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Risk and Resilience in Port Design Option Assessments

PIANC APAC 2024

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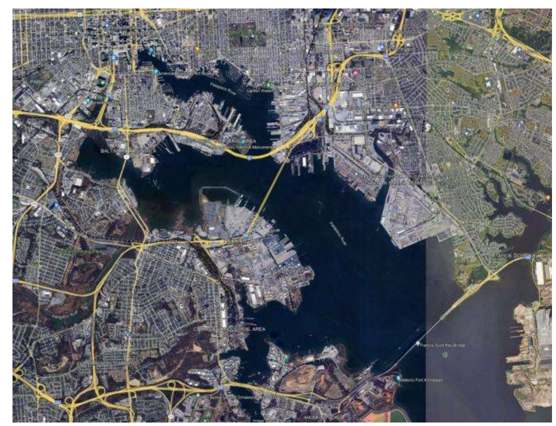
worley consulting

Why do ports need to be resilient?

What are the risks and consequences?

The Francis Scott Key Bridge sits on top of a container ship in Baltimore (Getty Images, March 2024)

- Baltimore's Francis Scott Key Bridge collapsed 26th March, 2024.
- Six people killed.
- Port of Baltimore closed for 4 weeks.
- Fort McHenry channel closed for 3 months.
- Bridge closed for several years.



Baltimore, USA (Google Earth, 29/02/2024)

Why do ports need to be resilient?

What are potential mitigations?

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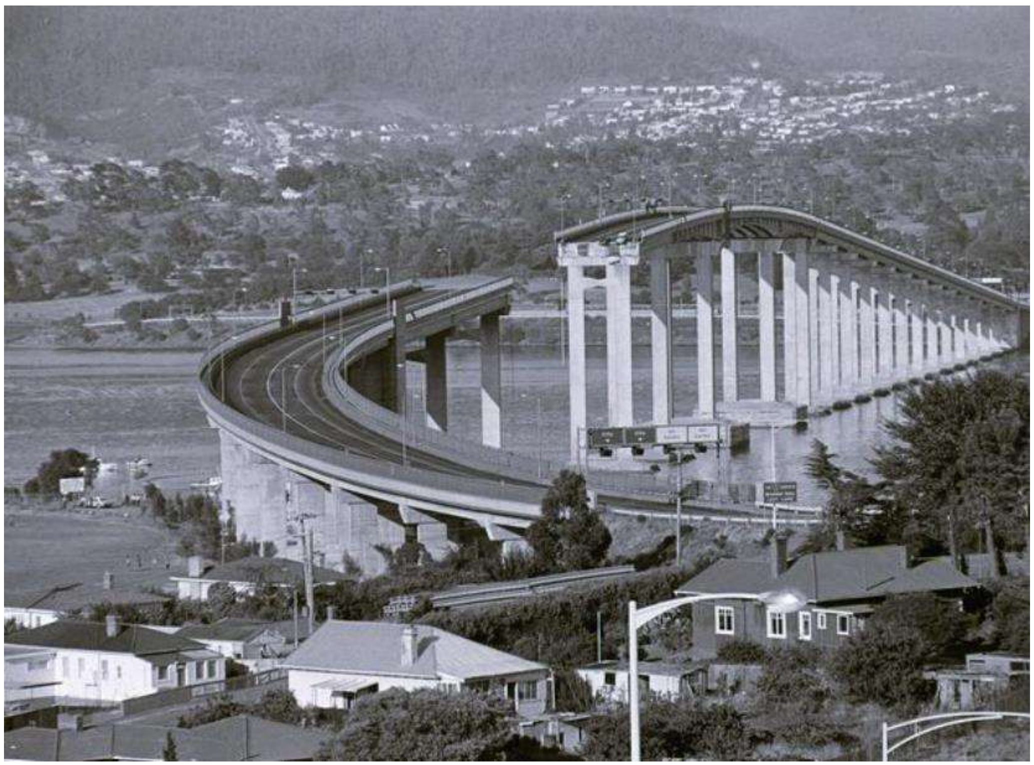
- Hobart's Tasman Bridge collapsed 5th January, 1975.
- 12 people killed (7 crew, 5 car occupants).
- Risks now understood and mitigated:
  - Metocean conditions monitored
  - Vessel size limits imposed
  - Pilotage and towage available for larger vessels.



Tasman Bridge disaster (Hobart Mercury, 1975)

Tasman Bridge, EK Holden and HQ Holden Monaro GTS (Hobart Mercury, 1975)

Options selection

- Typical port infrastructure design will include a **Basis of Design** identifying design criteria as per
  - codes,
  - industry practice, and
  - specific client requirements.

- Infrastructure options selection usually considers various assessment criteria (often focussed on cost) through a **multi-criteria analysis.**

- Important to ensure a rigorous **assessment of risks** is undertaken to ensure
  - the required level of resilience can be achieved, and
  - the client can afford the level or resilience specified.

TABLE 6.1

DESIGN LIFE OF STRUCTURES

Facility category	Type of facility	Design life (years)
1	Temporary works	5 or less
2	Small craft facility	25
3	Normal commercial structure	50
4	Special structure/residential	100

TABLE 5.4

ANNUAL PROBABILITY OF EXCEEDANCE OF DESIGN WAVE EVENTS

Function category	Category description	Design working life (years)			
		5 or less (temporary works)	25 (small craft facilities)	50 (normal maritime structures)	100 or more (special structures/ residential developments)
1	Structures presenting a low degree of hazard to life or property	1/20	1/50	1/200	1/500
2	Normal structures	1/50	1/200	1/500	1/1000
3	High property value or high risk to people	1/100	1/500	1/1000	1/2000

AS4997 – 2005, Guidelines for the design of maritime structures

Understanding the risks

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- To effectively manage the risks, the risks and associated consequences and mitigations need to be understood.

- For each risk, owners, operators and designers need to consider:
  - Probability of occurrence
  - Social and economic impacts of occurence
  - Costs associated with mitigations.

$$T = \frac{-N}{\ln\left(1 - \frac{R}{100}\right)}$$

Where: *T* (Threat) = Average Recurrence Interval (years)
N (Exposure) = Planning Horizon or Design Lifetime, (years)
R (Acceptability) = Risk of Encounter within that Lifetime (%).

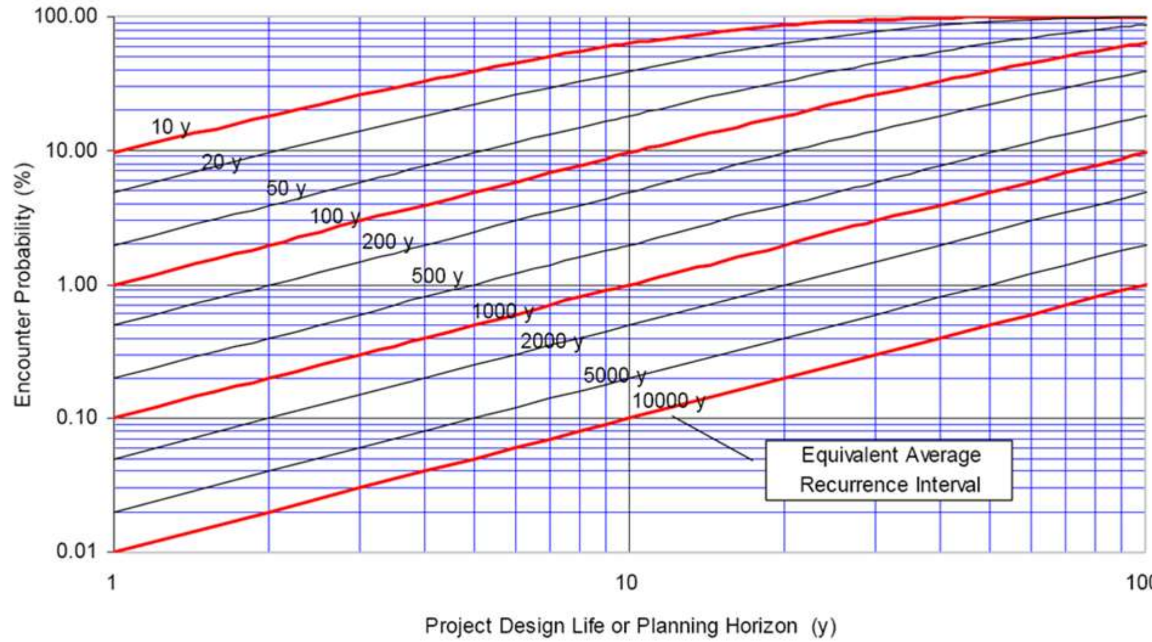

Figure 1. Design Average Recurrence Interval *T* in Years (Engineers Australia, 2004)

Documenting the risks

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No.	Design Element	Acceptable Risk Level	Life (Yr)	Design Parameter	ARI (Yr)	Comment
1	Harbour calmness for shipping ops	2%	1	H_s	50	Allows for 2% port downtime *per annum.*
2	Structural stability of the wharves etc.	1%	100	H_{10} SWL	10,000 10,000	Cannot afford a failure. Include high greenhouse emissions scenario
3	Breakwater stability	1%	100	H_1	10,000	Allow no damage Immediately adjacent to infrastructure – no maintenance structure.
4	Breakwater overtopping	2%	1	H1 SWL	50 50	Allows some overtopping during the severe event when not operational.
5	Protected reclamation	1%	100	SWL	10,000	Inundation of hardstand areas unacceptable.
6	Navigation channel	10%	10	Hs	100	Maintenance dredging programme.

Typical risks in maritime design

Storm events affecting coastal structures

RISKS: - Storm events with increasing intensity (sea level rise).

CONSEQUENCES: - Beach / dune erosion
- Damage to infrastructure (seawalls, roads, houses)

MITIGATIONS: - Identify coastal hazard zones
- Prepare coastal management plans (plan for future storm events)
- Piled structures to prevent undermining
- Protection structures: Seawalls, offshore reefs

Collaroy-Narrabeen Beach, Sydney (photo courtesy Bill Watkins, 01/08/2024)

Wattle Range Council, Lake George and Rivoli Bay Coastal Studies (Worley, 2015)

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Typical risks in maritime design

Sea level rise causing inundation

RISKS: - Storm events with storm surge
- Sea level rise.

CONSEQUENCES: - Public safety
- Loss of operations
- Damage to infrastructure (deck uplift).

MITIGATIONS: - Prepare coastal management plans
- Access management plans (for breakwaters, jetties)
- Elevate deck and hardstand levels
- Storm surge reduction utilising mangroves.

Wattle Range Council, Lake George & Rivoli Bay Coastal Studies (Worley, 2015).

Wattle Range Council, Lake George & Rivoli Bay Coastal Studies (Worley, 2015).

Typical risks in maritime design

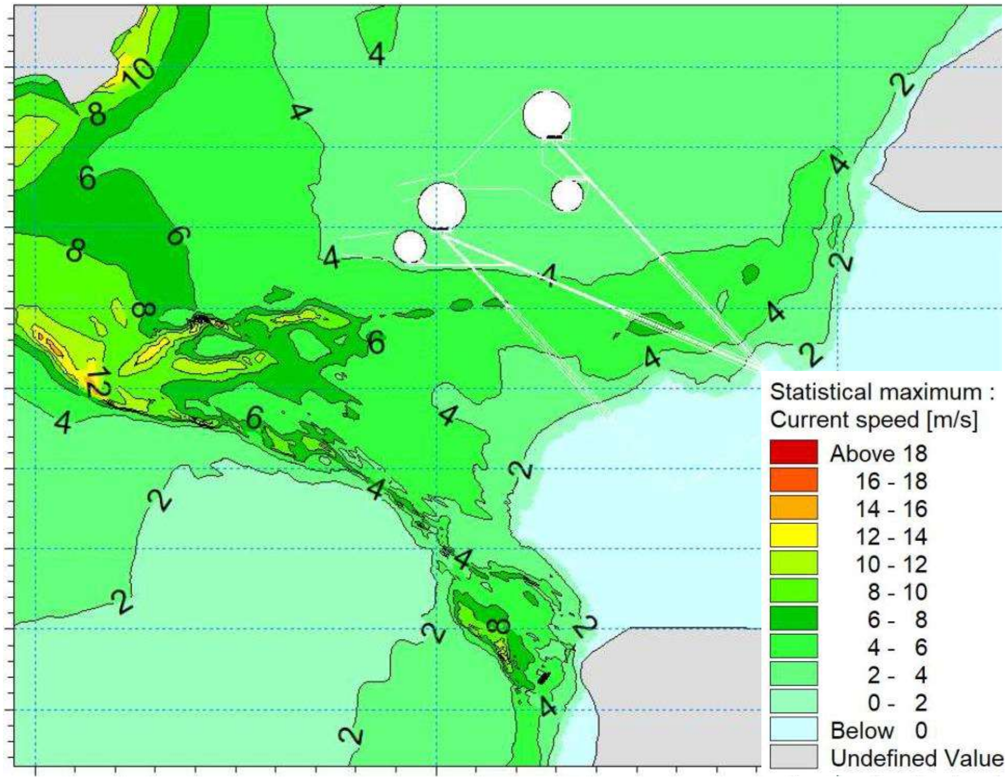
Tsunami events impacting port structures

RISKS: - Inundation
- Strong currents (particularly in estuaries, harbours and bays)

CONSEQUENCES: - Inundation causing damage to plant
- Strong currents / wave run-up causing damage to infrastructure
- Break vessel mooring lines, vessels impacting infrastructure

MITIGATIONS: - Increase deck levels
- Design infrastructure for loads / accept damage in low-risk event
- Tsunami early warning system
- Introduce operational mitigations in the event of loss of wharf
- Choose another port site

Ship after the 2004 Asia Tsunami (photo courtesy of Regine A. Webster, CDP)



Maximum current speed under tsunami wave due to M 8.3 earthquake (Worley, 2022)

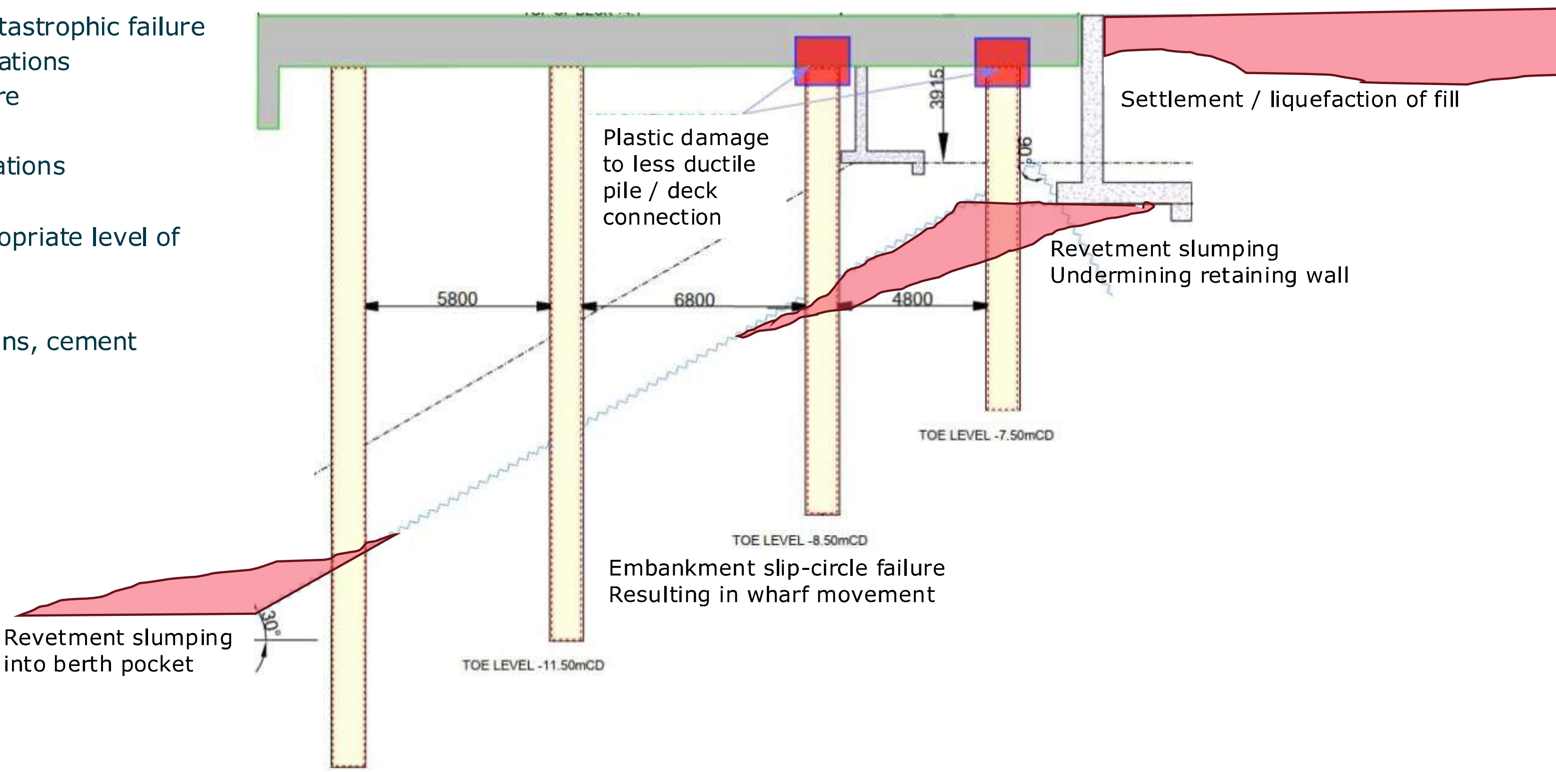
Typical risks in maritime design

Seismic events causing structural damage

RISKS: - Structural damage / catastrophic failure
- Liquifaction of sandy soil foundations
- Embankment / revetment failure

CONSEQUENCES: - Loss of operations

MITIGATIONS: - Design for appropriate level of damage (ductility of structure)
- Change type of structure
- Soil improvement (stone columns, cement stabilisation)



Risk based wharf option selection (Worley, 2021)

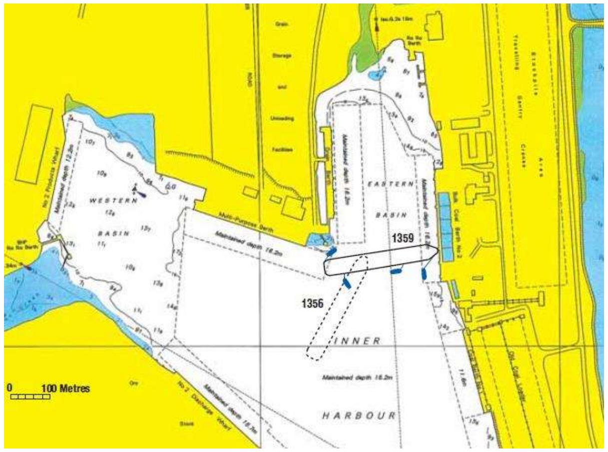
Typical risks in maritime design

Vessel navigation error

RISKS: - Ship navigation / mechanical error

CONSEQUENCES: - Damage to infrastructure
- Closure of facilities / ports

MITIGATIONS: - Operational procedures
- Navigation simulation



Ship position upon contact with wharf (Australian Transport Safety Bureau, Marine Safety Investigation Report 178, 2002)

Damage to wharf (Australian Transport Safety Bureau, Marine Safety Investigation Report 178, 2002)

Conclusion

- Early involvement of owners and operators
- Risk identification from site selection phase onwards
- Identify and document all risks and mitigations

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TasPorts

Division: Marine Services

Tasmanian Ports Corporation

Ports Procedures Manual

June 2019

Tasman Bridge disaster, Murray Ling moves his car the next day (Hobart Mercury, 1975) worley consulting

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