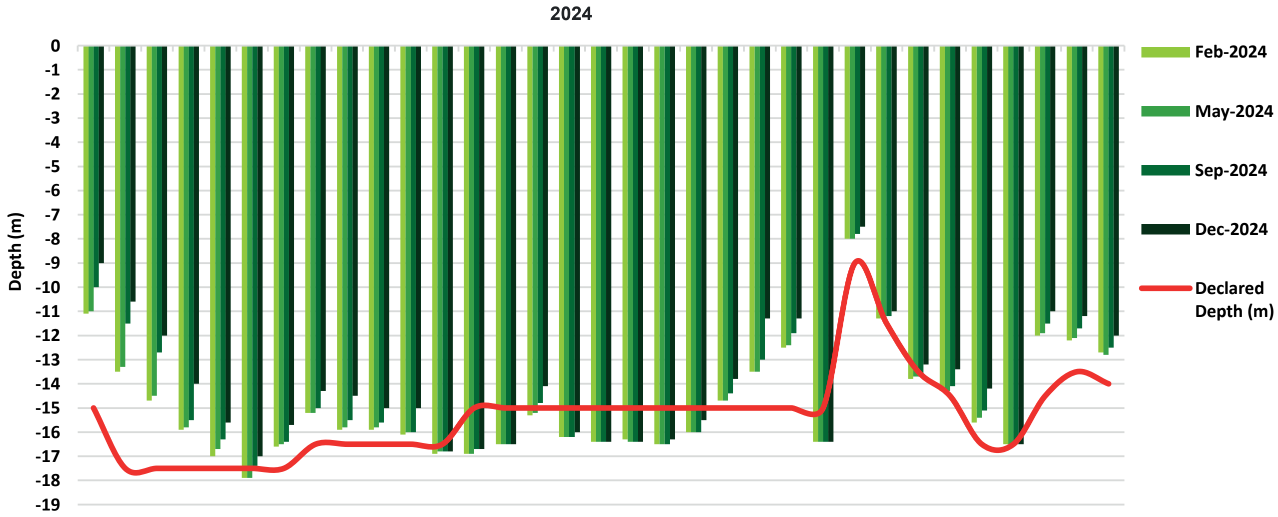
Location	Main Drivers	Effect	Influence of Dredging
B24–B17	Reclamation sediment, sand fill	Very high deposition	No dredging → depth loss is natural
B16–B09	Transport from reclamation	Medium	No dredging
B08–B01	River discharge	Medium–Low	Jul dredging at B02–B04
LBT1A–LBT5, DBT2, LBCT	Multiple river outlets + hydrodynamics	High & variable	Nov dredging resets depths to deeper values



The plot shows measured seabed depths along a continuous sequence of berths (B24 → B01 → LBT berths → OBT berths → LCT berths) for eight different survey periods in 2023 (Feb to Nov), compared against the Declared Depth (red line).

Segment	Dredged	Shoaling Level	Main Drivers
B24	Feb 2023	**Very High**	Reclamation sand movement
B05–B20	Feb 2023	**High** (esp. B13–B17)	Reclamation + seasonal currents
B21–B23	May 2023	**Medium**	Transition zone between construction & river influence
B01	May 2023	**Medium–High**	River discharge at B01–LBT1A
LBT2–LBT4	May 2023	**High**	River plumes + hydrodynamics
LBT5, LBCT, DBT2	No	**High variability**	River discharge + vessel-induced turbulence

Bathymetry along the Berths



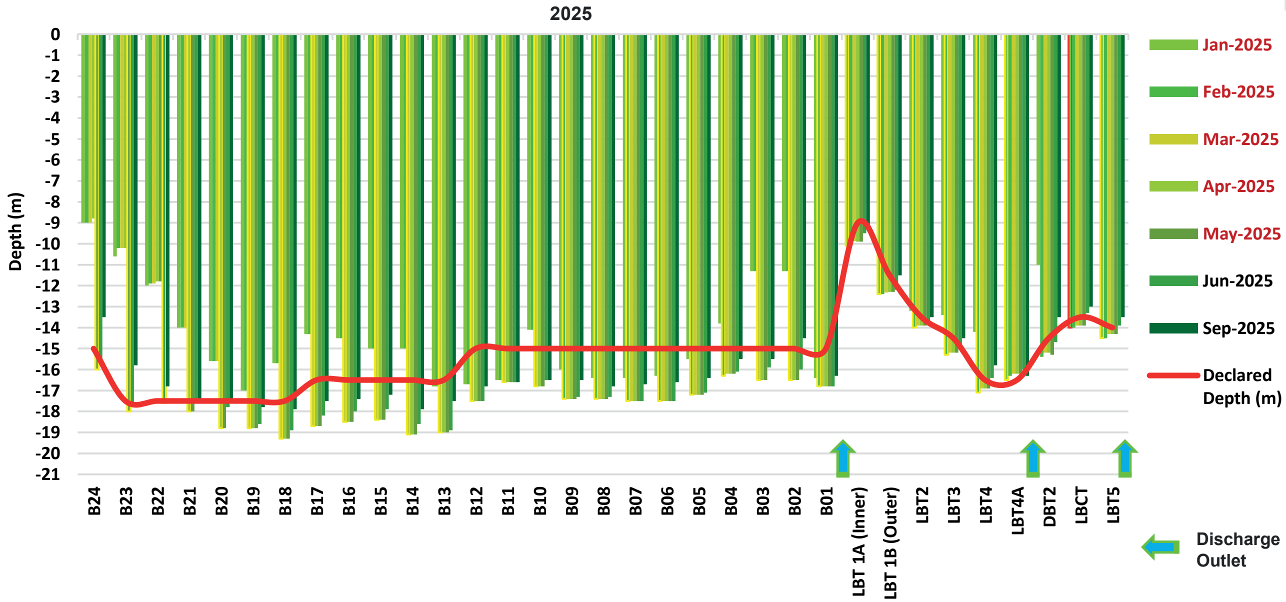
2024

The plot shows measured seabed depths along a continuous sequence of berths (B24 → B01 → LBT berths → OBT berths → LCT berths) for four different survey periods in 2024 (Feb, May, Sep, Dec), compared against the Declared Depth (red line).

2024 represents a pure natural-sedimentation year (no maintenance dredging), providing a clear view of intrinsic sediment dynamics across the port. Depth variations from Feb → May → Sep → Dec 2024 reflect the combined influence of:

- Reclamation-driven sediment supply near B24–B17
- River discharge sedimentation affecting B01–B04 and all LBT berths
- Hydrodynamic trapping zones near jetty structures
- Seasonal monsoon effects (increased suspended load and weaker flushing)

Overall, the port-wide trend in 2024 is progressive shoaling, with hotspots aligning with both reclamation influence and river inflow zones. 2024 provides a reliable baseline for **annual sedimentation rate estimation and long-term dredging optimisation.**



2025

The plot shows measured seabed depths along a continuous sequence of berths (B24 → B01 → LBT berths → OBT berths → LCT berths) for seven different survey periods in 2025 (Jan to Sept), compared against the Declared Depth (red line).

- **Reclamation Legacy (B24–B17):** Continued basin infill from residual sand mobility and altered flow paths near the new terminal footprint.
- **River Discharge Inputs:** Three river outlets (B01–LBT1A, LBT4–DBT2, near LBT5) deliver continuous fine sediments, especially during wet months (Feb–May and Sep).
- **Jetty & Hydrodynamic Effects at LBT:** Structural turbulence and thruster-induced resuspension accelerate localised deposition at tanker berths.
- **Seasonal Monsoon Influence:** Southwest monsoon pulses increase suspended sediment load, raising background infill rates across the central and lower basins.

Bathymetry Heatmap

Overall port- Terminal wise depth variation

The bathymetry heatmap tracks depth deviations from declared berth depths across multiple berths and dry / liquid bulk terminals (LBT) over a 3.5-year period. Color coding indicates sedimentation severity and dredging status:

BERTH	B24	B23	B22	B21	B20	B19	B18	B17	B16	B15	B14	B13	B12	B11	B10	B09	B08	B07	B06	B05	B04	B03	B02	B01	LBT 1A (Inner)	LBT 1B (Outer)	LBT2	LBT3	LBT4	LBT4A	DBT2	LBCT	LBT5
DECLARED DEPTH (m)	-15.0	-17.5	-17.5	-17.5	-17.5	-17.5	-17.5	-16.5	-16.5	-16.5	-16.5	-16.5	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	-11.5	-9.0	-13.5	-14.5	-16.5	-16.5	-14.5	-13.5	-14.0
Mar-22	4.6	6.7	6.2	3.6	3.5	1.7	3.6	4.0	3.1	4.6	5.0	3.6	3.5	2.1	4.3	1.2	2.0	2.5	2.7	3.9	4.8	3.7	3.9	-0.7	0.4	0.5	2.0	3.5	2.0	0.0	2.0	1.2	1.5
May-22	4.6	6.7	6.2	3.6	3.5	1.7	3.6	4.0	3.1	4.6	5.0	3.6	3.5	2.1	4.3	1.2	2.0	2.5	2.7	3.9	4.8	4.0	4.0	-0.7	0.4	0.5	2.0	3.5	2.0	0.0	2.0	1.2	1.5
Jul-22	4.2	6.6	5.3	3.0	2.1	1.4	3.6	3.1	2.7	3.6	3.4	2.7	2.0	1.6	3.4	1.0	0.5	2.0	2.5	3.8	-0.3	-2.5	-1.4	-1.0	0.6	1.0	1.1	3.2	2.3	0.0	2.4	1.5	2.0
Nov-22	5.7	7.5	6.3	4.0	2.8	2.3	4.0	4.3	3.3	4.2	4.3	3.1	2.3	1.6	3.2	1.2	1.0	2.3	3.5	5.2	0.0	-1.0	0.3	-1.2	-0.5	-1.3	0.1	-0.1	0.7	0.0	-0.6	-1.0	-1.0
Feb-23	-0.4	7.6	6.5	4.1	-0.6	-1.0	-0.9	-1.2	-1.6	-2.0	-2.2	-0.7	-1.8	-1.5	-1.3	-1.6	-1.7	-1.5	-1.3	-1.1	0.0	0.2	1.5	-0.5	-0.4	0.0	0.0	0.0	0.7	0.0	0.3	-0.3	-0.5
May-23	0.8	0.0	0.0	-0.2	0.0	-0.9	0.2	-0.4	-0.7	-0.9	-0.2	-0.5	-1.4	-1.1	-0.8	-1.2	-1.5	-1.2	-1.3	-0.8	0.0	0.7	1.8	-1.4	0.2	0.5	-1.0	-0.6	-0.8	0.0	1.0	0.2	0.0
Jun-23	1.3	0.0	0.0	0.0	-0.1	-0.7	0.2	-0.3	-0.9	-0.6	-0.2	-0.5	-1.7	-1.2	-1.3	-1.3	-1.7	-1.3	-1.3	-0.7	0.0	0.9	1.9	-1.4	0.2	0.5	-0.6	-0.6	-0.2	0.0	1.0	0.3	0.1
Jul-23	1.5	0.3	0.2	0.2	0.0	-0.6	0.1	0.2	-0.6	0.0	0.0	-0.5	-1.2	-1.0	-1.1	-1.3	-1.7	-1.2	-1.3	-0.8	0.0	0.7	2.0	-1.3	0.3	0.6	-0.6	-0.5	0.1	0.0	1.4	0.5	0.4
Aug-23	1.9	1.0	0.2	0.5	-0.3	-0.9	0.0	0.3	-0.4	-0.2	-0.2	-0.5	-1.7	-1.0	-1.0	-1.3	-1.5	-1.0	-1.2	-0.8	0.0	0.7	1.9	-1.3	0.3	0.5	-0.7	-0.5	0.1	0.0	1.4	0.7	0.5
Sep-23	3.0	2.1	0.8	0.5	0.0	-0.8	0.1	0.5	0.0	-0.1	0.1	-0.7	-1.8	-1.0	-1.1	-1.6	-1.7	-1.1	-1.3	-0.9	0.0	0.5	2.1	-1.2	0.3	0.5	-0.5	-0.5	0.2	0.0	1.5	0.6	0.5
Oct-23	3.9	2.7	1.6	1.1	0.5	-0.5	0.4	0.6	0.4	0.0	0.5	-0.5	-1.8	-1.1	-1.1	-1.4	-1.6	-1.1	-1.4	-0.7	0.2	1.1	2.4	-1.3	0.3	0.5	-0.6	-0.5	0.1	0.0	1.7	0.7	0.5
Nov-23	4.0	3.1	2.2	1.3	0.5	-0.5	0.6	1.1	0.5	0.1	0.3	-0.4	-1.6	-1.3	-1.0	-1.5	-1.8	-1.2	-1.5	-0.8	0.2	1.1	2.3	-1.2	0.4	1.0	-0.4	-0.2	0.5	0.0	2.1	0.9	0.8
Feb-24	3.9	4.0	2.8	1.6	0.5	-0.4	0.9	1.3	0.6	0.6	0.4	-0.4	-1.9	-1.5	-0.3	-1.2	-1.4	-1.3	-1.5	-1.0	0.3	1.5	2.5	-1.4	0.2	1.0	-0.3	0.2	0.9	0.0	2.5	1.3	1.3
May-24	4.0	4.2	3.0	1.7	0.8	-0.4	1.0	1.3	0.7	0.7	0.5	-0.3	-1.9	-1.5	-0.2	-1.2	-1.4	-1.4	-1.5	-1.0	0.3	1.5	2.6	-1.4	0.2	1.0	-0.2	0.2	1.1	0.0	2.6	1.4	1.2
Sep-24	5.0	6.0	4.8	2.0	1.2	0.1	1.1	1.5	1.0	0.9	0.5	-0.3	-1.7	-1.5	0.2	-1.2	-1.4	-1.4	-1.5	-1.0	0.6	2.0	3.1	-1.4	0.3	1.2	-0.2	0.4	1.4	0.0	3	1.8	1.5
Dec-24	6.0	6.9	5.5	3.5	1.9	0.5	1.8	2.2	2.0	1.5	1.5	-0.3	-1.7	-1.5	0.9	-1.0	-1.4	-1.4	-1.3	-0.5	1.2	3.7	3.7	-1.4	0.5	1.5	0.3	1.1	2.3	0.0	3.5	2.3	2.0
Jan-25	6.0	6.9	5.5	3.5	1.9	0.5	1.8	2.2	2.0	1.5	1.5	-0.3	-1.7	-1.5	0.9	-1.0	-1.4	-1.4	-1.3	-0.5	1.2	3.7	3.7	-1.4	-0.9	-1.1	0.3	1.1	2.3	0.0	3.5	-0.5	-0.5
Feb-25	6.0	7.3	5.6	3.5	1.9	0.5	1.8	2.2	2.0	1.5	1.5	-0.3	-1.7	-1.5	0.9	-2.4	-2.4	-2.5	-2.5	-2.2	-1.3	3.7	3.7	-1.8	-0.9	-1.1	-0.5	-0.8	-0.6	0.2	-0.9	-0.5	-0.5
Mar-25	6.0	7.3	5.6	3.5	1.9	-1.3	-1.8	-2.2	-2.0	-1.9	-2.6	-2.5	-2.5	-1.6	-1.8	-2.4	-2.4	-2.5	-2.5	-2.2	-1.2	-1.5	-1.5	-1.8	-0.8	-0.9	-0.4	-0.7	-0.4	0.3	-0.7	-0.4	-0.3
Apr-25	6.2	7.3	5.7	-0.5	-1.3	-1.3	-1.8	-2.2	-2.0	-1.9	-2.6	-2.5	-2.5	-1.6	-1.8	-2.4	-2.4	-2.5	-2.5	-2.2	-1.2	-1.5	-1.5	-1.8	-0.8	-0.9	-0.4	-0.7	-0.4	0.3	-0.7	-0.4	-0.3
May-25	-1.0	-0.5	5.7	-0.5	-1.3	-1.3	-1.8	-2.2	-2.0	-1.9	-2.6	-2.5	-2.5	-1.6	-1.8	-2.4	-2.4	-2.5	-2.5	-2.2	-1.2	-1.5	-1.5	-1.8	-0.8	-0.9	-0.4	-0.7	-0.4	0.3	-0.8	-0.4	-0.3
Jun-25	-0.7	-0.1	-0.1	-0.1	-0.3	-1.1	-1.4	-1.7	-1.5	-1.4	-2.1	-2.4	-2.5	-1.6	-1.5	-2.3	-2.3	-2.5	-2.5	-2.1	-1.1	-0.9	-1.0	-1.8	-0.7	-0.5	-0.3	-0.4	0.1	0.5	-0.2	0.2	0.1
Sep-25	1.5	1.7	0.7	-0.1	-0.1	-0.3	-0.4	-1.0	-0.9	-0.7	-1.4	-1.0	-1.8	-1.6	-1.5	-1.5	-1.8	-1.7	-1.6	-1.4	-0.5	-0.5	0.5	-1.3	0.0	-0.2	0.0	0.0	0.7	0.2	1.0	0.5	0.5

Outer Berths (B24–B21/B20)

- Highest siltation rates: Frequent orange/yellow/red zones indicate depth loss >2 m within months post-dredging.
- Requires short dredging cycles (6–9 months) to maintain operational clearance.

Mid Berths (B19–B12/B11)

- Moderate sedimentation: Mostly green/brown, occasional orange.
- Condition-based dredging recommended every 9–18 months

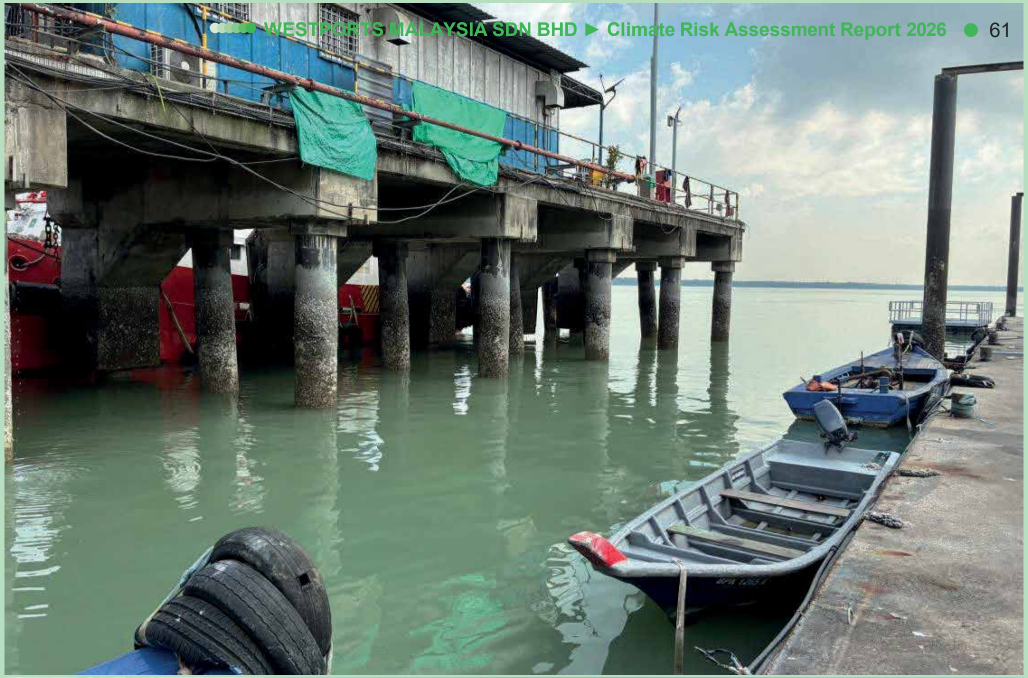
Inner Berths (B10–B06)

- Stable depths: Mostly green/light green.
- Minimal dredging; monitor semi-annually.

Post-Dredged
Above Declared Depth
Below Declared Depth (Less than 1.0m)
Depth Deviation (1.0m - 2.0m)
Depth Deviation (2.0m - 3.0m)
Depth Deviation (3.0m - 4.0m)
Depth Deviation (>4.0m)
Discharge Outlet

Liquid Bulk Terminals (LBT)

- Depths remain near declared values (light green).
- Monitoring only; dredging rarely required.

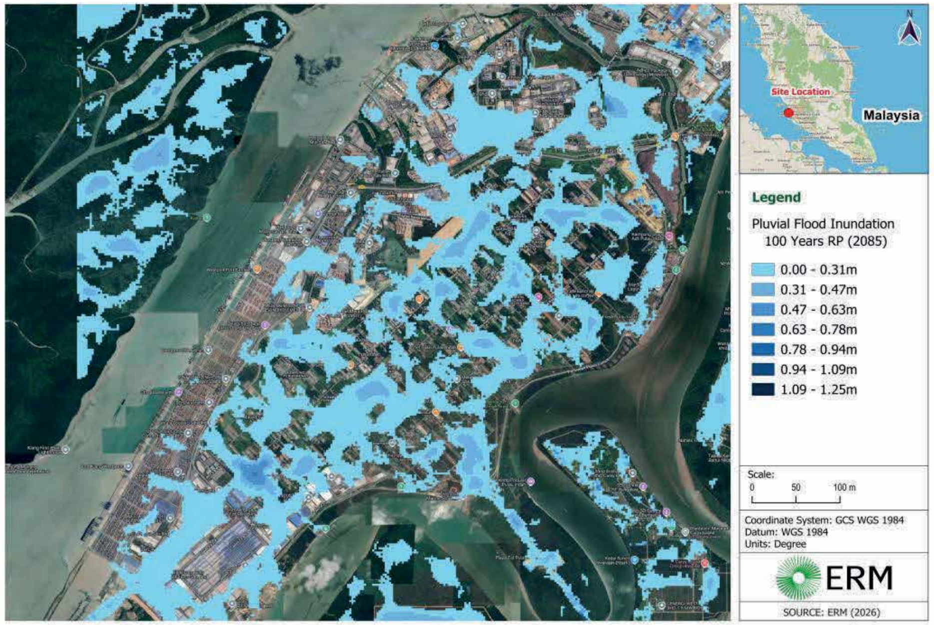


Flood Inundation Analysis

RAINFALL, RIVER AND COASTAL

Flooding - Rainfall, River and Coastal

Rainfall Flood Inundation



No.	Asset Location	Rainfall flood depth 2085 (m)
1	Main Power Supply Station-PMU PIDH 132KV	0.33
2	DBT-I-Yard 4 Zone 1, 5A & 5B, 11	0.29
3	BBT-Yard 4 Zone 2	0.21
4	DBTI-II-Cement Factory	0.20
5	CT1-2-Telecom Data Exchange	0.14
6	CT1-Yard-Sub Station No.8	0.14
7	CT1-Container GATE IN	0.14
8	CT1-KASTAM	0.14
9	CT1-Yard-Container Freight Station (CFS) 1	0.10
10	CT9-2-Telecom Data Exchange	0.10
11	CT1-Westports Distripark	0.09
12	CT1-Rail Freight Terminal	0.09
13	CT1-Yard-Sub Station No.7	0.08
14	CT1-Yard-Sub Station No.6	0.08
15	CT9-Yard-Sub Station No.23	0.08
16	CT2-Yard-Container Freight Station (CFS) 2	0.07
17	CT3-1-Telecom Data Exchange	0.07
18	CT3-Yard-Sub Station No.14	0.06
19	CT9-3-Telecom Data Exchange	0.06

Key findings

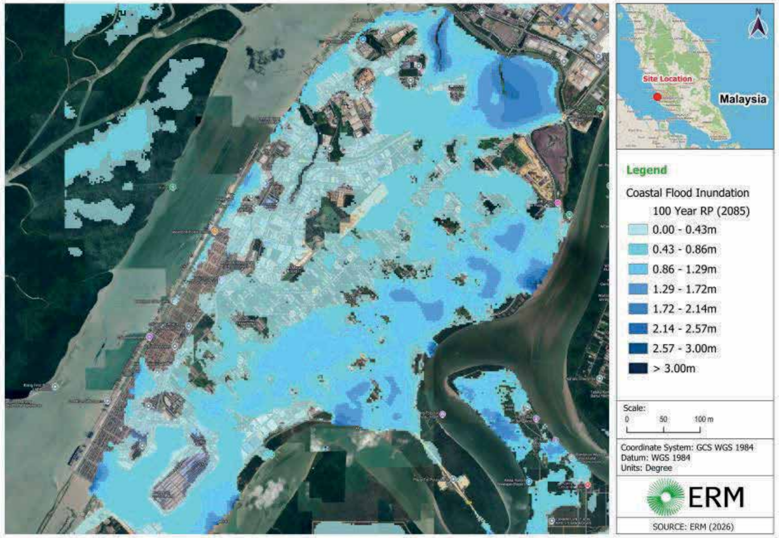
The map shows widespread **surface-runoff (pluvial) flooding** across Westports and adjacent industrial areas in 2085 under a 1-in-100-year storm. The table below shows the Westports assets and respective flood depths.

- No extreme (>0.5 m) pluvial flooding is detected inside core operational platforms by 2085.
- Flooding is predominantly shallow (0.10–0.33 m) across most affected assets.
- Flooding concentrates in: Low-lying back-of-yard areas behind container yards.
- Road corridors between terminals and support facilities.
- Older asset zones (CT1–CT3) with relatively lower platform elevations.
- Marine berths and quayline remain largely unaffected, consistent with elevated platform levels.
- The Main PMU 132kV is the single most high-risk vulnerability, with potential port-wide cascading impact.
- Critical supporting systems (power, telecom, substations) face frequent shallow flooding that can cause operational shutdowns without structural failure.
- Flooding is more operational than structural, but the repeatability and criticality make it highly material.

Rank	Asset	Flood Depth (m)	Risk Interpretation
1	Main Power Supply Station – PMU PIDH 132kV	**0.33**	*Highest criticality*: Even 0.3 m can damage switchgear, threaten continuity, and cause port-wide operational shutdown.
2	DBT-I Yard 4 Zone 1, 5A & 5B, 11	**0.29**	Yard-level flooding disrupts container movement, ground slots & rubber-tyred equipment.
3	BBT-Yard 4 Zone 2	**0.21**	Localised ponding affecting yard operation efficiency.
4	DBTII-Cement Factory	**0.20**	Flooding impacts conveyor motors, electrical rooms & hygiene requirements.
5–7	CT1-2 & CT1-Yard Sub Station No.8, CT1-Container Gate In	**0.14**	Electrical rooms & gate operations vulnerable to water ingress.

Flooding - Rainfall, River and Coastal

Coastal Flood Inundation



Coastal Flooding

The map shows widespread coastal flooding across Westports and adjacent industrial areas in 2085 under a 1-in-100-year storm. The table (right) shows the Westports assets and respective flood depths.

- Coastal flooding in 2085 is significantly deeper than rainfall-driven flooding, with depths ranging 0.4 m to >3.6 m across Westports' low-lying zones.
- Large parts of the port platform, especially older areas (CT1–CT3, BBT, DBT), fall within moderate to deep flood zones (>1 m).

Critical Lifeline Infrastructure at High Risk

- Drainage Network and Sewerage Network experience the deepest flooding (up to 3.62 m)—indicating full system failure, backflow, and overtopping risk.
- Multiple substations (CT9-23, CT1-4, CT6-ODD, CT1-5) face 0.39–1.43 m inundation—high probability of electrical failure and extended outages.
- Telecom Data Exchanges across CT1, CT2, CT3, CT9 experience 0.26–1.62 m flooding, risking widespread ICT and terminal system downtime.

High-Risk Operational Assets

- DBT-I Yard 4 (Zones 1, 5A, 5B, 11) and BBT Yard 4 record 1.4–1.6 m water depth—severe disruption to ground equipment, storage, and container movement.
- Bulk terminal revetments (Liquid Bulk, Dry Bulk I/II, Break Bulk) show 0.9–1.2 m inundation, indicating future overtopping along the waterfront.
- Warehouses (D, E, FGH) face 0.48–0.97 m flooding, threatening stored cargo, electrical panels, and internal facilities.

Nature of Risk (Structural + Operational)

- Coastal flooding poses both structural and operational impacts, unlike the mostly operational impacts from pluvial flooding.
- Deep and saline floodwaters significantly increase corrosion, equipment degradation, and pavement damage.
- Critical utilities (power, ICT, sewerage, drainage) face high failure probability and could trigger cascading port-wide outages.

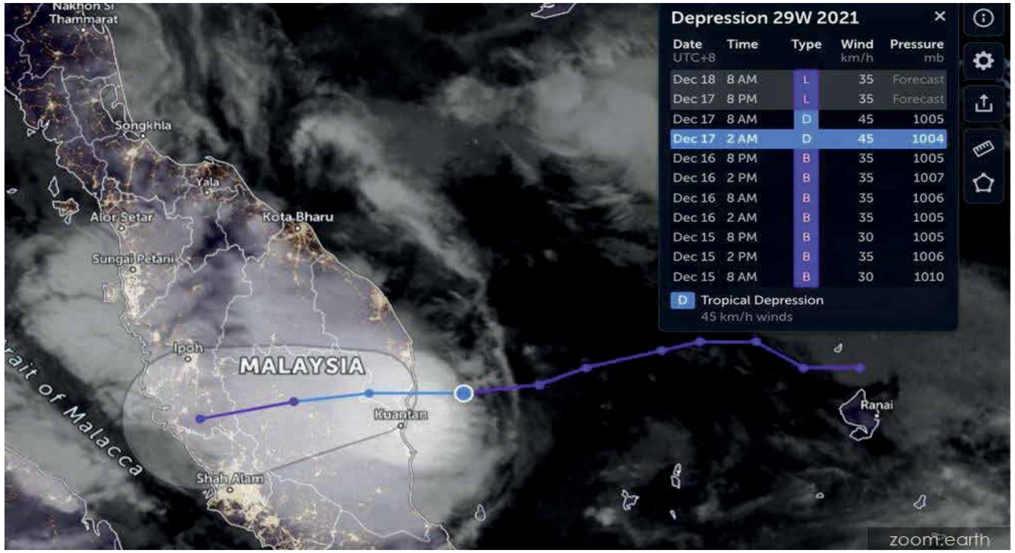
Strategic Implications for Westports

- Future waterfront protections (revetments, seawalls) need height upgrades to withstand 2085 water levels.
- Substations and telecom rooms require elevation, floodproofing or bunding to prevent service disruptions.
- Drainage outfalls need non-return valves and backflow prevention, given the >3 m flooding at drainage/ sewerage networks.
- Low-lying yards need platform raising, improved runoff management and critical equipment relocation.

No.	Asset Location	Coastal flood depth(2085)-m
1	Drainage Network	3.62
2	Sewerage Network	3.62
3	CT9-3-Telecom Data Exchange	1.62
4	DBT-I-Yard 4 Zone 1, 5A & 5B, 11	1.56
5	CT9-Yard-Sub Station No.23	1.48
6	BBT-Yard 4 Zone 2	1.43
7	BBT-Yard 11A	1.3
8	BBT-M&R Recond Store	1.24
9	DBT-I-Sub Station No.4	1.19
10	Revetment for Liquid Bulk terminal (LBT1- LBT5)	1.18
11	BBT-Warehouse D	1.04
12	BBT-M&R Conventional	0.91
13	BBT-Warehouse E	0.91
14	Revetment for Dry Bulk terminal I	0.81
15	Revetment for Dry Bulk terminal II	0.79
16	DBT-I-Sugar Refinery	0.79
17	BBT-Port Police Building	0.78
18	BBT-Yard 13AW	0.77
19	CT9-Logistic Company	0.76
20	LBT-Sub Station No.3	0.72
21	LBT-Stolthaven-Westports	0.72
22	LBT-Water Tank/ Pump House	0.7
23	DBTI-II-Cement Factory	0.69
24	BBT-Sub Station No.02	0.67
25	CT9-Logistic Company	0.66
26	Revetment for Break Bulk terminal	0.64
27	CT1-Yard-Sub Station No. 5	0.52
28	CT1-1-Telecom Data Exchange	0.52
29	CT9-2-Telecom Data Exchange	0.52
30	BBT-Fuel Bay No.01	0.5
31	DBT-I-Warehouse FGH	0.5
32	BBT-M&R Admin Centre	0.49
33	DBTI-II-LPG Terminal	0.48
34	CT2-Yard-Sub Station No.10	0.43
35	Revetment for CT2	0.42
36	CT6-Yard-On Dock Depot (ODD) 99	0.39
37	CT6-2-Telecom Data Exchange	0.39
38	CT9-Yard-Westports-PKFZ Gate	0.38
39	CT2-1-Telecom Data Exchange	0.36
40	CT7-2-Telecom Data Exchange	0.28
41	Revetment for CT3	0.27
42	BBT-Sub Station No.01	0.27
43	CT4-1-Telecom Data Exchange	0.26
44	BBT-Water Tank/ Pump House	0.26
45	BBT-Telecom Data Exchange	0.26
46	CT9-Logistic Company	0.22
47	CT3-2-Telecom Data Exchange	0.19
48	BBT-Yard 12AW &12AS	0.19
49	CT7-Yard-Sub Station No.20	0.15
50	BBT-Car Terminal-open	0.15

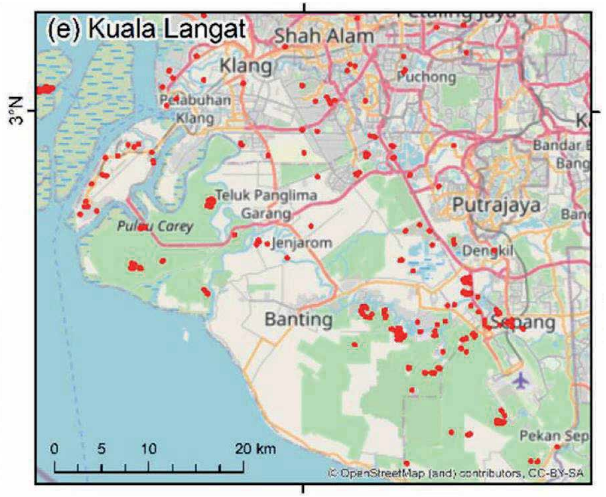
Peninsular Malaysia's Floods of 2021/2022- An overview

- On 17 December 2021, MetMalaysia issued an amber alert, which then swiftly rose to a red alert (the highest level) for the Klang Valley, Selangor and neighbouring states. It rained continuously for four days, a deluge equivalent to a month's worth of rainfall in the area.
- Most of Peninsular Malaysia experienced moderate to heavy rain with thunderstorms on 17-18 December, causing severe flooding. According to the Department of Irrigation and Drainage, 316.5mm of rain fell in Klang on Saturday,18 December, compared to the average monthly national rainfall of 202mm.
- The floods left almost 50 people dead, the evacuation of about 400,000 people, and resulted in an overall estimate of RM6.1 billion in financial losses.
- Unprecedented volumes of rainfall left areas on the west coast of Peninsular Malaysia under almost four meters of water and turned roads into rivers.
- Four rivers around Kuala Lumpur breached their banks.
- **Kapar in the Klang district of Selangor recorded 316 mm of rain in 24 hours on 18 December 2021.**
- Three water pumps were deployed to remove the floodwaters at the scene, while 134 floodgates were closed to prevent overflows from high tides.
- Residents of Kajang and Salak Tinggi were advised to evacuate.
- The main electrical substation at Glenmarie exploded during the night, causing a blackout across some parts of Shah Alam.
- Two water treatment plants were shut down due to the floods, leading to water cuts in 472 areas across Klang Valley.
- Water supply trucks could not reach the affected regions as most roads were closed down or cut off from the floods.



Source: Zoom Earth

A view of buildings and vehicles submerged in flood waters in Shah Alam, Selangor state, Malaysia, December 19, 2021. Picture taken with a drone. Source: REUTERS/Ebrahim Harris



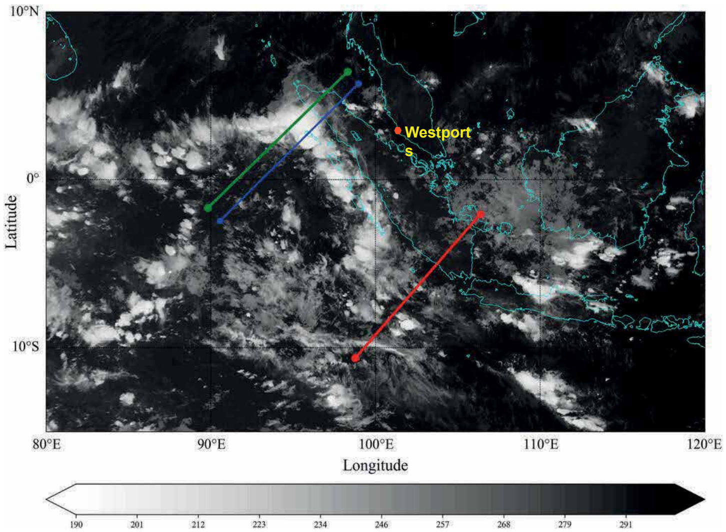
Flood inundation hot spots of Selangor during the 2021–2022 Malaysia flood

Source: Rapid Extreme Tropical Precipitation and Flood Inundation Mapping Framework (RETRACE): Initial Testing for the 2021–2022 Malaysia Flood

Extreme Wind-Squall Analysis

Sumatra Squall

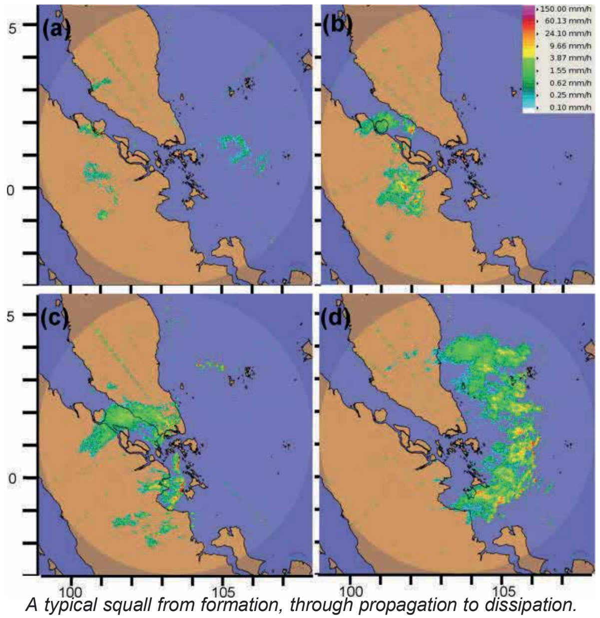
- Adverse Weather Caused by Sumatra Squall Lines (SSL)
- Sumatra squalls are narrow bands of thunderstorms, often associated with intense precipitation and strong wind gusts. In addition, squalls usually have rapid increases in wind speed and an intense period of precipitation. They affect areas across the Malacca Strait: Indonesia, Malaysia, and Singapore. SSL-induced extreme weather is categorized as dangerous weather conditions.
- Duration & Coverage
  - SSL events can last 6–8 hours.
  - They affect areas across the Malacca Strait: Indonesia, Malaysia, and Singapore.
- Rainfall
  - Rainfall intensity can reach 90.4 mm/hour.
  - This has led to flash floods in Malaysia and Singapore.
- Winds
  - Strong winds during SSL cause:
  - Tree collapses, roof damage to buildings.
  - Maximum recorded wind speed: 144 km/hour.
- Warning Systems
  - SSL can only be detected about 3 hours before occurrence.
  - Detection depends on real-time Doppler radar data analysis.



*Himawari-8 AHI brightness temperature (K) of band 13 (10.4-μm spectral band) during the squall-line propagation offshore Sumatra at 0700 LST 11 Jan 2016. Lines for the sections perpendicular to the west coast of Sumatra are indicated, the northern sections are indicated with the **green** and **blue** lines, and the southern section is indicated with the **red** line.*

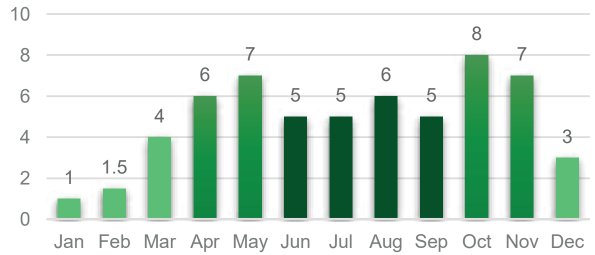
Source: 1. Lopez-Bravo C, Vincent CL, Huang Y, Lane TP. A Case Study of a West Sumatra Squall Line Using Satellite Observations. Mon. Wea. Rev.. 2023;151(2):523-543. doi:10.1175/MWR-D-21-0194.1

2. Hanh Nguyen, Muhammad E Hassim, Jia Yan Huan et al. Large-scale to local factors influencing Sumatra squalls affecting Singapore, 01 April 2025, Research Square [https://doi.org/10.21203/rs.3.rs-5607311/v1]

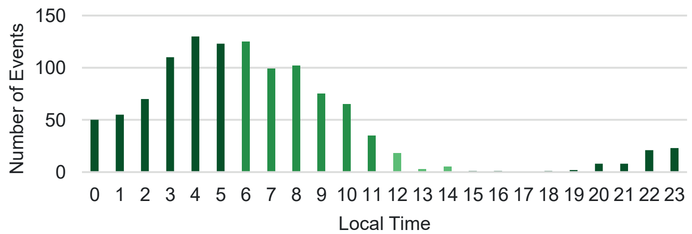


A typical squall from formation, through propagation to dissipation. This squall occurred overnight on the 31 July 2013 to 1 August 2013. Formation (a) occurs in the late evening (2017 LT) over Sumatra and on the coast of the Malacca Strait. Growth (b) occurs as the squall extends from a single cell thunderstorm to multi-cellular (2302 LT). A bow echo forms (c) (0302 LT) as the squall line becomes more prominent and propagates over Singapore and the islands to the south. Dissipation begins over the South China Sea (d) as the squall becomes disorganised and widespread (0902 LT).

a) Monthly distribution



b) Diurnal cycle of the Sumatra squalls



Distribution of the Sumatra squalls (SS) identified from 33 years of radar images. (a) Monthly distribution and (b) Diurnal cycle of the Sumatra .

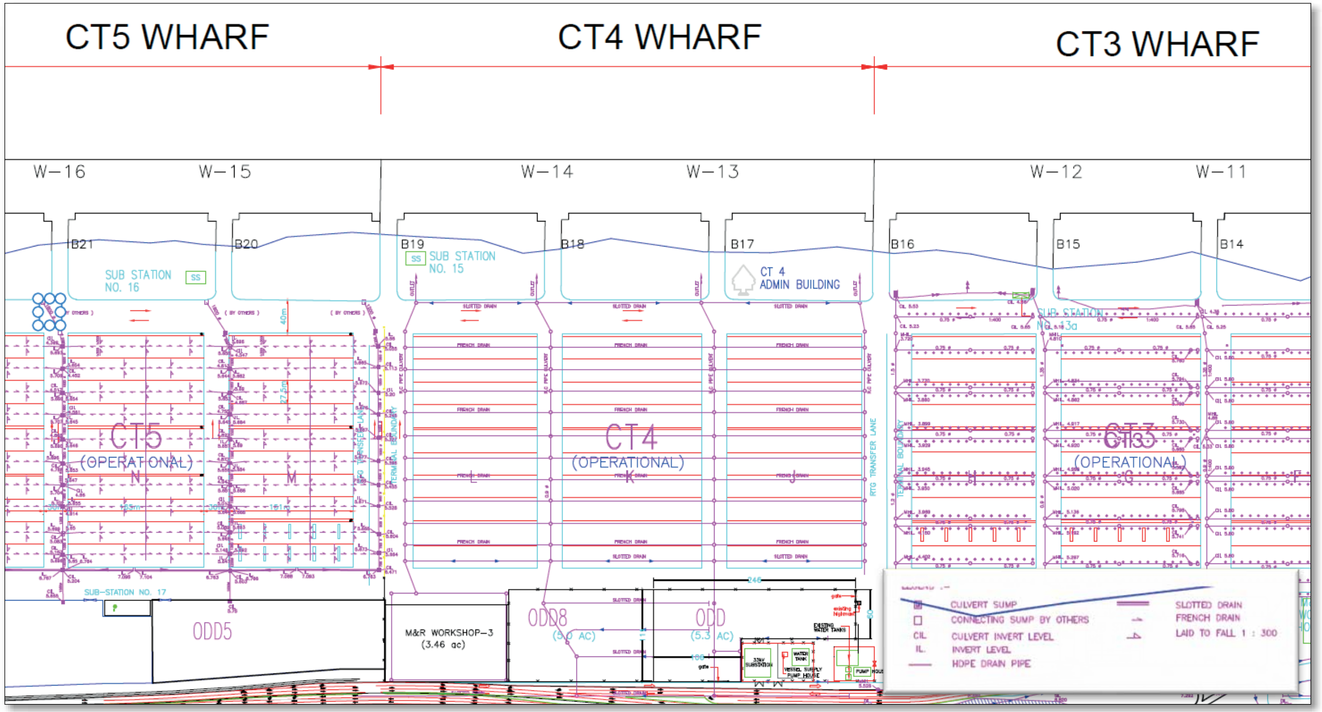
Climate Change Projection

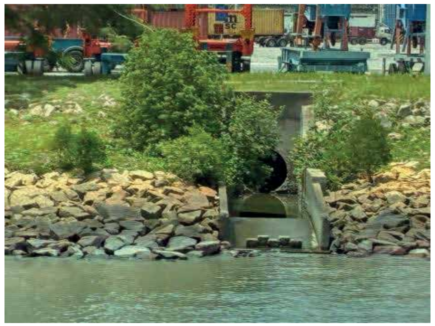
Future climate projections from Singapore's Third National Climate Change Study (V3) study indicate that **Sumatra squalls are likely to become more intense**, with stronger wind gusts and heavier rainfall. A warmer atmosphere will enhance convective activity, providing more energy for severe squall lines. However, changes in squall frequency remain uncertain, as these events are strongly influenced by complex regional climate drivers such as El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD).

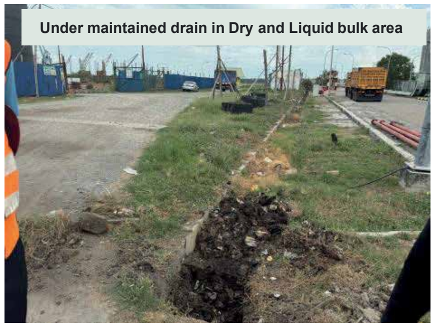
Source: CLIMATE CHANGE PROJECTIONS FOR SINGAPORE.pdf

Storm Water Drain System Analysis

Storm Water Drainage System






Under maintained drain in Dry and Liquid bulk area

Overview

The Port drainage design integrates surface and subsurface drainage, discharging through a network of sumps, RC pipe culverts, slotted drains, French drains, and outfalls leading to the sea. It covers container yards, RTG lanes, wharf areas, access roads, and ancillary facilities.

The figure on the left shows the drainage network for container terminals CT3-5. The image on the left bottom shows the open drain and outfall point.

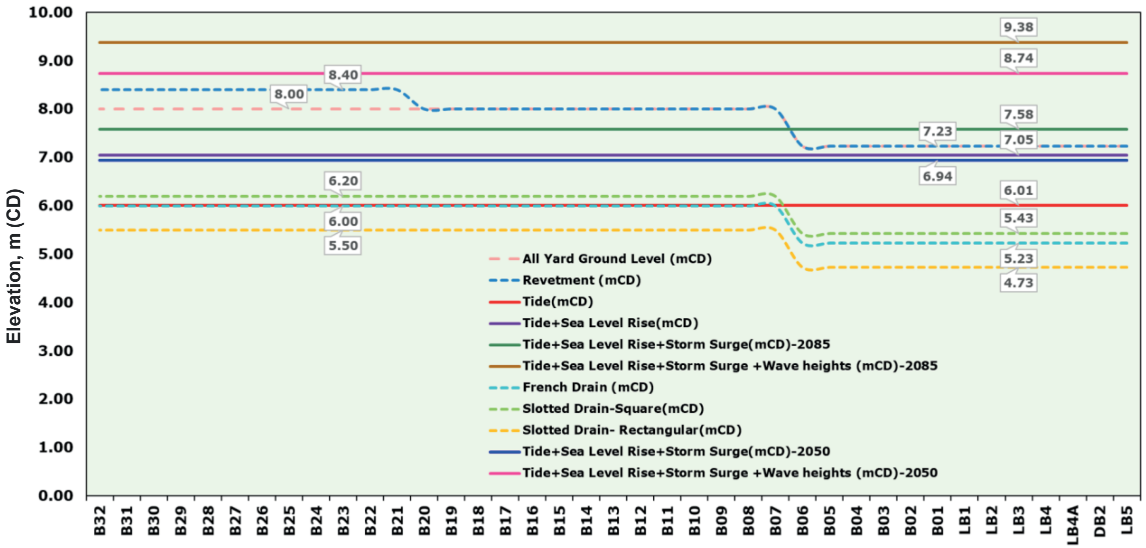
Key Components

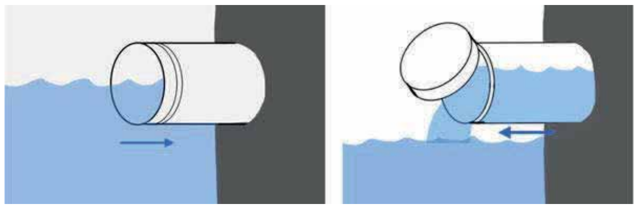
- **French Drains (450 mm perforated HDPE + geotextile)** under yards for subsurface drainage; laid in gravel beds with 1:30 pipe slope. The sump connected to the drain has depth of around 2.0m.
- **Slotted Drains with heavy-duty GI gratings** for yard and wharf surface runoff; HB-loading compliant.
- **RC Sumps & Manholes** with ladders, gratings, reinforced base/walls for collection and maintenance access. The depth of slotted square and rectangular drains are around 1.8m and 2.5m respectively.
- **RC Pipe Culverts (900–2100 mm)** conveying flow from sumps to outfalls; typical gradient 1:350.
- **Outfalls with wingwalls, geotextile & rip-rap protection** to safely discharge flow to sea/harbour.

Water movement

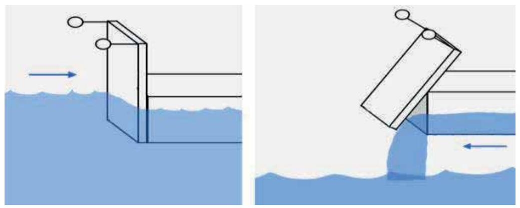
- French drains → Sumps → Large RC culverts → Outfalls
- Network spans CT1–CT9 with complete level control (IL/SIL/CIL shown at each sump & pipe run).
- Culvert discharges sized up to ≈3.10 m³/s, ensuring capacity during monsoon events.

Storm Water Drainage System



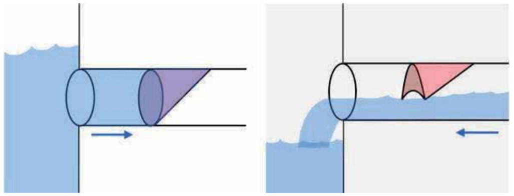


A **round flap gate** at the end of a pipe in closed position (left, at high tide) and open position (right, at low tide, conveying stormwater runoff).



A **rectangular flap gate** at the end of a channel (for example, ditch) in closed position (left, at high tide) and angled in open position (right, at low tide, conveying stormwater runoff).

A **duckbill check valve** at the end of a pipe outfall in closed position (left, at high tide) and open position (right, at low tide, conveying stormwater runoff).



An **inline check valve** inside of a pipe in closed position (left, at high tide) and open position (right, at low tide, conveying stormwater runoff).

Overall Drainage Vulnerability Pattern

The figure shows three drain types and their elevations relative to progressively higher water levels (Tide → Tide + SLR → Storm Surge → Waves).

French Drain Level (~5.23–6.0 mCD)

- The **100-year tide level (~6.01 mCD)** is consistently **above the French drain level**, which means:
  - **Backflow risk is present even under normal tide.**
  - Drain outflow can become **submerged**, reducing hydraulic gradient.
  - During high tides or spring tides, **drains operate under submerged conditions**, slowing discharge from yards toward the shoreline.

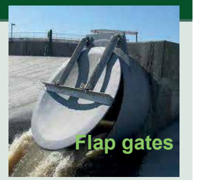
Slotted Drain – Square (~5.43–6.2 mCD)

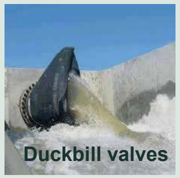
Slotted Drain – Rectangular (~4.73–5.5 mCD)

- Both slotted drain types sit **well below the tide line in some parts of the berth area**, resulting in:
  - **Permanent or near-permanent drowning** of the outlet.
  - Reliance on internal storage, trunk lines, or pump assistance (if provided).
  - **Rapid loss of discharge efficiency** during elevated tide conditions.

Details regarding probability, likelihood and consequence are provided in **Slides 49 & 50**.

Recommended Protection Strategy





Primary:

- Flap gates / duckbill valves at all outfalls.
- NRVs (non-return valve) at pump discharge lines.
- Raised outfall where possible.

Secondary:

- Pumping stations for low-lying zones.
- Surge-triggered outfall gates.

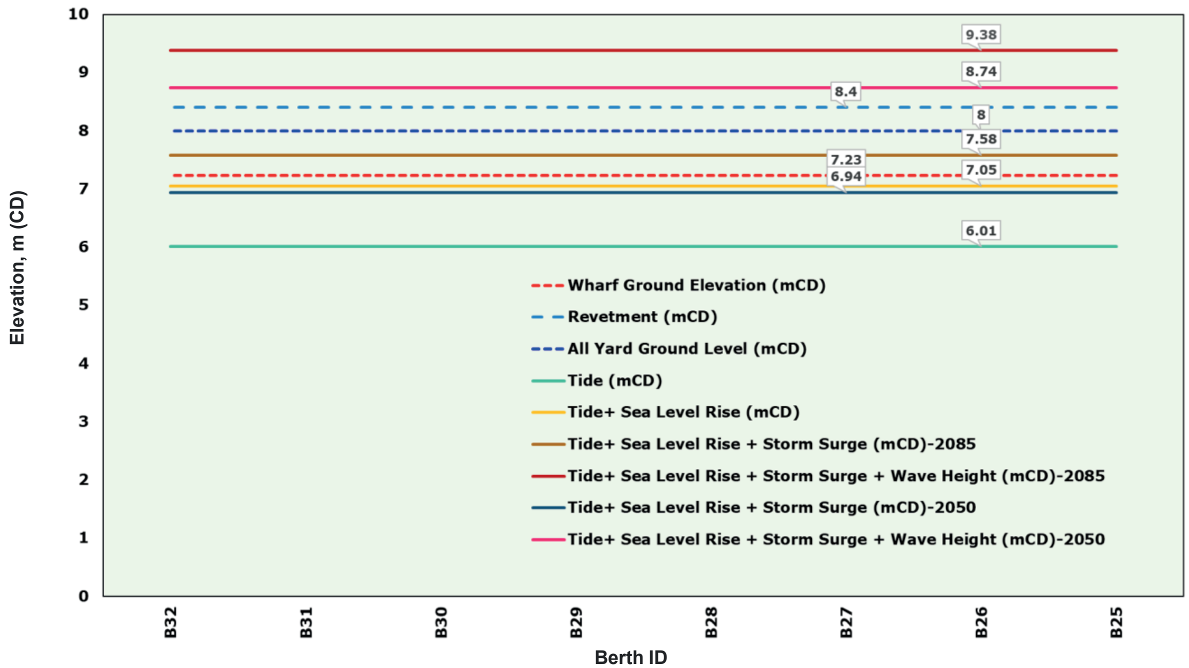
Tertiary:

- Deployable barriers during extreme storm forecasts.

Source: https://content.ces.ncsu.edu/devices-for-retrofitting-stormwater-management-systems-to-reduce-tidal-flood-impacts

Westports Expansion Analysis

Westports Expansion Analysis



The section compares port ground and coastal protection elevations against progressively more extreme water-level conditions. Under normal conditions, existing **wharf, yard, and revetment levels** remain well above the **present 100-year tide level**. When **sea-level rise** is included, baseline water levels rise closer to yard and wharf elevations, reducing freeboard. During **100-year storm surge conditions**, water levels overtops the wharf and approach closer to the yard and revetment.

- Under the combined Tide + SLR + Storm Surge + Wave Height scenario, all structures (wharf, yard, revetment) are overtopped.
- The critical exceedances are between 0.98–2.15 m, which is high.

Implication: These berths are highly vulnerable to coastal flooding and overtopping under extreme future conditions.

Details regarding probability, likelihood and consequence are provided in **Slides 49 & 50**.

Heat Map of Westports Assets (New Terminal)

Physical Hazard*	Baseline	SSP5-8.5: 2050	SSP5-8.5: 2085
Extreme Heat	0.96	3.44	3.92
Extreme Winds & Storms	0.66	0.78	0.84
Rainfall Flooding	0.00	0.00	0.00
Riverine Flooding	0.00	0.00	0.00
Coastal Flooding	0.00	0.00	0.00
Extreme Total Water level	7.128	8.00	8.00
Waves	1.20	1.20	1.20
Currents	3.00	2.677	2.727

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Overall Risk Outlook

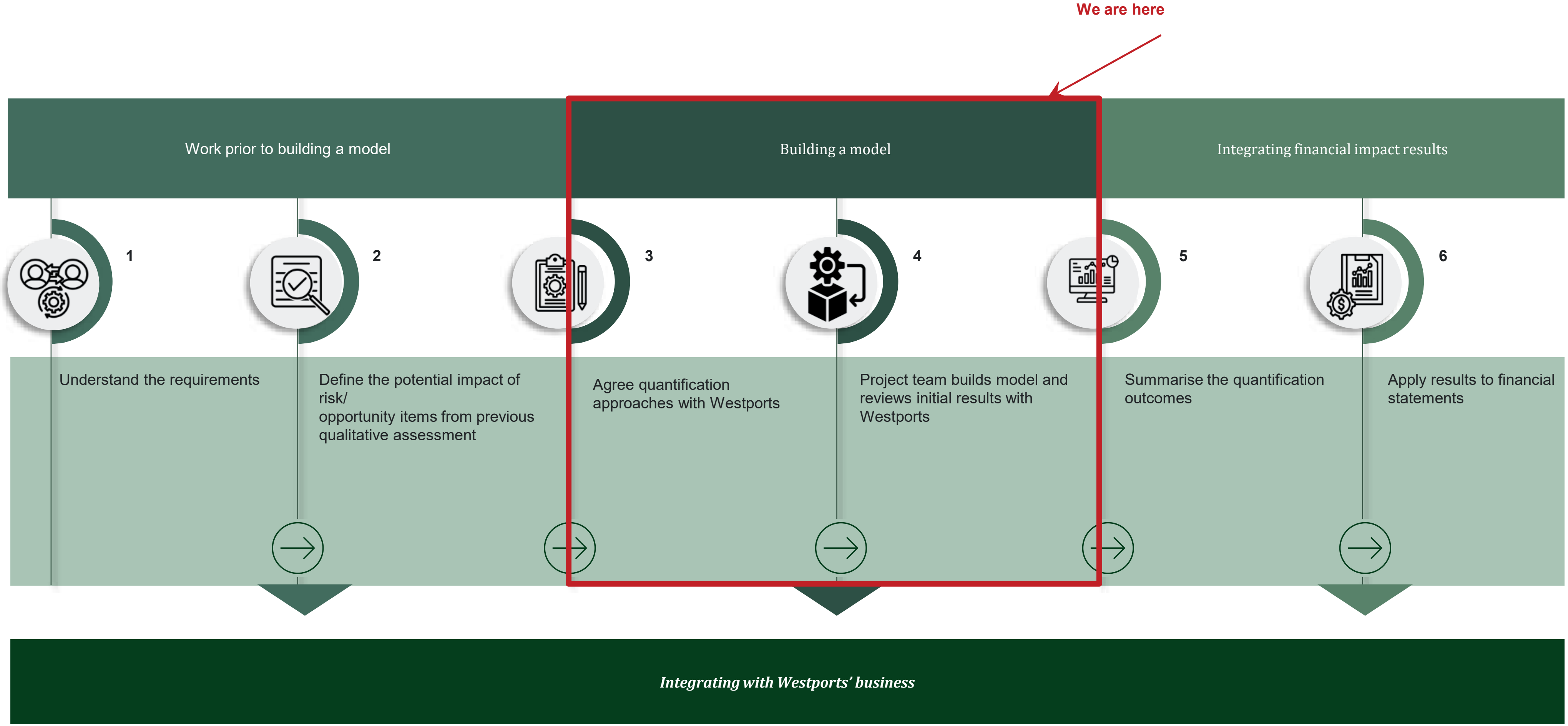
- A physical climate risk assessment was undertaken for the **new reclaimed-land terminal** to quantify baseline and future climate-driven hazard risks under the SSP5-8.5 high-emissions scenario for 2050 and 2085.
- Results indicate that **Extreme Total Water Level (ETWL)** is the dominant and persistent hazard, with an already High–Very High baseline risk (7.128) increasing to the maximum score of 8.0 by 2050 and remaining elevated in 2085, reflecting continued sea-level rise and storm surge amplification.
- **Extreme Heat** shows a significant escalation from Low (0.96) today to High (3.44) by 2050 and Very High (3.92) by 2085, signaling strong operational and structural heat-stress implications for exposed assets.
- **Currents** remain in the Moderate range, decreasing slightly by 2050 (2.677) before rising again by 2085 (2.727).
- **Extreme Winds & Storms** show only marginal increases but remain in the Low category across all timeframes.
- **Waves, Rainfall Flooding, Riverine Flooding, and Coastal Flooding** remain Minimal to Low, indicating that hydrological flooding pathways are not currently material for the reclaimed platform.
- Overall, the new terminal's long-term exposure is primarily governed by **Extreme Total Water Level and** escalating **Extreme Heat**, which will drive the need for forward-looking design allowances, operational thresholds, and phased adaptation planning.

Chapter 2

FINANCIAL IMPACT ASSESSMENT-QUANTIFICATION APPROACH

Introduction to the Quantification Process

Our approach follows six steps towards quantification aligned with IFRS requirements



Quantification Boundary – Climate Scenarios and Timeframes

Similarly to Physical Risk Qualitative Assessment in Task 1, in the financial quantification exercise:

Scenario Selected

We are using the latest Sixth Assessment Report (AR6) from the Intergovernmental Panel on Climate Change (IPCC). In this assessment SSP5-8.5 is used for scenario analysis.

- **SSP5-8.5**: a high emissions scenario, which follows a "**business as usual**" trajectory, assuming no additional climate policy and seeing CO_2 emissions triple by 2100. The selection of this scenario follows Tasked Force on Climate-Related Financial Disclosures (TCFD) guidance to assess **stressed exposure** to physical climate change risks.

Scenario	Best estimate temperature by 2100 (5%-95% likelihood)*
SSP1-1.9	1.4°C (1.0°-1.8°C)
SSP1-2.6	1.8°C (1.3°-2.4°C)
SSP2-4.5	2.7°C (2.1°-3.5°C)
SSP3-7.0	3.6°C (2.8°-4.6°C)
SSP5-8.5 (Selected)	4.4°C (3.3°-5.7°C)

Time Horizon

Depending on the type of the hazard, our assessment horizon may extend up to the year 2100:

Hazard	Baseline	2050s	2085s
Extreme heat	1985 – 2014	2035 - 2064	2065 - 2094
Extreme total water level	1985 – 2014	2035 - 2064	2065 - 2094
Current	1985 – 2014	2035 - 2064	2065 - 2094

Hazard and Impacts

We have shortlisted the top two (2) hazards identified in Phase 1 to quantify the financial impacts of these hazards to Westports' assets.

Climate Hazard	Justification and Potential Impacts
Extreme Heat	Under global warming, Westports' assets are exposed to elevated extreme heat risk. Affected assets include the container yards, office tower, and data center, all of which rely on cooling systems. Prolonged periods of extreme heat increase cooling demand and subsequently raise operational costs for these facilities.
Total Water Level	The combined effects of sea-level rise, storm surge, tides, and waves can generate extreme coastal water levels. Under global warming, sea levels are projected to rise progressively, increasing the potential severity of this hazard. As Westports' operations are located along the coast, its assets are expected to experience stronger impacts over time. Flooding of these assets may cause operational disruption, leading to business interruption and reduced revenue.

Quantification Boundary

For extreme heat, only Westports' assets that require cooling systems will be included in the quantification. For total water level, due to potential financial impact arising from operational disruptions, all 36 asset group types will be assessed.

Approach for Financial Quantification

Extreme Heat

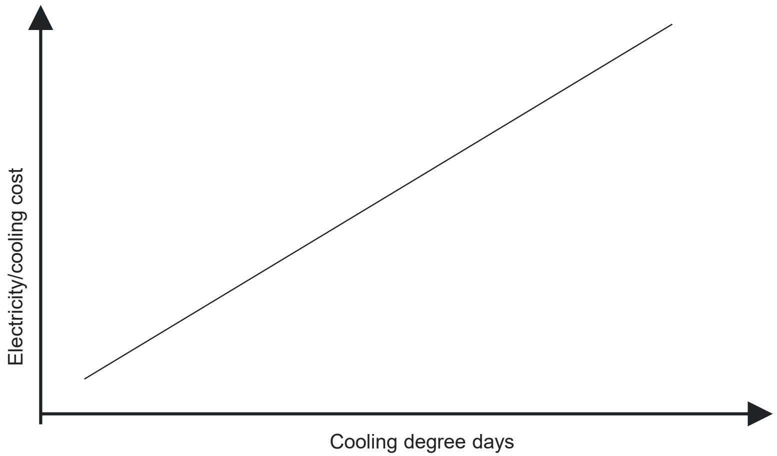
The **impact of increasing temperature** on the operation of an asset is determined by the electricity/cooling cost that is **proportional to the cooling degree days*** (the sum of daily-mean temperature over all calendar days with daily-mean temperature above 18.3°C [65°F] or cooling threshold).

Example

If the cooling cost of an asset in 2023 is $1 million, and the cooling degree days are projected to increase from 200°C day in the baseline period to 250°C day in 2050 time horizon under SSP5-8.5 scenario, the additional cooling cost of the asset is

$$\$1\text{ million} \times \frac{250-200°C\text{ day}}{200°C\text{ day}} = \$0.25\text{ million (25\% increase)}$$

Assuming that the electricity/cooling cost increases linearly with the increase in cooling degree days



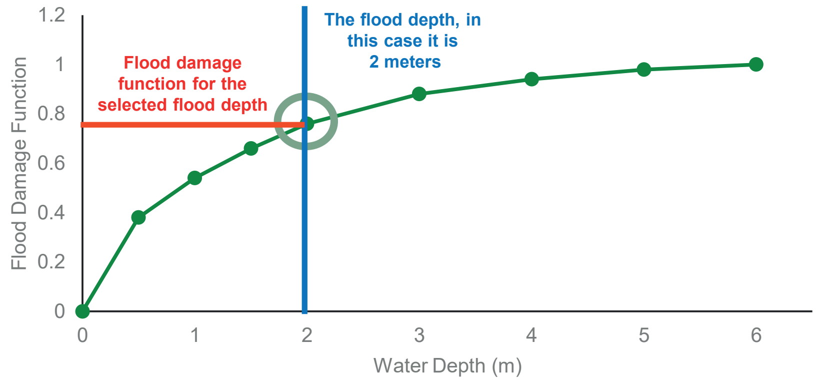
Extreme Total Water Level

Total water level may result in flooding, which can damage Westports' physical assets and affect on the business operation. The severity of damage depends on how deep the flood is. **The deeper the flood, the more impact it causes.**

To estimate this impact, we utilize a flood damage curve from Huzinga et al. (2017)*, where it will show the **flood damage function** or the proportion of an asset's damage resulted from flood impact at different flood depths. A value of 0 means no impact and a value of 1 means the asset is completely damaged. An example of this curve can be seen on the right.

The flood damage function will then be multiplied by number of days to completely recover the damage (Verschuur et al. 2022)** to estimate on the potential **revenue loss**. In other words, the graph will be used to quantify **revenue loss** arising from business disruption due to flood-related damage.

However, ERM notes that there has been no historical asset damage resulting from flooding. Therefore, for this assessment, ERM will focus on the additional (anticipated) financial impacts caused by the projected increase in the total water level.



Flood damage curve for commercial buildings in Asia, from the European Commission (EU) Joint Research Centre (JRC) (Huzinga et al. 2017)*. **ERM will use the most relevant damage function(s) from this source in the quantification,** along with **the maximum downtime due to flooding for ports/power assets** (Vershuur et al. 2022**).

Huzinga et al. (2017) – JRC Publications Repository - Global flood depth-damage functions: Methodology and the database with guidelines

***Verschuur et al. (2022) – Multi-hazard risk to global port infrastructure and resulting trade and logistics losses | Communications Earth & Environment*

Financial Quantification for Extreme Heat

Methodology for Quantifying the Impact of Extreme Heat on OPEX

Input Variables

Westports Data
Data points which ERM requires Westports to provide for **each site**

- a — Electricity/cooling cost per site per year ($) (i.e. cost for air conditioning for malls per year)
- b — *Co-ordinates of each site*

Physical Climate Variables
Climate data derived from Intergovernmental Panel on Climate Change (IPCC) Interactive Atlas* or World Bank's Climate Change Knowledge Portal**, supplemented by data from ERM and academic research

- c — Daily minimum temperature (°C)^
- d — Daily maximum temperature (°C)^

Calculation

Financial Impact (OPEX)

a × e

Electricity/cooling cost × *Additional cooling degree days*

e is derived from b, c and d^

Increase in electricity/cooling cost due to increase in cooling degree days

Financial Impact (Output)

OPEX

Additional costs due to electricity/cooling cost (RM)

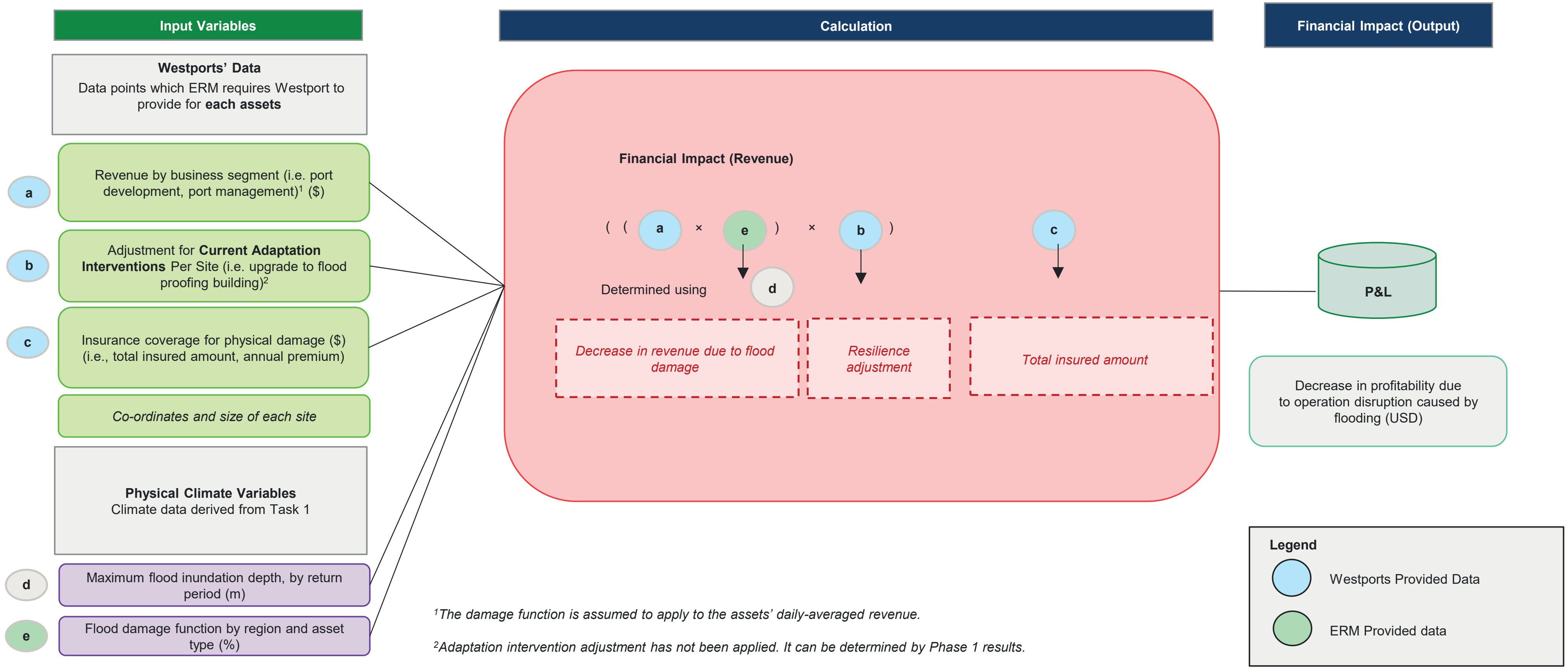
Legend
- Westports Provided Data
- Climate data

^Cooling degree days (item g) is derived from daily minimum and maximum temperatures (items e and f).
- Daily mean temperature = (daily minimum temperature + daily maximum temperature)/2
- When daily mean temperature in a day exceeds the cooling threshold (item d), the cooling degree days = daily mean temperature – cooling threshold. For example, if daily mean temperature on 1 Aug is 30°C and the cooling threshold is 25°C, cooling degree days on 1 Aug = 30-25°C = 5°C day.
- When daily mean temperature is lower than the cooling threshold, the cooling degree days = 0
- Cooling degrees day in a year = sum of cooling degree days from 1 Jan to 31 Dec (unit: °C days).

*https://interactive-atlas.ipcc.ch/
**https://climateknowledgeportal.worldbank.org/

Financial Quantification for Total Extreme Water Level

Methodology for Quantifying the Impact of Extreme Total Water Level on Profit and Loss (P&L)



[1]The damage function is assumed to apply to the assets' daily-averaged revenue.

[2]Adaptation intervention adjustment has not been applied. It can be determined by Phase 1 results.

Key Findings for Physical Risk Quantifications

Results of Financial Quantification

Summary of Key Findings

- The following two physical risks have been quantified based on Phase 1 results:
- **Impact of Extreme Heat on Electricity Cooling Cost (OPEX).**
- **Impact of Extreme Total Water Level on Revenue.**
- Comparatively, the **anticipated financial impact*** of extreme total water level is significantly larger than that of extreme heat. This is related to the potential of business interruption caused by higher projected water level.

Anticipated Financial Impacts due to Extreme Heat and Extreme Total Water Level (RM)*

Time Horizon	Extreme Heat	Extreme Total Water Level
2050	RM 1,710,000	RM 29,240,000 to 34,750,000 (1.50 to 1.78% of FY2024 revenue)
2085	RM 4,201,000	RM 87,280,000 to 96,790,000 (4.48 to 4.96% of FY2024 revenue)

Hence, it is crucial to enhance the climate resilience against future projected extreme water levels.

The following key assumptions were formulated as part of the model development.

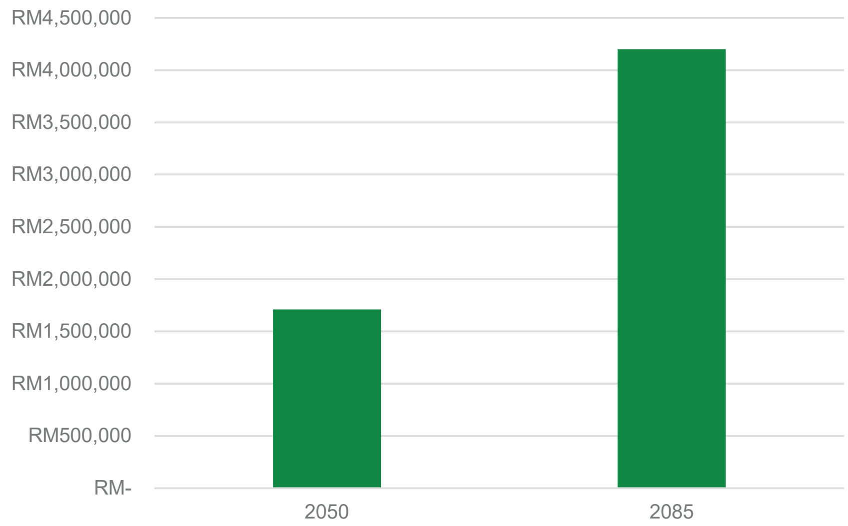
Hazard	Assumptions
Extreme Heat	Business growth and inflation are assumed to be excluded from this model.
	As it is assumed that cooling systems are expected to be a major driver of electricity consumption; therefore, the total electricity bill has been considered in estimating the projected increase in electricity costs.
	The total electricity cost for 2024 is used as the baseline to estimate the expected increase in electricity costs over the assessment period.
	It is assumed that extreme heat will not cause operational disruptions or result in any direct/indirect damage to the asset during model development, as there is no historical record of such damage.
Water Level	Business growth and inflation are assumed to be excluded from this model.
	It is assumed that the flood inundation depth will have directly impact the business operations.
	It is assumed that total water level will not result in any direct/indirect damage to the asset during model development, as there is no historical record of such damage.

All financial data provided by Westports were from FY2024. Therefore, the anticipated financial impacts represent additional financial impacts compared to FY2024 figures.* ***Note that business growth and inflation are not considered in the quantification. In other words, the results here reflect the financial impacts on the current operation under future climate conditions.*

Financial Quantification 1 – Extreme Heat

Additional financial impact of extreme heat is projected to increase over time

Projected Change in Electricity Cost due to Increasing Temperature (RM)*



- Higher temperature → Higher cooling demand under warmer climate → Higher electricity cost for cooling.
- Three buildings with electricity expenditure for cooling systems are affected – "Container – Westport building", "Building – TowerBlock WMSB" and "Building – BiZCentre WMSB".

Key assumptions:

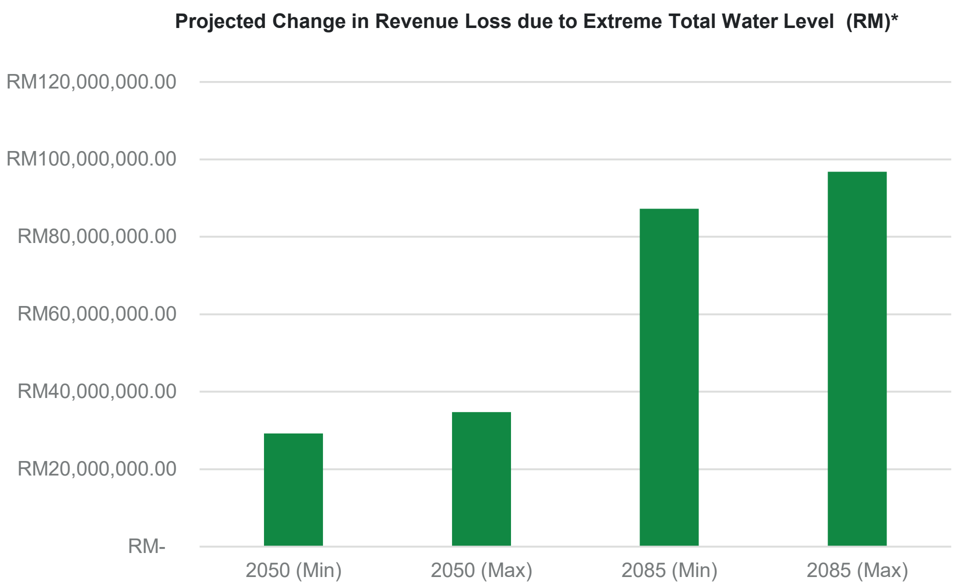
- *Electricity cost for each building is derived from the total electricity cost for Westports and the total electricity consumption for each building.*
- *Projected change in electricity cost is directly proportional to projected change in cooling degree days.*
- *No change in electricity grid price.*

Additional Financial Impact of Extreme Heat across All Building with Cooling Systems (RM) = Current Electricity Cost (FY2024; RM) × Projected Change in Cooling Degree Days (°C)

**All financial data provided by Westports were from FY2024. Therefore, the anticipated financial impacts represent additional financial impacts compared to FY2024 figures.*

Financial Quantification 2 – Extreme Total Water Level

Additional financial impact of extreme water level is projected to increase with time



- Extreme water levels → business interruption → reduction in revenue.
- Extreme total water level: +3.3 to +4.2 m (baseline) → +3.65 to +4.57 m (2050) → +4.29 to +5.21 m (2085).
- Additional financial impacts due to revenue loss:
  - 2050: RM 29,240,000 to 34,750,000 (1.50 to 1.78% of FY2024 revenue)
  - 2085: RM 87,280,000 to 96,790,000 (4.48 to 4.96% of FY2024 revenue)

- *Key assumptions:*
  - *Water level for each asset group takes the minimum (min) and maximum (max) value within the asset group.*
  - *Business interruption day for each asset group is derived from (1) X% of damage due to water level of N meters, and (2) restoration of operations due to X% of damage.*
  - *Min and max impact is derived from the largest business interruption days across all asset groups.*
  - *No change in revenue.*

Revenue Loss due to Extreme Total Water Level (RM) = Daily Revenue in FY2024 (RM/day) ✖ Maximum Business Interruption Days due to Extreme Total Water Level (day)

All financial data provided by Westports were from FY2024. Therefore, the anticipated financial impacts represent additional financial impacts compared to FY2024 figures.

Adaptation Measures

No.	Asset Group Types	Total Assets
1	Berth: Nearshore	39
2	Building: Data Center-Nearshore	1
3	Building: Maintenance Repair Nearshore	2
4	Building: Office	4
5	Building: Office Nearshore	1
6	Building: Operational	3
7	Building: Operational-Nearshore	1
8	Drainage system	1
9	Equipment: Nearshore	5
10	Equipment: Onshore	10
11	Jetty: Nearshore	2
12	Manufacturing: Chemicals	1
13	Manufacturing: Food Nearshore	4
14	Manufacturing: LPG	1
15	Manufacturing: LPG Nearshore	1
16	Manufacturing: Other	2
17	Openwater: Nearshore	2
18	Power: Substation	13
19	Power: Substation DG	1
20	Power: Substation NearRiver	1
21	Power: Substation Nearshore	12
22	Power: Substation Solar	1
23	Revetment: Onshore	14
24	Sewerage system	1
25	Telecommunications Services	11
26	Telecommunications Services: Nearshore	10
27	Transport: Waterways	1
28	Warehouses: Covered	14
29	Warehouses: Covered Nearshore	1
30	Warehouses: Dock Depot	6
31	Warehouses: Fuel	1
32	Warehouses: Fuel Nearshore	1
33	Warehouses: Uncovered	3
34	Warehouses: Uncovered Nearshore	5
35	Water Supply	4
36	Wharf: Nearshore	19
	Total	199

Adaptation Measures – Extreme Heat

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Heat	**Critical IT & Control** 02 Data Center-Nearshore 25 Telecommunications Services 26 Telecommunications Services: Nearshore	**Critical IT & Control** **Engineering Measures** ❖ Upgrade cooling systems to N+1 or N+2 redundancy; adopt high-efficiency chillers or liquid cooling for dense racks. ❖ Cold/hot aisle containment, server-room pressure control, and thermal zoning. ❖ Install thermal insulation, cool roofs, reflective paint, and external shading on building envelope. ❖ Indoor temperature/HVAC automatic load balancing during peak heat. ❖ Move critical servers to edge sites with lower thermal exposure where possible. ❖ Replace VRLA UPS batteries with LFP lithium-ion with higher heat tolerance. ❖ Implement real-time thermal monitoring (rack, room, cooling loop). **Operational Measures** ❖ Heat-based IT failover protocols to backup systems. ❖ Restrict maintenance windows during peak heat periods.	**Engineering (CAPEX)** ❖ Air-cooled chiller: RM 1,780–5,930 per ton; Water-cooled: RM 1,185–1,580 per ton. *N+1/N+2 premium:* +30–50% on baseline cooling CAPEX. Liquid cooling (direct-to-chip/immersion): RM 3,950–7,900 per kW of IT load. Aisle containment retrofit: RM 1,580–5,930 per rack; Sliding aisle doors: RM 9,085–10,665 per door; ❖ Building envelope (control rooms): ❖ Roof/wall insulation: RM 15.8–23.7/m² ❖ Cool roof/reflective coating: RM 3.95–11.85/m² (materials), ❖ External shading: RM 197–593/m² ❖ HVAC automation (BAS): RM 9.9–29.6/ft² (≈*RM 106–319/m²*); smart zone controllers/thermostats: RM 790–3,950 per unit. ❖ Thermal monitoring: Sensors RM 198–790 each; platform RM 2,963–19,750 (one-time) or low monthly. **Operational (OPEX)** ❖ Colocation rack: ~RM 3,160/month (≈RM 37,525/yr). ❖ Cloud-hosted critical workloads: RM 395–1,185 per server/month. ❖ Heat-triggered failover / planned maintenance windows: minimal CAPEX; possible overtime premiums only.
	Power & Energy Systems 18 Power: Substation 19 Power: Substation DG 20 Power: Substation Near River 21 Power: Substation Nearshore 22 Power: Substation Solar	**Power & Energy Systems** **Engineering Measures** ❖ Transformer uprating for >50–55°C ambient temperatures. ❖ Shading roofs or solar canopies over transformer yards, switchgear enclosures, and inverters. ❖ Install forced-air cooling, larger radiators, or improved oil circulation systems. ❖ Oversize critical feeders to reduce thermal ampacity limits. ❖ Upgrade cabling to XLPE-rated high-temperature insulation. ❖ Improve PV system ventilation; allow greater row spacing for cooling airflow. **Operational Measures** ❖ Heat-triggered load shedding and demand management. ❖ Protective relays adjusted for warm-day settings. ❖ Conduct summer preventative inspections (IR scanning, transformer oil checks).	**Engineering (CAPEX)** ❖ Transformer uprating for >50–55 °C ambient (new spec): +15–35% vs baseline transformer CAPEX. ❖ Distribution transformer replacement (~5–20 MVA): RM 0.59–3.16 million per unit. ❖ Steel shade canopy (transformers/switchgear yards): RM 593–1,975 per m². ❖ Solar canopy (PV + structure): RM 13.8–23.7 per W installed. ❖ Forced-air cooling retrofit (existing transformers): RM 79k–316k per transformer. ❖ New forced-cooled transformer (ONAF/OFWF, etc.): +20–30% CAPEX vs natural-cooled baseline. ❖ Feeder upsizing (capacity & temperature margin): RM 0.59–3.16 million per feeder. ❖ XLPE MV/LV cable (materials): RM 39.5–237 per m. ❖ Installed cable incl. civil works: RM 593–3,950+ per m. ❖ PV layout/ventilation: Row spacing change 1–5% CAPEX impact; inverter ventilation upgrades: RM 39.5k–395k per station. **Operational (OPEX)** ❖ Heat-triggered load-shedding & EMS logic: RM 395k–1.58 million. ❖ Warm-day relay settings & protection coordination: RM 197.5k–790k. ❖ IR thermography inspections: RM 7.9k–39.5k per visit. ❖ Transformer oil testing (DGA, furan, etc.): RM 1,185–5,925 per unit.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Heat (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Heat	**Fuels, LPG & Chemicals (Process & Storage)**	**Fuels, LPG & Chemicals (Process & Storage)**	
	12 Manufacturing: Chemicals	**Engineering Measures** ❖ Apply high-reflectivity/insulative coatings on tanks, spheres, and piping. ❖ Install or expand water-spray cooling rings for LPG and fuel storage. ❖ Shade fuel loading/unloading manifolds and hose stations. ❖ Upgrade gaskets/hoses/seals to heat-resistant elastomers. ❖ Activate Vapor Recovery Units (VRUs) to reduce VOC emissions in hot conditions. ❖ Overpressure protection: PRVs rated for higher peak temperatures. **Operational Measures** ❖ Avoid loading/unloading during peak heat hours. ❖ Increase thermal surveillance: tank temperature, vapor pressure, PRV activity.	**Engineering (CAPEX)** ❖ High-reflectivity coatings (tanks/spheres/piping): RM 79–237/m²; insulative coatings: RM 158–474/m²; conventional repaint: RM 316–593/m². ❖ Water-spray cooling rings (per tank): Retrofit RM 592.5k–1.975m; new system (incl. pumps/controls) RM 1.185–4.74m. ❖ Shading (manifolds, loading bays, hose racks): Steel canopy RM 593–1,975/m²; localized covers RM 39.5k–197.5k per station. ❖ Heat-resistant gaskets/hoses/seals: +10–30% vs standard; replacement program RM 79k–790k per system. ❖ Vapor Recovery Units (VRUs): New unit RM 3.95–19.75m each; capacity upgrade RM 1.975–7.90m. ❖ Overpressure protection (PRVs): RM 39.5k–395k per valve; system-wide relief review/upgrade RM 395k–1.975m. **Operational (OPEX)** ❖ Heat-avoidance loading practices (procedures & training): RM 98.8k–296.3k; scheduling changes = minimal CAPEX. ❖ Thermal & pressure surveillance: Tank temp/vapor sensors RM 19.75k–118.5k per tank; PRV monitoring RM 79k–395k per system; SCADA integration RM 197.5k–987.5k. **Portfolio-level envelope (indicative)** ❖ Engineering measures: RM 39.5–237 million (program of coatings, spray systems, VRUs, relief upgrades). ❖ Operational measures: RM 790k–3.16 million per year.
	Warehousing & Logistics (Cargo & Yard)	**Warehousing & Logistics (Cargo & Yard)**	
	28 Warehouses: Covered 29 Warehouses: Covered Nearshore 30 Warehouses: Dock Depot 33 Warehouses: Uncovered 34 Warehouses: Uncovered Nearshore 31/32 Fuel Warehouses	**Engineering Measures** ❖ Apply cool roofs, roof insulation, radiant barriers, and solar-reflective coatings. ❖ Install HVLS fans, ridge vents, and mechanical ventilation for heat dissipation. ❖ Build shaded staging areas for cargo, forklifts, and staff. ❖ Use reflective pavement, light-coloured yard surfacing, or permeable pavement where possible. ❖ Indoor temperature monitoring linked to work-rest cycles. **Operational Measures** ❖ Increase reefer plug capacity and reefer cooling efficiency. ❖ Set temperature stability SOPs for heat-sensitive cargo. ❖ Summer fire-prevention protocols (heat-driven spontaneous ignition risks).	**Engineering (CAPEX)** ❖ Cool roofs / reflective paint: RM 3.95–11.85/m² (materials); . ❖ Roof insulation retrofit: RM 15.8–39.5/m². ❖ Radiant barrier (foil systems): RM 11.85–31.6/m². ❖ HVLS fans (large-diameter): RM 39.5k–118.5k per fan. ❖ Ridge vents / roof ventilators: RM 395–1,580 per linear meter. ❖ Mechanical ventilation upgrades (per building): RM 197.5k–1.185 million. ❖ Shaded staging: Steel canopies RM 593–1,975/m²; fabric tensile RM 316–988/m²; modular shade tents RM 19.75k–98.8k per unit. ❖ Yard surfacing: Reflective coating RM 39.5–118.5/m²; light-coloured concrete RM 316–593/m²; permeable systems RM 395–988/m². ❖ Indoor temperature monitoring: Sensors RM 198–790 each; platform & alerts RM 19.75k–197.5k (site-scale). **Operational (OPEX)** ❖ Reefer capacity: Additional plugs RM 19.75k–59.25k per plug; electrical upgrades RM 1.975–7.90 million per yard section; efficiency tuning = low CAPEX. ❖ Temperature-sensitive cargo SOPs: RM 98.8k–296.3k for SOP development & training; monitoring embedded in operations. ❖ Summer fire-prevention: Fire-risk assessment RM 98.8k–395k; enhanced patrols = OPEX; temperature-triggered restrictions = minimal CAPEX. **Portfolio-level envelope (indicative)** ❖ Engineering measures: RM 39.5–197.5 million. ❖ Operational measures: RM 1.185–3.95 million per year.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Heat (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Heat	**Buildings & Workforce (Operations & Offices)**	**Buildings & Workforce (Operations & Offices)**	

	04 Building: Office
	05 Building: Office Nearshore
	06 Building: Operational
	07 Building: Operational-Nearshore
	03 Building: Maintenance/Repair Nearshore
	02 Data Center
		Engineering Measures
		❖ Upgrade to high-efficiency, variable-speed HVAC with humidity control.
		❖ Improve building envelope:
		  ❖ Low-SHGC glazing
		  ❖ External louvers
		  ❖ Green roofs or cool roofs
		  ❖ Thermal insulation
		❖ Provide cool rooms, air-conditioned shelters, hydration stations, and shaded walkways.
		❖ Install smart building controls to reduce internal heat gain.
		
		Operational Measures
		❖ Implement WBGT-index work-rest cycles.
		❖ Emergency response for heat exhaustion/heat stroke.
		❖ Schedule high-exertion tasks outside peak heat hours.
			Engineering (CAPEX)
			❖ High-efficiency VSD HVAC (retrofit): RM 79–197.5 per ft² of conditioned area *(≈RM 850–2,125 per m²)*.
			❖ Dehumidification modules (per zone): RM 19.75k–118.5k.
			❖ Precision cooling for control/dispatch rooms: RM 197.5k–1.185 million per room.
			❖ Building envelope
			❖ Low-SHGC glazing retrofit: RM 1,185–2,765 per m²; solar-control film: RM 197.5–593 per m².
			❖ External louvers/shading: Fixed RM 593–1,580 per m²; adjustable RM 1,185–3,160 per m².
			❖ Cool roof coating: RM 3.95–11.85 per m² (materials), ; extensive green roof: RM 593–1,185 per m².
			❖ Thermal insulation (roof/wall): RM 15.8–39.5 per m².
			❖ Workforce cooling & welfare
			❖ Air-conditioned cool rooms/rest shelters: RM 197.5k–987.5k per facility.
			❖ Shaded walkways/canopies: RM 593–1,975 per m².
			❖ Hydration stations (plumbed/mobile): RM 7.9k–39.5k per station.
			❖ Smart building controls
			❖ BMS: RM 9.9–29.6 per ft² *(≈RM 106–319 per m²)*.
			❖ Smart sensors (temp/RH/occupancy): RM 197.5–1,185 each.
			❖ Lighting & equipment load optimization: RM 39.5k–395k per building.
			
			Operational (OPEX)
			❖ WBGT-based work–rest: Policy & assessment RM 98.8k–296.3k; WBGT monitors RM 3.95k–19.75k per unit; training embedded in H&S.
			❖ Heat-illness emergency response: Plans RM 79k–237k; first-aid/cooling supplies RM 19.75k–98.8k per site; drills = OPEX.
			❖ Scheduling high-exertion tasks: Minimal CAPEX; supervision/productivity management = operational trade-off.
			
			Portfolio-level envelope (indicative)
			❖ Engineering measures: RM 39.5–158 million (HVAC, envelope, welfare infrastructure).
			❖ Operational measures: RM 1.185–3.95 million per year.

	Equipment & Mobile Assets	**Equipment & Mobile Assets**	
	09 Equipment: Nearshore 10 Equipment: Onshore	**Engineering Measures** ❖ Install larger radiators, upgraded hydraulic oil coolers, and heat shields on exposed parts. ❖ Use heat-rated tires, hoses, and cables. ❖ Improve ventilation on control cabinets and electronics housings. ❖ Provide shading for parking, maintenance areas, and charging stations. ❖ Retrofit machines with predictive thermal monitoring (coolant temp, hydraulic oil temp, inverter temp). **Operational Measures** ❖ Adjust duty cycles or reduce load during peak heat. ❖ Implement summer-specific PM schedules (oil changes, coolant checks). ❖ Limit idle time for engines under direct sun.	**Engineering (CAPEX)** ❖ Cooling upgrades (per machine): Larger radiator RM 39.5k–197.5k; hydraulic-oil cooler RM 19.75k–98.8k; heat shields RM 7.9k–39.5k. ❖ Heat-rated components: Tires +10–25% vs standard; high-temp hoses RM 790–5,925 per hose; heat-resistant cables RM 39.5–197.5/m. ❖ Electronics cabinet cooling (per cabinet): Fans/filters RM 1,975–11,850; air-to-air exchanger RM 7,900–31,600; small industrial AC RM 11,850–39,500. ❖ Shading for parking/maintenance/charging: Steel canopy RM 593–1,975/m²; fabric tensile RM 316–988/m²; solar canopy RM 13.8–23.7/W. ❖ Predictive thermal monitoring: Temp sensors RM 395–1,975 each; onboard telemetry RM 3,950–19,750 per machine; fleet platform RM 39.5k–395k. **Operational (OPEX)** ❖ Heat-aware duty limits & procedures: Minimal CAPEX (planning/training). ❖ Summer PM (per year, per machine): Extra oil/coolant changes RM 1,975–11,850; seasonal inspections/diagnostics RM 3,950–19,750. ❖ Idle-time management: Policies/training = minimal; auto-shutdown timers RM 1,975–7,900 per machine.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Heat (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Heat	**Marine Interfaces & Waterfront Structures**	**Marine Interfaces & Waterfront Structures**	
	01 Berth: Nearshore 11 Jetty: Nearshore 36 Wharf: Nearshore 27 Transport: Waterways 23 Revetment: Onshore 17 Open water: Nearshore	**Engineering Measures** ❖ Use high-temperature elastomers for fenders and seals. ❖ Ensure rail neutral temperature resets for RTG/RMG and crane rails. ❖ Add shading to sensitive elastomeric components and mooring systems. ❖ Improve expansion joints for decks, rails, and wharf surfaces. ❖ Use heat-resistant coatings on steel structures to reduce thermal cycling fatigue. ❖ Improve drainage to avoid drying+cracking cycles. **Operational Measures** ❖ Heat-day berthing SOPs (mooring line condition checks, fender hardness checks). ❖ Restricted crane operations during maximum heat if thermal tolerance is exceeded.	**Engineering (CAPEX)** ❖ High-temperature elastomers (fenders, seals, bearings): +10–30% vs standard components. ❖ Elastomeric seals/bearings (unit cost): RM 7.9k–59.25k per unit. ❖ Rail Neutral Temperature (RNT) study & reset (crane/yard rails): RM 0.593–1.975 million per rail system. ❖ Rail stress adjustment / destressing works: RM 197.5k–790k per intervention. ❖ Shading of elastomeric components & mooring points: Localized shade structures RM 593–1,975/m^2; protective covers RM 19.75k–98.75k per berth section. ❖ Expansion joints: Heavy-duty joint replacement RM 7.9k–39.5k per linear meter; rail expansion devices/sliding joints RM 197.5k–987.5k per location. ❖ Steel protection (heat-resistant/reflective coatings): RM 98.8–316/m^2; full marine-grade repaint RM 316–593/m^2. ❖ Deck drainage & crack management: Drainage improvements RM 790k–3.95 million per berth section; joint sealing & crack repairs RM 197.5k–1.185 million per intervention. **Operational (OPEX)** ❖ Heat-day berthing SOPs: RM 98.75k–296.25k (development & training); fender hardness and mooring-line checks embedded in routine inspections. ❖ Restricted crane operations under extreme heat: Thermal tolerance assessment & operating limits RM 197.5k–593k; implementation (procedures/alarms/training) = minimal CAPEX.
	Water, Sewer & Drainage Utilities	**Water, Sewer & Drainage Utilities**	
	35 Water Supply 24 Sewerage system 08 Drainage system	**Engineering Measures** ❖ Add storage buffering to water supply systems for peak heat demand. ❖ Upgrade pump motors with higher-temperature ratings or improve pump room ventilation. ❖ Install odor control at sewerage hotspots (biofilters, activated carbon). ❖ Use more heat-resistant gaskets and seals on pipelines and valves. ❖ Protect open channels or critical nodes with shading or reflective lining. **Operational Measures** ❖ Proactive water leakage repair during heat waves (pressure drops more common). ❖ Adjust chemical dosing for biological process stability in high temperatures. ❖ Inspect drainage for cracking, joint failures, and low-flow sections.	**Engineering (CAPEX)** ❖ Storage buffering for peak-heat demand: RM 3,160–9,875 per m^3 (steel/concrete tanks); modular/packaged: RM 5,925–13,825 per m^3. ❖ Pump stations: High-temperature motor upgrade: +10–25% vs standard; motor replacement: RM 79k–395k per unit; pump-room ventilation: RM 98.75k–592.5k per station. ❖ Odor control at sewer hotspots: Biofilters: RM 395k–1.975 million per installation; activated-carbon units: RM 197.5k–1.185 million per unit. ❖ Heat-resistant gaskets, seals & valve components: +10–30% vs standard; valve-seal replacement program: RM 19.75k–197.5k per intervention. ❖ Shading/reflective lining (open channels & chambers): Shade structures: RM 593–1,975/m^2; reflective/low-absorption lining: RM 118.5–395/m^2. **Operational (OPEX)** ❖ Targeted leak-detection surveys: RM 39.5k–197.5k per campaign; emergency repair allowance = OPEX contingency. ❖ Chemical dosing adjustments for high-temperature stability: Process review/recalibration: RM 79k–296.25k; incremental chemicals: typically <10% seasonal increase. ❖ Drainage inspections for heat-related degradation: CCTV/visual: RM 19.75k–118.5k per area; minor joint/crack repairs: RM 79k–790k per intervention.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Total Water Level

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Total Water level (ETWL)	**Marine Berthing & Loading Structures**	**Marine Berthing & Loading Structures**	
	01 Berth: Nearshore 11 Jetty: Nearshore 36 Wharf: Nearshore	**Structural** ❖ Raise/upgrade deck levels or provide localized crest height increases at low points (berth edge, access transitions) to reduce inundation frequency. ❖ Upgrade fenders, bollards, mooring fittings for higher storm loads and wave action; use corrosion-resistant materials (marine-grade). ❖ Add wave-overtopping reduction features (parapets/edge beams) were safe for operations. ❖ Improve scour protection around foundations and berth toes (ETWL + waves increases seabed mobility). **Operational** ❖ Define ETWL operating thresholds (water level + wave conditions) for: berthing, crane ops, bunkering, personnel access. ❖ Pre-storm securing: standardized mooring plans, equipment tie-downs, shut-off sequences. **Institutional** ❖ Embed ETWL criteria into design standards and renewal cycles (capex triggers when residual life is low), consistent with PIANC's emphasis on planning and life-cycle decisions.	**Engineering (structural) – CAPEX** ❖ RM 78.4 – 235.2 million (selective, phased upgrades across berths/quay assets). **Representative structural unit rates (typical ranges)** ❖ Localized deck raising (per linear meter): RM 11,762 – RM 31,366. ❖ Parapet / edge beam for overtopping control (per lm): RM 5,881 – RM 15,683. ❖ Fender panel system (per berth face): RM 1,568,316 – RM 4,704,948. ❖ Heavy-duty bollard / mooring hook (per unit): RM 156,832 – RM 470,495. ❖ Scour armoring (per m²): RM 7,842 – RM 19,604. **Operational – OPEX** ❖ RM 1.18 – 3.14 million (ETWL thresholds, manuals, training, pre-storm securing). **Representative operational line items** ❖ ETWL analysis & thresholds: RM 588,118 – RM 1,568,316. ❖ Operating manuals & decision matrices: RM 196,040 – RM 588,118. ❖ Training & drills (initial setup): RM 117,624 – RM 392,079. ❖ Standardized mooring & securing plans: RM 294,059 – RM 784,158. ❖ Equipment tie-down & shut-off procedures: RM 98,020 – RM 294,059. ❖ Annual drills & refreshers (per year): RM 78,416 – RM 196,040.
	Shoreline Protection & Coastal Interface	**Shoreline Protection & Coastal Interface**	
	23 Revetment: Onshore 17 Openwater: Nearshore	**Structural** ❖ Revetment upgrades: crest elevation, armor sizing, toe protection, and overtopping control based on future ETWL. ❖ Consider hybrid / Working with Nature buffers (where feasible) to reduce wave energy and provide adaptable protection pathways. **Operational** ❖ Routine post-event inspections (displacement, settlement, toe scour) + rapid repair contracts. **Institutional** ❖ Establish an adaptive pathway: interim upgrades now, scalable options later as SLR and extremes evolve.	**Engineering (structural) – CAPEX** ❖ RM 117.6 – 470.5 million (revetment crest raising, armor upsizing, toe protection, overtopping control; phased across vulnerable reaches). **Representative structural unit rates (typical ranges)** ❖ Revetment crest elevation increase (per lm): RM 11,762 – RM 31,366. ❖ Armor layer upsizing / replacement (per lm): RM 15,683 – RM 47,049. ❖ Toe protection enhancement (per lm): RM 7,842 – RM 23,525. ❖ Overtopping reduction elements (per lm): RM 5,881 – RM 19,604. ❖ Hybrid / Working with Nature (WwN) buffers ❖ Nearshore rock/gravel berms (per lm): RM 5,881 – RM 15,683. ❖ Modular reef / eco-armoring units (per unit): RM 3,921 – RM 11,762. ❖ Mangrove / vegetated buffer establishment (per ha): RM 196,040 – RM 784,158. **Operational – OPEX** ❖ RM 0.392 – 1.176 million per year (post-storm inspections, rapid-repair retainer). **Representative operational line items** ❖ Post-storm inspection program (per year): RM 196,040 – RM 588,118. ❖ Standing rapid-repair contracts (retainer): RM 392,079 – RM 1,176,237.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Total Water Level (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Total Water level (ETWL)	**Water, Wastewater & Drainage (Flood Pathway Controllers)**	**Water, Wastewater & Drainage (Flood Pathway Controllers)**	
	08 Drainage system 24 Sewerage system 35 Water Supply	**Structural** ❖ Increase drainage conveyance + storage, add pump stations where gravity drainage is insufficient during high tide/ETWL. ❖ Install tidal flap gates / backflow preventers on outfalls to prevent seawater intrusion during ETWL. ❖ Harden pump/electrical components: elevate MCCs, waterproof enclosures. **Operational** ❖ ETWL-triggered pre-emptive drawdown of retention basins (when feasible) and pump readiness checks. ❖ Rapid debris clearance teams (ETWL events often block drains; recovery speed depends on maintenance). **Institutional** ❖ Formalize an ETWL drainage performance standard (target time-to-drain, maximum ponding depth) and align it with asset renewal budgets—consistent with PIANC's emphasis on systematic risk management and adaptation planning	**Engineering (structural) – CAPEX** ❖ RM 58.8 – 274.5 million (storage, pumps, culvert/drain upsizing, gates, electrical hardening; phased across tide-locked/low-lying basins). **Representative structural unit rates (typical ranges)** ❖ Drain upsizing / culvert enlargement (per lm): RM 5,881 – RM 23,525. ❖ New detention/retention storage (per m³): RM 3,137 – RM 9,802. ❖ Stormwater pump station, 5–20 m³/s (per station): RM 7,841,580 – RM 39,207,900. ❖ Mobile/emergency pump deployment points (per site): RM 196,040 – RM 1,176,237. ❖ Outfall backflow prevention (tidal interface) ❖ Tidal flap gate retrofit (per outfall): RM 196,040 – RM 980,198. ❖ Automated tide gate / sluice (per outfall): RM 588,118 – RM 2,352,474. ❖ Backflow preventers for sewer/storm connections (per location): RM 78,416 – RM 588,118. ❖ Pump station hardening (electrical & resilience) ❖ Elevate MCCs & critical controls (per station): RM 392,079 – RM 1,960,395. ❖ Waterproof enclosures/doors (per station): RM 196,040 – RM 980,198. ❖ Backup power (genset/ATS integration) (per station): RM 784,158 – RM 3,920,790. **Operational – OPEX** ❖ RM 0.392 – 1.568 million per year (ETWL-triggered drawdown, readiness, debris clearance teams). **Representative operational line items** ❖ Drawdown protocols & control logic: RM 98,020 – RM 294,059. ❖ Pre-event pump inspections/testing (per event): RM 39,208 – RM 117,624. ❖ Debris clearance teams/contracts (per year): RM 196,040 – RM 588,118. ❖ Emergency access improvements (per location): RM 98,020 – RM 392,079.
	Critical Lifelines (Power + Digital/Control)	**Critical Lifelines (Power + Digital/Control)**	
	21 Power: Substation Nearshore 26 Telecommunications Services: Nearshore 02 Building: Data Center-Nearshore	**Structural** ❖ Floodproof/elevate substations, switchgear rooms, telecom nodes, and data center critical equipment above design flood + freeboard; seal cable trenches and penetrations. ❖ Add perimeter flood barriers (demountable or permanent) and backflow prevention for conduits. ❖ Provide redundant routing (dual feeds, diverse fiber routes) to avoid single-point failure. **Operational** ❖ ETWL pre-event shutdown/transfer protocols (safe isolation of electrical equipment) + rapid restart checklist. ❖ Deploy real-time monitoring (water level sensors at low points; alarms to control room). **Institutional** ❖ Update business continuity plans: prioritized load restoration (reefer yards, safety systems, comms) and mutual aid agreements.	**Engineering (structural) – portfolio envelope** ❖ RM 58.8 – 235.2 million (elevation/dry-proofing of substations/switchgear/telecom, perimeter barriers, and route redundancy; phased by consequence and outage risk). **Representative structural unit rates (typical ranges)** ❖ Elevate switchgear/MCCs (per room): RM 784,158 – RM 3,920,790. ❖ Floodproof substation buildings (per facility): RM 1,960,395 – RM 11,762,370. ❖ Raised plinths/platforms (per asset cluster): RM 196,040 – RM 1,176,237. ❖ Cable trench sealing & penetration protection (per area): RM 78,416 – RM 588,118. ❖ Perimeter flood barriers & backflow prevention ❖ Demountable flood barriers (per lm): RM 5,881 – RM 15,683. ❖ Permanent flood walls/bunds (per lm): RM 9,802 – RM 23,525. ❖ Backflow preventers for conduits/drains (per penetration): RM 39,208 – RM 392,079. ❖ Redundancy & diversity (power/fiber) ❖ Dual electrical feeds / tie-in works (per critical zone): RM 1,960,395 – RM 7,841,580. ❖ Diverse fiber route installation (per segment): RM 196,040 – RM 1,176,237. **Operational – portfolio envelope** ❖ RM 0.784 – 2.352 million (protocols, training, monitoring & SCADA/BMS integration). **Representative operational line items** ❖ Protocol development & risk assessment: RM 196,040 – RM 588,118. ❖ Training, drills & documentation: RM 98,020 – RM 294,059. ❖ Water level sensors (per sensor): RM 7,842 – RM 39,208. ❖ SCADA/BMS integration & alarms: RM 78,416 – RM 392,079.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Total Water Level (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Total Water level (ETWL)	**Nearshore Operations, Logistics & Hazardous/Industrial Nodes**	**Nearshore Operations, Logistics & Hazardous/Industrial Nodes**	
	32 Warehouses: Fuel Nearshore 29 Warehouses: Covered Nearshore 34 Warehouses: Uncovered Nearshore 09 Equipment: Nearshore 15 Manufacturing: LPG Nearshore 13 Manufacturing: Food Nearshore 07 Building: Operational-Nearshore 05 Building: Office Nearshore 03 Building: Maintenance Repair Nearshore	**Structural** ❖ Elevate/floodproof: warehouse door thresholds, critical control panels, LPG/fuel pump skids, emergency shutdown systems. ❖ Install bunding/containment and water-tight isolation valves to prevent pollutant release during flooding (especially fuel/LPG). ❖ Use corrosion-resistant materials and coatings; design for washdown and rapid drying post-flood. **Operational** ❖ ETWL cargo and hazardous material shutdown SOPs: stop transfer at thresholds; secure tanks; isolate utilities. ❖ Staging strategy: relocate high-value / hazardous inventory above flood levels ahead of forecast ETWL events. ❖ Post-event return-to-service inspections for equipment, forklifts, electricals. **Institutional** ❖ Integrate ETWL into HSE/HAZOP updates and emergency drills; update insurance/business interruption assumptions using scenario-based planning	**Engineering (structural) – CAPEX** ❖ RM 19.6 – 98.0 million (elevation/dry-proofing of near-water warehouses, control panels/ESD cabinets, pump skids, raised pads; phased by consequence and HSE risk). **Representative structural unit rates (typical ranges)** ❖ Raise warehouse door thresholds / flood sills (per doorway): RM 19,604 – RM 196,040. ❖ Elevate control panels / ESD cabinets (per unit): RM 39,208 – RM 392,079. ❖ Floodproof LPG/fuel pump skids (per skid): RM 196,040 – RM 1,176,237. ❖ Local equipment plinths / raised pads (per cluster): RM 78,416 – RM 588,118. ❖ Bunding, containment & isolation ❖ Secondary containment bunds (per lm): RM 3,921 – RM 19,604. ❖ Water-tight isolation valves (per valve): RM 78,416 – RM 392,079. ❖ Automated isolation tied to water-level alarms (per system): RM 196,040 – RM 784,158. ❖ Corrosion-resistant materials & rapid recovery design ❖ Marine-grade coatings (per m²): RM 118 – RM 392. ❖ Equipment upgrades to corrosion-resistant alloys: +10% – +30% vs standard. ❖ Washdown & drainage improvements (per area): RM 196,040 – RM 1,176,237. **Operational – OPEX** ❖ RM 0.784 – 2.352 million (shutdown SOPs/HAZOP alignment, training, staging/relocation planning, post-event inspections). **Representative operational line items** ❖ SOP development & HAZOP alignment: RM 196,040 – RM 588,118. ❖ Training & drills: RM 98,020 – RM 294,059. ❖ Staging plans & trigger definition: RM 98,020 – RM 294,059. ❖ Electrical & control inspections (per event): RM 78,416 – RM 392,079. ❖ Mechanical inspections (per event): RM 39,208 – RM 196,040. ❖ Temporary relocation logistics: OPEX; event-dependent.

List of assets and group types are detailed in Appendix A

Adaptation Measures – Extreme Total Water Level (Cont'd)

Hazard	Asset Group Types Cluster	Group specific adaptation measures	Cost Benchmarks
Extreme Total Water level (ETWL)	**Water, Wastewater & Drainage (Flood Pathway Controllers)**	**Water, Wastewater & Drainage (Flood Pathway Controllers)**	
	08 Drainage system 24 Sewerage system 35 Water Supply	**Structural** ❖ Increase drainage conveyance + storage, add pump stations where gravity drainage is insufficient during high tide/ETWL. ❖ Install tidal flap gates / backflow preventers on outfalls to prevent seawater intrusion during ETWL. ❖ Harden pump/electrical components: elevate MCCs, waterproof enclosures. **Operational** ❖ ETWL-triggered pre-emptive drawdown of retention basins (when feasible) and pump readiness checks. ❖ Rapid debris clearance teams (ETWL events often block drains; recovery speed depends on maintenance). **Institutional** ❖ Formalize an ETWL drainage performance standard (target time-to-drain, maximum ponding depth) and align it with asset renewal budgets—consistent with PIANC's emphasis on systematic risk management and adaptation planning	**Engineering (structural) – CAPEX** ❖ RM 58.8 – 274.5 million (storage, pumps, culvert/drain upsizing, gates, electrical hardening; phased across tide-locked/low-lying basins). **Representative structural unit rates (typical ranges)** ❖ Drain upsizing / culvert enlargement (per lm): RM 5,881 – RM 23,525. ❖ New detention/retention storage (per m³): RM 3,137 – RM 9,802. ❖ Stormwater pump station, 5–20 m³/s (per station): RM 7,841,580 – RM 39,207,900. ❖ Mobile/emergency pump deployment points (per site): RM 196,040 – RM 1,176,237. ❖ Outfall backflow prevention (tidal interface) ❖ Tidal flap gate retrofit (per outfall): RM 196,040 – RM 980,198. ❖ Automated tide gate / sluice (per outfall): RM 588,118 – RM 2,352,474. ❖ Backflow preventers (sewer/storm connections) (per location): RM 78,416 – RM 588,118. ❖ Pump station hardening (electrical & resilience) ❖ Elevate MCCs & critical controls (per station): RM 392,079 – RM 1,960,395. ❖ Waterproof enclosures/doors (per station): RM 196,040 – RM 980,198. ❖ Backup power (genset/ATS integration) (per station): RM 784,158 – RM 3,920,790. **Operational – OPEX** •RM 0.392 – 1.568 million per year (ETWL-triggered drawdown protocols, readiness checks, debris-clearance teams). **Representative operational line items** ❖ Drawdown protocols & control logic: RM 98,020 – RM 294,059. ❖ Pre-event pump inspections/testing (per event): RM 39,208 – RM 117,624. ❖ Debris-clearance teams/contracts (per year): RM 196,040 – RM 588,118. ❖ Emergency access improvements (per location): RM 98,020 – RM 392,079.

List of assets and group types are detailed in Appendix A
Detailed adaptation cost are given in Appendix G

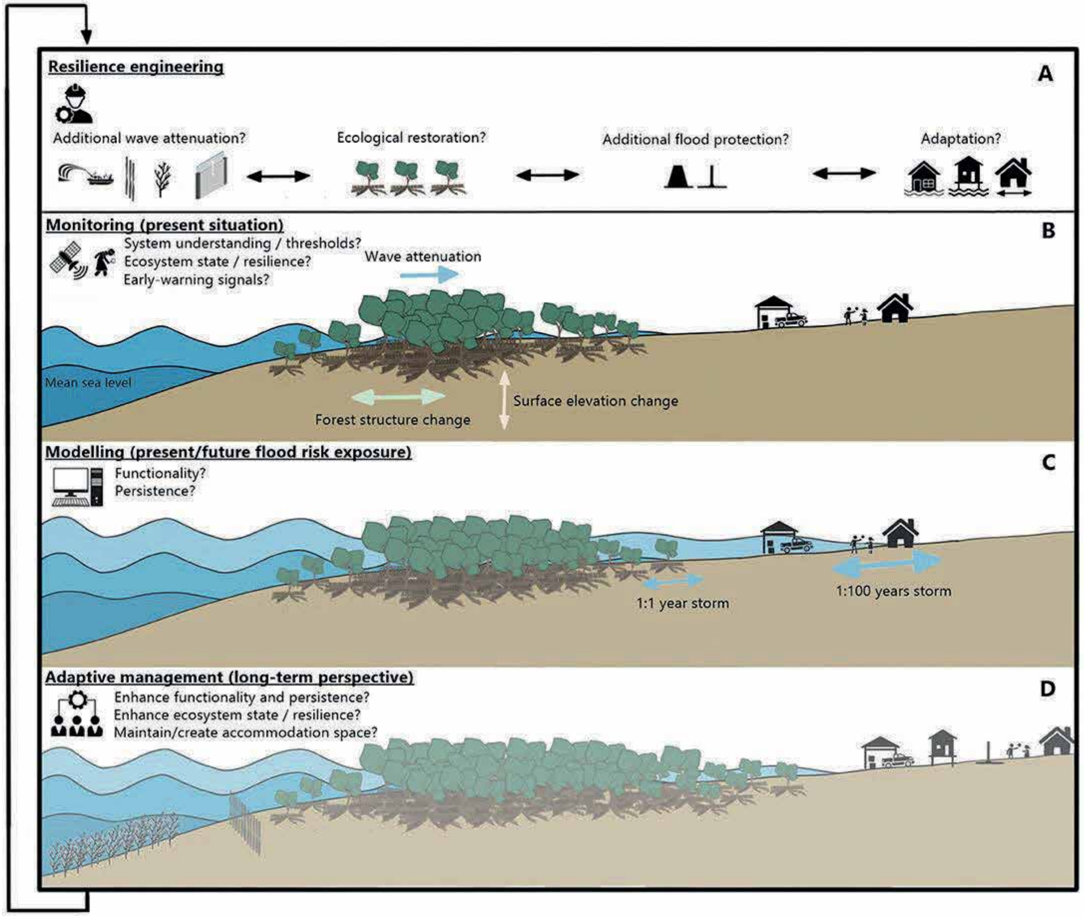
Adaptation measures - Nature Based Coastal Protection

Mangroves for Flood, Wave and Sea Level Rise Mitigation

Mangrove forests play a significant role in coastal protection by reducing the energy of wind-driven and swell waves, as well as attenuating storm surges. While mangroves do not act as solid barriers to water flow, their dense root and canopy structures help lessen flooding impacts—particularly in areas without levees or seawalls—by diminishing direct wave forces and lowering surge water levels before they reach inland areas. In addition, mangroves contribute to long-term shoreline stability by trapping sediments, reducing erosion, and promoting natural land accretion.

Key Aspects of Mangroves for Flood Mitigation

- **Wave Attenuation:**
  Mangrove trunks, branches, and prop roots create significant drag forces that dissipate incoming wave energy, helping reduce both wave heights and storm surge levels before they reach inland areas.
- **Sediment Stabilisation:**
  The dense root systems trap sediments and organic matter, gradually building soil elevation and reducing shoreline erosion during storms, high tides, or long-term sea-level rise.
- **Economic Value:**
  Mangrove restoration is a highly cost-effective, nature-based solution that provides substantial protection benefits. It reduces the financial impact of coastal flooding on vulnerable communities and lowers long-term maintenance costs compared with hard-engineered structures.
- **Structural Protection:**
  While mangroves do not fully block floodwater, they significantly reduce the force of waves and surge flow, thereby decreasing flood damage to infrastructure, utilities, and coastal settlements.
- **Optimal Width:**
  For effective flood mitigation, a mangrove green belt of **50–200 metres** is commonly recommended, depending on species, site conditions, and local hydrodynamic characteristics.



Schematic overview of an adaptive management approach with (A) (temporary) engineering interventions, in which humans enhance and adapt to the functionality and persistence of the mangroves. The mangroves are (B) monitored, (C) their functionality and persistence are assessed and predicted to determine the necessity of (temporary) engineering interventions within (D) a long-term perspective to reduce coastal flood risk with mangroves. The uncertainty of flooding events due to the variability in mangrove functionality and the uncertainty of monitoring and modelling tools is indicated with the blue arrows in (C). *Adopted from* Frontiers | Nature-Based Engineering: A Review on Reducing Coastal Flood Risk With Mangroves

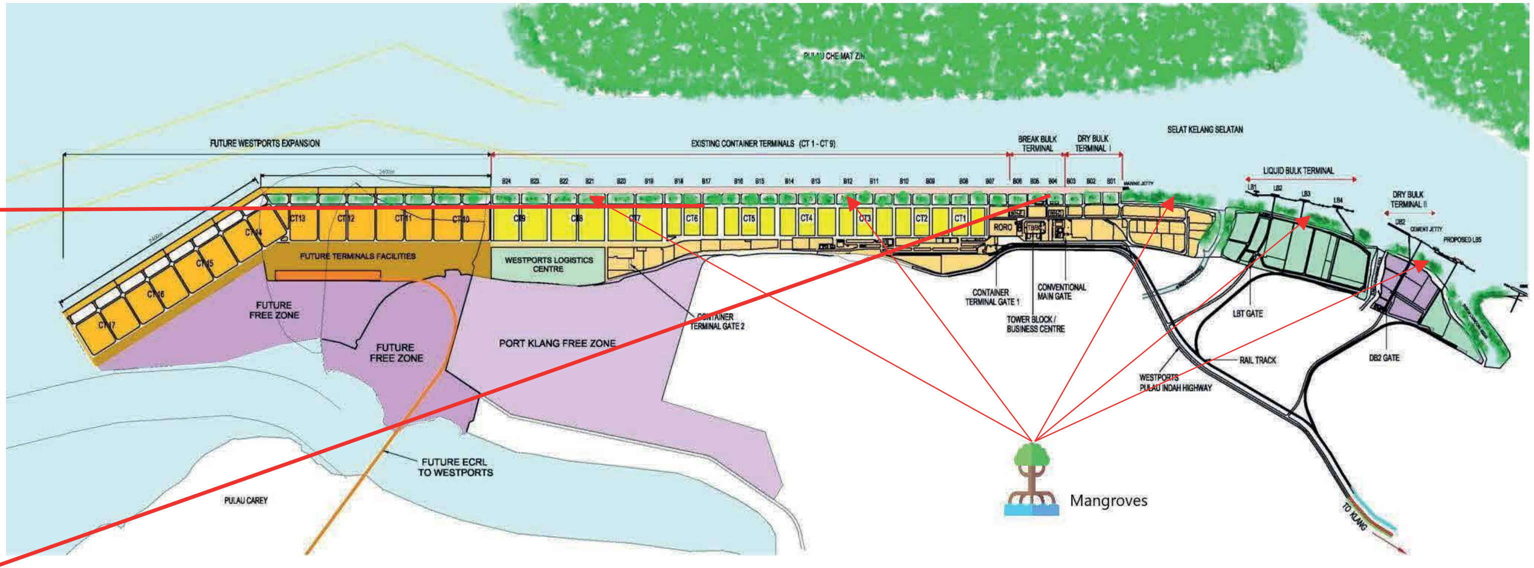
Adaptation measures - Nature Based Solutions

Mangroves for Flood, Wave and Sea Level Rise Mitigation

Plantation of Mangroves along the revetment

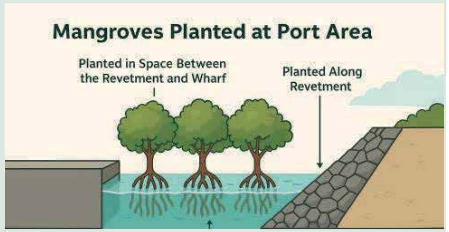
Current condition near B16 @CT

Current condition near Breakbulk Terminal



The pictorial (above) representation illustrates how **mangroves can be strategically integrated within the port waterfront**, specifically:

- **Between the Wharf Structure and the Revetment**
  - Mangroves can be planted in the tidal zone located between the vertical wharf face and the sloped rock revetment (Images on the left).
  - This zone typically has sufficient water depth and tidal exposure for species such as Bakau Minyak (*Rhizophora*) and Lenggadai (*Bruguiera*), allowing root systems to develop without obstructing port operations.
- **Along the Revetment Edge**
  - Mangroves can be established at the toe or lower slope of the rock revetment.
  - Their root systems help stabilise sediments, reduce wave energy, and create a natural buffer without compromising the structural integrity of the revetment.
- **Overall Concept**
  - The illustration (right) shows mangrove trees emerging from the intertidal waterline, with clear spacing to avoid interference with vessel berthing.
  - The revetment is shown as a stone-armoured slope, while the wharf is depicted as a vertical concrete structure, with mangroves positioned naturally between and in front of these elements.



Appendix A: List of Westports Assets

List of Westports Assets

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Berth: Nearshore**	WPA10	CT3- B11
		WPA11	CT3- B12
		WPA13	CT4- B13
		WPA14	CT4- B14
		WPA16	CT5- B15
		WPA17	CT5- B16
		WPA19	CT6- B17
		WPA20	CT6- B18
		WPA22	CT7- B19
		WPA23	CT7- B20
		WPA25	CT8- B21
		WPA26	CT8- B22
		WPA28	CT9- B23
		WPA29	CT9- B24
		WPA4	CT1- B07
		WPA43	Break Bulk terminal-BBT-B04
		WPA44	Break Bulk terminal-BBT-B05
		WPA45	Break Bulk terminal-BBT-B06
		WPA49	Dry Bulk terminal(DBT) I-B01
		WPA5	CT1- B08
		WPA50	Dry Bulk terminal(DBT) I-B02
		WPA51	Dry Bulk terminal(DBT) I-B03
		WPA53	Liquid Bulk terminal-LB1
		WPA54	Liquid Bulk terminal-LB2
		WPA55	Liquid Bulk terminal-LB3
		WPA56	Liquid Bulk terminal-LB4
		WPA58	Liquid Bulk terminal-LB4A
		WPA60	Liquid Bulk terminal-LB5
		WPA62	Dry Bulk terminal(DBT) - DB2
		WPA7	CT2- B09
		WPA8	CT3- B10
	Building: Data Center-Nearshore	WPA84	CT4-Yard-Admin Marshalling -Data Center
	Building: Maintenance Repair Nearshore	WPA157	BBT-M&R Conventional
		WPA158	BBT-M&R Recond Store

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Building: Office**	WPA121	CT1-KASTAM
		WPA168	BBT-Port Police Building
		WPA169	Business Centre Building
		WPA170	Tower Block Data Center-TBDC
	Building: Office Nearshore	WPA154	BBT-M&R Admin Centre
	Building: Operational	WPA119	CT9-Yard-Westports-PKFZ Gate
		WPA120	CT1-Container GATE IN
		WPA85	CT7-Yard-Admin Marshalling -W/S
	Building: Operational-Nearshore	WPA83	CT1-Yard-Admin Marshalling
	Drainage system	WPA197	Drainage Network
	Equipment: Nearshore	WPA64	Marker buoys navigation aids
		WPA65	Dredging / disposal
		WPA66	Maintenance of infrastructure
		WPA67	Cargo handling /Crane usage
		WPA68	Gangways
	Equipment: Onshore	WPA149	CT1-CT9-Cargo handling equipment
		WPA150	CT1-CT9-Cranes
		WPA171	BBT-Cargo handling equipment
		WPA172	BBT-Cranes
		WPA181	DBT-I-Cargo handling equipment
		WPA182	DBT-I-Cranes
		WPA186	LBT-Cargo handling equipment
		WPA187	LBT-Cranes
		WPA194	DBTI-II-Cargo handling equipment
		WPA195	DBTI-II-Cranes
	Jetty: Nearshore	WPA46	Dry Bulk terminal(DBT) I Upper Jetty
		WPA47	Dry Bulk terminal(DBT) I Lower Jetty
	Manufacturing: Chemicals	WPA192	DBTI-II-LPG Terminal
	Manufacturing: Food Nearshore	WPA176	DBT-I-Westport Grains Terminal
		WPA177	DBT-I-Warehouse FGH
		WPA178	DBT-I-Sugar Refinery
		WPA179	DBT-I-Flour Mills
	Manufacturing: LPG	WPA191	DBTI-II-LPG Terminal
	Manufacturing: LPG Nearshore	WPA185	LBT-Stolthaven-Westports
	Manufacturing: Other	WPA189	DBTI-II-Cement Factory
		WPA190	DBTI-II-Cement Factory

List of Westports Assets

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Openwater: Nearshore**	WPA1	Waterways
		WPA2	Anchorage
	Power: Substation	WPA100	CT1-Yard-Sub Station No.8
		WPA101	CT2-Yard-Sub Station No.12
		WPA102	CT3-Yard-Sub Station No.14
		WPA103	CT5-Yard-Sub Station No.17
		WPA104	CT7-Yard-Sub Station No.20
		WPA105	CT9-Yard-Sub Station No.23
		WPA164	BBT-Sub Station (TNB in take 11kV)
		WPA165	BBT-Sub Station No.01
		WPA174	DBT-I-Sub Station No.11
		WPA188	DBTI-II-Sub Station No.9
		WPA97	CT4-Yard-Sub Station (33kV)
		WPA98	CT1-Yard-Sub Station No.6
		WPA99	CT1-Yard-Sub Station No.7
	Power: Substation DG	WPA115	CT2-Yard-DG Shed
	Power: Substation Nearshore	WPA106	CT1-Yard-Sub Station No. 5
		WPA107	CT2-Yard-Sub Station No.10
		WPA108	CT3-Yard-Sub Station No.13A
		WPA109	CT4-Yard-Sub Station No.15
		WPA110	CT5-Yard-Sub Station No.16
		WPA111	CT6-Yard-Sub Station No.18
		WPA112	CT7-Yard-Sub Station No.19
		WPA113	CT8-Yard-Sub Station No. 21
		WPA114	CT9-Yard-Sub Station No. 22
		WPA155	BBT-Sub Station No.02
		WPA173	DBT-I-Sub Station No.4
		WPA183	LBT-Sub Station No.3
	Power: Substation Solar	WPA116	CT8-Yard-Solar Shed
	Revetment: Onshore	WPA69	Revetment for CT1
		WPA70	Revetment for CT2
		WPA71	Revetment for CT3
		WPA72	Revetment for CT4
		WPA73	Revetment for CT5
		WPA74	Revetment for CT6

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Revetment: Onshore**	WPA75	Revetment for CT7
		WPA76	Revetment for CT8
		WPA77	Revetment for CT9
		WPA79	Revetment for Break Bulk terminal
		WPA80	Revetment for Dry Bulk terminal I
		WPA81	Revetment for Liquid Bulk terminal (LBT1- LBT5)
		WPA82	Revetment for Dry Bulk terminal II
	Sewerage system	WPA198	Sewerage Network
	Telecommunications Services	WPA139	CT1-2-Telecom Data Exchange
		WPA140	CT2-2-Telecom Data Exchange
		WPA141	CT3-1-Telecom Data Exchange
		WPA142	CT4-3-Telecom Data Exchange
		WPA143	CT5-2-Telecom Data Exchange
		WPA144	CT6-2-Telecom Data Exchange
		WPA145	CT7-2-Telecom Data Exchange
		WPA146	CT8-2-Telecom Data Exchange
		WPA147	CT9-2-Telecom Data Exchange
		WPA148	CT9-3-Telecom Data Exchange
		WPA167	BBT-Telecom Data Exchange
	Telecommunications Services: Nearshore	WPA129	CT1-1-Telecom Data Exchange
		WPA130	CT2-1-Telecom Data Exchange
		WPA131	CT3-2-Telecom Data Exchange
		WPA132	CT4-1-Telecom Data Exchange
		WPA133	CT4-2-Telecom Data Exchange
		WPA134	CT5-1-Telecom Data Exchange
		WPA135	CT6-1-Telecom Data Exchange
		WPA136	CT7-1-Telecom Data Exchange
		WPA137	CT8-1-Telecom Data Exchange
		WPA138	CT9-1-Telecom Data Exchange
	Transport: Waterways	WPA63	Pilotage
	Warehouses: Covered	WPA117	CT6-Yard-CIC
		WPA123	CT1-Rail Freight Terminal
		WPA124	CT8-Logistic Company
		WPA126	CT9-Logistic Company
		WPA127	CT9-Logistic Company

List of Westports Assets

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Warehouses: Covered**	WPA128	CT9-Logistic Company
		WPA161	BBT-Warehouse D
		WPA162	BBT-Warehouse E
		WPA163	BBT-Car Terminal
		WPA193	DBTI-II-Logistic Company
		WPA86	CT2-Yard-Container Freight Station (CFS) 2
		WPA87	CT2-Yard-Container Freight Station (CFS) 2
		WPA88	CT1-Yard-Container Freight Station (CFS) 1
		WPA89	CT7-Yard-Container Freight Station (CFS) 4
	Warehouses: Covered Nearshore	WPA180	DBT-I-Logistic Company
	Warehouses: Dock Depot	WPA91	CT5-Yard-On Dock Depot (ODD) 5
		WPA92	CT4-Yard-On Dock Depot (ODD) 8
		WPA93	CT5-Yard-On Dock Depot (ODD) 9
		WPA94	CT2-Yard-On Dock Depot (ODD) 10
		WPA95	CT4-Yard-On Dock Depot (ODD) 11
		WPA96	CT6-Yard-On Dock Depot (ODD) 99
	Warehouses: Fuel	WPA90	CT3-Fuel Bay
	Warehouses: Fuel Nearshore	WPA151	BBT-Fuel Bay No.01
	Warehouses: Uncovered	WPA122	CT1-Westports Distripark
		WPA125	CT8-Logistic Company
		WPA160	BBT-Car Terminal-open
	Warehouses: Uncovered Nearshore	WPA152	BBT-Yard 11A
		WPA153	BBT-Yard 13AW
		WPA156	BBT-Yard 12AW &12AS
		WPA159	BBT-Yard 4 Zone 2
		WPA175	DBT-I-Yard 4 Zone 1, 5A & 5B, 11
	Water Supply	WPA118	CT4-Yard- Water Tank/ Pump House
		WPA166	BBT-Water Tank/ Pump House
		WPA184	LBT-Water Tank/ Pump House
		WPA196	DBTI-II-Water Tank/ Pump House

Port	Asset Group Type	Asset ID	Name of Assets/Structures/others
WP1	**Wharf: Nearshore**	WPA12	CT4- Wharf
		WPA15	CT5- Wharf
		WPA18	CT6- Wharf
		WPA21	CT7- Wharf
		WPA24	CT8- Wharf
		WPA27	CT9- Wharf
		WPA3	CT1- Wharf
		WPA42	Break Bulk terminal-BBT Wharf
		WPA48	Dry Bulk terminal(DBT) I Wharf
		WPA52	Liquid Bulk terminal-LBT I Wharf
		WPA57	Liquid Bulk terminal-LBT II Wharf
		WPA59	Liquid Bulk terminal-LBT III Wharf
		WPA6	CT2- Wharf
		WPA61	Dry Bulk terminal(DBT) II Wharf
		WPA9	CT3- Wharf
Port	**Asset Group Type**	**Asset ID**	**Name of Assets/Structures/others**
WP2	**Berth: Nearshore**	WPA31	CT10- B25
		WPA32	CT10- B26
		WPA34	CT11- B27
		WPA35	CT11- B28
		WPA37	CT12- B29
		WPA38	CT12- B30
		WPA40	CT13- B31
		WPA41	CT13- B32
	Revetment: Onshore	WPA78	Revetment for CT10-CT13
	Wharf: Nearshore	WPA30	CT10- Wharf
		WPA33	CT11- Wharf
		WPA36	CT12- Wharf
		WPA39	CT13 Wharf
Outside	**Asset Group Type**	**Asset ID**	**Name of Assets/Structures/others**
Outside	**Power: Substation NearRiver**	WPA199	Main Power Supply Station-PMU PIDH 132KV

Appendix B

METHODOLOGY

Details of Scenario Indicators

Hazard	Scenario Indicator (Unit)	Definition	Resolution	Data source
Extreme Heat	Warm Spell Duration Index (WSDI) (days)	Annual number of days with at least 6 consecutive days when daily maximum temperature is above 90th percentile of the daily climatic condition.	55 km × 55 km	ISIMIP3b: https://www.isimip.org/
Extreme Winds and Storms	Maximum Tropical Cyclone Windspeed (knots)	Maximum sustained wind speed within 200km of a tropical cyclone	25 km × 25 km	IBTrACs: https://www.ncei.noaa.gov/products/international-best-track-archive AMS: https://doi.org/10.1175/BAMS-D-18-0194.1
Extreme Rainfall Flooding	Pluvial Flooding Inundation Depth (metres)	Maximum inundation depth experienced within a 270m×270m area that is associated with a 1-in-100-year[#] pluvial (extreme-rainfall-induced) flooding event.		
River Flooding	River Flooding Inundation Depth (metres)	Maximum inundation depth experienced within a 270m×270m area that is associated with a 1-in-100-year[#] undefended river flooding event.	30 m × 30 m	Fathom-Global 3.0: https://www.fathom.global ISIMIP3b: https://www.isimip.org/
	Coastal Flooding Inundation Depth (metres)	Maximum inundation depth associated with a 1-in-100-year[#] coastal flooding event as a result of sea level rise, land subsidence, storm surges and/or high tide events.		
Coastal and Offshore	Extreme Total Water Level (ETWL) (metres)	Factors contributing to extreme sea levels (ETWL) are sea level rise, storm surge (e.g., associated with tropical cyclones and extratropical cyclones), tide, and extreme waves (resulting in high-wave setup at the shoreline). 1-in-100-year return period level.		https://doi.org/10.5194/gmd-9-1937-2016 Port Klang (Pelabuhan Kelang) Station, Malaysia's Survey and Mapping Department(JUPEM) https://psmsl.org/data/obtaining/stations/1591.php
	Waves (metres)	Ocean waves are oscillations of the water surface, primarily generated by wind transferring energy through friction at the air-sea interface.		https://doi.org/10.5194/gmd-9-1937-2016 Port Klang (Pelabuhan Kelang), Malaysia's Survey and Mapping Department(JUPEM) https://psmsl.org/data/obtaining/stations/1591.php
	Ocean currents (metres/seconds)	Ocean currents are continuous, predictable, directional movements of seawater on both the surface and in deep water, driven by a combination of wind, water density differences (temperature and salinity), gravity, and Earth's rotation		https://doi.org/10.5194/gmd-9-1937-2016

[#] *1-in-100 year return period represents 1% annual probability.*

Physical Scenario Indicators and Time Horizons

The Global Climate Database (GCD) by ERM covers eight (8) physical scenario indicators, including acute risks (Extreme Heat, Extreme Winds & Storms, Rainfall Flooding, River Flooding, Coastal Flooding, Extreme Total Water Level, Waves and Currents) to give a "headline" view of the most material climate-related physical risks for GCD.

TCFD Category (Acute, etc.)	Hazard	Scenario Indicator (Unit)	Baseline Period	2030s	2050s	2085s
Physical - Acute	Extreme Heat	Warm Spell Duration Index (WSDI) (days)	1985–2014	2015–2044	2035–2064	2065–2094
	Extreme Winds & Storms	Maximum Tropical Cyclone Windspeed (knots)	1980–2022			
	River Flooding	River Flooding Inundation Depth (metres)	2020#			
	Rainfall Flooding	Pluvial Flooding Inundation Depth (metres)	2020#			
	Coastal and Offshore	Coastal Flooding Inundation Depth (metres)	2020#			
		Extreme Total Water Level (ETWL) (metres)	1995–2014			
		Waves Height (metres)	1995–2014			
		Ocean Current (metre/seconds)	1995–2014			

The projections in this assessment are based on five CMIP6 global climate models used within the Inter-Sectoral Impact Model Intercomparison Project^ (ISIMIP3b) framework—GFDL-ESM4, MPI-ESM1-2-HR, MRI-ESM2-0, IPSL-CM6A-LR and UKESM1-0-LL—selected because together they span the full CMIP6 uncertainty range by combining both low- and high-climate-sensitivity models. These models are downscaled and bias-corrected (using WFDE5/ERA5) and then averaged into a multi-model ensemble to provide more robust, representative climate signals. Assumptions include the use of 30-year climate normals for each horizon, non-stationary extreme value analysis for rainfall extremes, and, for some hazards such as coastal flooding and water stress, reliance on WRI CMIP5-based datasets with interpolation/extrapolation where future time horizons are unavailable.

**Future projection of annual surface wind speed from IPCC WG1 Interactive Atlas (https://interactive-atlas.ipcc.ch/).*
 # Flooding indicators are flooding inundation depths with 1-in-100 year return period (1% annual probability).
^https://www.isimip.org/

Physical climate scenarios used in the assessment: IPCC Assessment Report 6 (AR6)

The Intergovernmental Panel on Climate Change (IPCC) released a key review of climate change science, referred to as AR6 (sixth assessment report), in 2021.

The report considers climate change trends provided by ~100 leading climate models. Projections trends are grouped into five **Shared Socioeconomic Pathways (SSPs)**. These reflect potential changes in net CO_2 emissions, by combining qualitative storylines of societal features and quantified measures of development alongside climate data to create plausible scenarios for how quickly humans can curb emissions.

In this assessment **SSP5-8.5** is used.

- **SSP5-8.5**: a high emissions scenario, which follows a "**business as usual**" trajectory, assuming no additional climate policy and seeing CO_2 emissions triple by 2100. The selection of this scenario follows Tasked Force on Climate-Related Financial Disclosures (TCFD) guidance to assess **stressed exposure** to physical climate change risks.

Scenario	Best estimate temperature by 2100 (5%-95% likelihood)*
SSP1-1.9	1.4°C (1.0°-1.8°C)
SSP1-2.6	1.8°C (1.3°-2.4°C)
SSP2-4.5	2.7°C (2.1°-3.5°C)
SSP3-7.0	3.6°C (2.8°-4.6°C)
SSP5-8.5	4.4°C (3.3°-5.7°C)

Selected → SSP5-8.5

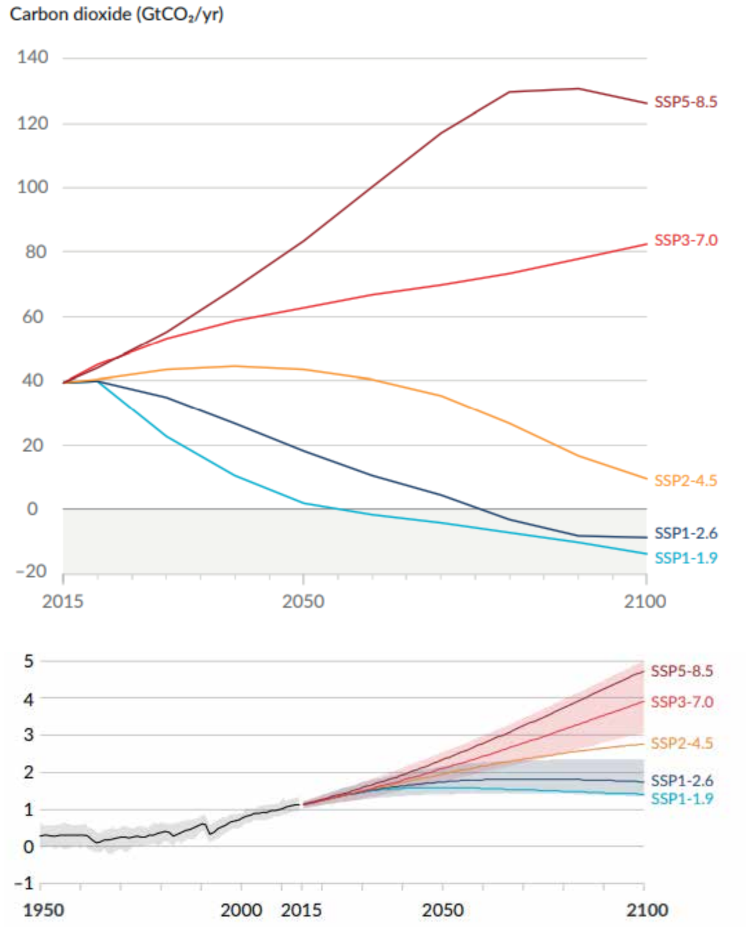


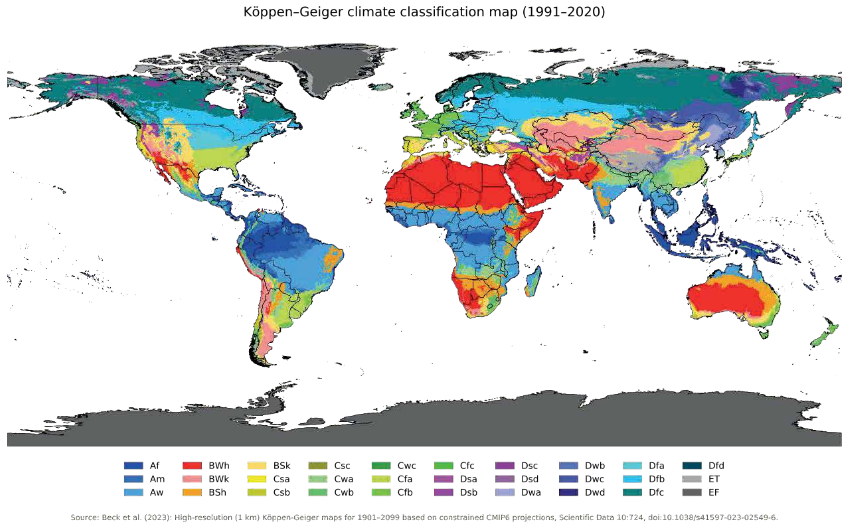
Figure: Projections of CO_2 emissions (top) and global surface temperature change (bottom) under the five SSPs.

* *From Cross-Section Box TS. 1, Table 1 of IPCC AR6 WG1 Technical summary (p.63). The warming level is relative to the period 1850-1900. Link: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf*

Normalization of Physical Indicators

- For “apples to apples” comparisons of physical risks across different hazards and assets, all physical indicators are normalized to the same scale (0 to 1) prior to risk score calculations as the raw scenario indicators are on different scales (e.g. warm spell duration days in days, flood inundation depths in metres, wind speed in knots), where 0 represents a minimal risk of a physical hazard and 1 represents a maximum risk of that hazard.
- Climate indicators measured by frequency of occurrence (Extreme Heat) are normalized according to classification by climate zones. Each climate zone is associated with distinct weather patterns and is therefore vulnerable to unique thresholds of physical hazards.
- Climate indicators measured by magnitude/intensity (Extreme Winds & Storms, Rainfall Flooding, River Flooding, Coastal Flooding, Extreme Total Water Level, Waves and Currents) are normalized based on severity of hazards.

Hazard	Scenario Indicator	Normalization
Extreme Heat	**Warm Spell Duration Index (WSDI) (days)**	**Climate zones**
Extreme Winds & Storms	**Maximum Tropical Cyclone Windspeed (knots)**	**Severity**
River Flooding	**River Flooding Inundation Depth (metres)**	**Severity**
Extreme Rainfall Flooding	**Pluvial Flooding Inundation Depth (metres)**	**Severity**
Coastal & Offshore	**Coastal Flooding Inundation Depth (metres)**	**Severity**
Coastal & Offshore	**Extreme Total Water Level (ETWL) (metres)**	**Severity**
Coastal & Offshore	**Waves (metres)**	**Severity**
Coastal & Offshore	**Ocean current (metre/second)**	**Severity**



A (tropical), *B* (arid), *C* (temperate), *D* (continental), and *E* (polar).

Figure illustrating the different areas dominated by a specific climate zone.

Exposure ratings are allocated to each asset type to incorporate predisposed exposure to physical risk

What is an Exposure Rating?

Considers the significance of each climate hazard on a business' **operations**

Developed based on **qualitative research** and supplemented by ERM's existing knowledge base of **climate-related exposures**

Combined with climate data in the Global Climate Database to produce **risk scores** for each hazard

*Note: The rating **DOES NOT consider the likelihood of the event** occurring and only looks to assess how exposed an asset could be if the event type occurred. The rating **DOES NOT take into account mitigation measures**.*

Exposure Rating	Exposure Rating Multiplier	Definition
Very High	10	Exposure to the Climate/Natural Hazard is very high. Potential impacts may: • Be long term (possibly permanent), severe and financially significant. • Have extensive social and health implications with national or international reputational impacts. • Affect large areas of the environment over a period of months, impacting high biodiversity areas. It is likely that **the entirety of the overall asset would be impacted.**
High	8	Exposure to the Climate/Natural Hazard is high. Potential impacts may: • Be long term (months) and financially significant to operations. • Have extensive social and health implications with national or international reputational impacts. • Affect large areas of the environment over a period of months impacting high biodiversity areas. It is likely that **a large proportion of the overall asset would be impacted.**
Moderate	6	Exposure to the Climate/Natural Hazard is moderate. Potential impacts may: • Be medium term (weeks) and moderately financially significant to operations. • Have minor/medium social and health implications with local reputational impacts. • Affect moderate areas of the environment over a period of weeks, impacting low biodiversity areas. It is likely that **a moderate proportion of the overall asset would be impacted.**
Low	4	Exposure to the Climate/Natural Hazard is low. Potential impacts may: • Be short term (days) and not financially significant to operations. • Have minimal social and health implications with limited reputational impacts. • Affect small areas of the environment over a short period. It is likely that **a small proportion of the overall asset would be impacted.**
Minimal	2	Exposure to the Climate/Natural Hazard is minimal with **limited potential effects to assets.**
N/A	0	Exposure to the Climate/Natural Hazard is not relevant with **no potential effects to assets.**

Exposure Ratings

Below are default exposure ratings for individual physical hazards of 39 asset group type covered in this physical risk assessment.

Hazard	Indicator (Unit)
Extreme Heat	**Warm Spell Duration Index (WSDI) (days)**
Extreme Winds & Storms	**Maximum Tropical Cyclone Windspeed (knots)**
River Flooding	**River Flooding Inundation Depth (metres)**
Rainfall Flooding	**Pluvial Flooding Inundation Depth (metres)**
Coastal & Offshore	**Coastal Flooding Inundation Depth (metres)**
Coastal & Offshore	**Extreme Total Water Level (ETWL) (metres)**
Coastal & Offshore	**Waves Height (metres)**
Coastal & Offshore	**Ocean Current (metre/seconds)**

Exposure Ratings

The corresponding exposure rating multipliers (the table at bottom right-next slide) are used jointly with the normalized scenario indicators to derive hazard type risk scores.

Asset Group Types	Extreme Heat	Extreme Winds & Storms	Rainfall flooding	Riverine flooding	Coastal Flooding	Extreme Total Water level	Waves	Currents
Berth: Nearshore	Low	Moderate	Low	Low	High	High	High	Moderate
Building: Data Center-Nearshore	Very High	High	Moderate	Moderate	High	High	Moderate	N/A
Building: Maintenance Repair Nearshore	High	High	Moderate	Moderate	High	High	Moderate	N/A
Building: Office	High	High	Moderate	Moderate	High	High	Low	N/A
Building: Office Nearshore	High	High	Moderate	Moderate	High	High	Low	N/A
Building: Operational	High	High	Moderate	Moderate	High	High	Low	N/A
Building: Operational-Nearshore	High	High	Moderate	Moderate	High	High	Moderate	N/A
Drainage System	Moderate	N/A	High	Low	High	High	Moderate	N/A
Equipment: Nearshore	High	High	Low	Moderate	High	High	High	Low
Equipment: Onshore	High	High	Moderate	Moderate	High	High	Low	N/A
Jetty: Nearshore	Low	High	Low	Moderate	Moderate	High	Very High	Very High
Manufacturing: Chemicals	Very High	High	High	High	High	High	Low	N/A
Manufacturing: Food Nearshore	High	High	High	Moderate	High	High	Moderate	N/A
Manufacturing: LPG	High	High	High	High	High	High	Low	N/A
Manufacturing: LPG Nearshore	High	High	High	High	High	High	Moderate	N/A
Manufacturing: Other	High	High	High	Moderate	High	High	Low	N/A
Openwater: Nearshore	Low	High	Low	Moderate	Moderate	High	High	Very High
Power: Substation	High	High	High	High	High	High	Low	N/A
Power: Substation DG	Very High	High	High	High	High	High	Low	N/A
Power: Substation NearRiver	High	High	High	Very High	Very High	Very High	Moderate	N/A
Power: Substation Nearshore	High	High	High	High	Very High	Very High	Moderate	N/A
Power: Substation Solar	Moderate	Moderate	Low	Low	Low	Low	N/A	N/A
Revetment: Onshore	Moderate	High	Low	Low	Very High	Very High	Very High	Moderate
Sewerage System	Low	N/A	High	Low	High	High	Low	N/A
Telecommunications Services	High	High	Moderate	Moderate	High	High	Low	N/A
Telecommunications Services: Nearshore	High	High	Moderate	Moderate	High	High	Moderate	N/A
Transport: Waterways	Moderate	High	High	High	High	High	High	Very High
Warehouses: Covered	High	High	Moderate	Moderate	High	High	Low	N/A
Warehouses: Covered Nearshore	High	High	Moderate	Moderate	High	High	Moderate	N/A
Warehouses: Dock Depot	High	High	High	Moderate	High	High	Low	N/A
Warehouses: Fuel	Very High	High	High	High	High	High	Low	N/A
Warehouses: Fuel Nearshore	Very High	High	High	High	High	High	Low	N/A
Warehouses: Uncovered	High	High	High	Moderate	High	High	Low	N/A
Warehouses: Uncovered Nearshore	High	High	High	Moderate	High	High	Moderate	N/A
Water Supply	High	High	High	High	Moderate	High	Low	N/A
Wharf: Nearshore	Low	Moderate	Low	Moderate	High	High	High	Moderate

Exposure Rating Multiplier					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

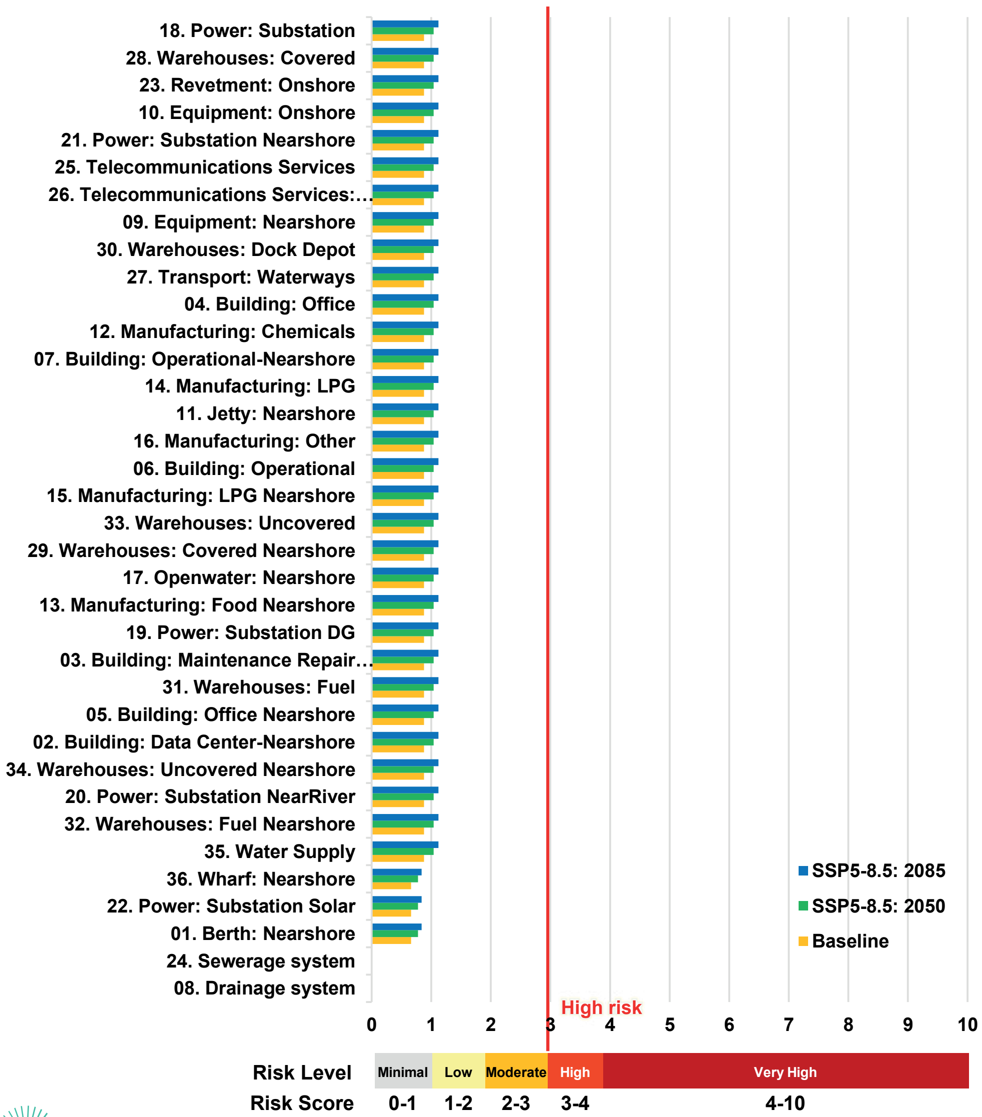
Detailed exposure rating of each asset groups types are given in Appendix E

Appendix C: Hazard Risk Score

BASELINE AND PROJECTED RISK SCORES BY ASSET GROUP TYPES- FIVE KEY HAZARDS

Extreme Winds & Storms: Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table shows the evolution of asset averaged risk scores for **Extreme Winds & Storms** across various asset types under baseline conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score increases modestly from **0.81** at baseline to **0.95** in 2050 and **1.03** in 2085, representing a **15% rise by 2050** and **21% by 2085**. While the escalation is less pronounced compared to other hazards, it signals a gradual increase in wind-related risks over time.

Risk Level

Most assets remain within the **Minimal to Low risk range (0–2)** throughout the projection period. However, the consistent upward trend suggests that even low-risk assets may require attention to maintain resilience.

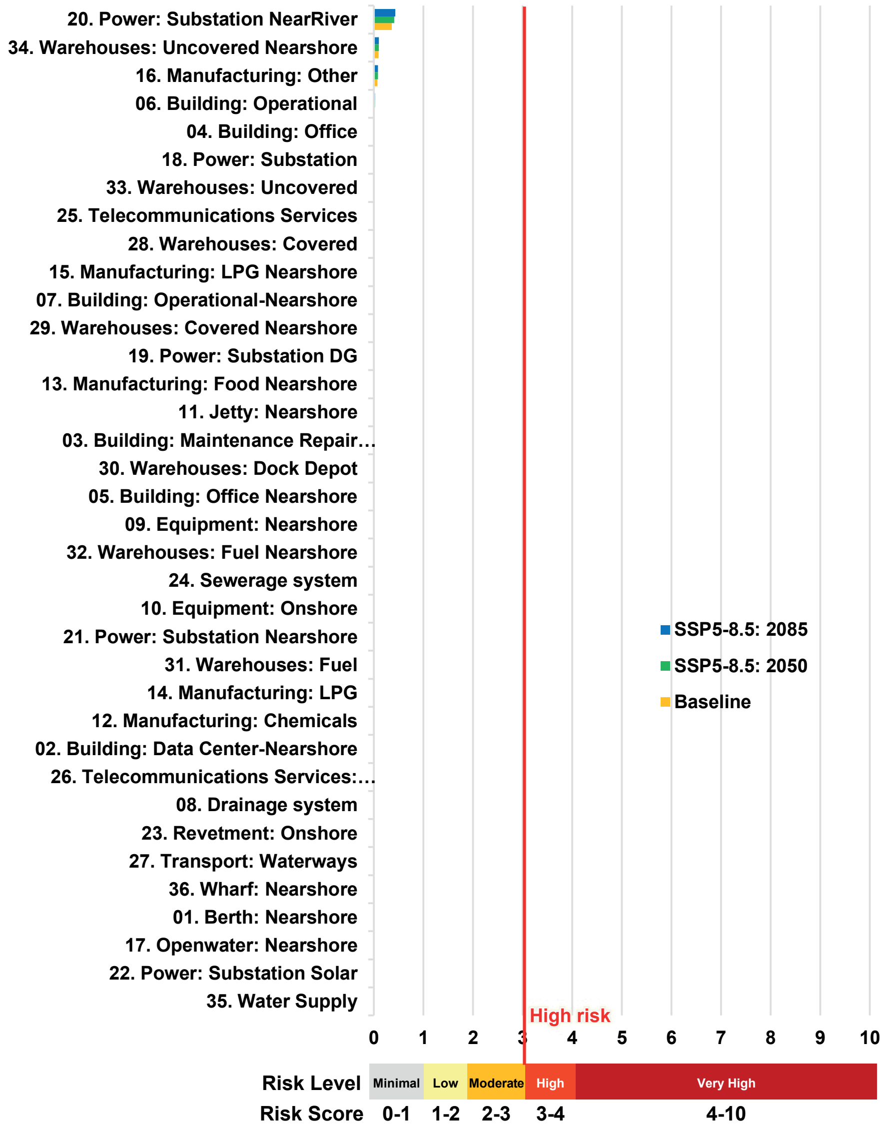
Assets with Noticeable Change

- **Nearshore Berths and Wharves** show slight increases from **0.66** to **0.84** by 2085.
- **Buildings (Data Centers, Offices, Operational)** and **Manufacturing Facilities** rise from **0.88** to **1.12**, moving closer to the upper bound of the **Low risk category**.
- **Power Substations** and **Telecommunication Services** follow similar patterns, reaching **1.12** by 2085.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	0.81	0.95	1.03
% Change from Baseline		15%	21%

Rainfall Flooding: Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table illustrates the change in asset-averaged risk scores for Rainfall Flooding across various asset types under baseline conditions and projected climate scenarios (SSP5-8.5 for **2050** and **2085**).

Overall Trend

The average risk score remains very low, increasing only slightly from **0.01** at baseline to **0.01** in 2050 and **0.01** in 2085. This indicates that rainfall-induced flooding poses **minimal risk** to most assets under the projected scenarios.

Risk Level

All assets remain within the **Minimal risk category (0–1)** throughout the projection period. The changes are negligible compared to other hazards, suggesting that rainfall flooding is not a major driver of vulnerability for these asset types.

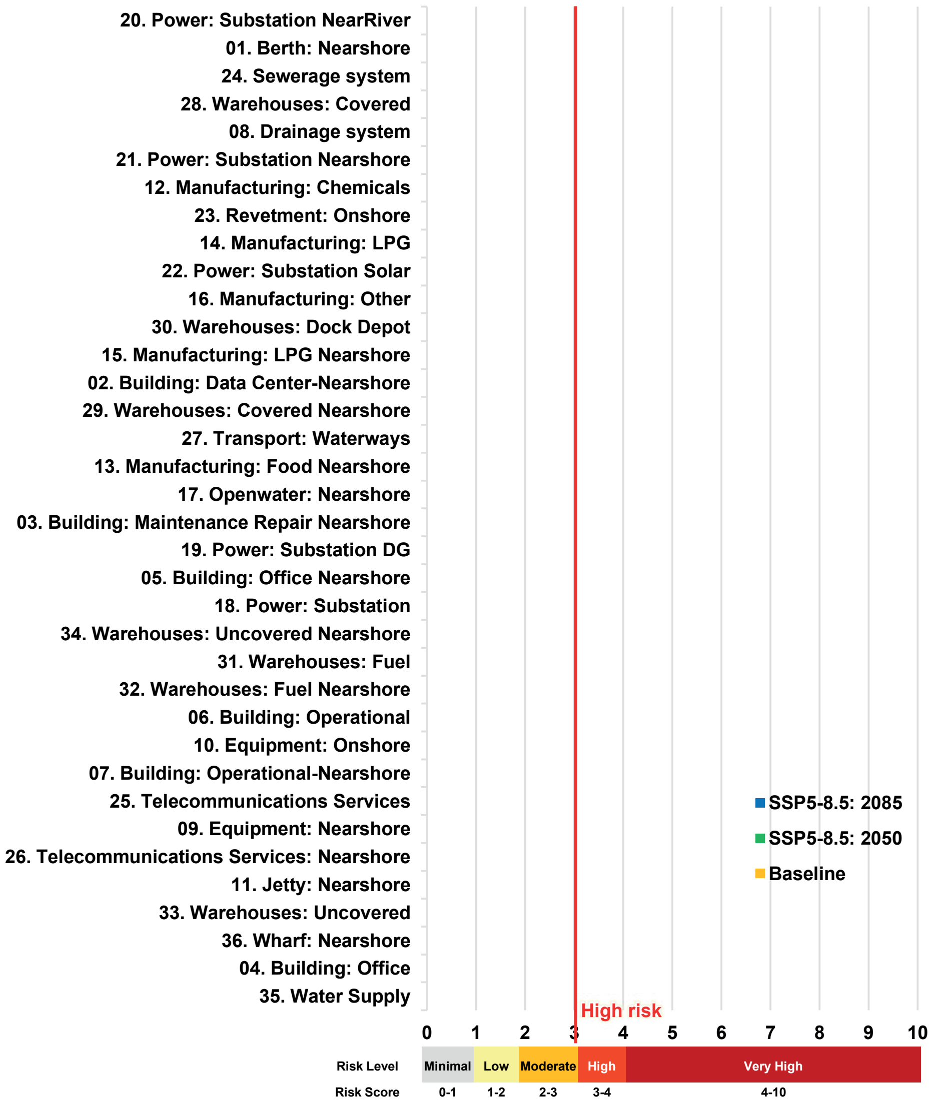
Assets with Slight Change

- **Power Substation Near River** shows the highest relative increase, from **0.36** to **0.43** by 2085, though still within minimal risk.
- **Manufacturing (Other)** and **Warehouses (Uncovered)** exhibit minor changes, moving from **0.07–0.10** range.
- Most other assets, including **Buildings**, **Telecommunication Services**, and **Drainage Systems**, remain at **0.00**, indicating no significant projected impact.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	0.01	0.01	0.01
% Change from Baseline		0%	0%

Riverine Flooding: Baseline and Projected Risk Scores by Asset Group Types

Risk Profile of 36 Asset Group Types



Key Trends & Risks

The table presents the asset averaged risk scores for **Riverine Flooding** across various asset types under **baseline** conditions and projected climate scenarios (**SSP5-8.5** for **2050** and **2085**).

Overall Trend

The average risk score remains **almost nil** across all timeframes, indicating **no measurable increase** in riverine flooding risk for the assessed assets under the projected scenarios. This suggests that riverine flooding is not a significant hazard for these asset types within the study area.

Risk Level

All assets consistently fall within the **Minimal risk category (0–1)**, with no observed changes from baseline to 2050 or 2085. This stability contrasts sharply with hazards such as **Extreme Heat**, which show substantial escalation.

Asset Type	Baseline	2050	2085
Asset Averaged Risk Score	0.00	0.00	0.00
% Change from Baseline		0%	0%

Appendix D: Hazard Risk Score

CHANGE FROM BASELINE RISK SCORE

Extreme Winds & Storms: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	0.66	0.12	0.18
02. Building: Data Center-Nearshore	0.88	0.16	0.24
03. Building: Maintenance Repair Nearshore	0.88	0.16	0.24
04. Building: Office	0.88	0.16	0.24
05. Building: Office Nearshore	0.88	0.16	0.24
06. Building: Operational	0.88	0.16	0.24
07. Building: Operational-Nearshore	0.88	0.16	0.24
08. Drainage system	0.00	0.00	0.00
09. Equipment: Nearshore	0.88	0.16	0.24
10. Equipment: Onshore	0.88	0.16	0.24
11. Jetty: Nearshore	0.88	0.16	0.24
12. Manufacturing: Chemicals	0.88	0.16	0.24
13. Manufacturing: Food Nearshore	0.88	0.16	0.24
14. Manufacturing: LPG	0.88	0.16	0.24
15. Manufacturing: LPG Nearshore	0.88	0.16	0.24
16. Manufacturing: Other	0.88	0.16	0.24
17. Openwater: Nearshore	0.88	0.16	0.24
18. Power: Substation	0.88	0.16	0.24
19. Power: Substation DG	0.88	0.16	0.24
20. Power: Substation NearRiver	0.88	0.16	0.24
21. Power: Substation Nearshore	0.88	0.16	0.24
22. Power: Substation Solar	0.66	0.12	0.18
23. Revetment: Onshore	0.88	0.16	0.24
24. Sewerage system	0.00	0.00	0.00
25. Telecommunications Services	0.88	0.16	0.24
26. Telecommunications Services: Nearshore	0.88	0.16	0.24
27. Transport: Waterways	0.88	0.16	0.24
28. Warehouses: Covered	0.88	0.16	0.24
29. Warehouses: Covered Nearshore	0.88	0.16	0.24
30. Warehouses: Dock Depot	0.88	0.16	0.24
31. Warehouses: Fuel	0.88	0.16	0.24
32. Warehouses: Fuel Nearshore	0.88	0.16	0.24
33. Warehouses: Uncovered	0.88	0.16	0.24
34. Warehouses: Uncovered Nearshore	0.88	0.16	0.24
35. Water Supply	0.88	0.16	0.24
36. Wharf: Nearshore	0.66	0.12	0.18
Asset Averaged Risk Score	0.81	0.15	0.22

Key Trends & Risks

The table presents the change in asset averaged risk scores for **Extreme Winds & Storms** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:

The average risk score **increases slightly** to **0.15 in 2050** and reaches **0.22 by 2085**. This indicates that wind-related risks remain **very low overall**, with only minimal increases projected over time.

Asset-Level Observations:

Most assets, including **buildings, power substations, warehouses, and manufacturing facilities**, show a consistent pattern of low risk, with scores remaining below **0.25** even under future scenarios.

Drainage systems and sewerage systems maintain negligible risk throughout the assessment.

These findings suggest that **Extreme Winds & Storms** pose limited threat to the assessed infrastructure under SSP5-8.5, though localized vulnerabilities may still require monitoring.

Projected Risk Escalation and Potential Operational Impacts

Extreme Winds & Storms – projected to have a **'minimal' risk level** by **2050 and 2085** under **SSP5-8.5** scenario. While overall risk remains low, potential impacts under extreme wind and storm conditions include:

- **Structural Stress:** Minor increases in wind intensity could lead to localized damage to exposed components such as roofing, cladding, and nearshore structures.
- **Operational Disruptions:** Temporary interruptions in transport and logistics during storm events, particularly for nearshore berths and wharves.
- **Safety Considerations:** Isolated risks to personnel during severe storm occurrences, requiring adherence to emergency protocols.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Rainfall Flooding: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	0.00	0.00	0.00
02. Building: Data Center-Nearshore	0.00	0.00	0.00
03. Building: Maintenance Repair Nearshore	0.00	0.00	0.00
04. Building: Office	0.01	0.00	0.00
05. Building: Office Nearshore	0.00	0.00	0.00
06. Building: Operational	0.02	0.00	0.00
07. Building: Operational-Nearshore	0.00	0.00	0.00
08. Drainage system	0.00	0.00	0.00
09. Equipment: Nearshore	0.00	0.00	0.00
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	0.00	0.00	0.00
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	0.00	0.00	0.00
14. Manufacturing: LPG	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	0.00	0.00	0.00
16. Manufacturing: Other	0.07	0.01	0.01
17. Openwater: Nearshore	0.00	0.00	0.00
18. Power: Substation	0.01	0.00	0.00
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.36	0.05	0.07
21. Power: Substation Nearshore	0.00	0.00	0.00
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	0.00	0.00	0.00
24. Sewerage system	0.00	0.00	0.00
25. Telecommunications Services	0.01	0.00	0.00
26. Telecommunications Services: Nearshore	0.00	0.00	0.00
27. Transport: Waterways	0.00	0.00	0.00
28. Warehouses: Covered	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	0.00	0.00	0.00
30. Warehouses: Dock Depot	0.00	0.00	0.00
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	0.00	0.00	0.00
33. Warehouses: Uncovered	0.01	0.00	0.01
34. Warehouses: Uncovered Nearshore	0.09	0.01	0.01
35. Water Supply	0.00	0.00	0.00
36. Wharf: Nearshore	0.00	0.00	0.00
Asset Averaged Risk Score	0.01	0.00	0.00

Key Trends & Risks

The table illustrates the change in aggregated risk scores for **Rainfall Flooding** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:
The average risk score shows a across all timeframes (baseline, 2050, and 2085), indicating **no significant change** in rainfall flooding risk under the assessed climate scenario.

Asset-Level Observations:
Nearly all assets—including **buildings, power substations, warehouses, and manufacturing facilities**—maintain a risk score of **0.00-0.01**, with only negligible increases (up to **0.07**) for a near river power substations by 2085.

Drainage and sewerage systems remain unaffected, reflecting minimal exposure to rainfall-induced flooding in this context.

These findings suggest that **Rainfall Flooding** poses **no material risk** to the assessed infrastructure under SSP5-8.5, though localized vulnerabilities should still be monitored as part of broader flood resilience planning.

Projected Risk Escalation and Potential Operational Impacts

Rainfall Flooding – projected to have a **'minimal' risk level** by **2050 and 2085** under **SSP5-8.5** scenario. Given the negligible risk scores, rainfall flooding is not expected to cause significant operational or structural impacts. However, potential considerations include:

Localized Drainage Issues:

Minor water accumulation in low-lying areas during extreme rainfall events.

Operational Disruptions:

Temporary delays in transport or site access during heavy precipitation.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score						
Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Riverine Flooding: Change from Baseline Risk Score

Risk Profile of 36 Asset Group Types

Asset Group Type	Baseline	2050	2085
01. Berth: Nearshore	0.00	0.00	0.00
02. Building: Data Center-Nearshore	0.00	0.00	0.00
03. Building: Maintenance Repair Nearshore	0.00	0.00	0.00
04. Building: Office	0.00	0.00	0.00
05. Building: Office Nearshore	0.00	0.00	0.00
06. Building: Operational	0.00	0.00	0.00
07. Building: Operational-Nearshore	0.00	0.00	0.00
08. Drainage system	0.00	0.00	0.00
09. Equipment: Nearshore	0.00	0.00	0.00
10. Equipment: Onshore	0.00	0.00	0.00
11. Jetty: Nearshore	0.00	0.00	0.00
12. Manufacturing: Chemicals	0.00	0.00	0.00
13. Manufacturing: Food Nearshore	0.00	0.00	0.00
14. Manufacturing: LPG	0.00	0.00	0.00
15. Manufacturing: LPG Nearshore	0.00	0.00	0.00
16. Manufacturing: Other	0.00	0.00	0.00
17. Openwater: Nearshore	0.00	0.00	0.00
18. Power: Substation	0.00	0.00	0.00
19. Power: Substation DG	0.00	0.00	0.00
20. Power: Substation NearRiver	0.00	0.00	0.00
21. Power: Substation Nearshore	0.00	0.00	0.00
22. Power: Substation Solar	0.00	0.00	0.00
23. Revetment: Onshore	0.00	0.00	0.00
24. Sewerage system	0.00	0.00	0.00
25. Telecommunications Services	0.00	0.00	0.00
26. Telecommunications Services: Nearshore	0.00	0.00	0.00
27. Transport: Waterways	0.00	0.00	0.00
28. Warehouses: Covered	0.00	0.00	0.00
29. Warehouses: Covered Nearshore	0.00	0.00	0.00
30. Warehouses: Dock Depot	0.00	0.00	0.00
31. Warehouses: Fuel	0.00	0.00	0.00
32. Warehouses: Fuel Nearshore	0.00	0.00	0.00
33. Warehouses: Uncovered	0.00	0.00	0.00
34. Warehouses: Uncovered Nearshore	0.00	0.00	0.00
35. Water Supply	0.00	0.00	0.00
36. Wharf: Nearshore	0.00	0.00	0.00
Asset Averaged Risk Score	0.00	0.00	0.00

Key Trends & Risks

The table illustrates the change in asset averaged risk scores for **Riverine Flooding** across various asset types from the **baseline** to future climate scenarios (**SSP5-8.5 for 2050 and 2085**).

Overall Trend:

The average risk score remains **0.00** across all timeframes (baseline, 2050, and 2085), indicating **no significant change** in riverine flooding risk under the assessed climate scenario.

Asset-Level Observations:

All assets—including **berths, wharves, nearshore warehouses, operational buildings, power substations, and manufacturing facilities**—maintain a risk score of **0.00**, with no measurable increase projected for 2050 or 2085.

Drainage and sewerage systems also remain unaffected, suggesting minimal exposure to riverine flooding in the current design and location context.

These findings confirm that **Riverine Flooding** poses **no material risk** to the assessed infrastructure under SSP5-8.5, though ongoing monitoring is recommended to address potential changes in river discharge patterns or upstream developments.

Projected Risk Escalation and Potential Operational Impacts

Riverine Flooding – projected to have a **'minimal' risk level** by **2050 and 2085** under **SSP5-8.5** scenario. Given the negligible risk scores, rainfall flooding is not expected to cause significant operational or structural impacts. However, potential considerations include:

Localized Overflow Risks:

Minor water level fluctuations near river-adjacent assets during extreme rainfall or upstream discharge events.

Operational Delays:

Temporary restrictions on cargo movement or vessel berthing if river conditions change unexpectedly.

Risk level	Minimal	Low	Moderate	High	Very High
Risk Score	0 to 1	1 to 2	2 to 3	3 to 4	4 to 10

Change from Baseline Risk Score

Significant Decrease	Moderate Decrease	Minimal Decrease	No Change	Minimal Increase	Moderate Increase	Significant Increase
-10 to -2	-2 to -1	-1 to -0.25	-0.25 to 0.25	+0.25 to +1	+1 to +2	+2 to 10

Appendix E: Exposure Rating

EXPOSURE FOR ALL ASSET GROUP TYPES

Physical Exposure Ratings

Berth: Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**Low**	Open-water exposure and continuous sea ventilation reduce local heat accumulation along berth decks. Structural and operational components are not highly heat-sensitive.
Extreme Winds & Storms	**Moderate**	Berths are directly exposed to southwest monsoon winds and thunderstorm gust fronts. Cranes and vessels at berth face moderate wind-related operational constraints but structural tolerance is generally adequate.
Rainfall Flooding	**Low**	Berth surface is fully open and graded towards drains/sea, limiting water ponding. Minimal equipment at ground level reduces flood vulnerability.
Riverine Flooding	**Low**	Berths sit on reclaimed coastal frontage with no direct river catchment influence. River discharge points nearby have limited effect on quay platform levels.
Coastal Flooding	**High**	Directly fronting the Malacca Strait with low freeboard areas near quay edge. Berths are exposed to tidal surges and elevated water levels during monsoon-driven high tides.
Extreme Total Water Level (SLR + tides + surge + waves)	**High**	Sea-level rise combined with storm surge and wave setup can exceed quay levels during extreme events, especially during King Tide periods. Overtopping risk increases with long-term SLR.
Waves	**High**	Nearshore berths face open fetch towards southwest monsoon. Long-period swells and wind waves disrupt mooring stability, berthing operations, and crane productivity.
Currents	**Moderate**	Tidal currents in the Strait influence vessel manoeuvring and berthing alignment. Moderate hydrodynamic forces act on moored vessels, affecting operational safety.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Building: Data Center-Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**Very High**	Data centers are highly sensitive to heat due to cooling demands. Rising temperatures and urban heat island effects significantly increase operational risks and energy costs.
Extreme Winds & Storms	**High**	Monsoonal winds and tropical storms can damage infrastructure and disrupt power supply, affecting uptime and equipment safety.
Rainfall Flooding	**Moderate**	Heavy rainfall can cause localized flooding, especially in low-lying nearshore zones, impacting access and electrical systems.
River Flooding	**Moderate**	Data centers near river mouths (e.g., Klang) may be affected by overflow events and sedimentation.
Coastal Flooding	**High**	Sea level rise and storm surges pose serious risks to nearshore data centers, especially in areas like Port Klang.
Extreme Total Water Level	**High**	Combined tidal and surge events can inundate facilities, threatening continuity and data integrity.
Waves	**Moderate**	While direct wave impact is limited, strong wave action during storms can affect structural integrity and access.
Currents	**N/A**	Currents have minimal direct impact on fixed nearshore buildings, though they may influence adjacent waterborne systems.

Physical Exposure Ratings

Building: Maintenance Repair Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Nearshore maintenance buildings are exposed to elevated temperatures due to urban heat island effects and proximity to industrial zones. Heat stress affects workers, equipment, and indoor conditions.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms pose risks to structural integrity and operational continuity, especially in exposed coastal zones.
Rainfall Flooding	Moderate	Heavy rainfall can cause localized flooding, particularly in poorly drained nearshore areas, affecting access and equipment.
River Flooding	Moderate	Facilities near river mouths (e.g., Klang, Perak) may be impacted by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges threaten low-lying maintenance buildings near ports and coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate nearshore facilities, affecting operations and safety.
Waves	Moderate	Strong wave action during storms can affect building foundations and access, especially for facilities close to the shoreline.
Currents	N/A	Currents have minimal direct impact on fixed nearshore buildings unless affecting adjacent marine systems.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Building: Office

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Office buildings in urban areas are highly exposed to heat stress due to rising temperatures and the urban heat island effect. This affects energy demand, indoor comfort, and building materials.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage roofs, windows, and external structures, especially in coastal zones.
Rainfall Flooding	Moderate	Heavy rainfall can cause localized flooding, especially in poorly drained urban areas. Office buildings with inadequate stormwater management are at risk.
River Flooding	Moderate	Offices near rivers (e.g., Klang River) may be affected by overflow events, impacting access and infrastructure.
Coastal Flooding	High	Sea level rise and storm surges pose risks to low-lying office buildings near the coast, especially in Selangor.
Extreme Total Water Level	High	Combined effects of tides, surges, and rainfall can inundate office zones, particularly in reclaimed or low-lying areas.
Waves	Low	Direct wave impact is minimal unless the building is extremely close to the shoreline.
Currents	N/A	Currents do not directly affect onshore office buildings.

Physical Exposure Ratings

Building: Office Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**High**	Office buildings have indoor workspaces, HVAC systems, and electronic equipment sensitive to prolonged heat. Higher cooling loads and indoor comfort issues drive a high rating.
Extreme Winds & Storms	**High**	Nearshore locations experience strong monsoon winds; façade, roofing, windows, and external utilities are exposed to uplift and pressure loads. Wind-driven rain can affect building envelopes.
Rainfall Flooding	**Moderate**	Although elevated above ground, office buildings rely on local drainage. Intense rainfall can cause entrance-level inundation, waterlogging around access areas, and minor disruptions.
Riverine Flooding	**Moderate**	Proximity to tidal rivers increases exposure during river-water rise and backflow events. Lower ground levels, basements, and access roads face potential inundation.
Coastal Flooding	**High**	Nearshore office structures are within the coastal influence zone. Elevated high-tide events and storm surges can reach building surrounds, affecting critical access points and utilities.
Extreme Total Water Level (ETWL)	**High**	ETWL combining tide + surge + wave setup poses intrusion risks at ground floors, electrical rooms, and building entrances. Increased vulnerability due to low coastal buffer.
Waves	**Low**	Buildings are typically set back from the quay and protected by port structures; wave action rarely reaches the building itself.
Currents	**N/A**	Not applicable as currents do not physically impact inland structures such as offices.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Building: Operational

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**High**	Operational buildings (e.g., power stations, control centers) are vulnerable to heat stress, which affects equipment, energy demand, and indoor working conditions. Urban heat island effects intensify this risk.
Extreme Winds & Storms	**High**	Monsoonal winds and tropical storms can damage structural components, disrupt operations, and require costly repairs.
Rainfall Flooding	**Moderate**	Heavy rainfall can cause localised flooding, especially in poorly drained or low-lying operational zones.
River Flooding	**Moderate**	Facilities near rivers (e.g., Klang, Perak) may be affected by overflow events, sedimentation, and access issues.
Coastal Flooding	**High**	Sea level rise and storm surges pose significant risks to coastal operational buildings, especially in Selangor.
Extreme Total Water Level	**High**	Combined tidal and surge events can inundate operational zones, affecting continuity and safety.
Waves	**Low**	Direct wave impact is minimal unless the building is located extremely close to the shoreline.
Currents	**N/A**	Currents do not directly affect onshore operational buildings.

Physical Exposure Ratings

Building: Operational-Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**High**	Nearshore operational buildings (e.g., power stations, control centers) are highly exposed to heat stress due to urban heat island effects and proximity to industrial zones. Heat affects equipment, energy demand, and indoor working conditions.
Extreme Winds & Storms	**High**	Monsoonal winds and tropical storms pose structural risks and operational disruptions, especially in exposed coastal zones.
Rainfall Flooding	**Moderate**	Heavy rainfall can cause localized flooding, particularly in low-lying or poorly drained nearshore areas.
River Flooding	**Moderate**	Buildings near river mouths (e.g., Klang, Perak) may be affected by overflow events and sedimentation.
Coastal Flooding	**High**	Sea level rise and storm surges threaten infrastructure and continuity of operations in nearshore zones.
Extreme Total Water Level	**High**	Combined tidal and surge events can inundate operational buildings, affecting safety and functionality.
Waves	**Moderate**	While direct wave impact is less than offshore structures, strong wave action during storms can affect building foundations and access.
Currents	**N/A**	Currents have limited direct impact on fixed nearshore buildings, though they may influence adjacent waterborne systems.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Drainage System

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	**Moderate**	Prolonged heat accelerates drying, cracking, and shrinkage of concrete drains; can also harden sediments and reduce hydraulic efficiency. Impacts are present but not severe.
Extreme Winds & Storms	**High**	Strong winds and storms increase debris loading (leaves, branches, litter) into drains, causing blockages and reduced flow capacity. Storm-driven inflows also exceed system limits.
Rainfall Flooding	**High**	Drainage networks are directly exposed to intense rainfall. High rainfall overwhelms design capacity, causing surcharging, backflow, and localized flooding around critical assets.
Riverine Flooding	**High**	When river levels rise, backflow enters the drainage system through outfalls, reducing discharge capacity and causing internal flooding. Tidal/river interfaces are particularly vulnerable.
Coastal Flooding	**High**	Coastal storm tides elevate downstream water levels, preventing drains from outflowing and causing seawater intrusion into the network. High likelihood of backflow and system overload.
Extreme Total Water Level (ETWL)	**High**	ETWL (tide + surge + setup) frequently exceeds drain outfall elevations, resulting in backflow, pressurization of pipes, and widespread drainage failure during extreme events.
Waves	**Moderate**	Wave action near outfalls can push water back into the drainage pipes and damage exposed sections. Risk is moderate where drains discharge close to shoreline.
Currents	**Moderate**	Strong tidal currents at outfalls hinder discharge efficiency and increase backflow potential, particularly during spring tides. Effects moderate but operationally relevant.

Physical Exposure Ratings

Equipment: Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Nearshore equipment (e.g., cranes, pumps, sensors) may suffer from heat-induced wear, reduced efficiency, and increased cooling demands. Urban heat island effects near ports intensify this risk.
Extreme Winds & Storms	High	Equipment is vulnerable to damage from strong winds and storm surges, especially during monsoon seasons.
Rainfall Flooding	Low	Direct impact is limited unless equipment is located in low-lying or poorly drained areas.
River Flooding	Moderate	Equipment near river mouths (e.g., Klang, Perak) may be affected by sedimentation, corrosion, and access issues during floods.
Coastal Flooding	High	Sea level rise and storm surges pose risks to fixed and mobile equipment near the shoreline.
Extreme Total Water Level	High	Combined tidal and surge events can submerge or damage sensitive equipment, especially in shallow nearshore zones.
Waves	High	Wave action can cause mechanical stress, corrosion, and operational disruption to exposed equipment.
Currents	Low	Strong currents affect moored or floating equipment, influence sediment transport, and increase maintenance needs.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Equipment: Onshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Onshore equipment in urban and industrial zones is highly vulnerable to heat stress, especially due to the urban heat island effect. Heat can degrade materials, reduce efficiency, and increase cooling demands.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage exposed equipment, disrupt operations, and increase maintenance costs.
Rainfall Flooding	Moderate	Heavy rainfall can cause localized flooding, affecting equipment in low-lying or poorly drained areas.
River Flooding	Moderate	Equipment near riverbanks (e.g., Klang River) may be impacted by sedimentation, corrosion, and access issues during floods.
Coastal Flooding	High	Sea level rise and storm surges pose significant risks to onshore infrastructure and equipment in coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate equipment, especially in low-lying industrial areas.
Waves	Low	Direct wave impact is minimal for inland onshore equipment, unless located very close to the shoreline.
Currents	N/A	Currents have limited direct impact on fixed onshore equipment, unless affecting adjacent waterborne systems.

Physical Exposure Ratings

Jetty: Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Low	Open marine structure with full airflow; jetty components (steel, concrete, ladders, fenders) have low sensitivity to heat and do not trap thermal loads.
Extreme Winds & Storms	High	Jetty platforms are directly exposed to monsoon winds and storm conditions. Wind-driven waves and vessel movement increase structural and operational stresses, especially during berthing.
Rainfall Flooding	Low	Rain drains freely off the jetty deck into the sea. No dependence on land-based drainage systems; no ponding risk on the structure.
Riverine Flooding	Moderate	Elevated river levels during heavy upstream discharge can affect jetties located near river mouths. Increased flow velocity and water levels can challenge vessel approach and jetty access.
Coastal Flooding	High	Jetties have low deck levels relative to sea elevation, making them highly exposed to storm tides, overtopping, and splash-inundation during monsoon surge events.
Extreme Total Water Level (ETWL)	High	Combined tide + surge + wave setup reduces freeboard and increases overtopping frequency. ETWL events cause mooring strain, fender submergence, and temporary shutdown of jetty operations.
Waves	Moderate	Jetties face more direct wave action than inland structures. While partial harbour sheltering exists, wave heights rise significantly during monsoon winds, affecting berthing safety.
Currents	Moderate	Tidal currents influence vessel positioning, berthing alignment, and mooring line loads. Stronger currents during spring tides can affect jetty accessibility and operational windows.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Manufacturing: Chemicals

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Chemical manufacturing is highly sensitive to heat due to risks of thermal expansion, pressure buildup, and volatility of stored chemicals. Heat stress also affects worker safety and equipment reliability.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage chemical tanks, pipelines, and safety systems, increasing the risk of leaks or explosions.
Rainfall Flooding	High	Heavy rainfall can flood chemical plants, compromise containment systems, and contaminate nearby water sources.
River Flooding	High	Facilities near rivers (e.g., Klang, Perak) are vulnerable to overflow events that can damage infrastructure and lead to environmental hazards.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to coastal chemical manufacturing zones, especially in industrial hubs like Port Klang.
Extreme Total Water Level	High	Combined tidal and surge events can inundate chemical facilities, increasing risks of leakage, contamination, and fire.
Waves	Low	Direct wave impact is limited but can affect infrastructure near the shoreline during storm events.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine transport systems or intake structures.

Physical Exposure Ratings

Manufacturing: Food Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Food manufacturing is highly sensitive to heat due to cooling requirements, spoilage risks, and worker health. Nearshore facilities face intensified heat stress from urban heat island effects and humidity.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage infrastructure, disrupt supply chains, and halt production.
Rainfall Flooding	High	Heavy rainfall can flood nearshore manufacturing zones, affecting raw material storage, machinery, and access routes.
River Flooding	Moderate	Facilities near river mouths (e.g., Klang, Perak) may be impacted by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to low-lying food manufacturing plants near ports and coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate facilities, affecting operations, food safety, and logistics.
Waves	Moderate	Strong wave action during storms can affect access and structural integrity of nearshore facilities.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine transport systems.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Manufacturing: LPG

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	LPG manufacturing and storage are highly sensitive to heat due to pressure buildup risks, increased evaporation, and fire hazards. Rising temperatures and urban heat intensify these risks.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage tanks, pipelines, and safety systems, increasing the risk of leaks or explosions.
Rainfall Flooding	High	Heavy rainfall can flood LPG facilities, compromise containment systems, and disrupt operations.
River Flooding	High	Facilities near rivers (e.g., Klang, Perak) are vulnerable to overflow events that can damage infrastructure and lead to environmental hazards.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to coastal LPG manufacturing zones, especially in industrial hubs like Port Klang [cidb.gov.my].
Extreme Total Water Level	High	Combined tidal and surge events can inundate LPG facilities, increasing risks of leakage, contamination, and fire.
Waves	Low	Direct wave impact is limited but can affect infrastructure near the shoreline during storm events.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine transport systems.

Physical Exposure Ratings

Manufacturing: LPG Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	LPG handling systems, compressors, pumps, and storage cylinders are sensitive to heat. Elevated temperatures increase tank pressure, equipment fatigue, and safety-control loading.
Extreme Winds & Storms	High	Nearshore exposure increases wind loading on piping racks, elevated platforms, and outdoor equipment. Storms raise risk of mechanical damage, leaks, and ignition if protective barriers are compromised.
Rainfall Flooding	High	Heavy rainfall can inundate low-lying processing areas, affecting electrical cabinets, control panels, and pumps. Floodwater increases corrosion and heightens risk around hazardous materials.
Riverine Flooding	High	Nearshore LPG facilities close to river influence zones face backflow and elevated water levels that can reach process areas, impacting equipment integrity and emergency access routes.
Coastal Flooding	Very High	LPG facilities are highly sensitive to seawater intrusion. Coastal flooding can submerge critical valves, electrical systems, and tank foundations, significantly increasing fire and explosion risk.
Extreme Total Water Level (ETWL)	High	ETWL events (tide + surge + wave setup) can exceed platform grades, exposing LPG systems to dangerous flooding conditions. This increases operational shutdowns and emergency hazards.
Waves	Moderate	Wave action near the shoreline can impact exposed pipelines or jetty-connected LPG transfer systems. Facilities set back from the waterfront experience reduced but still relevant exposure.
Currents	Moderate	Strong tidal currents affect marine LPG transfer lines and berthing operations. While onshore equipment is not directly affected, jetty-linked systems face operational risks during transfer.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Manufacturing: Other

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Moderate	General manufacturing areas contain machinery, electrical panels, and workers affected by prolonged heat, but less thermally sensitive than LPG/chemical facilities. Higher cooling demand and worker fatigue are the primary concerns.
Extreme Winds & Storms	High	Many manufacturing structures are lightweight steel buildings with large wall/roof surfaces exposed to uplift forces. Storm winds also affect external equipment yards, loading zones, and utilities.
Rainfall Flooding	High	Typically located on low/flat industrial platforms that depend on site drainage. Intense rainfall can cause floor-level flooding, affecting equipment, production lines, and finished goods storage.
Riverine Flooding	Moderate	Nearshore manufacturing areas close to tidal rivers may experience water-level rise and backflow at drainage outlets. While not as sensitive as hazardous-material facilities, operations and access may still be disrupted.
Coastal Flooding	High	High-tide events and storm surges can inundate surrounding yards and building entrances. Floodwater may affect electrical systems, conveyor areas, and ground-level machinery.
Extreme Total Water Level (ETWL)	High	ETWL can exceed platform elevation, causing seawater intrusion into production floors, damaging equipment and interrupting operations. Vulnerability increases with limited coastal buffer.
Waves	Low	Manufacturing buildings are typically set back from the shoreline and shielded by port structures; wave energy rarely reaches the facility itself.
Currents	N/A	Currents have no direct impact on land-based manufacturing operations or equipment.

Physical Exposure Ratings

Openwater: Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Low	Rising sea surface temperatures have led to coral bleaching and harmful algal blooms, especially near Penang and Port Dickson.
Extreme Winds & Storms	High	Monsoonal winds and occasional tropical storms impact wave dynamics and coastal mixing.
Rainfall Flooding	Low	Direct impact on open waters is limited, though nutrient runoff from heavy rains can trigger algal blooms.
River Flooding	Moderate	Rivers like the Klang and Perak influence salinity and nutrient levels in adjacent nearshore zones.
Coastal Flooding	Moderate	Sea level rise and storm surges affect infrastructure and ecosystems along the west coast.
Extreme Total Water Level	High	Combined effects of tides, storm surges, and sea level rise are significant in shallow shelf areas like the Straits of Malacca.
Waves	High	Monsoonal and storm-driven waves affect sediment transport and coastal morphology.
Currents	Very High	Currents in the Straits of Malacca are vital for nutrient cycling, larval transport, and ecosystem connectivity.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Power: Substation

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Substations are sensitive to heat stress, which affects transformer efficiency, cooling systems, and increases risk of equipment failure. Urban heat island effects intensify this risk.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage substation structures, overhead lines, and control systems, leading to outages.
Rainfall Flooding	High	Heavy rainfall can flood substations, especially in low-lying or poorly drained areas, affecting electrical safety and continuity.
River Flooding	High	Substations near rivers (e.g., Klang, Perak) are vulnerable to overflow events that can damage infrastructure and disrupt power supply.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to coastal substations, especially in industrial zones like Port Klang.
Extreme Total Water Level	High	Combined tidal and surge events can inundate substations, affecting operations and safety.
Waves	Low	Direct wave impact is limited but can affect substations located very close to the shoreline during storm events.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine infrastructure or intake systems.

Physical Exposure Ratings

Power: Substation DG

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	DG substations are highly sensitive to heat due to reliance on electronics, inverters, and cooling systems. Rising temperatures and urban heat island effects increase failure risks and reduce efficiency.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage rooftop solar arrays, wind turbines, and associated DG infrastructure, disrupting supply and safety.
Rainfall Flooding	High	Heavy rainfall can flood DG substations, especially in low-lying or poorly drained areas, affecting electrical safety and continuity.
River Flooding	High	DG systems near rivers (e.g., Klang) are vulnerable to overflow events and sedimentation, which can damage infrastructure and cause outages.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to DG substations located near coastal zones or ports.
Extreme Total Water Level	High	Combined tidal, surge, and rainfall events can inundate DG infrastructure, leading to outages and long-term damage.
Waves	Low	Direct wave impact is limited but can affect DG systems located very close to the shoreline during storm events.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine infrastructure or intake systems.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Power: Substation NearRiver

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Transformers, switchgear, and control panels are heat-sensitive. High temperatures reduce cooling efficiency, increase internal temperatures, and accelerate insulation ageing.
Extreme Winds & Storms	High	Substations contain outdoor transformers, busbars, towers, and cables exposed to strong winds. Storms can topple auxiliary structures, cause conductor oscillation, and damage overhead lines.
Rainfall Flooding	High	Heavy rainfall can inundate substation yards, affecting transformers, RMUs, protection systems, and cable trenches. Water ingress risks short circuits and extended outages.
Riverine Flooding	Very High	Being near the river significantly increases the risk of overflow and backwater flooding reaching electrical equipment. Even shallow flooding can cause catastrophic failures and long shutdowns.
Coastal Flooding	Very High	If the river is tidally influenced, storm surges propagate upstream and raise water levels around the substation. Critical components sit close to ground level, increasing exposure.
Extreme Total Water Level (ETWL)	Very High	ETWL pushes tidal/river levels well above normal, creating severe inundation risk. Submersion of transformers and switchgear results in total electrical failure and long-term rehabilitation needs.
Waves	Moderate	Substations are inland from the shoreline; wave action does not typically reach the asset. Only minimal risk at riverbank edges where minor wave agitation may occur.
Currents	N/A	Strong river currents increase bank erosion, potentially undermining foundations, cable routes, or access roads. Does not directly affect electrical equipment but contributes to site instability.

Physical Exposure Ratings

Power: Substation Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Nearshore substations are exposed to elevated temperatures, which affect transformer efficiency, increase cooling demands, and raise fire risk. Urban heat island effects intensify this exposure.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage substation structures, disrupt power supply, and increase maintenance needs.
Rainfall Flooding	High	Heavy rainfall can flood low-lying nearshore substations, compromising electrical safety and continuity of operations.
River Flooding	High	Substations near river mouths (e.g., Klang, Perak) are vulnerable to overflow events and sedimentation, which can damage infrastructure.
Coastal Flooding	Very High	Sea level rise and storm surges pose severe risks to nearshore substations, especially in industrial zones like Port Klang.
Extreme Total Water Level	Very High	Combined tidal and surge events can inundate substations, leading to outages and long-term damage.
Waves	Moderate	Strong wave action during storms can affect access and structural integrity of substations located close to the shoreline.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine infrastructure or intake systems.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Power: Substation Solar

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Low	Solar substations typically have minimal indoor heat-sensitive equipment. Heat may reduce inverter efficiency slightly, but overall systems are designed for high-temperature outdoor operation.
Extreme Winds & Storms	Moderate	Solar substations include lightweight structures, cable trays, and inverter units that can be affected by strong winds. Equipment is outdoors, but risks remain lower than grid substations with tall structures.
Rainfall Flooding	Low	Solar substations are usually sited on elevated, graded platforms with good drainage. Rainwater rarely affects electrical components mounted above ground.
Riverine Flooding	Low	Not typically located near riverbanks; platforms are chosen to avoid fluvial flood zones. Minimal exposure unless adjacent access roads are affected.
Coastal Flooding	Low	Solar farms/substations are generally inland with buffers from the coastline. Limited exposure to storm tides or saltwater inundation.
Extreme Total Water Level (ETWL)	Low	ETWL impacts are minimal unless site elevation is very low. Most solar substations are positioned well above high-water levels.
Waves	N/A	As an inland electrical installation, wave action has no direct physical impact.
Currents	N/A	Not applicable; no interaction with marine or river currents.

Physical Exposure Ratings

Revetment: Onshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Moderate	Revetments are generally resilient to heat, but prolonged exposure may affect material integrity (e.g., concrete, geotextiles) over time.
Extreme Winds & Storms	High	Strong winds and storm surges can increase wave energy and overtopping, stressing revetment structures.
Rainfall Flooding	Low	Revetments are not directly affected by inland rainfall unless combined with poor drainage or runoff from adjacent land.
River Flooding	Low	Exposure depends on proximity to river mouths; generally low unless near estuarine zones.
Coastal Flooding	Very High	Revetments are frontline defenses against coastal flooding. Rising sea levels and storm surges increase overtopping and erosion risks.
Extreme Total Water Level	Very High	Combined effects of tides, surges, and sea level rise challenge the design limits of existing revetments, requiring elevation or reinforcement.
Waves	Very High	Revetments are directly exposed to wave action, especially during monsoons and storms. Wave energy influences erosion and structural wear.
Currents	Moderate	Coastal currents can influence sediment transport and scouring around revetment bases, affecting long-term stability.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Sewerage System

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Low	Sewerage networks are predominantly underground and not heat-sensitive. Minor impacts include accelerated pipe material ageing and odour generation during prolonged heat.
Extreme Winds & Storms	High	Storm events increase debris and sediment inflow into manholes and pump stations. Power loss and storm surges can disrupt pumping operations and overload treatment units.
Rainfall Flooding	High	Heavy rainfall rapidly overloads sewer lines, causing surcharge, manhole overflow, and infiltration. Mixed stormwater inflow increases treatment volume and risk of system failure.
Riverine Flooding	Low	Sewer systems are usually below-ground and protected, but prolonged river flooding can infiltrate through manholes and joints, increasing hydraulic load on pipes and pump stations.
Coastal Flooding	High	Coastal floodwaters enter manholes, lift stations, and treatment plant inlets. Saltwater intrusion damages biological processes, pumps, electrical units, and pipe integrity.
Extreme Total Water Level (ETWL)	High	ETWL pushes water above manhole covers and outfall elevations, causing significant backflow, infiltration, and system surcharging across multiple network segments.
Waves	Low	Minimal direct impact because assets are underground. Only exposed outfalls near the coast may experience wave splash or structural scouring.
Currents	N/A	Not applicable. Currents do not directly affect buried sewerage infrastructure except at marine outfalls, where the impact remains negligible.

Physical Exposure Ratings

Telecommunications Services

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Heat stress increases cooling demands for base stations, data centers, and network equipment. Urban heat island effects intensify risks in built-up areas.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage towers, disrupt service, and affect power supply.
Rainfall Flooding	Moderate	Heavy rainfall can flood access roads and low-lying infrastructure, affecting maintenance and service continuity.
River Flooding	Moderate	Infrastructure near rivers (e.g., Klang, Perak) may be impacted by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges pose risks to coastal telecom infrastructure, especially in Selangor and Penang.
Extreme Total Water Level	High	Combined tidal and surge events can inundate telecom facilities, affecting uptime and safety.
Waves	Low	Direct wave impact is minimal unless infrastructure is located extremely close to the shoreline.
Currents	N/A	Currents do not directly affect terrestrial telecom infrastructure.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Telecommunications Services – Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Nearshore telecom infrastructure (e.g., base stations, relay towers, data hubs) is highly vulnerable to heat stress, especially in urban coastal zones. Heat increases cooling demands and risks equipment failure.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage towers, disrupt service, and affect power supply. Coastal exposure amplifies these risks.
Rainfall Flooding	Moderate	Heavy rainfall can flood access roads and low-lying infrastructure, affecting maintenance and service continuity.
River Flooding	Moderate	Infrastructure near river mouths (e.g., Klang, Perak) may be impacted by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to coastal telecom infrastructure, especially in Selangor.
Extreme Total Water Level	High	Combined tidal and surge events can inundate telecom facilities, affecting uptime and safety.
Waves	Moderate	While direct wave impact is limited, strong wave action during storms can affect structural integrity and access.
Currents	N/A	Currents have minimal direct impact on fixed nearshore telecom infrastructure, though they may influence adjacent waterborne systems.

Physical Exposure Ratings

Transport: Waterways

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Moderate	Prolonged heat increases evaporation, reduces water depth marginally, and affects operator comfort for small craft. Infrastructure (jetties, pontoons) remains largely unaffected.
Extreme Winds & Storms	High	Southwest and inter-monsoon winds generate choppy conditions, reducing navigability for small craft and causing service disruption. Wind-driven waves and currents also affect maneuvering safety.
Rainfall Flooding	High	Heavy rainfall increases river discharge and turbidity, reduces visibility, and creates floating debris. Waterway transport slows or stops during intense rainfall episodes.
Riverine Flooding	High	Westports' adjacent rivers can rise rapidly during monsoon and high-flow events, increasing flow velocities and overtopping risk. Strong river influence reduces safe navigation windows.
Coastal Flooding	High	Tide-driven water-level rise and storm surges elevate water depths in navigation channels, affecting docking/embarkation points and increasing the risk of wash-over on low-lying pontoons.
Extreme Total Water Level (ETWL)	High	ETWL significantly alters current strength and water levels, causing hazardous navigation conditions, reduced control of small vessels, and operational shutdowns during extreme events.
Waves	High	During monsoons, wind-driven waves propagate into estuarine and nearshore waterways. Even within partially sheltered areas, wave heights increase vessel roll/pitch and reduce transit safety.
Currents	Very High	Spring-tide and monsoon-enhanced currents greatly affect vessel maneuvering, increase collision/grounding risk, and limit navigation time windows. Small craft navigation becomes unsafe under strong tidal flows.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Warehouses: Covered

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Covered warehouses are vulnerable to heat buildup, especially in urban and industrial zones. Rising temperatures increase cooling demands, affect stored goods, and reduce worker productivity.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage roofing, walls, and loading infrastructure, especially in coastal areas.
Rainfall Flooding	Moderate	Heavy rainfall can cause localized flooding, especially in poorly drained warehouse zones, affecting access and inventory.
River Flooding	Moderate	Warehouses near rivers (e.g., Klang, Perak) may be impacted by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges pose risks to low-lying warehouse facilities near ports and coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate warehouse zones, affecting operations and stored goods.
Waves	Low	Direct wave impact is minimal unless the warehouse is located extremely close to the shoreline.
Currents	N/A	Currents do not directly affect onshore warehouse structures.

Physical Exposure Ratings

Warehouses: Covered Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Moderate	Large roofed structures trap heat, increasing indoor temperatures and affecting stored goods and workers. Heat can also degrade packaging and reduce ventilation performance.
Extreme Winds & Storms	High	Lightweight steel structures and wide roof spans are vulnerable to uplift, cladding damage, and wind-driven rain ingress. Nearshore winds intensify exposure to structural and operational disruption.
Rainfall Flooding	High	Warehouses rely on yard drainage; intense rainfall can cause water accumulation around loading bays and entrances. Floodwater can damage stored goods, forklifts, and electrical systems.
Riverine Flooding	Moderate	Nearshore sites influenced by river systems face backflow and elevated water levels that may reach warehouse perimeters. Potential for ingress at shutter doors and service ducts.
Coastal Flooding	High	Storm tides and surge can inundate the warehouse surroundings, compromising access, loading operations, and ground-level goods. Saltwater exposure poses corrosion risk to structures and equipment.
Extreme Total Water Level (ETWL)	High	ETWL events exceed yard/platform elevations, allowing seawater to reach loading docks and internal floors. High likelihood of operational shutdown and goods damage during extreme events.
Waves	Low	Warehouses are typically set back from the shoreline and buffered by port infrastructure. Direct wave impact is minimal except for occasional splash in extreme scenarios.
Currents	N/A	No direct interaction between tidal currents and the warehouse structure. Impacts limited to marine areas only.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Warehouses: Dock Depot

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Open-yard dock depots store containers, equipment, and cargo directly exposed to solar heating. Heat accelerates material degradation, affects equipment operators, and increases risk to heat-sensitive goods.
Extreme Winds & Storms	High	Near-coastal depots face strong monsoon winds. High stacks and temporary structures are vulnerable to wind overturning, while storm gusts can displace empty containers and disrupt operations.
Rainfall Flooding	High	Heavy rainfall frequently causes surface flooding and ponding in large open yards. Poor drainage slows water removal, affecting container handling, ground stability, and equipment movement.
Riverine Flooding	Moderate	Dock depots located near tidal river influence zones may experience elevated water levels or backflow into yard drains. Moderate risk due to large ground-contact areas and dependence on drainage outlets.
Coastal Flooding	High	Storm tides and surge can reach dock depot surfaces, particularly low-lying yard zones near wharves. Saltwater intrusion can affect cargo, corrode equipment, and restrict depot operations.
Extreme Total Water Level (ETWL)	High	ETWL (tide + surge + setup) increases yard inundation risk, especially during spring tides. Seawater entry disrupts lifting operations, affects container foundations, and forces temporary shutdowns.
Waves	Low	Depots are inland from the quay line and shielded by port structures; direct wave action does not reach the yard. Only minor spray may occur in extreme monsoon events.
Currents	N/A	Currents do not affect inland dock depot yards. Operational relevance applies only to berths and marine transfer points, not land-based depots.

Physical Exposure Ratings

Warehouses: Fuel

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Fuel storage is highly sensitive to heat due to risks of evaporation, pressure buildup, and fire hazards. Rising temperatures and urban heat intensify these risks.
Extreme Winds & Storms	High	Strong winds and storms can damage fuel tanks, pipelines, and safety systems, increasing the risk of spills or fires.
Rainfall Flooding	High	Heavy rainfall can flood fuel storage areas, compromise containment systems, and contaminate nearby water sources.
River Flooding	High	Warehouses near rivers (e.g., Klang, Perak) are vulnerable to overflow events that can damage fuel infrastructure and lead to environmental hazards.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to coastal fuel storage facilities, especially in low-lying industrial zones like Port Klang.
Extreme Total Water Level	High	Combined tidal and surge events can inundate fuel warehouses, increasing risks of leakage, contamination, and fire.
Waves	Low	Direct wave impact is limited but can affect infrastructure near the shoreline during storm events.
Currents	N/A	Currents have minimal direct impact on fixed fuel storage infrastructure unless affecting adjacent marine transport systems.

Exposure Rating Key					
Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Warehouses: Fuel Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Fuel products and associated storage systems are heat-sensitive. High temperatures increase vapour pressure, heighten fire/explosion risk, accelerate material degradation, and stress ventilation/containment systems.
Extreme Winds & Storms	High	Strong monsoon winds expose fuel warehouses to uplift forces, cladding damage, and potential roof failures. Wind-driven rain can infiltrate indoor areas and compromise electrical and fire-safety systems.
Rainfall Flooding	High	Heavy rainfall can inundate loading bays, bunded areas, and transfer points. Water intrusion increases contamination risk, disrupts operations, and may compromise fire-suppression and electrical controls.
Riverine Flooding	High	If located near a river-influenced shoreline, rising river levels can reach the warehouse perimeter and bunded zones. Floodwater can reduce containment effectiveness but full inundation is less frequent.
Coastal Flooding	High	Fuel warehouses are highly sensitive to seawater intrusion. Storm tides and surge can overtop bunds, flood fuel handling areas, and create severe fire and contamination hazards.
Extreme Total Water Level (ETWL)	High	ETWL (tide + surge + setup) raises water levels beyond platform elevation, increasing the likelihood of seawater entering bunds, electrical rooms, and fuel transfer zones, leading to shutdowns.
Waves	Low	Facilities are generally set back from the waterfront and shielded by port structures; direct wave impact on the warehouse is minimal except at exposed transfer lines near jetties.
Currents	N/A	Currents do not directly affect land-based fuel warehouses. Operational relevance is limited to jetty-side marine transfer systems, not the warehouse itself.

Physical Exposure Ratings

Warehouses: Uncovered

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Uncovered warehouses are highly exposed to direct solar radiation and ambient heat. Without insulation or cooling systems, they pose serious risks to goods, equipment, and worker health.
Extreme Winds & Storms	High	Structural elements like fencing, temporary roofing, and stored materials are vulnerable to damage or displacement during monsoonal winds and tropical storms.
Rainfall Flooding	High	Lack of roofing and drainage systems makes uncovered warehouses highly susceptible to water damage and operational disruption during heavy rainfall.
River Flooding	Moderate	Warehouses near rivers (e.g., Klang, Perak) may be affected by overflow events, sedimentation, and access issues.
Coastal Flooding	High	Sea level rise and storm surges pose significant risks to uncovered storage areas near ports and coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate uncovered facilities, damaging goods and infrastructure.
Waves	Low	Direct wave impact is minimal unless the warehouse is located extremely close to the shoreline.
Currents	N/A	Currents do not directly affect onshore uncovered warehouse structures.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Warehouses: Uncovered Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Very High	Uncovered nearshore warehouses are highly exposed to direct solar radiation and ambient heat. Rising temperatures and urban heat island effects significantly increase risks to stored goods, equipment, and worker health.
Extreme Winds & Storms	High	Monsoonal winds and tropical storms can damage temporary structures, displace stored materials, and disrupt operations.
Rainfall Flooding	High	Lack of roofing and drainage systems makes these warehouses highly vulnerable to water damage during heavy rainfall.
River Flooding	Moderate	Warehouses near river mouths (e.g., Klang, Perak) may be affected by overflow events and sedimentation.
Coastal Flooding	High	Sea level rise and storm surges pose serious risks to low-lying uncovered storage areas near ports and coastal zones.
Extreme Total Water Level	High	Combined tidal and surge events can inundate uncovered facilities, damaging goods and infrastructure.
Waves	Moderate	Strong wave action during storms can affect access and structural integrity of nearshore facilities.
Currents	N/A	Currents have minimal direct impact unless affecting adjacent marine transport systems.

Physical Exposure Ratings

Water Supply

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	High	Rising temperatures increase evaporation rates, reduce reservoir levels, and stress treatment systems. Heat also exacerbates water quality issues due to reduced dilution capacity.
Extreme Winds & Storms	High	Storms can damage water treatment plants, disrupt supply lines, and contaminate sources through overland runoff.
Rainfall Flooding	High	Intense rainfall events cause downstream flooding, damaging dams and treatment facilities, and leading to service interruptions.
River Flooding	High	Riverine floods can overwhelm intake systems, contaminate raw water sources, and damage infrastructure.
Coastal Flooding	Moderate	Coastal water supply systems are vulnerable to saltwater intrusion and infrastructure damage during storm surges.
Extreme Total Water Level	High	Combined effects of tides, surges, and rainfall can inundate water infrastructure, especially in low-lying areas.
Waves	Low	Direct wave impact is minimal unless infrastructure is located very close to the shoreline.
Currents	N/A	Currents have limited direct impact on water supply systems, though they may affect intake structures in coastal zones.

Exposure Rating Key

Very High	High	Moderate	Low	Minimal	N/A
10	8	6	4	2	0

Wharf: Nearshore

Climatic Indicator	Exposure Rating	Rationale for Rating
Extreme Heat	Low	Open waterfront structure with natural ventilation; concrete deck and steel fixtures have low thermal sensitivity. Minor impacts limited to expansion joints, elastomers, and worker comfort.
Extreme Winds & Storms	Moderate	Monsoon winds influence operations (mooring, cargo handling), but the wharf itself is a robust, low-profile structure designed for lateral loads; primary risk is operational downtime rather than structural damage.
Rainfall Flooding	Low	Wharf deck drains directly to the sea via scuppers/edge discharge; minimal ponding and limited dependence on land drainage networks.
Riverine Flooding	Moderate	Nearshore wharves are primarily marine-exposed; tidal action limits persistent river backflow impacts on the deck. Structural elevations typically exceed river flood stages.
Coastal Flooding	High	Low deck freeboard relative to high tides and storm surges leads to overtopping/splash and temporary access/operational disruption (e.g., wet deck, electrical isolation).
Extreme Total Water Level (ETWL)	High	Combined tide + surge + wave setup reduces freeboard, increases fender submergence and mooring loads, and raises frequency of deck wetting and operational shutdowns.
Waves	High	Usually within sheltered basins protected by breakwaters and harbour geometry; direct wave energy at the quay face is limited except during peak monsoon episodes.
Currents	Moderate	Spring-tide currents affect berth approach, tug assistance, and mooring line tensions; operationally relevant but generally within design allowances.

Voon Jye Yng
Partner & Project-in Charge,

ERM Malaysia

Jyeyng.Voon@erm.com

Steve Duckworth
Country Managing Partner,

ERM Malaysia & Brunei

Steve.Duckworth@erm.com

Yulia Dobrolyubova
Partner, Lead for Corporate Sustainability & Climate Change,

Asia ERM Thailand
Yulia.Dobrolyubova@erm.com

Dr. Venkat Kolluru
Technical Consulting Director,
Technical Lead for Climate Change and Water Resources,
ERM North America
Venkat.Kolluru@erm.com

Edmund Ang
Project Manager,

ERM Malaysia
Edmund.Ang@erm.com

Dr. Senthil Gurusamy
Managing Consultant
Climate Physical Risk and Water Resources,
ERM Malaysia
Senthil.Gurusamy@erm.com

Dr. Hoffman Cheung
Managing Technical Consultant (Climate Change),
ERM Hongkong
Hoffman.Cheung@erm.com