MID WEST PORTS

TECHNICAL GUIDELINE

MWPA402 – ROCK STRUCTURES GUIDELINE

UNCONTROLLED WHEN PRINTED

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APPENDICES

1 PREFACE

This document has been compiled for the Mid West Ports Authority (MWPA) to provide developers, designers, contractors and inspectors guidance on MWPA's rock structures. It does not replace bespoke project basis of design, design criteria, or specifications, but it is intended to provide a benchmark for the minimum technical requirements for new construction, refurbishment and repair of rock structures and other forms of coastal protection found within Geraldton Port.

The chapters of this Guideline include guidance and statutory requirements for rock structures in general, and Geraldton Port specific design and construction requirements for the existing coastal protection structures, site conditions and operations.

This Guideline will be used as a basis for identifying any shortcomings in the technical content and ultimately accepting or rejecting proposed, underway or complete projects.

2 SCOPE

2.1. GENERAL

This Guideline defines the minimum requirements for the design, construction and maintenance of the following types of structure and forms of slope protection:

- Breakwaters
- Rock walls and revetments
- Concrete armour units
- Slope protection mattresses

Where documents are referred to in this Guideline, the reference should be taken to mean the most recent revision, unless noted otherwise.

2.2. PRECEDENCE

As a general guide, where particular aspects are not covered in the MWPA Technical Guidelines or where conflict between documents exists, the following precedence for standards applies:

1. Statutory Regulations;
2. Design Codes and Standards;
3. Project Specific Specification;
4. MWPA Technical Guidelines; and
5. Other References (e.g. Recognised Industry Best Practice).

Regardless of the general order of precedence, if there is a conflict between documents the clause presenting the more conservative and pragmatic guidance will govern. If in doubt, or in all cases where non-compliance is anticipated, clarification should be sought from the MWPA.

3 GLOSSARY

The following definitions have been provided to ensure a good understanding of terms across a wide range of readers. For full technical definitions refer to Reference No.'s 8 and 9, Section 4.6.

Table 1: Glossary of Terms

Term	Definition
Armour	A relatively large quarry stone or concrete block that is selected to fit specified design requirements of mass and shape. It is placed in a cover layer.
Bathymetry	Underwater topography of seabed.
Berm	A horizontal step in the sloping profile of a rock wall or breakwater.
Bund	Refer embankment.
Breakwater	A structure armoured on two faces built to provide protection from wave action.
Core	An inner, often much less permeable, portion of a rock structure.
Crest	Highest part of a breakwater or rock wall.
Damage	Proportion of armour layer removed or displaced by wave action.
Datum	Any permanent line, plane or surface used as a reference datum to which elevations are referred.
Deep water	Water so deep that the seabed has minimal impact on surface waves. Generally, water deeper than half the surface wavelength is considered deep water.
Design storm	A hypothetical extreme storm with waves that a coastal structure will often be designed to withstand. The severity of the storm is chosen in view of the acceptable level of risk of damage or failure. A design storm consists of a design wave condition, a design water level and a duration.
Design Life	The length of service the structure is designed to provide in a functional state.
Effective mean mass	The average mass of a sample (excluding the small fragments inherent in rock production). Refer to Reference No.6 (Section 4.6) for relationship to M_{50}.
Embankment	A mound of earth or rock built to prevent the flooding of an area or to support a roadway.

Term	Definition
Extreme Value Analysis (EVA)	Statistics dealing with the extreme deviations from the median of probability distributions. It seeks to assess, from a given ordered sample of a given random variable, the probability of events that are more extreme than any previously observed.
Fetch (length)	Relative to a particular point (on the sea), the area (or distance) of sea over which the wind can blow to generate waves at a point.
Filter	Intermediate layer preventing the fine materials of an underlayer from being washed through the voids in an upper layer.
Geotextile	A synthetic fabric, woven or non-woven, used as a filter or separation layer.
Grading	Distribution defined by nominal and extreme limits, with regard to size or mass of individual stones.
Head	Seaward end of a breakwater.
Highest Astronomical Tide (HAT)	The highest level of water which can be predicted to occur under any combination of astronomical conditions. This level may not be reached every year.
Incident wave	Wave moving landward.
Lowest Astronomical Tide (LAT)	The lowest level of water which can be predicted to occur under any combination of astronomical conditions. This level may not be reached every year.
Mean Sea Level (MSL)	The average height of the sea for all stages of the tide over a 19 year period, usually determined from hourly height readings.
Mean wave period	The mean period of the wave defined by zero crossing analysis of a wave record.
Numerical model	Mathematical equations that attempt to describe reality and permit prediction of the behaviour of flows, sediment and structures.
Overtopping	Passing of water over the top of a structure as a result of wave run-up or surge action.
Peak period	The wave period determined by the inverse of the frequency at which the wave energy spectrum reaches a maximum.
Permeability	The property of bulk material (sand, crushed rock, soft rock in situ) that permits movement of water through its pores.
Physical model	Refer scale model.
Placement density	Mass per unit volume of armour units or number of units per unit area placed during construction.
Porosity	Property of a material or armour layer expressed as a percentage of the total volume occupied by air and water rather than by solid particles.

Term	Definition
Porous	For revetments and armour layers, the permitting of rapid through movement of water, such as during wave action. Many geotextiles can be non-porous under the action of waves but are porous in soil mechanics terms.
Quarry run	Material without fines control and including all granular material found in the quarry blastpile that can be picked up in a typical loading shovel, i.e. only blocks too large for easy loading are left behind. Sometimes referred to as Run of Mill.
Reflected wave	The part of an incident wave that is returned seaward when a wave impinges on a beach, rock wall or other reflecting surface.
Refraction	The process by which the direction of a wave moving in shallow water at an angle to the depth contours is changed so that the wave crests tend to become more aligned with those contours.
Return period	Inverse of probability that a given event will occur in any one year. It can also be considered as the statistical average period of time between occurrences of the event.
Revetment	Refer Rock wall.
Rip-rap	Wide graded quarry stone normally bulk-placed as a protective layer to prevent erosion of the sea bed or other slopes by current and/or wave action.
Rock wall	The term rock wall is used within this Guideline to describe a formal or informal sloped rock or rip-rap revetment or seawall protecting an embankment or shoreline against erosion.
Run of mill	Refer quarry run.
Run-up	The upper level reached by a wave on a beach or coastal structure relative to still water level, measured vertically.
Scale or physical model	Simulation of a structure and/or its (hydraulic) environment, usually in much smaller dimensions, to enable the consequences of future changes to be predicted. The model can be built with a fixed bed or movable bed.
Scour	Erosion resulting from shear forces associated with flowing water and wave actions.
Scour protection	Works to prevent or mitigate scour.
Screed	To create a level surface by scraping to relocate high points into voids.
Sea state	Description of the sea surface with regard to wave action.
Seawall	A structure of rock, concrete or other construction protecting a shoreline against erosion. The term Rock wall is used in this Guideline to describe rock seawall structures more specifically.

Term	Definition
Significant wave height	Average height of the highest one third of the waves in a given sea state.
Significant wave period	Average of the periods of the highest one third of the waves in a given sea state.
Slope	The inclined face of a rock wall or breakwater.
Slope protection	Material or structure constructed on a slope to provide protection from geotechnical instability and coastal processes including wave attack.
Still water level	The water level that would exist in the absence of waves.
Storm surge	A rise in water level in the open coast caused by the action of wind stress as well as atmospheric pressure on the sea surface. Includes surge due to cyclones.
Swell (waves)	Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch.
Toe	The lowest part of a rock wall or breakwater. Often it provides support for the slope protection.
Underlayer	Granular layer beneath an armour layer that serves either as a filter, or provide protection to a geotextile against damage from armour units or evens out the formation level.

For the purposes of this Guideline the following particular abbreviations apply:

Table 2: Abbreviations

Abbreviation	Meaning
CD	Port of Geraldton Chart Datum
AHD	Australian Height Datum
AS	Australian Standard
AS/NZS	Australian/New Zealand Standards
MWPA	Mid West Ports Authority
M_{50}	Median rock mass
D_{50}	Median rock diameter
NATA	National Association of Testing Authorities

4 RELEVANT DOCUMENTATION

4.1. GUIDELINE SERIES

This guideline should be read in conjunction with other parts of the MWPA Technical Guideline series, where relevant, as listed below:

- MWPA 000 Series – Port Development Guidelines;
- MWPA 100 Series – General Guidelines;
- MWPA 200 Series – Drafting and Surveying Guidelines;
- MWPA 300 Series – Mechanical Guidelines;
- MWPA 400 Series – Guidelines for Maritime Structures;
- MWPA 500 Series – Civil Engineering Guidelines;
- MWPA 600 Series – Buildings and Structures Guidelines;
- MWPA 700 Series – Electrical and Instrumentation Guidelines;
- MWPA 800 Series – Guidelines for Rail; and
- MWPA 900 Series – Additional Guidelines.

Where the referenced MWPA Guidelines do not yet exist, the relevant Australian standards and industry best practice shall apply.

4.2. MID WEST PORTS AUTHORITY POLICIES AND PROCEDURES

All parties involved in a rock structures project should be aware of and comply with MWPA policies and procedures. A full list of MWPA's policies and procedures can be found in **MWPA100**, and obtained either from the MWPA website *www.midwestports.com.au* or requested from the MWPA Project Coordinator or Owner's Engineer.

4.3. LOCAL, STATE AND FEDERAL STATUTORY REQUIREMENTS

In addition to the requirements of this part of the MWPA Technical Guidelines, all projects should meet the requirements of Local, State and Federal statutory, health, safety and environmental requirements and regulations and include, but not be limited to, the following:

- Western Australian Environmental Protection
- Western Australian Occupational Safety and Health Act (1984) and Regulations (1996)
- Western Australian Marine (Certificates of Competency and Safety Manning) Regulations (1983)
- Western Australian Mines Safety and Inspection Act (1994)
- Western Australian Mines Safety and Inspection Regulations (1995)
- Dangerous Goods Safety Act (2004)
- Port Authorities Act (1999)
- Maritime Transport and Offshore Facilities Security Act (MTOFSA) (2003)
- Environmental Protection Act and Regulations (1986)

4.4. AUSTRALIAN STANDARDS AND DESIGN CODES

The latest version of the following standards and documents should be adopted for all works covered by this Guideline.

Table 3: Australian/New Zealand Standards and Design Codes

No.	Title
AS 1012	Methods of testing concrete
AS/NZS 1050	Methods for analysis of iron and steel
AS 1074	Steel tubes and tubulars for ordinary service
AS 1085	Railway track materials
AS/NZS 1111	ISO metric hexagon bolts and screws
AS/NZS 1112	ISO metric hexagon nuts
AS/NZS 1163	Cold-formed structural steel hollow sections
AS/NZS 1170.0	Structural design actions – General principles
AS/NZS 1170.1	Structural design actions – Permanent, imposed and other actions
AS/NZS 1170.2	Structural design actions – Wind actions
AS 1170.4	Structural design actions – Earthquake actions in Australia
AS 1199	Sampling procedures for inspection by attributes
AS 1214	Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series)
AS 1379	Specification and supply of concrete
AS 1478	Chemical admixtures for concrete, mortar and grout
AS/NZS 1554	Structural steel welding
AS/NZS 1594	Hot-rolled steel flat products
AS 1604.1	Specification for preservative treatment – Sawn and round timber
AS 1657	Fixed platforms, walkways, stairways and ladders – Design, construction and installation
AS/NZS 1664	Aluminium structures

4.5. INTERNATIONAL STANDARDS AND DESIGN CODES

In the absence of suitable Australian Standards, the latest version of the following international standards and design codes may be adopted for works covered by this Guideline:

Table 4: International Standards and Design Codes

No.	Title
DNV Classification Note 30.5	Environmental Conditions and Environmental Loads
BS6349-1	Maritime structures. Code of practice for general criteria
BS6349-7	Maritime structures. Guide to the design and construction of breakwaters

4.6. ADDITIONAL REFERENCES

The following documents have been used in the production of this guideline and provide additional reference information:

Table 5: Additional References

No.	Reference
1	*www.transport.wa.gov.au*
2	*www.midwestports.com.au*
3	*www.planning.wa.gov.au*
4	General Recommendations for the Acceptance and Laying of Geotextiles, The French Committee of Geotextiles and Geomembranes
5	Fore and Aft Mooring Study, report prepared for Maritime Services Board, Patterson Britton and Partners [PBP] (1997)
6	Guidelines for the Design of armoured slopes under open piles quay walls (PIANC, 1997)
7	Geraldton Port Enhancement – Wave and Sediments Studies – Vol 3 Design Wave Conditions For Foreshore Structures, report prepared for MWPA, Feb 2001 (Coastal Engineering Solutions [CES], 2001)
8	Coastal Engineering Manual (USACE, 2007)
9	The Rock Manual C683 (CIRIA/CUR, 2007)
10	Eurotop Manual (EA, et al, 2007)
11	Sea Level Change in Western Australia – Application to Coastal Planning (Department of Transport, 2010)
12	Beresford Foreshore Coastal Protection and Enhancement – Master Plan Report, Prepared for City of Greater Geraldton, Cardno (2012)
13	Australian Hydrographic Service Australian National Tide Tables 2013 (AHS, 2012)
14	Report for Northern Reclaim Development, Revetment Detailed Design, prepared for MWPA, (GHD, 2012)
15	Preliminary Technical Report, PGE-35-ASMT-001 Asset Condition Assessment, Mid West Ports Authority (SMEC, 2013)

4.7. EXISTING DATA

Appendix A contains a list of bathymetric, wave and general data held by MWPA which may be of use in the application of this Guideline.

5 GENERAL AND MWPA SPECIFIC REQUIREMENTS

Developers, designers, contractors and inspectors should familiarise themselves with relevant MWPA marine operations, permits, access and HSEQ requirements. General guidance on these can be found in **MWPA100**, the MWPA Contractor Handbook and on the MWPA website *www.midwestports.com.au*

5.1. LEVELS AND SURVEYING

All surveying should be undertaken using horizontal survey datum Geraldton Coastal Grid 95 (GCG-95) unless otherwise noted on construction drawings. Vertical levels for all offshore components for rock structures should be relative to Chart Datum (CD).

The Contractor should ensure that all survey controls that are installed remain visible and undisturbed and is responsible for establishing and maintaining coordinate reference points and level control on site. MWPA or its representative should be notified in the event of any disturbance of survey controls.

There are three key methods of surveying rock structures that are very different to surveying normal structures:

1. Pre-determined grid;
2. Top of rock survey; and
3. Rock void survey, which includes the use of a hemispherical base to the staff.

Each technique applies to cross sections at prescribed intervals and requires a different formula to be applied to determining the effective slope level of the rock structure. For further information regarding best practice for surveying rock structures refer to **Reference No. 8, Section 4.6**.

For further information on levels refer to **MWPA100 Section 11.5.1**. Further information on surveying is provided in **MWPA201**.

5.2. HEALTH AND SAFETY

For general safety requirements and documentation to be submitted prior to commencement of any work, refer to **MWPA100 Section 6**.

5.2.1. SAFETY IN DESIGN

A safety in design risk review, considering all stages of the assets life, should be undertaken for all rock structure projects.

The types of situations or hazards which may occur on rock structure projects include, but are not limited to, the following:

- Manual handling of materials;
- Flying debris;
- Hazardous substances;
- Work afloat;
- Inter vessel transfers;
- Working over water;
- Unstable surfaces and voids;

- Cranage of heavy items over or into water;
- Constrained work areas with large plant.

For further information on Safety in Design, refer to **MWPA100 Section 11.3**.

5.2.2. SAFETY DURING CONSTRUCTION

Remedial or construction works to rock structures require management of numerous safety risks. Consideration should be given to the following to eliminate or mitigate hazards:

- Assess the risk of undermining and sink holes occurring behind rock walls. This has been identified as a risk within the Geraldton Port reclamation areas due to loss of fines through rock walls. At locations where concrete has been poured over rocks (for example on the Fishing Boat Harbour Northern Reclaim), there may be bridging where voids have formed beneath the concrete.
- Assess the load carrying capacity along the crest of breakwaters or rock walls to accommodate plant loads. The use of tracked plant could be considered to distribute loads.
- Assess the capacity of cranes to lift armour through consultation with crane distributors and operators.
- Assess overtopping of breakwaters and rock walls by considering forecasting and monitoring requirements to ensure overtopping events do not pose a risk to plant or construction personnel.
- Assess the wind loading on construction plant by considering forecasting and monitoring requirements to ensure wind loads do not pose a risk to plant or construction workers.
- Determine the clearance requirements for construction plant to ensure safe working conditions for construction personnel.
- Establish safe lifting methods using fit for purpose equipment.

5.2.3. PERSONAL PROTECTIVE EQUIPMENT

MWPA's mandatory Personal Protective Equipment (PPE) for work performed within the Port is detailed in **MWPA100 Section 6.5.1** and includes high visibility long sleeved shirts with reflective strips, long pants with reflective strips, safety footwear, safety glasses, gloves and helmets.

As detailed in **MWPA100 Section 6.6.2**, personal flotation devices (PFD's) are to be worn when working near or above water.

5.2.4. NAVIGATION REQUIREMENTS

All parties should observe the regulations and requirements of MWPA and other government agencies which apply to navigation and obtain all necessary permits.

Contractors should make all necessary arrangements with MWPA for temporary removal and replacement of any navigation aids (lights, buoys, markers etc.) that may obstruct the works. In addition, any lighting required as part of the works should be in accordance with MWPA requirements.

Floating plant and equipment used by Contractors should display the correct navigation signals and should be clearly marked and lit at night to the satisfaction of MWPA. Floating plant and equipment should be positioned in such a manner that it minimises interference with other waterway users.

Contractors must seek the approval of the Duty Pilot before entering the harbour, before moving any floating plant and equipment within the harbour and before exiting the harbour. Contractors must adhere to any instructions issued by the Duty Pilot, which may include exiting the harbour during ship movements. Contractors should allow for attending daily site operations meetings with MWPA personnel.

5.2.5. PLANT AND EQUIPMENT

Contractors are responsible for ensuring that all plant and equipment is suitable for the intended purpose. Contractors must familiarise themselves with the works required, lifting capabilities, load limits, access restrictions and environmental site conditions. Contractors are expected to visit the site to assess the suitability of their proposed plant and equipment and to confirm their construction methodology.

Contractor’s plant and equipment should be maintained in a good and serviceable condition and must comply with all Workcover and MWPA requirements throughout the works.

MWPA has the right to carry out inspections of all equipment prior to its mobilisation and during the works. During such inspections, the Contractor should extend full cooperation to MWPA and should allow access to any dismantled items of equipment. The inspections may include, but need not be limited to, the checking and calibration of equipment. If an inspection reveals that equipment provided is not in a condition acceptable to MWPA, the Contractor shall, at no additional cost to MWPA, carry out the necessary repairs or replacements.

5.2.6. SERVICES AND UTILITIES

Developers, Designers and Contractors should locate existing buried utilities to limit disturbance of existing services and reduce the risk of incidents occurring during the works.

5.3. ENVIRONMENT

The environmental consequences of the works and means of reducing environmental impacts should be considered at each stage of a project. An example of environmental considerations may include the provision of floating booms with silt curtains for breakwater or rock wall construction works.

Details on environmental requirements for construction works are provided in **MWPA100 Section 6.3.**

6 EXISTING COASTAL PROTECTION STRUCTURES

Geraldton Port contains three main breakwaters, two reclamation areas protected by rock revetments and numerous rock walls.

Brief descriptions of the rock structures within Geraldton Port are provided in **Table 6.** The latest information regarding any asset is presented in MWPA's Asset Maintenance software.

A plan showing the locations of MWPA rock structures is provided in **Figure 1.**

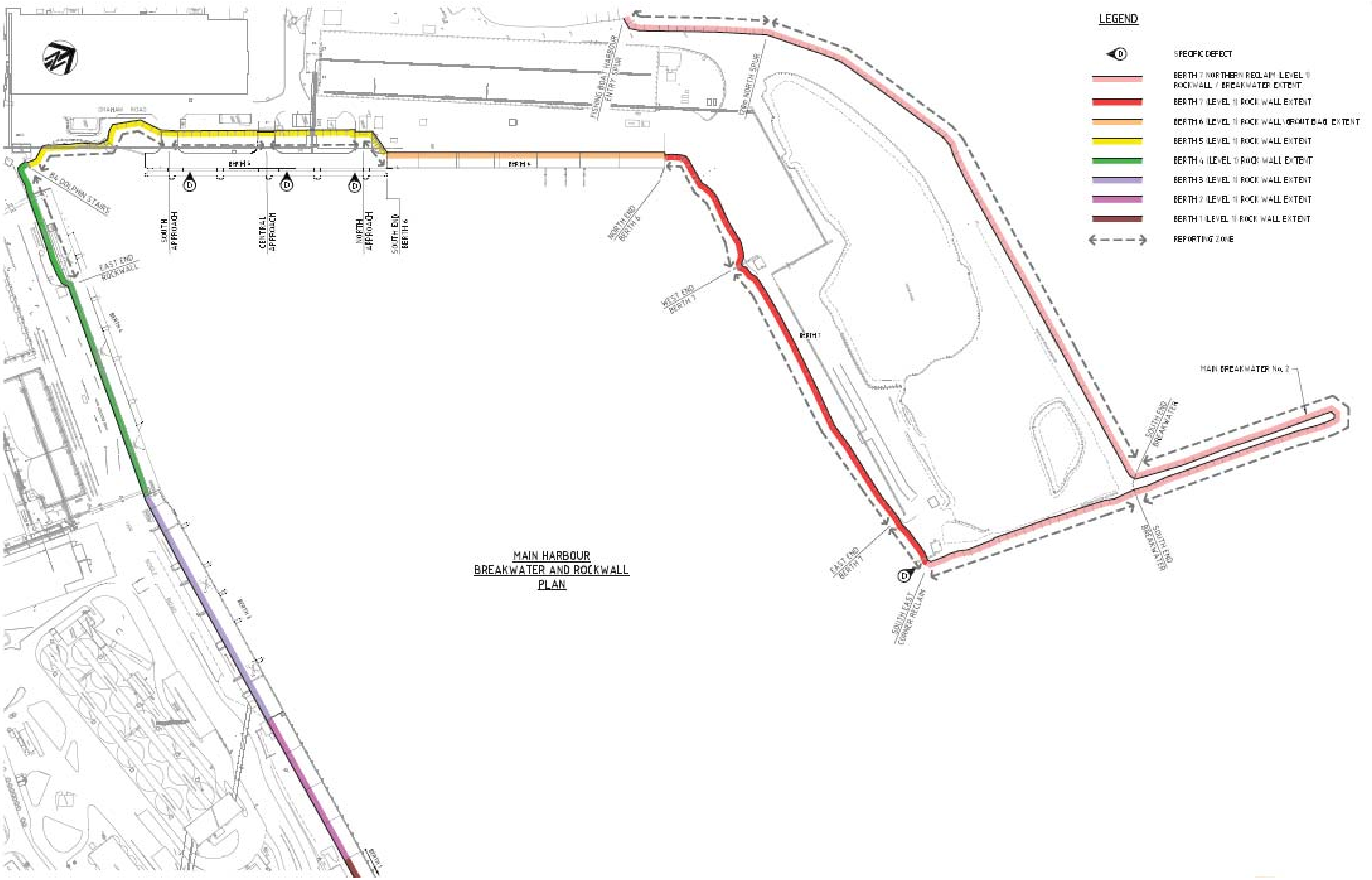
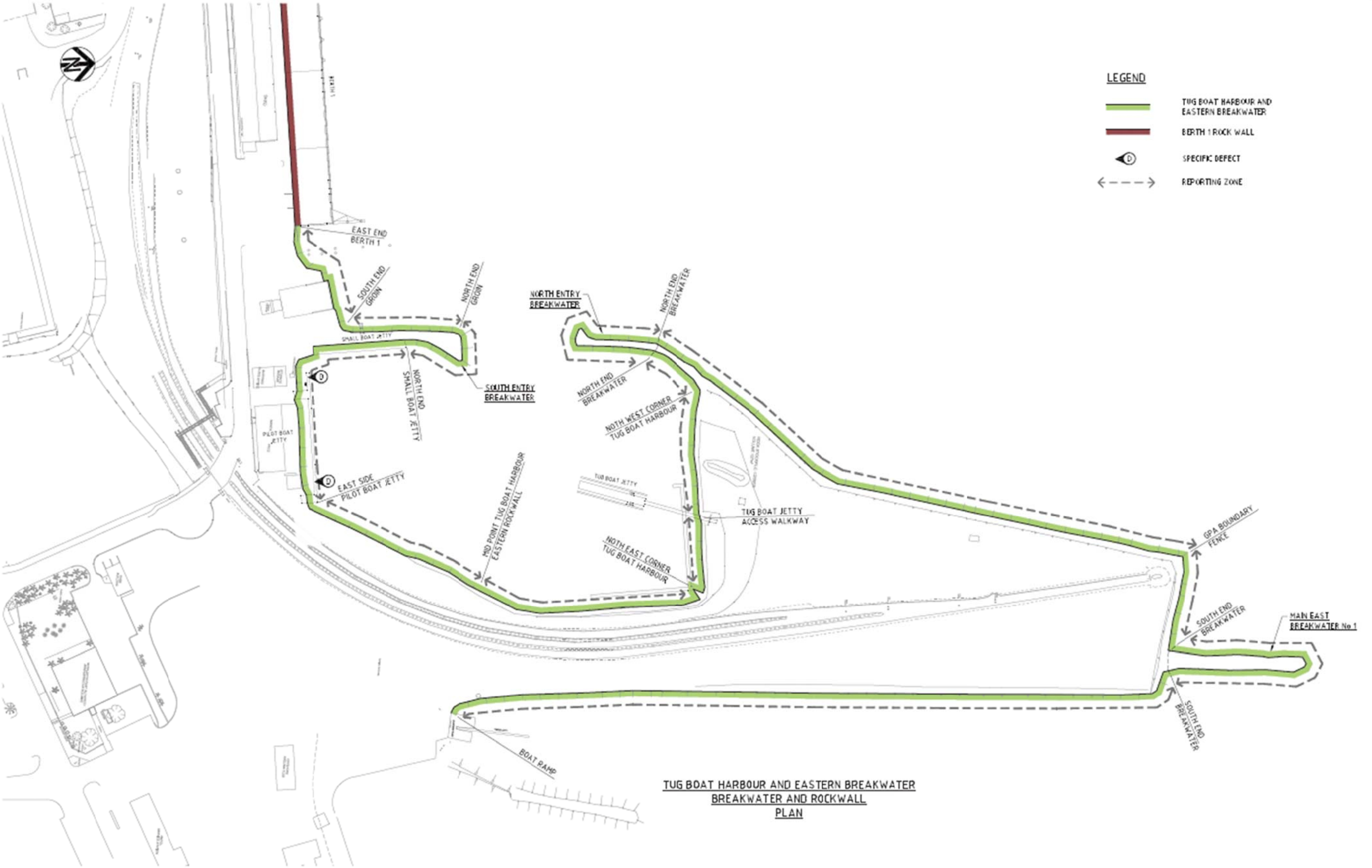
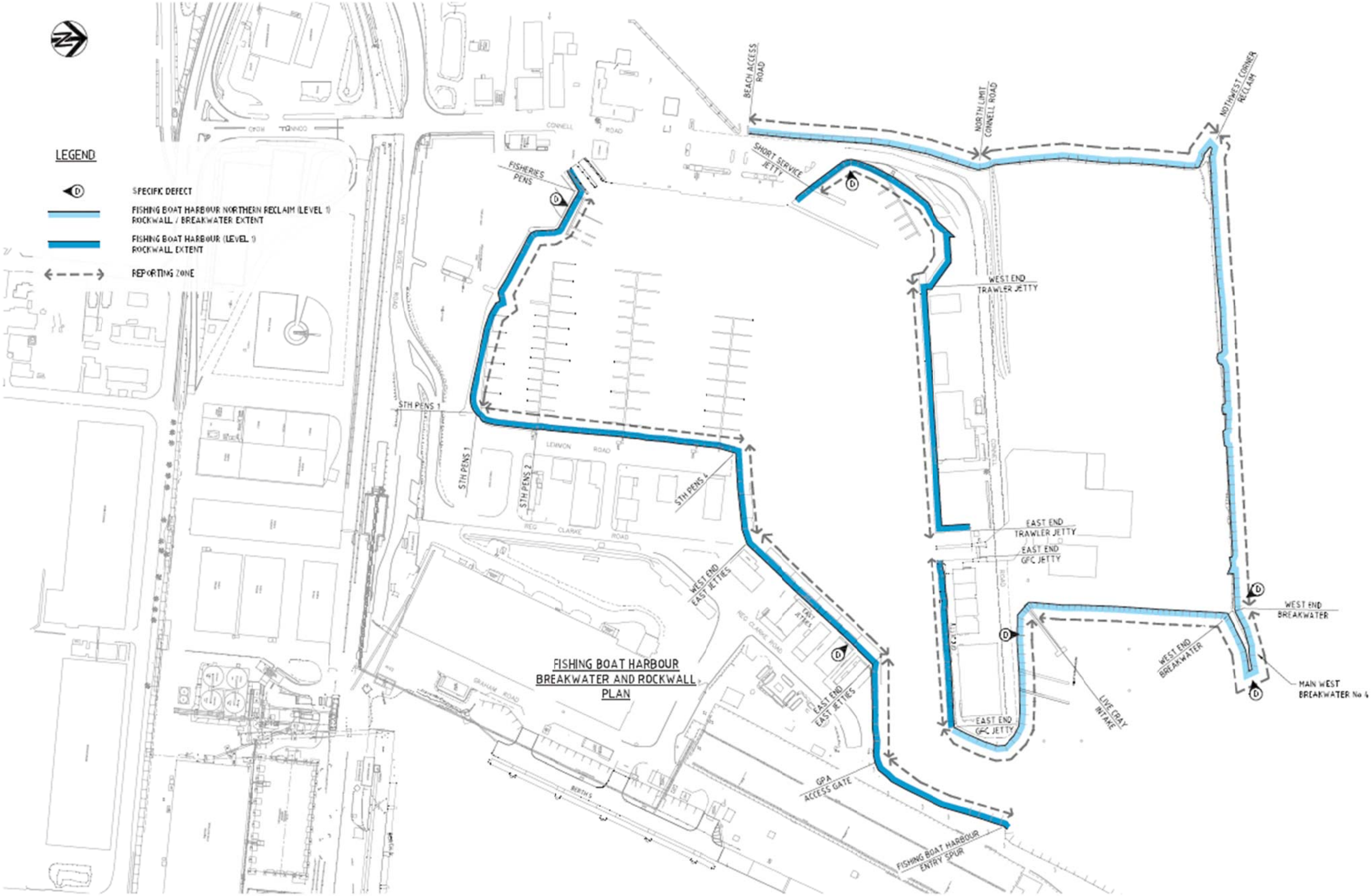


Figure 1: MWPA Rock Structures


LEGEND
TUG BOAT HARBOUR AND EASTERN BREAKWATER
BERTH 1 ROCK WALL
SPECIFIC DEFECT
REPORTING ZONE
EAST END BERTH 1
SOUTH END GROIN
NORTH END GROIN
NORTH ENTRY BREAKWATER
NORTH END BREAKWATER
SOUTH ENTRY BREAKWATER
NORTH END SMALL BOAT JETTY
NORTH END BREAKWATER
NOTH WEST CORNER TUG BOAT HARBOUR
EAST SIDE PILOT BOAT JETTY
MID POINT TUG BOAT HARBOUR EASTERN ROCKWALL
TUG BOAT JETTY ACCESS WALKWAY
NOTH EAST CORNER TUG BOAT HARBOUR
GPA BOUNDARY FENCE
SOUTH END BREAKWATER
MAIN EAST BREAKWATER No 1
SOUTH END BREAKWATER
BOAT RAMP
TUG BOAT HARBOUR AND EASTERN BREAKWATER
BREAKWATER AND ROCKWALL
PLAN



LEGEND
SPECIFIC DEFECT
FISHING BOAT HARBOUR NORTHERN RECLAIM (LEVEL 1) ROCKWALL / BREAKWATER EXTENT
FISHING BOAT HARBOUR (LEVEL 1) ROCKWALL EXTENT
REPORTING ZONE
BEACH ACCESS ROAD
NORTH LIMIT CONNELL ROAD
NOTHWEST CORNER RECLAIM
SHORT SERVICE JETTY
FISHERIES PENS
WEST END TRAWLER JETTY
EAST END TRAWLER JETTY
EAST END GFC JETTY
STH PENS 1
STH PENS 2
STH PENS 4
LEMNON ROAD
REG CLARKE ROAD
WEST END EAST JETTIES
EAST END EAST JETTIES
GPA ACCESS GATE
FISHING BOAT HARBOUR ENTRY SPUR
LIVE CRAY INTAKE
WEST END BREAKWATER
MAIN WEST BREAKWATER No 4
FISHING BOAT HARBOUR BREAKWATER AND ROCKWALL PLAN

Table 6: Description of Rock Structures within Geraldton Port.

Location	Asset Name	Description	Photos
Main Harbour	Berth 1	Between the Tug Boat Harbour and Berth 1 there are low crested ad hoc rock walls (refer photo). At Berth 1 there are rock walls beneath the deck which are backed by a vertical wall at the rear of the wharf.	
Main Harbour	Berth 2	Rock walls beneath the deck which are backed by a vertical wall at the rear of the wharf.	
Main Harbour	Berth 3	Rock walls beneath the deck which are backed by a vertical wall at the rear of the wharf.	
Main Harbour	Berth 4	Rock walls beneath the deck which are backed by a vertical sheet pile wall. A section of Berth 4 and the area between Berths 4 and 5 comprises rock walls which are backed by a roadway or building.	
Main Harbour	Berth 5	A rock wall is located landward of the deck. Beneath the three vehicular access points, the rock wall is backed by a sheet pile wall.	

Location	Asset Name	Description	Photos
Main Harbour	Berth 6	A rock wall and sheet pile structure is located beneath the deck at Berth 6 and is overlaid with grout filled mattresses up to low water and has toe stabilisation piles. The original rock wall was constructed in 1997 and the toe stabilisation pile and grout filled mattresses were installed in 2005.	
Main Harbour	Berth 7	A rock wall is located over the area between Berth 6 and Berth 7 and to landward of the Berth 7 deck. The rock wall between the berths is highly variable.	
Berth 7 Northern Reclaim	Berth 7 Northern Reclaim	A protective rock wall extends approximately 840m around the northern and eastern sides of the reclamation area.	
Berth 7 Northern Reclaim	Main Breakwater No. 2	A rock structure extending approximately 180m north from the north eastern corner of the reclamation area.	
Tug Boat Harbour	Various rockwalls	The Tug Boat Harbour's perimeter is approximately 350m long and consists of rock walls with varying form.	

Location	Asset Name	Description	Photos
Tug Boat Harbour	North Entry and South Entry Breakwaters	Low crested rock structures, each around 55m in length providing protection to the Tug Boat Harbour.	
Eastern Reclaim	Eastern Reclaim	A protective rock wall extends approximately 560m around the perimeter of the reclamation area.	
Eastern Reclaim	Main Breakwater No. 1	Rock breakwater structure extending approximately 60m to the north of the reclamation area.	
Fishing Boat Harbour	Various rock walls	Approximately 1700m of rock walls of varying form around perimeter. At a number of locations concrete has been poured over the top layer of rocks.	
Fishing Boat Harbour Northern Reclaim	Fishing Boat Harbour Northern Reclaim	A rock wall extends approximately 750m around the perimeter of the reclamation area.	

Location	Asset Name	Description	Photos
Fishing Boat Harbour Northern Reclaim	Main Breakwater No. 4	Provides protection to the entrance of the Fishing Boat Harbour and comprises a rock breakwater structure that extends approximately 50m from the north eastern corner of the reclamation area.	

7 SITE CONDITIONS

7.1. ELEVATED WATER LEVELS

The primary factors that contribute to elevated still water levels on the coast comprise:

- Astronomical tide;
- Storm surge (barometric setup and wind setup);
- Wave setup (caused by breaking of waves);
- Individual waves also cause water levels to temporarily increase above the still water level due to the processes of wave runup or uprush. Wave runup can then lead to overtopping of the structure, which is discussed in **Section 8.2.7**. Future sea level rise, which is considered likely due to climate change, is discussed further in **Section 8.2.4**.

7.1.1. ASTRONOMICAL TIDES

The tidal planes for Geraldton Port are provided in **MWPA100 Section 10.3.1**.

7.1.2. STORM SURGE AND WAVE SETUP

The Eurotop Manual (**Reference No. 10**) reports design water levels for various ARI design return intervals developed from an Extreme Value Analysis (EVA) of approximately 10-years of measured water level data recorded in the Geraldton area. It is noted that an extrapolation of a 10-year sample to develop 100-years design criteria is beyond the normal application of EVA (Reference No. 8). However, this available information is considered suitable for idealised design purposes. The 50-year and 100-year ARI values are reproduced in **Table 7** below.

Table 7: Design Water Levels

ARI (years)	Design Water Level (m CD)
100	2.3
50	2.2

Source: Adopted after Cardno (2012)

7.2. WIND

For design purposes Terrain Categories vary within the port and should be assessed in accordance with the provisions of AS 1170.2. Local monthly wind speed data is provided in **MWPA100 Section 10.2**. Wind data can also be obtained from *www.bom.gov.au*.

The Geraldton Port area is exposed to significant wind energy which has the potential to disrupt remedial or construction works. For planning and operations, Contractors should familiarise themselves with the local wind conditions, giving consideration to potential operational downtime and safety issues.

7.3. WAVES

7.3.1. WIND WAVES

The wave climate at Geraldton Port is dominated by the influence of the Houtman Abrolhos Island Chain on waves generated in the deep water of the Indian Ocean. Geraldton Port is affected by deep water swell waves, including occasional long period swell waves (period of 30s to 70s) that have been altered by the effects of refraction, diffraction, shoaling, breaking and seabed friction. The Port is also affected by locally generated wind waves, predominantly from the north to north-west sector. A number of studies of the wave climate in the Geraldton Port have been undertaken, as listed in **Table A1.2** of Appendix A.

Coastal Engineering Solutions undertook numerical modelling of the wave climate at Geraldton Port in 2001 to assess breakwater options (**Reference No.7, Section 4.6**). The modelling was based on eight years of hindcast wave data. Generic wave heights have been developed for outer and inner structures on the basis of those presented in the Coastal Engineering Solutions report. The values are presented in **Table 8** below.

Table 8: Wave Heights Developed by Coastal Engineering Solutions (2001)

Location	Estimated Significant Wave Height (Hs) (m)		
	25 year ARI*	**50 year ARI ***	**100 year ARI***
Outer structures	2.6	2.8	3.0
Inner structures (inside harbours)	0.8	0.8	0.85

* It is reasonable to extend an eight years wave data base for determining a 25 year return period wave height, however there is more inherent inaccuracy in the 50 year and 100 year ARI estimates.

It is noted that whilst the long period swell waves do not generally dictate the design of rock revetment or breakwater structures, they can be problematic within the port due to the surge affect that creates peak loadings on mooring lines and subsequent breakages.

7.3.2. BOAT WASH

There is currently limited information available relating to the magnitude of tug and vessel wash waves that can be expected within Geraldton Port. Vessel wash is of a very transitory nature and wave heights decay with distance from the vessel track. However, within well protected areas such as the Fishing Boat Harbour, it can be a dominant factor and should be considered. **Table 9** provides indicative boat wash wave heights taken from a study in 1996 by Patterson Britton and Partners in Sydney Harbour (**Reference No.5, Section 4.6**).

Table 9: Indicative Vessel Wave Heights Developed by Patterson Britton and Partners (1996)

Vessel Type	Maximum Wave Height (m)	Wave Period (s)
Ferry	0.40	2.2
Water taxis	0.48	2.2
15 m Motor Cruiser	0.80	3.6
13 m tug	0.76	2.0
Power Boat	0.40	2.0

Strong currents from tugs are generated in a jet extending from their propellers when in operation. The effect of these currents on rock stability will depend on: the type of tug (and propeller), its operation, and the distances or geometry of the surrounding harbour. There are a number of examples from Australian and International ports where rock revetments have considered currents created by tugs. Suitable references on tug propeller jet currents include PIANC Guidelines (**Reference No. 6, Section 4.6**).

7.4. CURRENTS

There is limited data currently available relating to currents within the port. Strong localised currents can be generated by tugs and other vessels as outlined in **Section 7.3.2**.

7.5. BATHYMETRY

Seabed levels around the Port of Geraldton, and more specifically those around the base of rock structures, can be sourced from various charts and hydrographic surveys as listed in **Table A1.1** of Appendix A.

Water depths alongside berths are provided in **MWPA100 Section 9.1**.

7.6. SEISMICITY

Seismic parameters specific to Geraldton Port are provided in **MWPA100 Section 10.5**.

8 GUIDELINES FOR DESIGNERS

8.1. SITE INVESTIGATION

The following site investigations should be considered prior to the design of new rock structures or prior to the upgrade or rehabilitation of existing rock structures:

- Geotechnical investigations to assess:
  - stability of slopes.
  - the condition, capacity and stability of the crest of an existing structure, by identifying any voids, undermining or sink holes.
  - properties of the seabed material and likely settlement.
- Wave studies to determine site specific design wave heights.
- Bathymetric and topographic surveys.
- Condition of above and below water portions of an existing structure to assess the extent and form of the rehabilitation works.
- Current investigations.
- Vessel movements and associated currents/wash (refer Section 7.3.2).

It is also recommended that quarry investigations be undertaken to determine a suitable rock source for armour. Local rock supply contractors in the Geraldton Port area are generally able to supply Granite or Limestone. It is noted that whilst Granite is generally a preferable rock type for coastal structures, many of the rock structures in the area are constructed using Limestone. This is due to the difficulty and cost involved in sourcing other suitable rock armour, as discussed further in Section 8.4.1. Some local rock suppliers include Holcim (Granite), WA Limestone (Granite or Limestone) and Winchester (Limestone).

8.2. DESIGN CRITERIA

8.2.1. DESIGN LIFE

The design life for rock structures should comply with Table 6.1 of AS 4997 or the minimum Design Life listed below in **Table 10**, whichever is greater:

Table 10: Design Life

Structure	Design Life (years)
Temporary works	5 or less
Rock walls and revetments	50
Breakwaters	50*

* This may be increased to 100 years for more significant structures.

8.2.2. ACCEPTABLE LEVEL OF DAMAGE/MAINTENANCE REQUIREMENTS

Options for acceptable design damage levels (for use in application of hydraulic stability equations such as Hudson's Equation) should be assessed by the designer considering cost, constructability and performance. The design should be optimised in consultation with MWPA to achieve the best balance of these aspects of the design. The acceptable level of damage for rock structures should not exceed 10%.

8.2.3. DESIGN STORM EVENT AND RISK

Economic factors, constructability and consequences of failure influence the selection of the design storm event or the return period to be used. The impact of possible 'failure' of the rock structure as a result of a large storm could have both direct and indirect consequences. When choosing a design event it should be assessed in terms of the primary risk outcomes such as cost, safety and environmental impact.

A typical relationship between encounter probability, design life and average recurrence interval (ARI) of design events is illustrated in **Figure 2.**

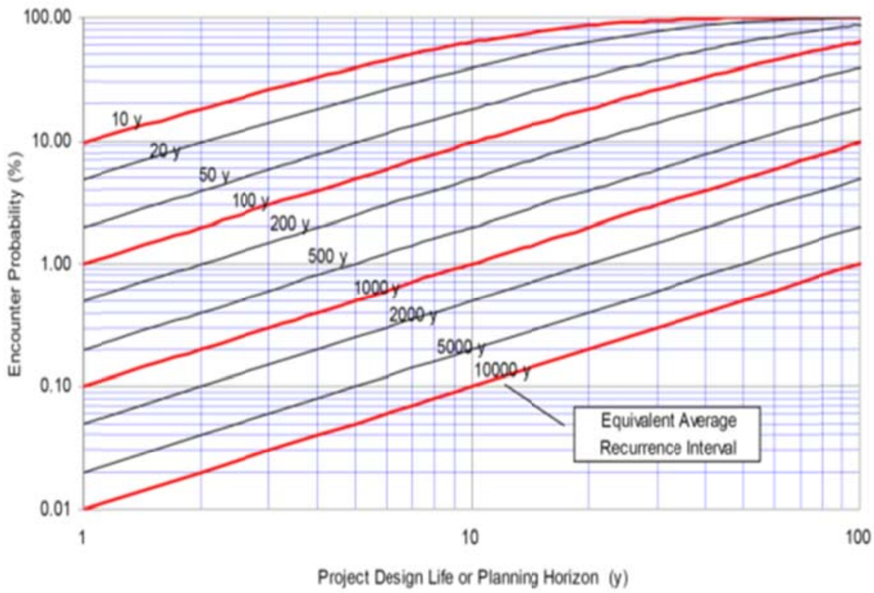


Figure 2: Typical relationship between encounter probability, design life and ARI for design events

It is recommended that the design storm event be a minimum of 50-year ARI and potentially increased for more significant structures. A six hour duration should be adopted for the design event. Further details are provided in Section 8.2.6.

8.2.4. CLIMATE CHANGE – SEA LEVEL RISE

Rock structures and breakwaters should be designed to cater for an increase in sea level resulting from global warming.

It is recommended that a sea level rise determined from Figure 11 of MWPA100 Section 10.3.2 be adopted for the design life of rock structures.

8.2.5. ELEVATED WATER LEVELS

Consideration of elevated water levels during ocean storms is fundamental to the design of coastal structures. A 100-year ARI design water level (2.3m CD) should be adopted in accordance with Section 7.1. Sea level rise from global warming should be additional to this and in accordance with Section 8.2.4.

8.2.6. WAVE CLIMATE

A six hour storm duration should be adopted for determining design wave heights for armour stability calculations. A six hour storm duration is typical for armour design as it takes into account a full tidal cycle and can therefore be combined with the extreme water levels without being excessively conservative. A minimum 50-year ARI wave height should be adopted for the design wave heights for armour stability. For significant structures such as major breakwaters it is recommended that site specific design wave heights be determined through modelling and the ARI increased to 100-years. Refer to Section 7.3 for further information on wave heights.

Consideration should be given by the Designer to the possibility of successive design storm events and the potential for cumulative damage impacts.

8.2.7. OVERTOPPING

Guidelines on overtopping discharges that can cause damage to coastal structures or danger to pedestrians are typically related to mean overtopping discharges. The tolerable discharge guidelines for pedestrians and vehicles from Reference No.'s 9 and 10, Section 4.6 are outlined in **Table 11**. Limits on overtopping for damage to buildings behind the defence structure and the defence structure itself, also from Reference No.'s 9 and 10, Section 4.6, are outlined in **Table 12.**

Table 11: Limits for Overtopping for Pedestrians and Vehicles

Hazard Type and Reason	Mean discharge q (l/m/s)	Max volume[1] Vmax (l/m)
Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jet, low danger of fall from walkway.	1 - 10	500 at low level
Aware pedestrian, clear view of the sea, not easily upset or frightened, able to tolerate getting wet, wider walkway[2].	0.1	20 - 50 at high level or velocity
Vehicle driving at low speed, overtopping by pulsating flows at low flow depths, no falling jets, vehicle not immersed.	10 - 50	100 - 1000
Vehicle driving at moderate or high speed, impulsive overtopping giving falling or high velocity jets.	0.01 0.05	5 - 50 at high level or velocity

1. These limits relate to overtopping velocities well below v_c= 10 m/s. Lower volumes may be required if the overtopping process is violent and/or overtopping velocities are higher.

2. Not all of these conditions are required, nor should failure of one condition on its own require the use of a more severe limit.

Table 12: Limits for Overtopping for Damage to Buildings and the Defence Structure

Hazard Type and Reason	Mean discharge q (l/m/s)
Buildings	
Minor damage to fittings etc.	0.001 - 0.03
Structural damage	0.03
Defence Structure	
Damage to paved or armoured promenade behind revetment	200
Damage to lightly protected promenade	50

8.2.8. TUG OR VESSEL WASH

Designers should understand the types of tugs or vessels and their likely movement in relation to the rock structures to ensure that consideration is given to vessel wash (including waves and currents). A feature of tug wash is that it extends down the water column to significant depths. A filter layer may be required to prevent fine material being washed out as a result of tug wash, which could cause subsequent slumping of the rock structure.

Refer to **Reference No.6, Section 4.6**, for further guidance on the design of rock structures beneath piled berths with tug wash.

8.3. DESIGN REQUIREMENTS

A Safety in Design risk review should be undertaken for all rock structure projects as outlined in **Section 5.2.1**.

8.3.1. HYDRAULIC STABILITY

The size of the armour, profile slope and number of armour layers should be determined using Hudson's and Van Der Meer's equations to check hydraulic stability in accordance with the Coastal Engineering Manual (**Reference No. 8, Section 4.6**) and current best practice.

8.3.2. CREST DESIGN

Crest level and width should be designed to ensure overtopping volumes satisfy the design criteria and meet operational and safety requirements, as well as limiting structural damage to the crest and assets behind it. Crest width is generally a minimum of three primary armour stones in width in conventional breakwater design (**Reference No. 8, Section 4.6**). A narrower crest width may be considered on the basis of a detailed review of overtopping.

Crest width should also take into account vehicle width for maintenance purposes.

8.3.3. TOE DESIGN

The toe of a rock structure is critical for supporting the upper slope and preventing rock armour from sliding. A rock toe berm should be a minimum of three primary armour stones in width and two primary armour stones in height (**Reference No. 8, Section 4.6**). Other methods of stabilising the toe of a rock revetment include sheet piles at the base of the structure.

Many of the rock walls within the Main Harbour at MWPA are founded limestone where dredging of the berth pockets has involved rock (limestone) excavation.

8.3.4. CONSTRUCTABILITY

Due consideration should be given to the constructability of any rock structure design or remedial works proposal. Idealised designs may be difficult to achieve due to constructability issues and constraints, particularly when the rock structures are beneath existing wharves or jetty structures.

Wharves or jetties may limit the working space and inhibit the use of conventional working methods making it difficult to upgrade rock structures in a cost effective manner. An example of such limited work space is below Berth 4.

Rip-rap may be considered, rather than graded primary armour construction, in low wave and current environments. Rip rap is easier to construct since it can be readily placed.

8.3.5. MAINTAINABILITY

Designers should consider the maintainability of the completed structure when undertaking design of new rock structures or rehabilitation of existing rock structures. New works should not preclude future maintenance.

8.3.6. SCOUR POTENTIAL

Designers should assess the impact of dredging operations and the associated potential of toe scour when determining the overall stability of rock structures.

8.3.7. SEISMICITY

Designers should consider the stability of rock slopes under seismic loads using the appropriate design parameters given in **MWPA100 Section 10.5.**

8.3.8. POTENTIAL KNOCK-ON EFFECTS

Designers should consider the potential knock-on effects of new or altered rock structures ensuring that there is no negative impact on surrounding areas such as increased erosion or scour downstream of the site.

8.4. MATERIAL SPECIFICATION – SUPPLY AND INSTALLATION

8.4.1. ROCK ARMOUR

The imported rock armour should satisfy all of the following criteria:

- Individual rocks should be hard, durable and clean and should be free from cracks, cleavage planes, joints, seams, chemical alteration or weathering and other defects which would result in the breakdown of the rock in the marine environment;
- Rock should be igneous and have a minimum dry density of 2,600 kg/m^3. Where such rock is not available other types may be considered, although durability and density need to be factored into the design;
- Rock should be rough and angular;

- The ratio of the maximum dimension of any rock to the minimum dimension, measured at right angles to the maximum dimension should not exceed 2.5;
- Rock should have no more than 10% (by volume) olivine material and should exhibit no zones of secondary alteration such as chloritisation;
- Rock should have a saturated point load strength index (Is50) no less than 5.0 MPa;
- Rock should exhibit a maximum Los Angeles abrasion value of 25%;
- Rock should exhibit a maximum sodium sulfate weight loss of 5%; and
- Rock should exhibit no signs of stress relief.

Recommendations for the quality of rock for use in primary armour layers are also provided in BS 6349 Part 1. Guidance on the production of rock is given in BS 6349: Part 7. The CIRIA Rock Manual (**Reference No. 9, Section 4.6**) also covers the subject in detail.

Rock grading should be in accordance with recommendations in (**Reference No. 8, Section 4.6)**.

Contractors should provide evidence of the rock selection quality control procedures at the proposed quarry. This evidence should include, but not be restricted to, the following:

a) Details of the quarry from which the rock is to be supplied, including identification of the sections of the quarry where the rock complies with the technical design specification;
b) A test report from a NATA registered independent testing authority on the physical and chemical properties of the rock to be supplied;
c) Where the scale of the project allows, a report from an independent and suitably experienced chartered geologist commenting on the suitability of the rock to be supplied for its intended purpose. The geologist should prepare the report based on an inspection of the rock and the results of the laboratory testing undertaken.

Armour stone should be placed such that:

- The specified design requirements for mass (maximum, minimum and 50% or median), finished slopes, crest and toe levels, number of layers, layer thicknesses and density requirements are satisfied;
- Minimal breakdown on handling, production of fines and water contamination occur;
- The finished slope is no steeper than 1:1.5;
- Rocks are wedged and locked together such that they are not free to move;
- There are no free rocks on the surface of the armour stone; and
- The completed profile comprises good interlocking of rocks to provide effective load transfer.

8.4.2. CONCRETE ARMOUR

For structures where concrete armour units are selected over rock armour, the concrete should satisfy the concrete strength, mix design and reinforcement cover requirements provided in **MWPA400**.

Concrete armour should be installed to a specified placement density using remote release hooks to ensure interlocking of units is achieved in a safe manner.

8.4.3. GEOTEXTILE/FILTER LAYER

Geotextile should be designed to meet the requirements of placement activities and the required service life. Prior to placement of geotextile the slope should be screeded to minimise surface irregularities below 150mm. Geotextile placed in water will require ballast to secure it in position.

The geotextile should be installed in accordance with Manufacturers Guidelines and the General Recommendations for the Acceptance and Laying of Geotextiles (**Reference No. 4, Section 4.6**). Allowance should be made for material creep.

It can be difficult to place geotextile over areas where existing rock revetments have been excavated as part of rehabilitation works due to rough, uneven slopes and sharp rocks which can puncture the material. For such sites, either the existing rock should be removed, or a gravel/rock screeding layer should be considered, formed by dumping small rip-rap and regrading the slope.

8.4.4. PHYSICAL SCALE MODELS

Physical scale modelling of significant rock structures is often undertaken to test and refine the design. The model may be a two-dimensional model of a typical cross section tested in a wave flume or a three-dimensional model of the entire structure tested in a large basin. Quasi three-dimensional models can also be undertaken in a wide wave flume whereby some three-dimensional effects such as wrapping of waves around the head may be observed. Models are often at a scale of approximately 1:50. Designers should consider the use of a physical model for any significant MWPA rock structure projects.

9 CONSTRUCTION GUIDELINES

9.1. PORT OPERATIONS

MWPA conducts operations, including shipping and ship loading, on a 24 hour basis. In most cases port operations, in particular shipping movements and activities, will take priority over Contractor's work activities. Port operations should therefore be taken into account in all stages of a rock structures project.

Depending on location, work may be scheduled during MWPA nominated maintenance shutdown periods to avoid hampering operations.

For more details on Port Operations refer to **MWPA100 Section 9**.

9.2. MONITORING, REPAIR AND MAINTENANCE WORKS

Regular monitoring of rock structures is recommended by undertaking both above and below water inspections. Post storm event inspections should be undertaken to identify damage, where minor remedial works may avoid the need for later major repair works or reconstruction.

Maintenance works on rock structures may include the following:

- Placement of additional rock on slopes to fill voids where armour has been displaced.
- Placement of additional rock at the toe of the rock structure if scour has occurred and created over steepening or overhangs.
- Placement of additional rock at the top of the rock structure due to settlement resulting from scour.
- Replacement of rock, filter layer or geotextile at the crest of the rock structure to repair damage due to overtopping.
- Drainage improvements such as grading crest towards the landside so that water is collected in roadside drains and discharged in a controlled manner rather than draining back through the rock wall.

Major remediation or upgrade works may be required when damage is severe as a result of inadequate design or other reasons.

9.3. DIVING OPERATIONS

Diving work should be undertaken strictly in accordance with:

a) The Construction Safety Act and Regulations in particular Section 17A of the Act and Regulation 99.

b) AS 2299 – Occupational Diving.

c) The Occupational Health and Safety Act and associated legislation.

d) Any other relevant Acts and Regulations and requirements of WorkSafe, WA.

9.3.1. CERTIFICATES

Divers must be licensed and hold the necessary certificates to carry out the proposed work and evidence of such licences or certificates should be furnished to MWPA prior to any diving activity. Divers should have recent experience of diving in the conditions in which they will be operating, and be technically experienced in the type of work being undertaken.

9.3.2. EQUIPMENT

Dive equipment should be well maintained and in good condition in accordance with the requirements of the Australian Standards, OHS&R and other regulatory authorities. Spare equipment in sound working order should be available on standby during all dives.

9.4. CONSTRUCTION METHODOLOGY

9.4.1. CONSTRUCTION PLANT

The type of plant used for the construction of rock structures depends on the scale, type and location of the works (refer to **Reference No.'s 8 and 9, Section 4.6** for detailed information). Generally, it is preferable for rock to be placed in a controlled manner using a grab rather than dumped using a bucket or truck. Some projects may also require barge based construction due to limited land access.

9.4.2. CONSTRUCTION LOADS

Construction loads should be considered during all phases of rock structure projects. Designers should consult with experienced Contractors to ensure that construction methods are considered in the design. Likewise, Contractor's should have an appropriate construction methodology in place for the construction load limits at all stages of construction or repair.

9.4.3. DAMAGE DURING CONSTRUCTION

Contractors should consider the possibility of an extreme event occurring during the construction of the works and plan their methodology and sequencing to minimise the potential for damage and loss of materials.

9.5. CONSTRUCTION TOLERANCES

9.5.1. ROCK GRADING

Armour rock size and grading should be in accordance with the specification. Samples of rock defining each specified grading should be displayed on site to facilitate visual inspections. The rock gradings should be quality controlled on site and stockpiled into relevant categories of primary armour, secondary armour, core material and a non-conforming stockpile where necessary.

9.5.2. ROCK PLACEMENT TOLERANCES

The construction tolerance that can be achieved depends on the size and type of armour, in addition to the type of equipment and method of placement. When using standard types of equipment, the approximate tolerances summarised in **Table 13** apply in practice, based on the nominal diameter (D50).

Table 13: Vertical Placing Tolerances with Land Based Equipment (Reference No. 9, Section 4.6)

Depth of placing relative to LW	Bulk-placed armour stone		Armour layers and individually placed stones, with M_{em}>300kg	
	M_{em}<300kg	M_{em}>300kg	Individual measurements	Design profile to actual mean profile
Above LW = dry	+0.2m to -0.2m	+0.4m to -0.2m	±0.3 of the nominated armour D_{50}	+0.35 to -0.25 of the nominated armour D_{50}
0 to -5m	+0.5m to -0.3m	+0.8m to -0.3m	±0.5 of the nominated armour D_{50}	+0.6 to -0.4 of the nominated armour D_{50}
-5m to -15m		+1.2m to -0.4m		
Below -15m		+1.5m to -0.5m		

Notes: M_{em} = effective mean mass

All tolerances refer to the difference between the design profile and the actual mean profile excluding for the individual measurements. The tolerances on two consecutive mean actual profiles should be positive. Notwithstanding any accumulation of positive tolerances on underlayers, the thickness of the layer should not be less than 80% of the nominal thickness when calculated using mean actual profiles. Where an accumulation of positive tolerances arises and is acceptable to the designer, the position of the design profiles will need to be adjusted to suit.

Contractors are responsible for the completion of a post construction survey to demonstrate that the finished rock structure is within the required construction tolerance.

Further information on construction tolerances for rock structures is set out in **Reference No. 9, Section 4.6.**

9.6. INSPECTION, TESTING AND QUALITY CONTROL

Contractors are responsible for achieving the specified standards and demonstrating such achievement through inspections, testing and measurement in accordance with MWPA and contractual requirements. Documentation should cover all work under the Contract, both onsite and offsite, including the activities of Subcontractors and Suppliers.

MWPA's Representative should at all times be provided access to facilities where work, inspections or testing associated with the Contract is being performed, including the facilities of Subcontractors or Suppliers either onsite or elsewhere. All inspections and tests should be conducted within normal office hours, unless otherwise authorised by MWPA.

Surveying processes to verify conformance should be conducted by personnel with a minimum qualification for acceptance to the Surveying and Spatial Sciences Institute (SSSI).

9.6.1. NOTIFICATION

Contractors should notify MWPA at least seven (7) days in advance of the date, time and place where inspections or tests will be carried out and provide a detailed test plan. MWPA may, at its discretion, nominate a representative who will witness all or part of the inspections or testing. If a MWPA representative attends an inspection or test, the Contractor should ensure that all inspection and test sheets that were witnessed are appropriately annotated and signed by the MWPA representative.

If a MWPA representative is not nominated or does not attend, the Contractor should proceed with all inspections and tests on the date and time proposed and submit all inspection and test sheets to the MWPA representative.

9.7. DOCUMENTS TO BE SUBMITTED

Contractors should undertake as-built surveys to illustrate that the design has been achieved within the tolerances specified in the Contract. This may include the results of diving inspections to verify the standard of the as-built structure below water.

Details of documents required to be submitted by Contractors before, during and after construction are provided in **MWPA100 Sections 5.3, 5.4, 6.1, 6.2, 6.3** and **12.1**.

APPENDIX A

EXISTING DATA

ITEM A1 – LISTS OF EXISTING DATA

A1.1 BATHYMETRY DATA

Item	Title	Format
1	Aus0081 – Approaches to Geraldton Harbour and Port of Geraldton (AHS, 2005)	Chart
2	WA939 – Geraldton (W.A. Dept. of Transport, 2005)	Chart
3	MWPA Bathymetric survey, Berths 1, 2, 3, 6 by Mapping & Hydrographic Surveys Pty Ltd, 14 June 2004	Drawing
4	MWPA Bathymetric survey, Berth 7 cross sections by 3D Marine Mapping, 30/5/05	Drawing
5	HTD Survey – Eastern Breakwater: Detailed Survey 01705DS5-1-1, 22/8/12	Drawing
6	HTD Survey – Eastern Breakwater: Cross sections, 01705XS1-1-0, 22/8/12	Drawing

A1.2 WAVE DATA

Item	Title	Format
1	Coastal Engineering Solutions [CES] (2001), Geraldton Port Enhancement – Wave and Sediments Studies – Volume 3 Design Wave Conditions For Foreshore Structures, report prepared for Mid West Ports Authority, February, 2001	Report
2	Reducing Long Period Wave Energy at Geraldton, Numerical modelling of changes to long period wave energy in the Geraldton harbour basin resulting from breakwater extensions, (MetOcean Solutions, 2011)	Report
3	Surge in Geraldton Harbour – A numerical study of migration options, (MetOcean Solutions, 2008)	Report
4	Long Period Waves at Geraldton Harbour – An investigation into the generation, prediction and forecasting of infragravity event in the harbour, (MetOcean, 2006)	Report
5	Preliminary Assessment of Swan Modelling at Geraldton – Improvements to spectral transfer modelling, (MetOcean, 2005)	Report
6	Surge in Geraldton Harbour – A numerical study of mitigation options (MetOcean, 2008)	Report
7	Long Period Waves at Geraldton Harbour – Review of numerical model studies of long wave propagation and penetration (MetOcean, 2013)	Report
8	Long Period Wave Modelling – Boussinesq modelling of changes to long period wave energy in the Geraldton harbour basin resulting from breakwater modifications (MetOcean, 2012)	Report
9	Comparison of Long Period Wave energy at Geraldton and Oakajee – Numerical modelling of long period wave energy in the Geraldton and Oakajee harbour basins (MetOcean, 2010)	Report

A1.3 GENERAL

Item	Title	Format
1	MWPA Tug Pen Structural Assessment (URS, 2012)	Report
2	Report on Condition Inspection of the Eastern Breakwater, doc no. ENG_0012, (MWPA, 2012)	Report