MOTT MACDONALD

Old Colwyn Coastal Defence and Active Travel

Flood Consequence Assessment (FCA)

July 2020

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Abbreviations and Acronyms

CCBC	Conwy County Borough Council
FCA	Flood Consequence Assessment
FR&I	Flood Risk and Infrastructure
HM	Harbourmaster
Hs	Significant wave height
NGR	National Grid Reference
NWC	North West & Central – Network Rail
NWR	Natural Resources Wales
PPW	Planning Policy Wales
OD	Ordnance Datum
OS	Open Spaces
RCP	Representative Concentration Pathway
RP	Return period
TAN15	Technical Advice Note 15: Development and Flood Risk

1 Introduction

1.1 Overview

Mott MacDonald has been appointed by Conwy County Borough Council (CCBC) Environment, Roads and Facilities Team (hereafter referred to as "the Applicant") to prepare a Flood Consequence Assessment (FCA) to accompany the Environmental Statement, for the Old Colwyn Coastal Defence and Active Travel Scheme (hereafter referred to as the 'Scheme'). A location plan and the current coastal defences are included in Appendix A.

1.2 Current Flood Risk

As early as 1991, the Colwyn Borough Sea Defence Review[1] identified that "overtopping, which occurs regularly when onshore winds coincide with spring tides, results in large quantities of shingle and cobbles being thrown over the wall. The road is closed up to a dozen times a year for several days at a time while the shingle is cleaned back onto the beach". These conditions have continued to the present day with increasing frequency and severity.

The observed impacts of present-day conditions from more recent storm events – February 2005, March 2007, March 2010, December 2013, December 2016, December 2017, February/March 2018, January 2019 etc[2], confirms the overtopping behaviour identified by HR Wallingford but also identifies the following as taking place:

- Damage/loss of railings;
- Damage to promenade/highway surfacing and removal of fill behind sea wall;
- Damage to boundary wall and erosion at toe of railway embankment;
- Lowering of beach levels in front of the wall;
- Undermining of sea wall; and
- Removal of facing blocks to the sea wall.

Examples of this damage are provided in Figure 1.1.

Furthermore, with sea levels predicted to rise in the future, due to anticipated climate change, by the end of the 21st century the tide is anticipated to reach approximately the crest of the current wall (which varies between +5.00m OD to +6.20m OD) on each spring tide i.e. every 2 weeks.

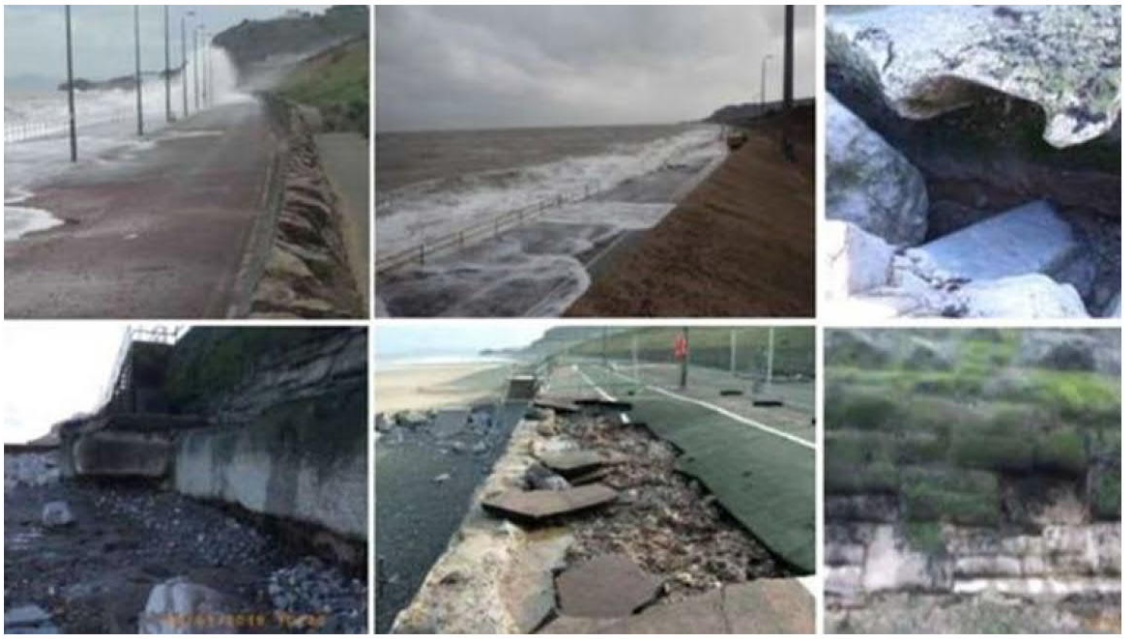
The current seawall provides protection to the following assets:

- The pedestrian promenade and designated cycle path, which is part of the National Cycle Network Route 5;
- The promenade highway, linking Old Colwyn to Rhos-on-Sea;
- The North West & Central (NWC) Railway Line;
- The A55 trunk highway; and
- Utilities services buried underneath the promenade or promenade highway surfacing.

[1] HR Wallingford, 1991. Colwyn Borough Sea Defence Review (Report EX 2367). UK: H R Wallingford.

[2] Mott MacDonald. (2020a). Old Colwyn Promenade Coastal Defence & Active Travel Improvement – Basis of Design Report - 415437-MMD-00-XX-RP-C-3100. Mott MacDonald

Figure 1.1: Examples of Storm Damage at Old Colwyn



Source: BBC, 2019[3]

CCBC currently have an operational procedure to manage the risk to promenade users from high tides and or damage[4]. The key elements of this procedure are summarised below:

- The trigger conditions for potential closure of the promenade is a tide level of 3.9m OD or greater, which typically is predicted to occur for periods of up to 7 days at a time, 1-2 times per month, concurrently with strong onshore winds, from directions north-west to north-east (onshore);
- Following review of the data the decision for closure is taken by Council staff from the Flood Risk and Infrastructure (FR&I), Open Spaces (OS) and Harbourmaster (HM) departments. County Councillors for the immediate location are informed directly and CCBC's marketing department inform the general public via social media;
- The road barrier at Cliff Gardens (by the arches at Splashpoint) is closed first, followed by a walk through the Promenade length to inform remaining cars, followed by closure of the road barrier at Rotary Way junction and Marine road junction;
- When the high tide has passed, an inspection of the coastal defence is carried out by FR&I to record condition and to ensure that the promenade is safe to re-open. Any debris thrown up onto the Promenade during the storm is cleared before re-opening; and
- County Councillors for the immediate location are informed directly and CCBC's marketing department inform the general public via social media that the promenade has been re-opened.

[3] BBC. (2019). Weather and storm defences: Who pays when sea walls crumble? [online]. Available at: https://www.bbc.co.uk/news/uk-wales-50069665, photos by CCBC [Accessed 13 July 2020].

[4] Mott MacDonald. (2020b). Old Colwyn Promenade Coastal Defence & Active Travel Environmental Statement – Volume 1: Main Text. - 415437-MMD-00-XX-RP-N-1719. Mott MacDonald.

During autumn and winter seasons when there are consecutive days of high tides and onshore winds, or when repairs are required following storm damage, the promenade can remain closed for a few days or longer at a time.

Should construction of this Scheme not be implemented in the near future, CCBC have indicated that it is highly likely that a decision will have to be made as to whether to continue to carry out repairs. Should the decision be that repairs will not sustain the defences any further, then a decision to permanently shut the promenade, with the associated consequences for general users and particularly the emergency services, would have to be made.

The current overtopping rates for the frontage have been assessed and are presented in Appendix C. The results indicated that for a current 1 in 10-year return period the maximum overtopping discharge (*q*) estimated is 690 l/m/s with a maximum overtopping volume (*Vmax*) of 57,500 l/m. These values are significantly higher than the limits proposed by guidelines and impose risk to public health and safety, as well as risk for the protected assets beyond the sea wall.

1.3 Proposed Scheme

The Scheme is located in the Old Colwyn area of Colwyn Bay and comprises coastal defence works in the form of a new rock revetment and promenade raising. This is in combination with improvements to the promenade to facilitate active travel. The proposed Scheme and sections are included in Appendix B.

The proposed rock revetment is +7.5m OD at approximately 32m in cross sectional width, 1.2km in length with an approximately 5m wide crest and a slope of 1:3 down to beach level. The revetment is required to protect the active travel routes along the promenade along with the Promenade highway, underground services, NWC Railway Line and A55 Expressway. The revetment will tie-in to the existing rock revetment east of Porth Eirias to the west and Splashpoint to the east – the toes and crests would merge as cross-sections are very similar.

Modifications to five existing outfalls would be required along the length of the revetment including extensions and protective slabs where necessary. The revetment toe would need to be widened locally to 7.2m (from typically 3.6m) at two locations. Stainless steel grills would be fixed to the end of each of the three culverts which are to be extended.

A new access build out area would be constructed in the western half of Area 1, located between Porth Eirias and the first set of beach groynes, to the north-east of the picnic area.

New pedestrian accesses through the proposed revetment to comprise three sets of beach access steps perpendicular to the linear rock revetment, would be constructed at the location of each of the three longest groynes within the Scheme area to the west of Rotary Way

The existing groynes present would be retained, maintained and enhanced ecologically. Concrete access steps would be provided across the southernmost section of each groyne adjacent to the revetment.

The existing slipway at Splashpoint would be retained in its current location.

A fishing platform would be constructed in the Splashpoint Area to ensure anglers to not block active travel routes (as is currently the case). The platform would be accessed from a pedestrian only area and extend out over the revetment with supporting steelworks to be pocketed into the raised sea wall structure at this location. Access to fishing platform walkway would have a galvanised steel chain with signage prohibiting access during dangerous weather condition.

The raising of the promenade and the construction of the rock revetment are required to reduce overtopping levels for present day, whilst considering future sea levels as a result of climate change. The new promenade finished level is to be +7.0m OD at directly behind the seawall, with the promenade slabs typically falling approximately 1:40 towards the seawall to allow over the edge drainage for surface water run-off .

In additional to the above works the Scheme will provide:

- Improvements to pedestrian and cycle paths;
- Picnic and outdoor education area;
- Landscape improvements;
- Parking improvements;
- Highway improvements; and
- Concessions building foundation - The actual building for the site is currently unknown and will therefore be subject to its own FCA.

1.4 Construction Works Methodology

The Scheme is currently at detailed design stage and the following is based discussions with the Applicant, examining information from previous Phases of the Colwyn Bay Waterfront Project and some limited Early Contractor Engagement. The below is a preliminary outline methodology and is subject to amendment, consent and construction stage contractor methodology and risk assessments.

1.4.1 Timescales

CCBC are currently seeking funding for these critical works. There are a number of stakeholders and the amount of funding required is considerable, therefore it is not possible at this time to predict when the works may go ahead. However, the following programme assumptions have been made:

- Detailed design of the Project will be complete in Summer 2020;
- Finance is available to enable a Spring 2021 start;
- Planning is granted prior to tender action; and
- The Project is delivered as one scheme.

1.4.2 Promenade and Active Travel Improvements

To provide improved costal protection to the promenade, highway, railways embankment and welsh water assets the promenade crest height would be raised. The existing sea walls would be raised by constructing new reinforced concrete (RC) sea walls on top of the existing, therefore reusing the existing structures as much as possible and reducing associated structural disturbance.

The new RC structures along the promenade seaward edge would not be constructed nor the promenade raised until the new rock revetment is constructed to the existing promenade level. To provide restraint to the existing sea wall, the lower section of existing sea wall would be embedded by fill material and the rock armour would be constructed to rest against the sea wall (as discussed in Paragraph 4.4.54). In the western section, the existing recurved sea wall upstand would remain in place and a mass gravity reinforced concrete stepped wall would be constructed on top. Along the majority of the remaining seaward edge the existing sea wall coping would be locally removed, and a new reinforced concrete balanced cantilevered wall would be built on top.

Possible localised existing voids in the highway and promenade would be remediated (by excavating voids and backfilling with compacted granular fill). Along the lower western highway section and splash point, new drainage pipes, kerbing, services ducts, street lighting / sign foundations and back of promenade retaining wall foundations which are lower than the new finished promenade level would be installed.

Elsewhere where the promenade / Promenade highway would be raised, and the existing surfacing would be perforated for drainage by core drilling on a local grid (so the existing highway can typically remain in-situ). Suitable compacted granular fill in accordance with the specification of highway works (ideally from recycled suitable materials) would be installed in layers. During this process new drainage pipes, services ducts, kerbing, street lighting and sign foundations would be constructed. After the promenade and highway is raised the new RC promenade slabs, highway sub-base and asphalt pavement and footway paving would be installed.

Once the heavy civil engineering works are complete, the street furniture, signs, artwork features, lighting, landscaping, road markings etc would be installed.

1.4.3 Construction Compounds

The location of the construction compounds for the Scheme have not yet been finalised. It is likely that there would be more than one and that there may be several different locations along the promenade within the red line boundary as the Scheme progresses (as dictated by the phasing of construction).

1.5 Requirements of the FCA

This FCA establishes *'whether appropriate mitigation measures can be incorporated within the design of the development to ensure that development minimises risk to life, damage to property and disruption to people living and working on the site or elsewhere in the floodplain*[5].

[5] Welsh Assembly Government. (2004). Planning Policy Wales – Technical Advice Note 15: Development and Flood Risk. [online]. Welsh Assembly Government Available at: https://gov.wales/sites/default/files/publications/2018-09/tan15-development-flood-risk.pdf [Accessed 13 July 2020].

2 Flood Zone Category and Justification

Planning Policy Wales (PPW) edition 9 was published in 2016 and outlines the land use planning policies and the planning system for the Wales. The PPW is supported by the Technical Advice Notes (TANs), including TAN15: Development and Flood Risk. The TAN15 is guidance for Welsh local planning authorities to reduce flood risk and encourage developments away from high risk areas. The TAN 15 provides a framework within which risks arising from both river and coastal flooding, and from additional run-off from development in any location, can be assessed. The TAN15 has been followed within this FCA to justify the proposed Scheme.

Within the TAN15, Wales is divided into three flood zones, with flood zone A representing little to no risk to flood zone C being the areas of higher flood risk. Flood zone C is then further subdivided into flood zones C1 and C2, indicating if the area has defences or not. Table 2.1, taken from the TAN15, outlines these flood zones.

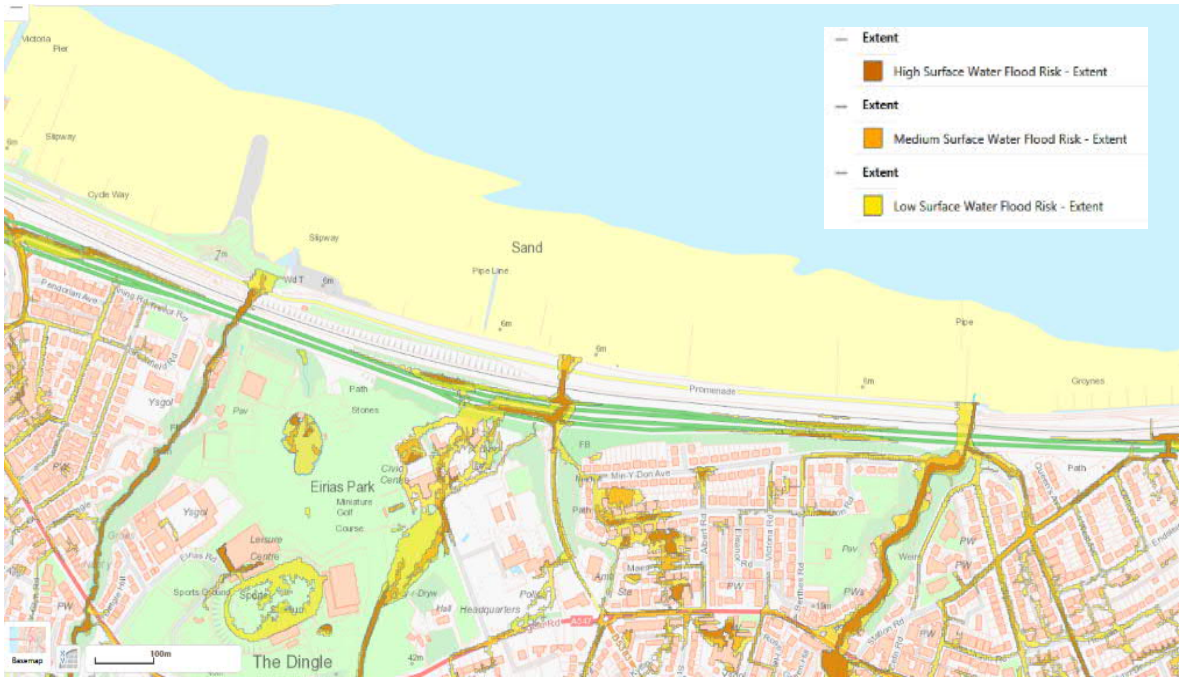
Table 2.1: Flood Zone Classification

Description of zone	Zone	Use Within the Precautionary Framework
Considered to be at little or no risk of fluvial or tidal/coastal flooding.	A	Used to indicate that justification test is not applicable and no need to consider flood risk further
Areas known to have been flooded in the past evidenced by sedimentary deposits.	B	Used as part of a precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. If site levels are greater than the flood levels used to define adjacent extreme flood outline there is no need to consider flood risk further.
Based on Environment Agency extreme flood outline, equal to or greater than 0.1% (river, tidal or coastal)	C	Used to indicate that flooding issues should be considered as an integral part of decision making by the application of the justification test including assessment of consequences.
Areas of the floodplain which are developed and served by significant infrastructure, including flood defences.	C1	Used to indicate that development can take place subject to application of justification test, including acceptability of consequences.
Areas of the floodplain without significant flood defence infrastructure.	C2	Used to indicate that only less vulnerable development should be considered subject to application of justification test, including acceptability of consequences. Emergency services and highly vulnerable development should not be considered.

Source: Welsh Assembly Government, 2004.

Indicated in the Welsh Government Development Advice Map (Figure 2.1), the site is located within Flood Zone C2. This classification indicates the areas is at flood risk of a 1 in 1000-year return period (RP) within any given year.

Figure 2.1: Colwyn Bay Surface Water Flood Risk



Source: Welsh Government, 2017. (Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved. Some features of this information are based on digital spatial data licensed from the UK Centre for Ecology & Hydrology © UKCEH, the Environment Agency © EA and Getmapping Plc and Bluesky International Limited [2015]. Defra, Met Office and DARD Rivers Agency © Crown copyright. © Cranfield University. © James Hutton Institute. Contains OS data © Crown copyright and database right. Land & Property Services © Crown copyright and database right.)

The Welsh Government's Technical Advice Note 15 - Development and Flood Risk (TAN15) Figure 2 outlines the different land uses to flooding. However, coastal defence Schemes are not classified within this land use classification, and therefore fall under 'other' for this FCA assessment. In Section 9 'Summary of Policy Requirements' of the TAN15, development types that are classified as 'other' can be considered within Flood Zone C2. However, the proposed Scheme by virtue of its purpose must be located within the coastal frontage, and as it is a form of flood defence infrastructure, it is not required to be subjected to the justification test of the TAN15.

3 TAN15 Acceptability Criteria

Section 9 ‘Summary of Policy Requirements’ of the TAN15, states that developments classified as ‘other’ within Zone C2 must satisfy the below Acceptability Criteria:

- Acceptable consequence for nature of use;
- Occupiers aware of flood risk;
- Effective flood warning provided;
- Flood resilient design; and
- No increase in flooding elsewhere.

The criteria listed above are reviewed in Section 5 to Section 8. However, the potential sources of flooding are considered in Section 4 to assist with this assessment.

4 Potential Sources of Flooding and Probability

4.1 Coastal Flooding

As the proposed Scheme is a coastal flood defence infrastructure project the primary source of flood risk within the project area is therefore from coastal flooding.

The extreme wave and water levels for the Scheme area were extracted from Modelling completed by Royal Haskoning in 2010[6] at a location offshore from Colywn Bay. These values were propagated from the offshore location to the project area (toe of the proposed rock revetment) by applying the Goda shoaling formula. This calculation was done for four beach profiles within the project area[7]. Present day water levels and climate change water levels (based on UK Climate Projections RCP 8.5 (UKCP 18)[8] in 50 years were assessed to determine the flood risk to the local area from the proposed coastal defence Scheme. A summary of the water levels and extreme wave height is provided in Table 4.1.

It should be noted that the proposed Scheme is adaptable, where the sea defences can be raised in the future in line with sea level rise. This was agreed with the CCBC in order for the Scheme to be cost-effective. Therefore, 50-years of climate change induced sea level rise and a 1 in 100-year return period were the highest events reviewed in this assessment.

[6] Colwyn Bay Detailed Modelling Study for Coast Defence Scheme, Royal Haskoning, June 2010

[7] Mott MacDonald. (2020c). Old Colwyn Promenade Defence & Active Travel Improvements – Wave Overtopping Assessment - 415437-MMD-C-R-00-XX-3000 | P02. Mott MacDonald.

[8] Met Office Hadley Centre. (2018). UK Climate Projections (UKCP 18). [online]. Available at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index [Accessed 14 July 2020].

Table 4.1: Extreme Wave Height and Water Levels

	Present Day					Climate Change Levels - In 50 years				
RP [yrs]	**Water levels [m OD]**	**Profile 1 – Hs***	**Profile 2 – Hs***	**Profile 3 – Hs***	**Profile 4 – Hs***	**Water levels [m OD]**	**Profile 1 – Hs***	**Profile 2 – Hs***	**Profile 3 – Hs***	**Profile 4 – Hs***
1	2.84	1.76	1.68	2.43	2.22	3.43	2.09	2.02	2.44	2.46
	3.29	1.98	1.91	2.22	2.24	3.88	2.18	2.25	2.20	2.24
	3.75	2.00	2.07	2.01	2.05	4.34	1.92	1.96	1.86	1.89
	4.21	1.54	1.56	1.48	1.50	4.8	1.50	1.52	1.46	1.47
	4.67	0.56	0.57	0.55	0.55	5.26	0.55	0.56	0.55	0.55
10	2.84	1.88	1.80	2.55	2.34	3.43	2.20	2.14	2.88	2.67
	3.29	2.12	2.06	2.80	2.59	3.88	2.44	2.4	3.14	2.93
	3.75	2.36	2.31	3.05	2.85	4.34	2.68	2.66	3.27	3.18
	4.21	2.59	2.56	3.09	3.09	4.8	2.91	2.90	3.09	3.11
	4.67	2.82	2.80	2.93	2.95	5.26	2.88	2.98	2.92	2.95
	5.13	2.00	2.03	1.94	1.96	5.72	1.97	1.99	1.91	1.93
50	3.29	2.17	2.12	2.86	2.65	3.88	2.49	2.46	3.19	2.98
	3.75	2.42	2.38	3.11	2.91	4.34	2.74	2.72	3.45	3.24
	4.21	2.66	2.63	3.36	3.15	4.8	2.98	2.97	3.63	3.49
	4.67	2.88	2.87	3.45	3.39	5.26	3.21	3.21	3.45	3.47
	5.13	2.99	3.08	3.03	3.07	5.72	2.99	3.09	2.98	3.02
	5.58	1.86	1.88	1.81	1.83	6.17	1.83	1.85	1.79	1.80
100	3.29	2.20	2.14	2.88	2.67	3.88	2.52	2.48	3.21	3.01
	3.75	2.44	2.40	3.13	2.93	4.34	2.76	2.74	3.46	3.26
	4.21	2.68	2.65	3.38	3.18	4.8	3.00	2.99	3.71	3.52
	4.67	2.91	2.89	3.62	3.42	5.26	3.23	3.23	3.63	3.65
	5.13	3.12	3.12	3.34	3.36	5.72	3.27	3.38	3.31	3.36
	5.58	2.88	2.98	2.90	2.94	6.17	2.89	2.98	2.87	2.90

Source: Mott MacDonald, 2020

**Hs – significant wave height*

As shown on the cross-section drawings in Appendix B, the proposed Scheme will have the revetment set at +7.50m OD and the promenade at +7.00 OD. Comparing the extreme wave height and water levels in Table 4.1 above, it is evident that the proposed coastal defences will not results in flooding behind the promenade due to high water levels or extreme wave height under present day condition up to a 1 in 50 year RP and up to a 1 in 1 year RP in 50 years with climate change, but it is likely to flood under a 1 in 100 RP under present day conditions and for a 1 in 10 year RP or higher in 50 years with climate change.

However, the risk of flooding along the frontage arises from wave overtopping of the coastal defences. Both mean overtopping discharge (*q*), which is the average overtopping from all waves, and individual maximum overtopping volume (*Vmax*), which is the maximum discharge from a single wave, were assessed in the Mott MacDonald Overtopping Assessment[7]. These values are present in Table 4.2 below.

Table 4.2: Overtopping Results

		Present Day		In 50 years	
Profile	**Return period [yrs]**	**q [l/m/s]**	**Vmax [l/m]**	**q [l/m/s]**	**Vmax [l/m]**
1	1	0	89	0	252
	10	13	575	35	7,143
	50	39	958	81	12,520
	100	54	1,010	138	19,809
2	1	0	120	0	563
	10	12	557	41	8,434
	50	48	1,122	91	13,574
	100	68	1,200	154	22,345
3	1	0	215	0	265
	10	18	692	37	7,477
	50	60	1,622	98	17,052
	100	83	2,077	144	20,478
4	1	0	153	0	294
	10	19	714	39	7,810
	50	54	1,496	100	17,376
	100	86	1,795	150	21,136

Source: Mott MacDonald. (2020c). Old Colwyn Promenade Defence & Active Travel Improvements – Wave Overtopping Assessment - 415437-MMD-C-R-00-XX-3000 | P02. Mott MacDonald

Following the criteria set out in the EurOtop II Manual[9] and in the EurOtop Manual[10], the overtopping limits for structural designs and to people and vehicles were reviewed. **Error! Reference source not found.** presents these overtopping discharge limits.

Table 4.3: Recommended Discharge Limits for Assets and Users

Type	Limit	Return Period [yrs]
Surface	**q [l/m/s]**	
Paved	200	100
Grass	50	100
User	**Vmax [l/m]**	
Pedestrian	600	1 - 10
Vehicle	2,000	1 - 10

Source: EurOtop II Manual and EurOtop Manual

The proposed Scheme consists of a revetment set at +7.50m OD and the promenade at +7.00 OD. From the overtopping assessment it can be seen that the paved area of the promenade will not be damaged during the lifetime of the project. However, mitigation measures, such as road / promenade closures during severe storms will be required, along with barriers to prevent vehicle and pedestrian access along the promenade.

[9] Van der Meer, J., Allsop, N., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., . . . Zanuttigh, B. (2018). EurOtop. Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. [online]. Available at: www.overtopping-manual.com [Accessed 13 July 2020].

[10] Pullen, T., Allsop, N. W., Bruce, T., Kortenhaus, A., Schüttrumpf, H., & Meer, J. W. (2007). EurOtop. Wave Overtopping of Sea Defences and Related Structures: Assessment Manual. Die Küste.

4.2 Fluvial Flooding

There are three fluvial watercourses which discharge to the beach to the east of Porth Eirias, two of which are located within the red line boundary:

- The Nant-y-Groes (classified as a Main River by NRW flood mapping) is present to the immediate west of the Scheme area, discharging to the beach via a culvert that passes beneath Porth Eirias at approximate NGR 285760, 378946. The Nant-y-Groes is classified as a Main River by NRW flood mapping ;
- A small watercourse, Llwyd, (classified as a Main River by NRW flood mapping although in reality is a small overflow from the lake at Eirias Park) is culverted and is understood to discharge to the beach at approximate NGR 285877, 378888 within the Scheme area to the east of Porth Eirias. The culvert flows beneath a sports centre and recreational ground before discharging to the beach; and
- The Nant-y-Fynnon (Ordinary Watercourse) passes through Old Colwyn, flowing in an artificial channel down Beach Road and beneath the A55 Expressway before being culverted beneath the NWC Railway Line and outfalling directly onto the beach at Splashpoint at approximate NGR 287008, 378709.

This Scheme focuses on the impact of overtopping on the frontage. The diversion of the existing outfalls along the beach within the Scheme will allow the rivers to flow as they do at present and therefore not result in an increase in fluvial flooding.

4.3 Surface Water Flooding

The Environment Agency's 'Risk of Flooding from Surface Water' online maps shows that there is some surface water flood risk in the area of interest (Figure 2.1). However, the majority of these surface water sources are culverted under the promenade before discharging to the beach. In general, surface water runoff from the promenade and highway area flows into outfalls and directly to the foreshore and into the sea. Additionally, for the Scheme, the promenade will be at a higher elevation at the retainer wall and will have a decreasing profile of 1:40 towards the top of the rock revetment, so that any surface water on the promenade will drain out towards the sea. Furthermore, kerbside drains, along the highway, will direct surface water flooding through outfalls under the promenade out to sea as well.

4.4 Construction Flood Risk Management

During site clearance, existing rock armour is to be removed and re-used where appropriate in accordance with specification.

The Contractor would produce a Construction Flood Risk Management Plan to set out the methodology to be followed during construction to ensure coastal protection of the site is maintained throughout the construction phase.

This plan would also set out the emergency access and egress procedures and specific site precautions necessary to protect both human life and the environment in the case of storm overtopping events occurring during the construction period.

The placement of stockpiled rock armour immediately seaward of where it is to be used within the revetment would help to dissipate wave energy and provide some limited additional protection during any storm events.

4.5 Potential Flooding impacts of Proposed Scheme

The impacts on flood risk during the construction of the Scheme are considered to be mostly negligible[4]. It is also assumed that the Contractor would develop and implement a robust flood management plan during the works. The construction site, equipment and timing of construction activity would need to consider the risk of flooding from tidal and wave conditions as best practice.

Table 4.4: Potential impacts of proposed Scheme

Effects	Construction	Operation
Potential Insignificant Effects	Construction site and equipment could be at risk of getting inundated from overtopping. It is assumed the Contractor would have a flood risk management plan in place.	The Scheme would provide additional tidal flood protection for Colwyn Bay, however, there is still a residual risk and the Flood Management Plan would need to be reviewed and updated.
Potential Significant Effects	N/A	The installation of the new coastal defences strongly complies with policy objectives. Overall, the impact of the Scheme is considered to be significantly beneficial as it would provide additional tidal flood protection for Colwyn Bay

Source: Mott MacDonald Ltd, 2020

5 Acceptable Consequences for Nature of Use

Section A1.14 of the TAN15 outlines that there is '*a frequency threshold of flooding below which flooding of development should not be allowed.*'[5]. **Error! Reference source not found.**, from the TAN15, outlines an indicative guidance on what the frequency threshold might be for different type of developments, in terms of annual probability of occurrence.

Table 5.1: Flood Frequency Thresholds from TAN15

Type of Development	Threshold Frequency (Yrs)	
	Fluvial	**Tidal**
Residential	1%	0.5%
Commercial/ retail	1%	0.5%
Industrial	1%	0.5%
Emergency services	0.1%	0.5%
General infrastructure	1%	0.5%

Source: Welsh Assembly Government, 2004

As shown in **Error! Reference source not found.**, no flooding should occur during a 0.5% (1 in 200-year RP) for general infrastructure over the lifetime of the proposed Scheme. As presented in Table 4.1 in Section 4, the proposed Scheme will not flood due to high water levels or extreme wave height.

From A1.15 of the TAN15, beyond the threshold frequency outlined above, the proposed development would be expected to flood under extreme conditions. **Error! Reference source not found.** presents the indicative guidance from the TAN15 on what is considered to be tolerable flood conditions for different types of developments.

Table 5.2: Tolerable Conditions from TAN15

Type of Development	Maximum Depth of Flooding (mm)	Maximum Rate of Rise of Floodwaters (m/hr)	Maximum Speed of inundation (of flood risk area (hrs))	Maximum Velocity of Foodwaters (m/s)
	Property Access			**Property Access**
Residential (habitable rooms)	600 600	0.1	4	0.15 0.3
Commercial/ retail	600 600	0.3	2	0.15 0.3
Industrial	1000 1000	0.3	2	0.3 0.45
Emergency services	450 600	0.1	4	0.15 0.3
General infrastructure	600 600	0.3	2	0.3 0.3

Source: Welsh Assembly Government, 2004

As outlined in Table 4.2 and table 4.3 indicates the proposed Scheme will experience significant overtopping but the flood depths will not exceed the discharge limit for a paved surface, such as the paved promenade. Therefore, the paved promenade will not be damaged during extreme events. The proposed Scheme is adaptable, and the sea defences can be raised in the future in line with sea level rise. This was agreed with the CCBC in order for the Scheme to be cost-effective. At present the promenade is closed during events, approximately a dozen times a year that lead to significant overtopping. The proposed Scheme would reduce the number of times the promenade would need to be closed, whilst remaining economically viable and minimising the carbon footprint of the Scheme which would be better used for future Schemes when raising the coastal defences in line with sea level rise.

Mitigation measures for the risks to pedestrians and vehicles are discussed and outlined in Section 7.

6 Occupiers Awareness of Flood Risk and Flood Warnings Procedures

As this is a coastal defence Scheme, there will be no direct resident or business occupants to inform in the event of a flood warning being issued. However, in the event of a flood warning being issued the Council will install signs at either end of the promenade road and where road barriers are located to inform users that the promenaded is closed and that a flood warning has been issued.

Presently CCBC close the promenade to the public during times of flooding caused by overtopping. The key elements of this procedure are:

- The trigger tide levels of 3.9m OD or greater are predicted;
- The trigger conditions and relevant data are reviewed. This is followed by the decision of the closure of the promenade, which is taken by Council staff from the FR&I, OS and HM departments. County Councillors for the immediate location are informed directly and CCBC's marketing department inform the general public via social media;
- The road barrier at Cliff Gardens is closed first, followed by a walk through the Promenade length to inform remaining cars, followed by closure of the road barrier at Rotary Way junction. Temporary signs are installed at all road barrier locations to inform users the promenaded is closed;
- When the high tide has passed, an inspection of the coastal defence is carried out by FR&I to record condition and to ensure that the promenade is safe to re-open. Any debris on the promenade from the storm cleared before re-opening; and
- County Councillors for the immediate location are informed directly and CCBC's marketing department inform the general public via social media that the promenade has been re-opened.

As the closure of the promenade occurs approximately a dozen times a year for several days, the procedure outlined above should therefore continue when a flood warning is issued in the case of extreme storm events beyond a 1 in 10-year return period.

7 Flood Resilient Design

The primary flood resilient design aspect of this Scheme is the raising of both the revetment and promenade. The rock revetment will be raised to +7.50m OD and the promenade to +7.00m OD. Raising these structures will reduce the current frequency of coastal flooding and overtopping volumes.

The promenade will also be at a higher elevation at the retainer wall and will have a decreasing profile of 1:40 towards the top of the rock revetment, so that any surface water on the promenade will drain out towards the sea.

Additionally, between the promenade highway and the retainer wall of the promenade, kerbs drains will be installed. These kerb drains will direct any surface water away from the highway through an outfall that drains under the promenade and into the rock revetment at approximately +7.00m OD. As water levels do not reach this elevation these outfalls will not experience tidal locking and thus will remain free draining during an overtopping event.

The Scheme will also tie into the current sea defences at Porth Eirias to the west, which are already at +7.00m OD and into the raised footpath defences to the east at Splashpoint, where a flood gate will be installed across the current slipway.

Furthermore, the new promenade and rock revetment are proposed to be adaptable for future sea level rise, beyond the current 50-year allowance, through the modification of the cross section by adding additional layers of rock or reconstructing the design profile. Raising the sea defences later on is judged as a more cost-efficient approach rather than raising the promenade to 120-year design criteria at present day.

8 No Increase in Flooding Elsewhere

The proposed coastal defences are at risk of significant overtopping under a 1 in 10-year event and beyond, under present conditions. However, the risk of overtopping is only restricted to the promenade area and promenade highway, and the proposed defences will improve the level of protection from present day levels.

Existing drainage outfalls through the seawall will be maintained by extending outfalls through the proposed rock revetment. The promenade will be profiled to encourage drainage out to sea, and kerbside drains will direct surface water flooding through outfalls under the promenade out to sea as well.

The Scheme is also tying into sea defences at both Porth Eirias and at Splashpoint. This will therefore significantly reduce flood waters entering areas adjacent to the Scheme therefore, lowering the risk of coastal flooding for both these Scheme and surrounding areas.

Consequently, the proposed design will have an improvement on flood risk to the infrastructure at present rather than a negative impact.

Additionally, , the impacts on flood risk during the construction of the Scheme are considered to be mostly negligible. The construction site, equipment and timing of construction activity would need to consider the risk of flooding from tidal and wave conditions as best practice.

9 Summary and Conclusions

The proposed Scheme comprises of coastal defence works in the form of a new rock revetment and promenade raising. The development forms part of the for the Old Colwyn Coastal Defence and Active Travel Scheme. The coastal defences must be located along the coastal frontage by virtue of their purpose.

The proposed Scheme will have the revetment set at +7.50m OD and the promenade at +7.00 OD. The Scheme will experience significant overtopping, though impacts are restricted to the promenade area and promenade highway, and will exceed the discharge limit for users under a number of return periods for both present day and in 50 years. Pedestrians on the promenade will be at risk under a 1 in 10-year event under present day conditions, and both pedestrians and vehicles (on the promenade highway) will be at risk under a 1 in 10-year event in 50 years. However, overtopping will not exceed the discharge limit for a paved surface, such as the paved promenade. Therefore, the paved promenade and promenade highway will not be damaged during extreme events, behind the crest of the revetment / seawall of this Scheme.

The flood risk to pedestrians and vehicles will be mitigated through flood warning systems, signage, barriers to restrict access to the promenade, maintaining existing drainage outfalls through the seawall, and by extending outfalls through the proposed rock revetment. The promenade will be profiled to encourage drainage out to sea, and kerbside drains will direct surface water flooding through outfalls under the promenade out to sea as well. The Scheme is also tying into sea defences at both Porth Eirias and at Splashpoint, this will therefore significantly reduce flood waters entering areas adjacent to the Scheme. Therefore, lowering the risk of coastal flooding for both these Scheme and surrounding areas.

10 Recommendations

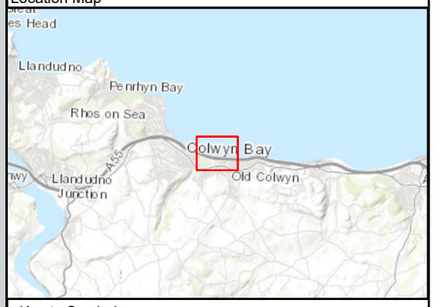
The proposed Scheme should maintain the existing drainage outfalls through the seawall and extend the outfalls through the proposed rock revetment. The promenaded will also need to be graded to encourage surface water drainage out to sea and kerb drains to be installed to direct surface water from the promenade highway under the promenade out to sea.

A Flood Management Plan, defining the conditions requiring promenade/road closures during the operational phase, should be prepared, and signage install along the promenade to inform users of the risk of flooding in the area.

A copy of this report should be submitted to the Planning Authority in support of the planning application.

A. Location Plan and Existing Arrangement

Location Map



Key to Symbols

Red line boundary

Notes

1. For information only, not for construction.
2. Contains Ordnance Survey data © Crown copyright and database rights 2019 Ordnance Survey. All rights reserved.
3. Contains OS data © Crown Copyright and database right 2020 Contains data from OS Zoomstack, Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	23/07/20	MH	For information	NS	CW

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Client

CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Conwy County Borough Council

Title

Old Colwyn Coastal Defence and Active Travel Scheme
Anticipated principal working area buffer (approximate only)
Red Line Boundary

Designed	N Spofforth	NS	Eng. Check	N Spofforth	NS
Drawn	M Hayward	MH	Coordination	N Spofforth	NS
GIS Check	G O'Donovan	GO	Approved	C Williams	CW

Scale at A3	Status	Rev	Security
1:5,000	INF	P1	STD

Drawing Number
415437-MMD-00-XX-DR-N-1707

0 100 200 300 400 500 Meters

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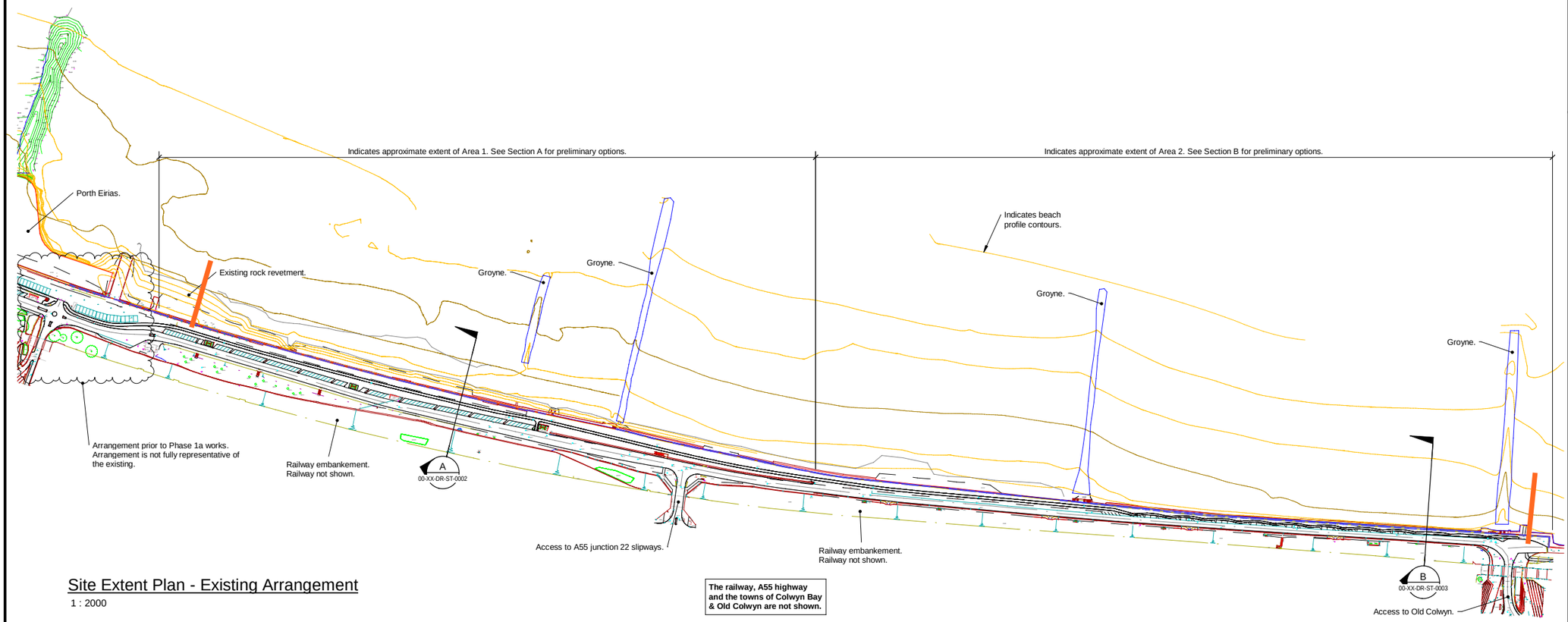
Location Plan

1 : 20000



Site Extent Plan - Existing Arrangement

1 : 2000

The railway, A55 highway and the towns of Colwyn Bay & Old Colwyn are not shown.

Notes

1. Unless otherwise noted (UNO), all dimensions are in millimetres, all levels are in meters above ordnance datum (AOD). Do not scale from drawing, if in doubt ask.
2. The offshore topographical survey was supplied by Survey Operations Ltd in April 2010. The onshore topographical survey was supplied by Conwy County Borough Council in xxxxxx.
3. Structural drawings do not show full extent and location of services. See statutory undertakers plans for services information.
4. Proposals are preliminary and subject to change pending detail design and consultation.
5. Further options are possible subject to review of coastal modelling and consultation.

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	04.02.2020	JH	PRELIMINARY ISSUE	GWM	DRG

Status Stamp

NOT FOR CONSTRUCTION

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Client

CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Title

Old Colwyn Promenade Coastal Defence & Active Travel Improvements
LOCATION PLAN & SITE EXTENTS
LOCATION PLAN & SITE EXTENTS
LOCATION PLAN & SITE EXTENTS

Designed	J. Hughes		Eng.check.	Not applicable	
Drawn	J. Hughes		Coordination	G. Mitchell	
Dwg.check.	G. Mitchell		Approved	Approver	

MMD Project Number	Scale at A1	Security
415437	As indicated	STD

Suitability Description	Suit. Code
Suitable for Review & Comment	D4

Drawing Number	Rev
415437-MMD-00-XX-DR-ST-0001	P1

Porth Eirias

Splashpoint

Location Map

Key to Symbols

- Red line boundary
- Area of permanent construction
- Ecological enhancements only

Notes

1. For information only, not for construction.
2. Contains Ordnance Survey data © Crown copyright and database rights 2019 Ordnance Survey. All rights reserved.
3. Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	23/07/20	SA	For information	NS	CW

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CONWY CYNGOR BWRDEISTREF SIROL COUNTY BOROUGH COUNCIL

Conwy County Borough Council

Title Old Colwyn Coastal Defence and Active Travel Scheme
Area of Permanent Construction

Designed	N Spofforth	NS	Eng. Check	N Spofforth	NS
Drawn	S Anstice	SA	Coordination	N Spofforth	NS
GIS Check	G O'Donovan	GO	Approved	C Williams	CW

Scale at A3	Status	Rev	Security
1:5,000	INF	P1	STD

Drawing Number
415437-MMD-00-XX-DR-N-1708

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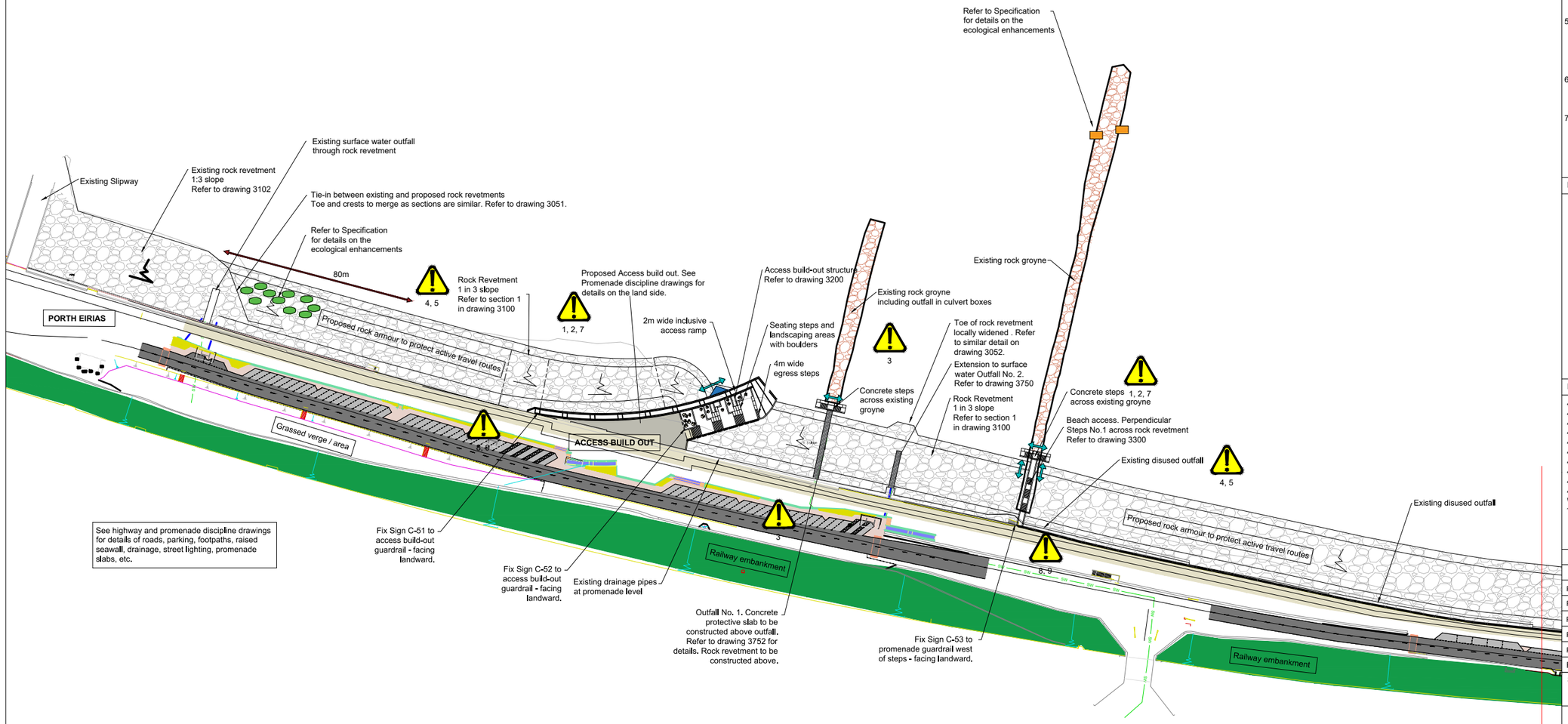
B. Proposed Scheme Plan and Cross-Sections



Location Plan - Area 1
1:1000

Safety, Health & Environmental Information

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement.

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following risks and information:

CONSTRUCTION

1 Depth and full extent of existing seawall foundations are unknown. Existing seawall becomes destabilised (DHER Ref. 19 & 23).
2 Unforeseen ground conditions/obstructions prevent sheet piles being driven (DHER Ref. 20).
3 The status (i.e. disused or live) and precise positions of some outfalls are unknown (DHER Ref. 21).
4 Falling from height. Falling objects from promenade (DHER Ref. 22).
5 Working in tidal zone (DHER Ref. 27).
6 Presence of Unexploded ordnances (UXOs). Site area categorised as low risk. (DHER Ref. 30).

OPERATION AND MAINTENANCE

7 Beach levels to be reinstated to existing levels or higher after completion of works. Beach levels shall be monitored at regular intervals including before and after storms and at least once a year in spring (DHER Ref. 4).
8 Marine growth to be removed periodically from pedestrian access surfaces (DHER Ref. 5).

1:1000 0 50m 100m

Notes

1. This drawing is to be read in conjunction with all discipline drawings, specifications and standards.
2. Unless otherwise noted (UNO), all dimensions are in millimetres, all levels are in meters above ordnance datum (AOD), and all setting-out points in millimeters to the British National Grid (OSGB36). Do not scale from drawing, if in doubt ask.
3. All relevant setting-out points, dimensions & levels are to be checked by Contractor on-site prior to commencement of the works.
4. The onshore topographical survey was supplied by Survey Operations Ltd in April 2008. The offshore topographical (beach) survey was supplied by Environmental & Engineering Services in 2019. The CCTV survey was supplied by Invek Surveys Ltd in May 2020.
5. Drawings show approximate position of known services. See Site Information for further information. Further unknown services maybe present. Contractor to undertake survey to determine full extent of services present within working area. Results to be forwarded to the Structural Design Engineer 2 week prior to commencement of works, or ordering of materials, whichever occurs first.
6. See 415437-MMD-00-XX-DR-C-2000 series drawings for the proposed promenade works. See 415437-MMD-00-XX-DR-D-0000 to 1399 series drawings for the proposed highway & drainage works.
7. Refer to Appendix 12/1 of the Works Specification for all the sign details.

Key to symbols

- Existing railway enbankment
- Proposed extent of highway
- Group of 5 Vertipools fixed to wall
- Textured outer walls
- Enhancement of rocks
- Rock structures
- Fishing platform
- Outfall extension/ protection
- Tidal pools
- Ecological Armouring unit

Reference drawings

415437-MMD-00-XX-DR-C-3051 - Plan at Porth Eirias End
415437-MMD-00-XX-DR-C-3052 - Plan at Splash Point End
415437-MMD-00-XX-DR-C-3100 - Revetment Cross Sections - Sheet 1 of 3
415437-MMD-00-XX-DR-C-3102 - Revetment Cross Sections - Sheet 3 of 3
415437-MMD-00-XX-DR-C-3200 - Access Build-Out Plan
415437-MMD-00-XX-DR-C-3300 - Perpendicular Steps No.1 Plan
415437-MMD-00-XX-DR-C-3750 - Outfall Extensions and Culvert Cross Sections
415437-MMD-00-XX-DR-C-3752 - Outfall No. 1 Protection Details
415437-MMD-00-XX-DR-C-2000 series - Promenade Works
415437-MMD-00-XX-DR-D-0000 to 1399 series drawings - Highway and Drainage Works
19.537 - 100 Old Colwyn GA Landscape Drawing

Rev	Date	Drawn	Description	Ch'k'd	App'd
P05	17/07/20	AA	Construction Issue for Client Approval	AD	ZH
P04	26/06/20	AA	Construction Issue for Client Approval	AD	ZH
P03	27/04/20	ZD	Tender Issue for Client Comments	AD	ZH
P02	25/03/20	ZD	Second Issue for Internal Comments	AD	ZH
P01	12/03/20	ZD	First Issue for Comments	AD	ZH

Status Stamp

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CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Title
Old Colwyn Promenade Coastal Defence & Active Travel Improvements

General Arrangement Plan - Area 1 Sheet 01 of 02

Designed	P. Kacperek	PK	Eng check	A Douglas	AD
Drawn	A. Al-Abdullah	AA	Coordination	F. Loy	FL
Dwg check	D. Sciuto	DS	Approved	Z. Hutchison	ZH

MMD Project Number	Scale at A1	Security
415437	1:1000	STD
Suitability Description: Issue for Construction Approval		Suit. Code: S4
Drawing Number: 415437-MMD-00-XX-DR-C-3001		Revision: P05

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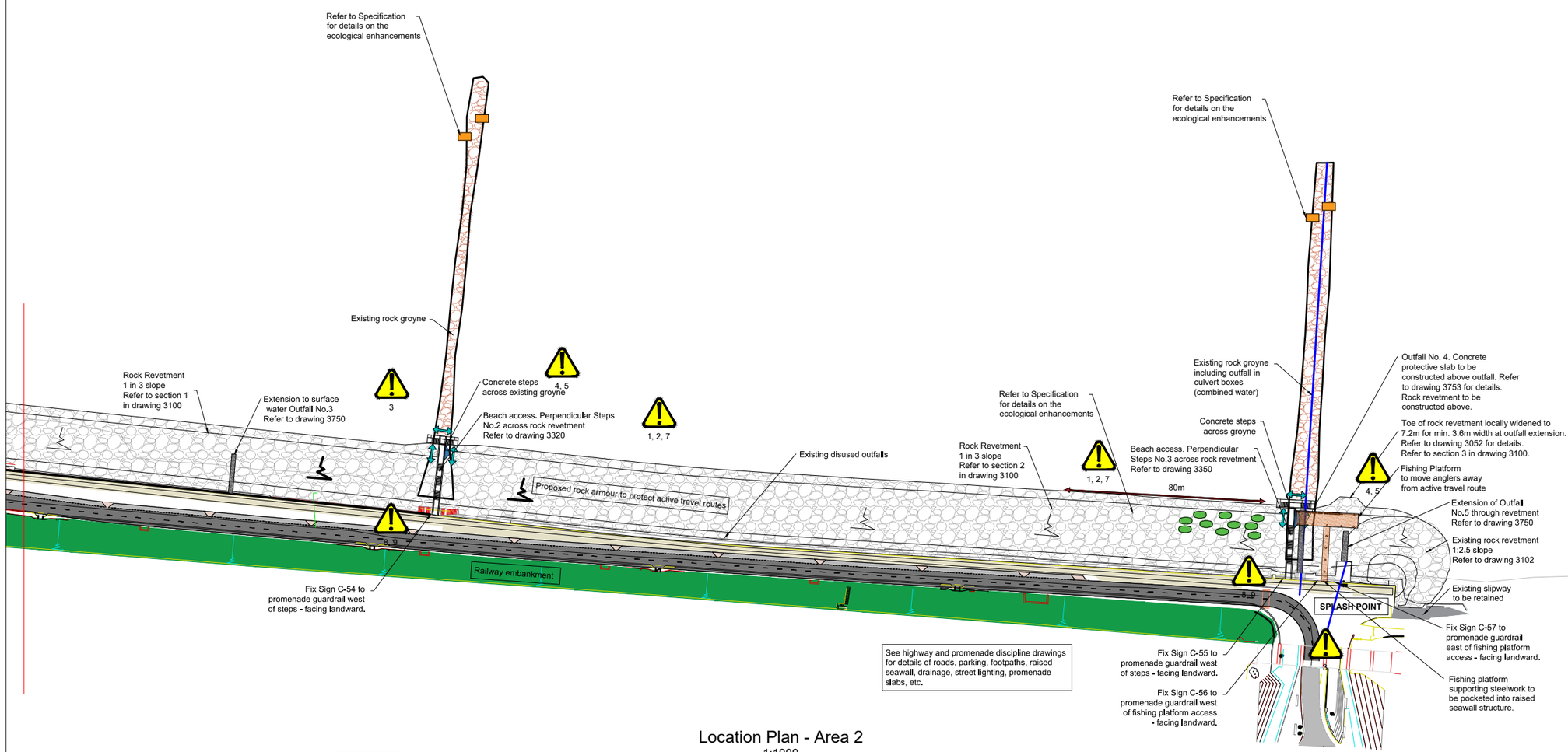

Location Plan - Area 2
1:1000

0 50m 100m
1:1000

Safety, Health & Environmental Information

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement.

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following risks and information:

CONSTRUCTION

1 Depth and full extent of existing seawall foundations are unknown. Existing seawall becomes destabilised (DHER Ref. 19 & 23).
2 Unforeseen ground conditions/obstructions prevent sheet piles being driven (DHER Ref. 20).
3 The status (i.e. disused or live) and precise positions of some outfalls are unknown (DHER Ref. 21).
4 Falling from height. Falling objects from promenade (DHER Ref. 22).
5 Working in tidal zone (DHER Ref. 27).
6 Presence of Unexploded ordnances (UXOs). Site area categorised as low risk. (DHER Ref. 30).

OPERATION AND MAINTENANCE

7 Beach levels to be reinstated to existing levels or higher after completion of works. Beach levels shall be monitored at regular intervals including before and after storms and at least once a year in spring (DHER Ref. 4).
8 Marine growth to be removed periodically from pedestrian access surfaces (DHER Ref. 5).

Notes

1. This drawing is to be read in conjunction with all discipline drawings, specifications and standards.
2. Unless otherwise noted (UNO), all dimensions are in millimetres, all levels are in meters above ordnance datum (AOD), and all setting-out points in millimeters to the British National Grid (OSGB36). Do not scale from drawing, if in doubt ask.
3. All relevant setting-out points, dimensions & levels are to be checked by Contractor on-site prior to commencement of the works.
4. The onshore topographical survey was supplied by Survey Operations Ltd in April 2008. The offshore topographical (beach) survey was supplied by Environmental & Engineering Services in 2019. The CCTV survey was supplied by Invek Surveys Ltd in May 2020.
5. Drawings show approximate position of known services. See Site Information for further information. Further unknown services maybe present. Contractor to undertake survey to determine full extent of services present within working area. Results to be forwarded to the Structural Design Engineer 2 week prior to commencement of works, or ordering of materials, whichever occurs first.
6. See 415437-MMD-00-XX-DR-C-2000 series drawings for the proposed promenade works. See 415437-MMD-00-XX-DR-D-0000 to 1399 series drawings for the proposed highway & drainage works.
7. Refer to Appendix 12/1 of the Works Specification for all the sign details.

Key to symbols

- Existing railway enbankment
- Proposed extent of highway
- Group of 5 Vertipools fixed to wall
- Textured outer walls
- Enhancement of rocks
- Rock structures
- Fishing platform
- Outfall extension/ protection
- Tidal pools
- Ecological Armouring unit

Reference drawings

415437-MMD-00-XX-DR-C-3052 - Plan at Splash Point End
415437-MMD-00-XX-DR-C-3100 - Revetment Cross Sections - Sheet 1 of 3
415437-MMD-00-XX-DR-C-3102 - Revetment Cross Sections - Sheet 3 of 3
415437-MMD-00-XX-DR-C-3320 - Perpendicular Steps No. 2 Plan
415437-MMD-00-XX-DR-C-3350 - Perpendicular Steps No. 3 Plan
415437-MMD-00-XX-DR-C-3450 - Fishing Platform Plan
415437-MMD-00-XX-DR-C-3750 - Outfall and Culvert Cross Sections
415437-MMD-00-XX-DR-C-3753 - Outfall No.4 Protection Details
415437-MMD-00-XX-DR-C-2000 series - Promenade Works
415437-MMD-00-XX-DR-D-0000 to 1399 series drawings - Highway and Drainage Works
19.537 - 100 Old Colwyn GA Landscape Drawing

Rev	Date	Drawn	Description	Ch'k'd	App'd
P05	17/07/20	AA	Construction Issue for Client Approval	AD	ZH
P04	26/06/20	AA	Construction Issue for Client Approval	AD	ZH
P03	28/04/20	ZD	Tender Issue for Client Comments	AD	ZH
P02	13/04/20	ZD	Second Issue for Internal Comments	AD	ZH
P01	12/03/20	ZD	First Issue for Comments	AD	ZH

Status Stamp

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Client
CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Title
Old Colwyn Promenade Coastal Defence & Active Travel Improvements General Arrangement Plan - Area 2

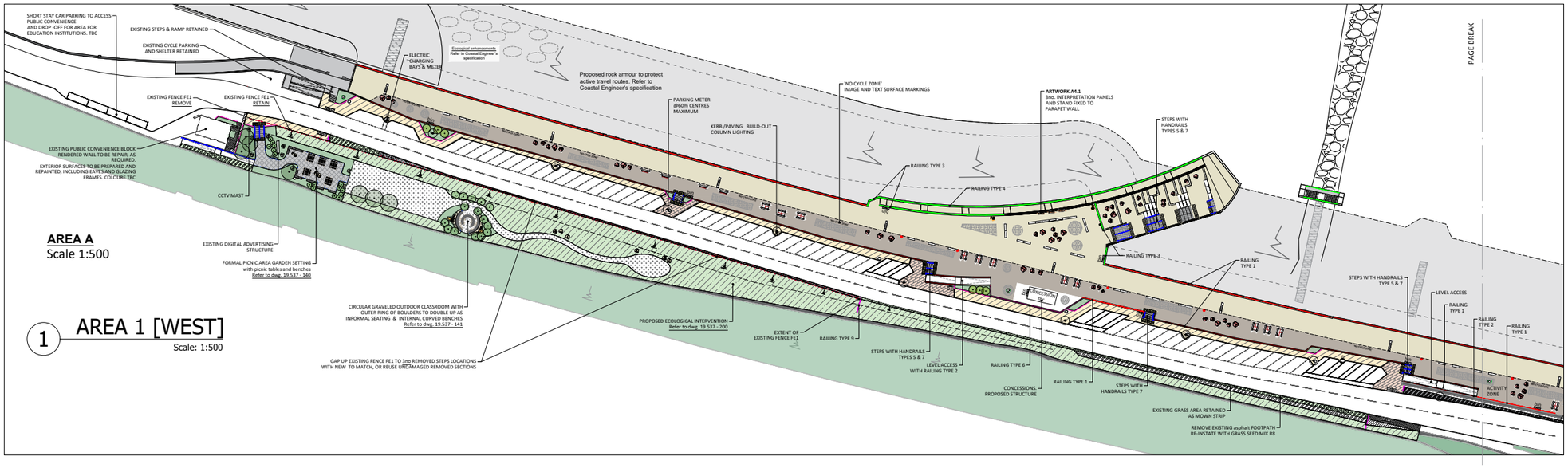
Sheet 02 of 02

Designed	P. Kacperek	PK	Eng check	A. Douglas	AD
Drawn	A. Al-Abdullah	AA	Coordination	F. Loy	FL
Dwg check	D. Sciuto	DS	Approved	Z. Hutchison	ZH

MMD Project Number	Scale at A1	Security
415437	1:1000	STD

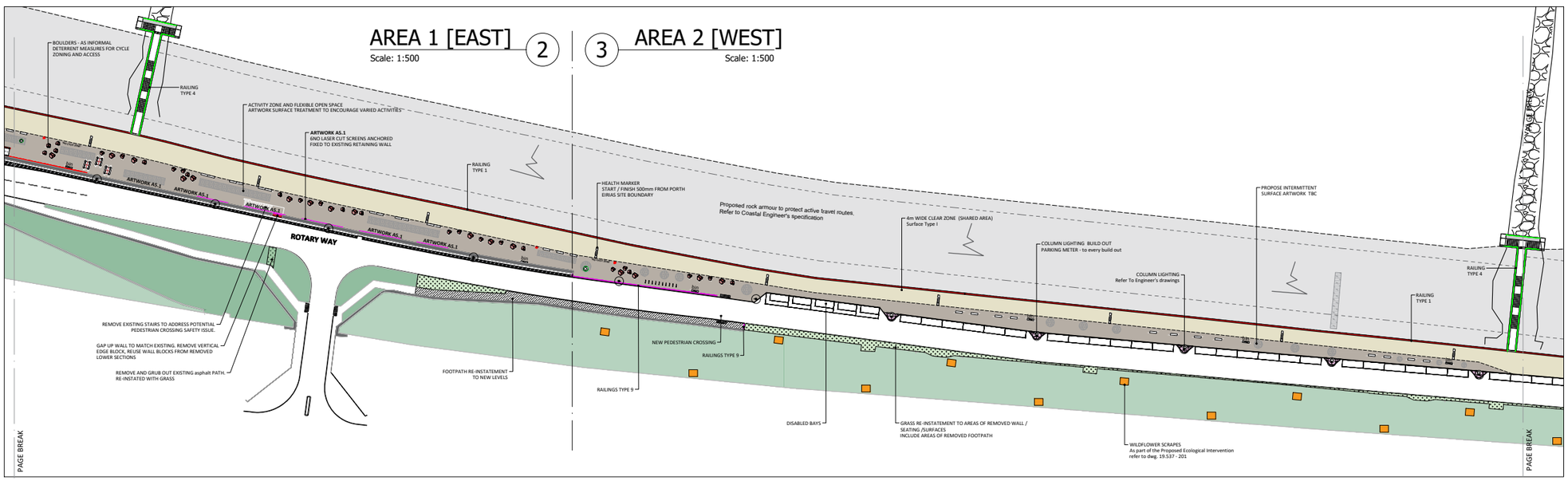
Suitability Description	Suit. Code
Issue for Construction Approval	S4

Drawing Number	Revision
415437-MMD-00-XX-DR-C-3002	P05



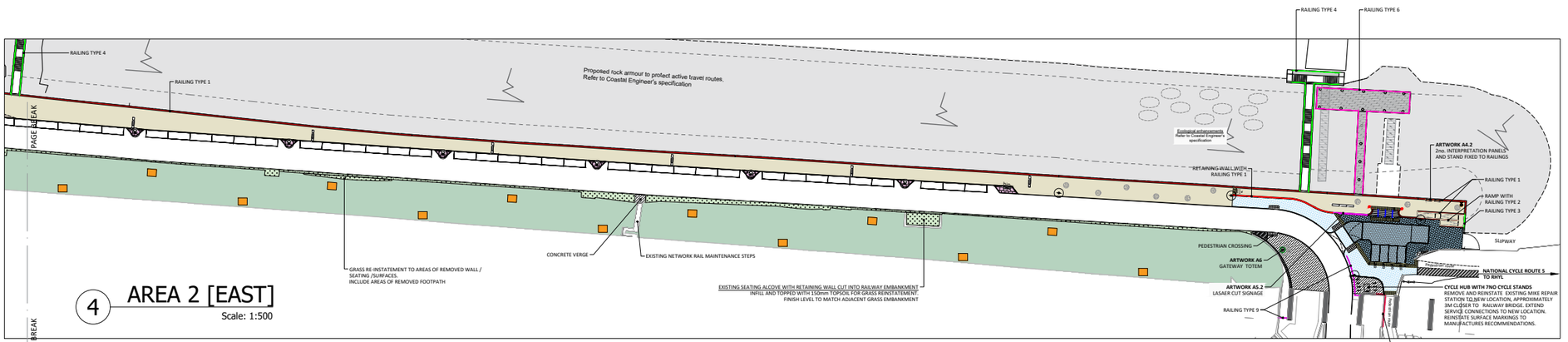
AREA A
Scale 1:500

1 AREA 1 [WEST]
Scale: 1:500



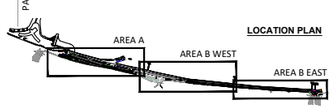
2 AREA 1 [EAST]
Scale: 1:500

3 AREA 2 [WEST]
Scale: 1:500



4 AREA 2 [EAST]
Scale: 1:500

LOCATION PLAN



N

0 10 20 30 40 50 75 100
metre

EDGINGS
ALL HIGHWAY KERBS AND EDGINGS TO MOTT'S SPECIFICATIONS AND DESIGN

PCC granite aggregate edgings

- Type EF1: 145 x 255 Conservation Kerb 100mm upstand
- Type EF2 : 145 x 145 Conservation Centre Stone Flush edging
  Product: Conservation Kerb Edging. Supplier: Marshalls or similar approve
- Type EF5: 50 x 150 pcc flat top pin kerb, flush

Picnic Area Metal Edging:

- Type EF3 Picnic Area only. Product: Pro Edge DP7. 150mm high x 2500mm long x 2.5mm thick. Finish: galvanised, slate
- Type EF4 Outdoor Classroom only. Product: Pro Edge BP7. 100mm high x 2500mm long x 2.5mm thick. Finish: galvanised, slate

SURFACES
REFER TO MOTT'S SERIES 1100 DRAWINGS FOR FOR BUILD-UP SPECIFICATIONS

UNIT PAVING.
All unit paving to be 'Kellen', to match previous phases. Supplier: Hardscape Ltd

AREA 1

TYPE A 653m²
Flexible construction.
60mm thick
Location: footpath adjacent to parking zone
Sizes flinshes:
General paving : 300 x (300/600): Finish: Wit
Wall trim and banding : 100 x 300; Finish: Rood

TYPE B 153m²
Flexible construction.
Location: pavement build outs at promenade access points
80mm thick, Kellen
Size: 200 x 600
Finishes: Rood, Rood/Zwart, Oranje, Girjs/Rood, Grijs

AREA 2

TYPE C 65m²
Rigid construction.
Location: pavement build outs
Size: 200 x 600
Finish: Wit

SPLASH POINT

TYPE D1 143m²
Rigid construction.
Pedestrian Area: laid as stretched bond;
Size: 200 x 600
Finishes: Girjs/rood: Girjs/

TYPE D2 212m²
Rigid construction.
Cycle track: laid as stretched bond;
Size: 200 x 600
Finish: Girjs

TYPE D3 167m²
Rigid construction.
Vehicle zone: laid as herringbone;
Size: 200 x 600
Finishes: As per Pedestrian Zone

PICNIC AREA

TYPE E 176m²
Flexible construction.
Size: 150 x 150 x 80mm thick
Finish: grijs/rood, grijs & wit.

OUTDOOR CLASSROOM

TYPE F 41m²
LOOSE AGGREGATE
500 x 500mm interlocking format Suregreen PP50 plastic cell blocks on 35mm 10-20 free draining, sharp angular 10-20mm Welsh Brown gravel on 100mm Type 3 sub base.
Edging Type EF3

ASPHALT

TYPE G 401m²
FOOTPATH RE-INSTATEMENT
Dense asphalt concrete surface course on 50mm AC20 dense asphalt concrete binder course on 200mm Type 1 sub-base.

TYPE H 38m²
ASPHALT SURFACE COURSE RE-INSTATEMENT
Remove existing surface course, re-instate with dense asphalt concrete surface course as part of adjacent new bitmac surface works to avoid patchwork surface finishes

NOTE:
Carriageway asphalt surfaces and road markings to be as per Highway Engineer's Series 700 drawings and specification

PROMENADE IN-SITU CONCRETE. TO MOTT'S SPECIFICATIONS AND DESIGN

TYPE I
Proposed in-situ concrete slab. Citrus finish
PROMENADE 1 - Clear Zone 3468m²
ACCESS BUILD OUT BEACH ACCESS 549m²

TYPE J 3807m²
PROMENADE 2
Proposed in-situ concrete slab. Smoke grey finish.

CONCRETE VERGES

TYPE K 66m²
Concrete verge
100mm thick fibre reinforced air entrained PAV2 concrete to BS 8500 on 150mm Type 1 sub-base. Saw cut contraction joints at 4.4m spacing. Depth of contraction joints to be approx. 35mm and sealed with Nitoseal 12 or similar approved. Brushed finish to match Phase 2 finish.

TYPE L 135m²
Concrete verge
Hard verge with deterrent paving to match existing. 25mm sand bedding on 220mm Type 1 sub-base. 2-5mm flexible sand joints.

HAZARD PAVING

TYPE M PEDESTRIAN CROSSING
50mm thick, 450 x 450 thick buff colour 'Blister' paving, Where the back edge is not parallel to the kerb, and as a result the depth of the tactile surface varies, it should be no less than 800mm at any point

TYPE N TOP AND BOTTOM OF STEPS; END OF SHARED SURFACE AREA
50mm thick, 400 x 400 'corduroy' paving
Colours - ensure contrast with adjacent surface:
- 'charcoal' finish to Splash Point
- 'buff' finish to all other locations

TOP AND BOTTOM OF ACCESS BUILD OUT STEP RUNS
800mm wide 'corduroy' markings to Maritime Engineer's detail

EDGE RESTRAINTS AND HANDRAILS

REFER TO DRAWINGS:
19.537 - 106 FOR TYPES AND LOCATIONS; 19.537 - 123 INDICATIVE DETAILS

PROPOSED FERROCAST HARBOUR STYLE POST AND RAIL SYSTEMS BY MARSHALLS OEA
50mm Ø horizontal rails, surface fixed as standard. Post & rail system to resist class 3 loading to BS 7818. Base plate & holding down bolt arrangement to withstand loading requirements for class 3 post & rail pedestrian restraint system as detailed in table 2 of BS 7818-1995. Supplier /fabricator to provide final construction detail drawings package and components schedule including post and rail variations to suit different applications.

- **TYPE 1** To Promenade Edge — 3-rail system. Top rail @1.15m high
- **TYPE 2** Ramps (excluding beach access ramps) — 3-rail system. Top rail @ 1.15m high above ramp pitch. Post with 'swivel' sockets for diagonal rail fixing. 50mm Ø DDA handrail bracket fixed to post 750mm above surface pitch. Hockey stick end to handrails. Post fixed atop 100mm upstand.
- **TYPE 3** To 500mm high parapet walls. — 2-rail system. Top rail @ 605mm high above parapet wall. Post and rail arrangement varies depending on transition with other edge restraint elements
- **TYPE 4** To 500mm high parapet wall ramp and steps — 2-rail system. Top rail @ 605mm high above parapet wall. Swivel post to sloped wall and rail arrangement varies depending on location e.g. beach access ramps and steps
- **TYPE 5** Free Standing Handrails to Wide Steps — 2- rail system. Top rail @ 1000mm and second rail @ 600mm above step pitch. End handrails to return connecting post fixing holes
- **TYPE 6** Wall mounted handrails — 50mm Ø handrail 1000mm above steps pitch. Saddle bracket fixed to wall. Hockey stick end handrails
- **TYPE 7** To Concessions Area & Fishing Platform — 2- rail system with vertical rail panel infill. Top rail @ 1.15m high above surface level. 50mm Ø horizontal rails to have flat section for welding vertical bars to. Panel infill consist of 954mm high 20mm Ø vertical rails @ 115mm centres. Overall post height for Fishing Platform dependent on fixing details to platform structure. Engineer to confirm with fabricator

PICNIC AREA

- **TYPE 8** Stainless steel post and rail — 1000mm overall height, 50mm Ø post, handrail and intermediate handrail Steps : Root fixed (soft areas) and base plate surface fixed (hardstanding). Ramp: Surface fixed to ramp upstand (100mm)

EXISTING FENCE

- FE1 Frame and mesh fence to bottom of picnic area grass bank. RETAIN. Remove section along new step access to picnic area Gap up at removed steps locations
- FE2 Protective barrier to Splash Point storm drain (RETAIN)

NEW FENCE

- **TYPE 9** Protective barrier adjacent to selected pedestrian crossings and pedestrian access restriction at Splash Point. Product: V4 Optirail. Supplier: Alpharail OEA; Height: 1050 Support Posts: 50 x 50 x 3 mm SHS and 50 x 10 RSF @ 2m centres 2m long panel. Concrete root fixed posts Finish: Polyester powder coated; RAL colour TBC

LIGHTING
Refer to Highway Engineers drawings and specification

- **Light columns** Twin 'Kinium' LED luminaire
- **Light Beacon** 4m high cylindrical luminaire

STREET FURNITURE
Refer to dwg. 19.537 - 102 Furniture

- **SEATING - GENERAL**
- **PICNIC SETS**
- **TOURIST TELESCOPE** Product: HDC DFNT4 Dual Head, Wheelchair Accessible Non-coin Operated Telescope X20 Magnification Supplier: HDC International OEA
- **LITTER BINS** ML/B446 Large capacity Quad Recycling Bin Size: 872 (h) x 1952 (l) x 472 (w) Supplier: Wybone
- **SHEFFIELD FERROCAST CYCLE STANDS** Supplier : Marshalls OEA Dimensions: 50mm diameter x 950mm long x 770mm high Root Fixed
- **WOLVERHAMPTON FERROCAST BOLLARD** Supplier : Marshalls OEA. Dimensions: 1000mm high; Domed top Root Fixed
- **FLOOD GATE TO REPLACE EXISTING** Location: Splash Point slipway To Engineer's detail
- **BIKE REPAIR STATION WITH INTEGRATED PUMP** Supplier: Turvec Solutions Ltd Dimensions: 440mm (w) x 300mm (d) x x1440mm (h) Finish: Powder Coated ; RAL colour TBC Fixing: Surface mounted on baseplate

ACTIVE TRAVEL NORTH WALES BOULDERS
Refer to dwg. 19.537 - 101 GA 02

For fixing details:
19.537 - 126 for landscape boulder detail
2000 series for Promenade boulder detail
3000 series for Access Build Out boulder detail

ARTWORK
Refer to dwg. 19.537 - 104 Artwork Strategy

- **A1 ACTIVE TRAVEL HEALTH MARKER** **as per previous phases** — 3m long granite blocks @ 50m intervals, with etched / inset artwork, and as inset to in-situ promenade surface. Each marker is made up of 3no. 1m long x 500mm wide x 100mm deep blocks.
- **A2 ACTIVE TRAVEL SURFACE ARTWORK** — Surface artwork treatment to selected areas. Product : Decomark - preformed thermoplastic sheets; applied to promenade concrete surfaces Artwork design to be confirmed following further consultations Assume artwork area as 477m²
- **A3 ACTIVE TRAVEL NORTH WALES BOULDERS** — Artwork to selected boulders only @ 20% of overall boulder quantity
  A3.1 Artwork consist of geological classification: geographical identification; composition; process; timeline; origin etc. Artwork letters to be of either carved, insets, different finish.
  A3.2 Carved boulders as a sunken and bas relief. E.g. mythical creatures
- **A4 INTERPRETATION PANELS AND STAND** — 1.6m length x 0.9m high. Quantity: 5no
  1. 3no fixed to parapet Access Build Out parapet wall
  2. 2no fixed to Harbour Style railings by Splash Point
  Supplier: Photocast Ltd. OEA
- **A5 LASER CUT PANEL** — Powder coated steel. Resin anchored to new/existing walls. LED strip back lighting
  1. Active Area existing retaining wall: 4no 12m long x 1.5m high; 2no 9m long x 1.5m high
  2. Splash Point rear retaining wall including bespoke edge restraint details: 1no 10m long (approx.) x 1.150m high
- **A6 GATEWAY TOTEM** — PROVISIONAL SUM. To be designed

SOFT LANDSCAPE

Refer to dwg. 19.537 -
104 Soft Landscape Strategy
121 Planting Bed Details
122 Tree Planting Details

GROUNDCOVER PLANTING
Area 1 75m²
Picnic Area 193m²
Outdoor Classroom 57m²

Plant specification:
General planting: 2 -3 Lt pots @ 5no/m² average density
Specimen plants : 5-7lt pots @ 2no/m² average density;
landscape membrane topped with 75mm deep loose gravel (50mm depth bark mulch for picnic area only).
400mm depth topsoil for shrub planting.
Plant species to be predominantly low maintenance small shrubs, with selected areas of grass and herbaceous mixes.

TREE /SHRUB PLANTING

Picnic Area & Outdoor Classroom Trees
Mix deciduous and evergreen species; various sizes

Promenade edge small tree/shrub planting

ECOLOGICALLY RICH HABITAT CREATION

AREA 1 INTERVENTION
Refer to dwg. 19.537 - 200 for full planting mix and specification
ECOLOGICAL PLANT MIXES
Picnic Area & Grass verge

AREA 2 INTERVENTION
Refer to dwg. 19.537 - 201 for full planting mix and specification
WILDFLOWER SEED MIX
Rotary Way to Splash Point Railway Embankment
24no- 2x 2.6m scrapes
Locations to be determined on site

BULB PLANTING 55m²
To selected locations of existing and and re-instated grass areas
Planting density: 30no/m² average between species

GRASS RE-INSTATEMENT 688m²
To gap-up removed wall sections, footpath, and to re-graded areas. Re-instate with removed grass from immediate site. Removed grass to including 50mm soil depth

MOWN GRASS
Existing lawn area to be retained

REMOVAL OF EXISTING TURF FOR RE-USE
Works to be in accordance with BS 3969

NOTE:
This drawing is to be read in conjunction with all relevant discipline drawings, specifications and standards.

Client	MottMacDonald	Scale 1:500 @ A0	Created by HR	Last edited by RAZAK.H	Date 24 July 2020
Job title	Old Colwyn Promenade Coastal Defence And Active Travel Improvements	Project number 19.537	Drawing number 100	Issue C 01	Checked TH
Drawing title	General Arrangement				

CONSTRUCTION

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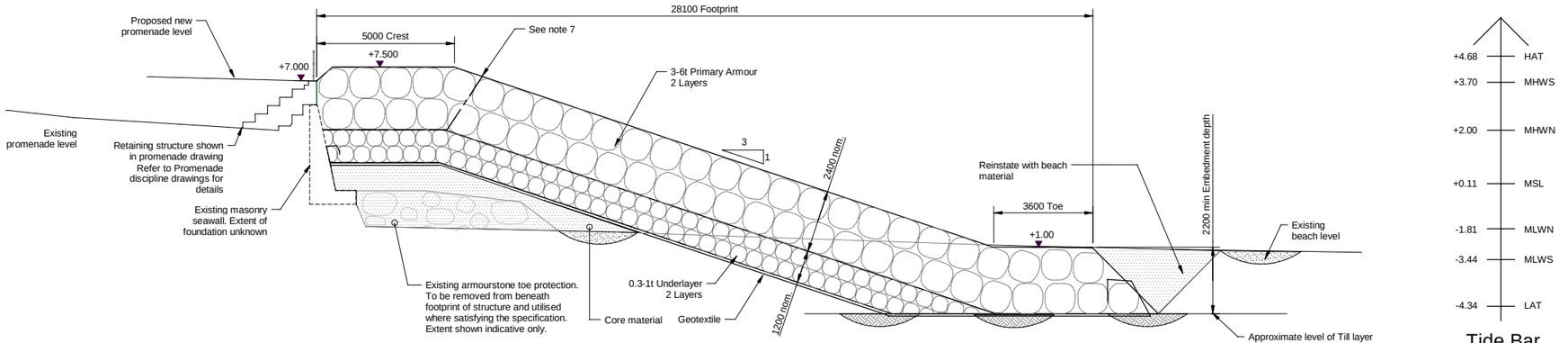
FACSIMILE +44 (0)151 236 4467
e-MAIL mail@bcalandscape.co.uk
WEB SITE www.bcalandscape.co.uk

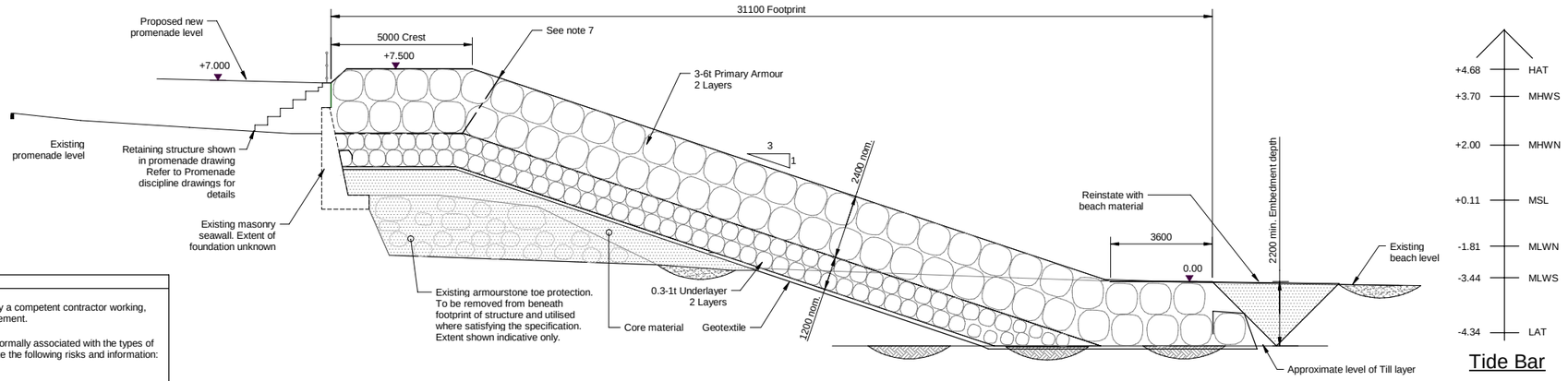
Revision	Description	By	On
C 1	Construction Issue	HR	16/07/2020



Tide Bar

Section 1 - Rock Revetment Cross-section (between Porth Eirias and Perpendicular steps 2)

1 : 100



Tide Bar

Section 2 - Rock Revetment Cross-section (between Perpendicular steps 2 and 3)

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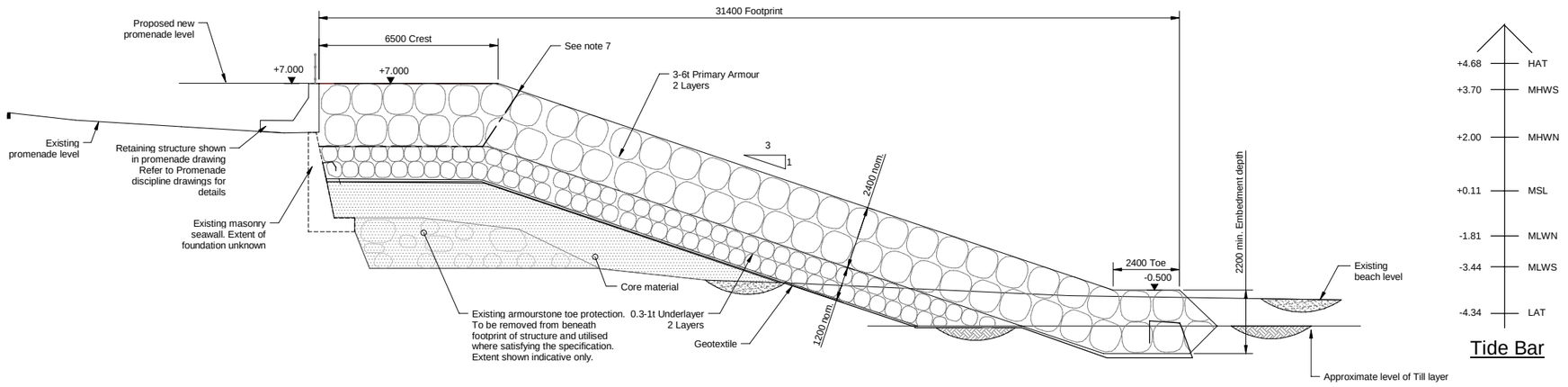

Tide Bar

Section 3 - Rock Revetment Cross-section (between Perpendicular Steps 3 and Splash Point)

1 : 100

Safety, Health & Environmental Information

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement.

In addition to the hazards/ risks normally associated with the types of work detailed on this drawing, note the following risks and information:

Construction:

1 Depth and full extent of existing seawall foundations are unknown. Existing seawall becomes destabilised (DHER Ref. 19 & 23).
2 Falling from height. Falling objects from promenade (DHER Ref. 22).
3 Working in tidal zone (DHER Ref. 27).

Operation & Maintenance:

4 Beach levels to be maintained to within 0.5m of current levels. Beach levels shall be monitored at regular intervals including before and after storms and at least once a year in spring (DHER Ref. 4).

1:100 0 5m 10m

Notes

1. All dimensions in millimetres unless otherwise stated.
2. All levels shown are in metres relative to Ordnance Datum (mOD).
3. Horizontal control points are relative to the National Grid OSGB36.
4. Beach survey information based on PENRHYN BAY - COLWYN BAY POST STORM SURVEY undertaken in 2019 by Environmental & Engineering Services.
5. Contractor to undertake trial holes to determine full extent and depth of existing seawall foundations present at least two weeks prior to the commencement of affected works, or ordering of materials, whichever occurs first.
6. Contractor to survey the existing wall at tie in locations to confirm the extent and geometry of the existing seawall at least two weeks prior to the commencement of affected works, or ordering of materials, whichever occurs first.
7. Rock revetment to be partially constructed from the toe up to the line indicated prior to the promenade raising works. Construction of remaining part of revetment to follow after completion of promenade raising works.

Key to symbols

Reference drawings

415437-MMD-00-XX-DR-C-3051 - Plan at Porth Eirias End - Area 1
415437-MMD-00-XX-DR-C-3052 - Plan at Splash Point End - Area 2
415437-MMD-00-XX-DR-C-3101 - Revetment cross section - Sheet 2 of 3
415437-MMD-00-XX-DR-C-3102 - Revetment cross section - Sheet 3 of 3
415437-MMD-00-XX-DR-C-3200 - Access Build-Out Plan
415437-MMD-00-XX-DR-C-3750 - Outfall & Culvert Sections
415437-MMD-00-XX-DR-S-2000s - Promenade Discipline Drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P4	17.07.20	AA	Construction Issue for client approval	AD	ZH
P3	26.06.20	AA	Construction Issue for client approval	AD	ZH
P2	29.04.20	AA	Tender Issue for Client comment	AD	ZH
P1	28.02.20	SD	Issue for Client comment	NC	AD

Status Stamp

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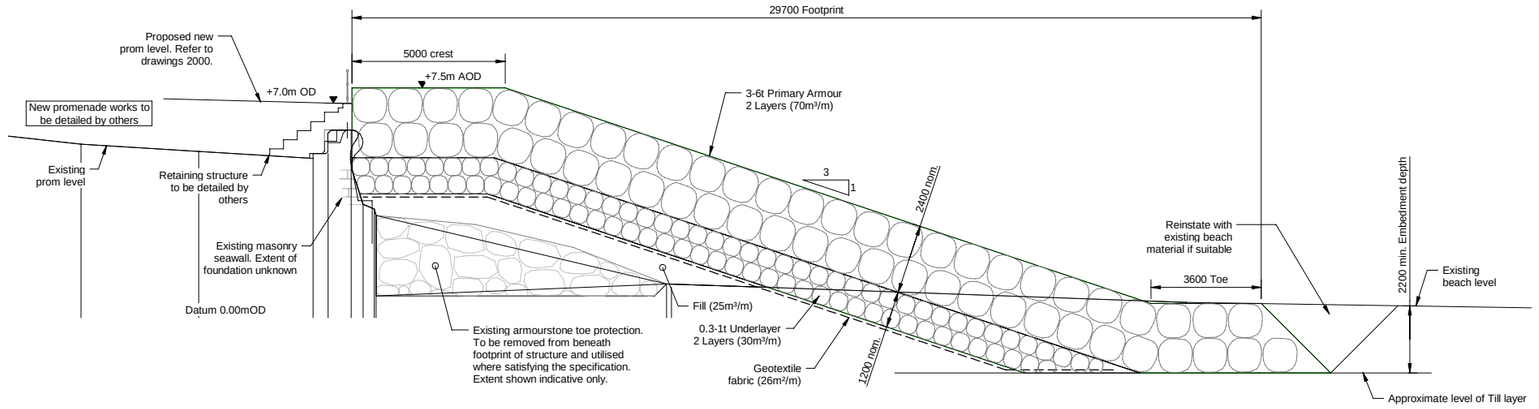
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Title

Old Colwyn Promenade Coastal Defence & Active Travel Improvements Revetment Cross Sections Sheet 1 of 3

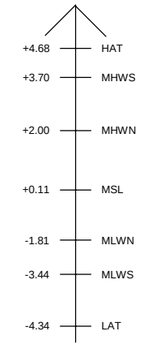
Designed	P Kacperek	PK	Eng. Check	A Douglas	AD
Drawn	A Al-Abdullah	AA	Coordination	F Loy	FL
Dwg. Check	D Sciuto	DS	Approved	Z Hutchison	ZH

MMD Project Number: 415437
Scale at A1: 1:100
Security: STD
Suitability Description: Issue for Construction Approval
Suit. Code: S4
Drawing Number: 415437-MMD-00-XX-DR-C-3100
Rev: P4

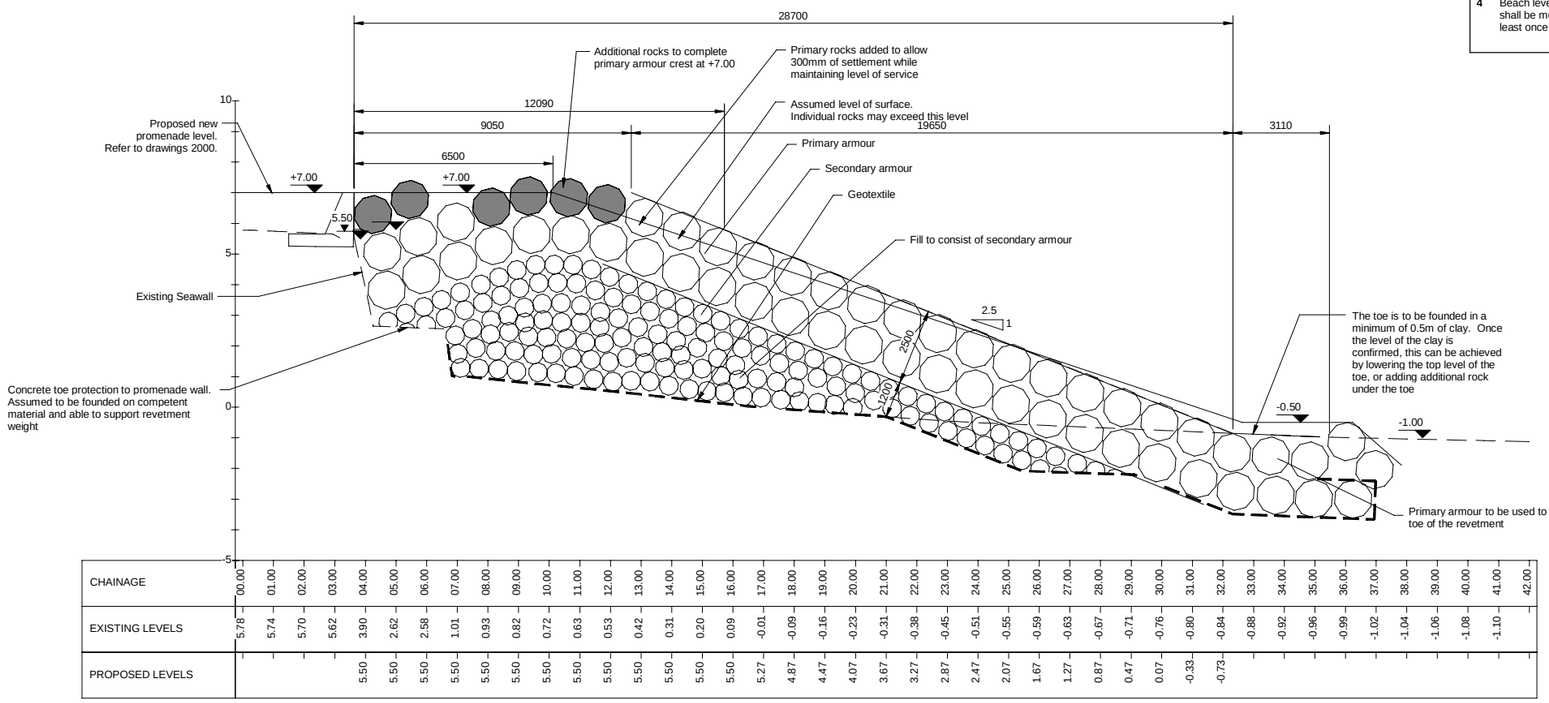


Section 3 - Section through Rock Revetment at Porth Eirias End

From drawing MMD-277894-C-DR-000-XX-1012 produced by Mott MacDonald on 05/02/2012.

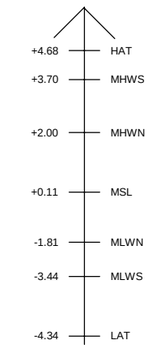


Tide Bar



Section 4 - Section through Rock Revetment at Splash Point

From drawing OCSP-ACM-XX-XX-DR-CE-010002 C02 - Splash Point produced by AECOM on 07/02/2020



Tide Bar

Safety, Health & Environmental Information

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement.

In addition to the hazards/ risks normally associated with the types of work detailed on this drawing, note the following risks and information:

Construction:
1 Depth and full extent of existing seawall foundations are unknown. Existing seawall becomes destabilised (DHER Ref. 19 & 23).
2 Falling from height. Falling objects from promenade (DHER Ref. 22).
3 Working in tidal zone (DHER Ref. 27).

Operation & Maintenance:
4 Beach levels to be maintained to within 0.5m of current levels. Beach levels shall be monitored at regular intervals including before and after storms and at least once a year in spring (DHER Ref. 4).

Notes

1. All dimensions in millimetres unless otherwise stated.
2. All levels shown are in metres relative to Ordnance Datum (mOD).
3. Horizontal control points are relative to the National Grid OSGB36.
4. Beach survey information based on PENRHYN BAY - COLWYN BAY POST STORM SURVEY undertaken in 2019 by Environmental & Engineering Services.

Key to symbols

Reference drawings

415437-MMD-00-XX-DR-C-3051 - Plan at Porth Eirias End - Area 1
415437-MMD-00-XX-DR-C-3052 - Plan at Splash Point End - Area 2
415437-MMD-00-XX-DR-C-3100 - Revetment cross section - Sheet 1 of 3
415437-MMD-00-XX-DR-C-3101 - Revetment cross section - Sheet 2 of 3
415437-MMD-00-XX-DR-C-3200 - Access Build-Out Plan
415437-MMD-00-XX-DR-C-3750 - Outfall & Culvert Sections
415437-MMD-00-XX-DR-S-2000s - Promenade Discipline Drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P3	17.07.20	AA	Construction Issue for client approval	AD	ZH
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Client
CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

Title
Old Colwyn Promenade Coastal Defence & Active Travel Improvements Revetment Cross Sections Sheet 3 of 3

Designed	P Kacperek	PK	Eng. Check	A Douglas	AD
Drawn	A Al-Abdullah	AA	Coordination	F Loy	FL
Dwg. Check	D Sciuto	DS	Approved	Z Hutchison	ZH

MMD Project Number 415437	Scale at A1 1:100	Security STD
Suitability Description Issue for Construction Approval		Suit. Code S4
Drawing Number 415437-MMD-00-XX-DR-C-3102		Rev P3

1:100 0 5m 10m

C. Wave Overtopping Assessment

Appendix 10.3 – Wave Overtopping Assessment

MOTT MACDONALD

Old Colwyn Promenade Defence & Active Travel Improvements

Wave Overtopping Assessment

15 June 2020

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Conwy County Borough Council
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Old Colwyn Promenade Defence & Active Travel Improvements

Wave Overtopping Assessment

15 June 2020

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
P01	06/02/2020	F Loy	N Clarke A Douglas	R Griffiths	First Issue - Draft
P02	15/06/2020	F Loy N Sigalas	N Clarke	Z Hutchison	Second Issue - Final

Document reference: 415437-MMD-C-R-00-XX-3000 | P02

Information class: Standard

Contents

Tables

Figures

Photos

1 Introduction

1.1 Project Background

Conwy County Borough Council (hereinafter referred to as the Client) require a detailed design to be carried out for a new coastal defence and active travel improvements on an approximately 1,250m long section of frontage at Old Colwyn.

Coastal defence works include:

- a large rock revetment
- protection works to existing outfalls that will be covered by the revetment
- a new pedestrian beach accesses to replace the existing ones,
- the raising and widening of the promenade.

Mott MacDonald have previously worked on nearby projects including Colwyn Bay Promenade Phase 1a & b, Colwyn Bay Promenade Phase 2 and regularly undertakes inspections along this frontage.

The existing promenade is inundated during storms, causing flooding. This will be exacerbated with future climate change. The promenade requires raising to safeguard the area from overtopping including allowances for future climate change.

Additionally, the provision of new coastal defences should enable additional regeneration and amenity benefits. This will include widening the promenade along the narrow sections to improve access for cyclists, pedestrians and vehicles.

1.2 Site Location

The site is in Colwyn Bay, North Wales. The project area is located between Porth Eirias carpark (by Colwyn Bay Watersports Centre) and Splash Point Old Colwyn.

Figure 1.1: Site Location

Source: Google Maps

This part of the frontage is fairly narrow and is mainly used by the public for cycling, walking, and fishing. There is currently no amenity on the beach or shops and restaurants on the landward side of the promenade. A railway runs along the back of the promenade on top a large embankment.

1.3 Purpose of this Report

This report aims to:

- Define existing waves, water levels and wave overtopping rates along the promenade
- Assess options and scenarios to reduce the amount of overtopping
- Make a recommendation of crest levels for revetment and promenade levels for the outline stage of the scheme based on international guidelines

2 Site Information

2.1 Design Life

The following design lives are based on the Employer's Requirements and Basis of Design (Mott MacDonald, 2020).

The design life of the coastal structures (revetment, fishing platform and steel sub-structures) is 50 years.

The design life for the other structural elements (walls, piles, new highway and promenade) is 120 years.

The design life for other ancillary design items such as guardrails, handrails and outfall grills are likely to have limited design lives in accordance with manufacturers designs.

2.2 Promenade and Beach Levels

Existing levels are derived from topographical drawings supplied by the Client (undertaken by Survey Operations dated April 2008.

Beach survey information is based on Penrhyn Bay – Colwyn Bay post storm survey undertaken in 2019 by Environmental & Engineering Services.

All levels used are in metres above ordnance datum (AOD). Horizontal control points are relative to the National Grid (OSGB36).

2.3 Tide Levels

Table 2.1 presents the tide levels which represent typical water level conditions along the frontage.

Table 2.1: Tide Levels at Colwyn Bay

Tide		Chart Datum (mCD)	Ordnance Datum (mOD)
Highest Astronomical Tide	HAT	+8.78	+4.68
Mean High Water Spring	MHWS	+7.80	+3.70
Mean High Water Neap	MHWN	+6.10	+2.00
Mean Sea Level	MSL	+4.21	+0.11
Ordnance Datum		+4.10	0.00
Mean Low Water Neap	MLWN	+2.29	-1.81
Mean Low Water Spring	MLWS	+0.66	-3.44
Lowest Astronomical Tide	LAT	-0.24	-4.34

Source: (Royal Haskoning, 2010)

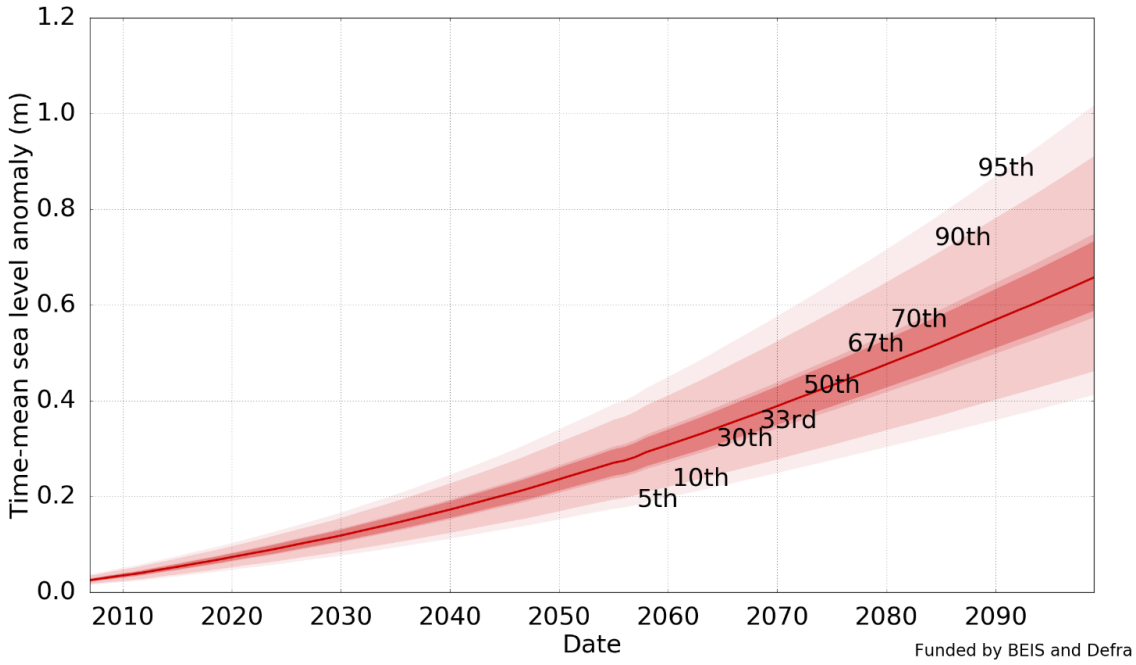
Note: MLWN and MLWS for Colwyn Bay calculation by interpolation between Llandudno and Hilbre Island.

2.4 Sea Level Rise

Tide data provided in Section 2.3 was published in the 2010 report but the actual baseline date for the levels was not provided. To allow adjustment of these levels to current mean sea levels, it has been conservatively been assumed that the data originates from 2007.

The assessment of the sea level rise covering the design life of the coastal structures is based on UK Climate Projections (UKCP 18) from (Met Office Hadley Centre, 2018). The value used in the overtopping calculation has been extracted from the data comprising the curve shown in Figure 2.1. The 95th percentile of the RCP8.5 scenario has been considered as a conservative approach at this stage. For the 50-year design life used to determine the proposed seawall design, a sea level rise allowance of 0.59m has been added to the sea levels.

Figure 2.1: UKCP18 Projections at Colwyn Bay – RCP8.5



Source: (Met Office Hadley Centre, 2018).

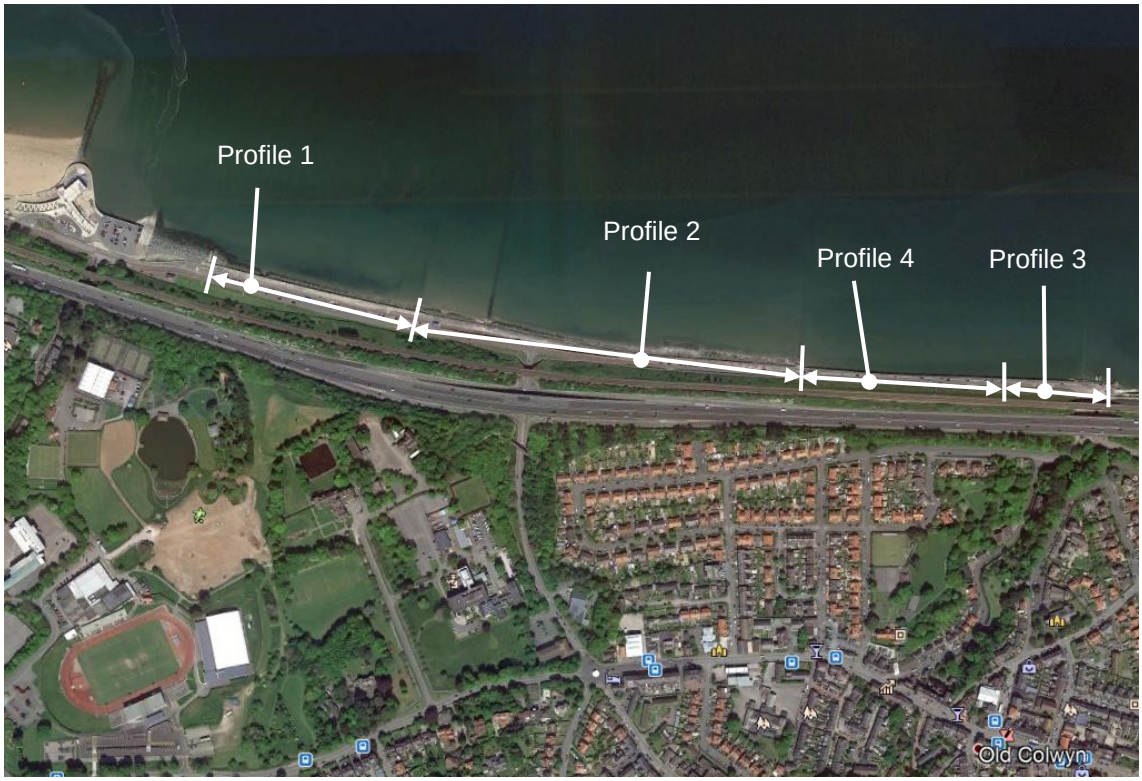
2.5 Beach Profile

The Old Colwyn Promenade frontage consists of a gently sloping sandy beach, with the geometry of the rock revetments varying along the project area. The eastern area does not include a rock revetment in front of the seawall.

The beach includes a number of stepped accesses from the promenade and a series of outfalls (owned by Welsh Water) and groynes.

The beach slope has been estimated from the beach survey at the location of four profiles. The location of these profiles can be seen in Figure 2.2.

Figure 2.2: Location of Beach Profiles



Source: Google Earth Pro (modified)

The geometry of the existing seawalls at the location of the four profiles is described in Table 2.2 as follows:

Table 2.2: Existing Seawall Levels

	Top of Seawall (m OD)	Toe of Seawall (m OD)	Wall Height (m)	Beach Slope
Profile 1	6.13	3.00	3.13	1 in 100
Profile 2	5.50	3.30	2.20	1 in 40
Profile 3	5.47	0.00	5.47	1 in 50
Profile 4	5.75	0.84	4.91	1 in 45

Photos of the structures and the beach at those profiles are shown in Photo 2.1 to Photo 2.4 below.

Photo 2.1: Profile 1

Source: MML Site Visit on 17th January 2020

Photo 2.2: Profile 2

Source: MML Site Visit on 17th January 2020

Photo 2.3: Profile 3

Source: MML Site Visit on 17th January 2020

Photo 2.4: Profile 4

Source: MML Site Visit on 17th January 2020

2.6 Beach Drawdown

Historic beach surveys dating back to 2005 along the Old Colwyn Promenade provided by the Client were reviewed to assess changes in beach levels over the years. The levels were checked at eight locations by the future beach step accesses.

The comparison between beach levels indicate that the beach is generally stable and that levels do not vary significantly with the control structures in place. The maximum variation in beach level is 0.7m while the variation at the other 7 locations varies between 0.1m and 0.5m. In light of those results a beach drawdown value of 0.5m from the current survey data has been adopted for the design of the beach steps with possibility for the steps to be extended in the future should localised erosion occur in the future (Mott MacDonald, 2020).

Local beach recharge or recycling may also be implemented if required over time.

2.7 Existing Storm Events

There is no formal record of road closures of the promenade highway from Rotary Way to Beach Road. However, it has been noticed that the number of closures has increased in recent years. The promenade is now routinely closed whenever spring tides coincide with forecast north or northwest winds.

In the past, overtopping has caused the surfacing of the promenade to get broken up, the handrails failed, sections of the seawalls have suffered from risk of undermining / voids to rear of the promenade, and the rear wall along the toe of the railway embankment has been damaged. These are repaired by the Client on a reactionary basis.

Photo 2.5: Damages to the promenade and the seawall

Source: https://www.bbc.co.uk/news/uk-wales-50069665

3 Wave Overtopping Assessment

To undertake an overtopping assessment, information on the existing extreme wave and water levels are required.

3.1 Joint Probability Analysis between Waves and Water Levels

The following joint probability of extreme waves and water levels have been extracted from (Royal Haskoning, 2010) a location offshore from Colwyn Bay.

Table 3.1: Joint probability of design waves and water levels

Return periods	WL (mOD)	Sop	Tm (s)	Hs (m)
1	2.84	0.03	6.35	2.18
	3.29	0.03	6.01	1.96
	3.75	0.03	5.58	1.71
	4.21	0.03	4.95	1.37
	4.67	0.03	2.89	0.54
10	2.84	0.03	7.70	3.15
	3.29	0.03	7.70	3.15
	3.75	0.03	7.61	3.08
	4.21	0.03	7.38	2.91
	4.67	0.03	7.02	2.65
	5.13	0.03	5.63	1.81
50	3.29	0.03	8.21	3.56
	3.75	0.03	8.17	3.54
	4.21	0.03	8.03	3.42
	4.67	0.03	7.82	3.25
	5.13	0.03	7.35	2.88
	5.58	0.03	5.58	1.71
100	3.29	0.03	8.42	3.74
	3.75	0.03	8.34	3.68
	4.21	0.03	8.25	3.60
	4.67	0.03	8.03	3.42
	5.13	0.03	7.70	3.15
	5.58	0.03	7.04	2.65
200	3.29	0.03	8.68	3.97
	3.75	0.03	8.67	3.96
	4.21	0.03	8.60	3.90
	4.67	0.03	8.41	3.74
	5.13	0.03	8.04	3.42
	5.58	0.03	7.57	3.05

Source: (Royal Haskoning, 2010) (part of table)

The offshore mean wave periods available in (Royal Haskoning, 2010) presented in Table 3.1 were propagated from the offshore location to the project area (toe of the proposed rock revetment) by applying the Goda shoaling formula. The effect of beach level fluctuations on the waves has also been included, including a 0.5m beach drawdown (section 2.6). An increase to the extreme water levels of Table 3.1 by 0.59m (section 2.4) was applied to assess the extreme water levels in 50 years' time accounting for sea level rise.

The results of the joint probability analysis of the design waves and water levels are shown in Table 3.2 and Table 3.3.

Table 3.2: Joint probability of design waves and water levels (present day)

Return period (joint probability) [yrs]	WL [mOD] (present day)	Extreme Wave Return Period R [yrs]	Tm [s]	Hs (toe) [m] Profile 1	Hs (toe) [m] Profile 2	Hs (toe) [m] Profile 3	Hs (toe) [m] Profile 4
1	2.84	0.45	8.90	1.76	1.68	2.43	2.22
	3.29	0.38	8.50	1.98	1.91	2.22	2.24
	3.75	0.33	8.05	2.00	2.07	2.01	2.05
	4.21	0.28	7.43	1.54	1.56	1.48	1.50
	4.67	0.21	5.92	0.56	0.57	0.55	0.55
10	2.84	2.68	10.66	1.88	1.80	2.55	2.34
	3.29	2.68	10.66	2.12	2.06	2.80	2.59
	3.75	1.93	10.54	2.36	2.31	3.05	2.85
	4.21	1.16	10.23	2.59	2.56	3.09	3.09
	4.67	0.73	9.75	2.82	2.80	2.93	2.95
	5.13	0.35	8.23	2.00	2.03	1.94	1.96
50	3.29	33.30	11.34	2.17	2.12	2.86	2.65
	3.75	28.54	11.31	2.42	2.38	3.11	2.91
	4.21	15.37	11.12	2.66	2.63	3.36	3.15
	4.67	6.11	10.85	2.88	2.87	3.45	3.39
	5.13	1.09	10.17	2.99	3.08	3.03	3.07
	5.58	0.33	8.05	1.86	1.88	1.81	1.83
100	3.29	108.34	11.62	2.20	2.14	2.88	2.67
	3.75	72.22	11.52	2.44	2.40	3.13	2.93
	4.21	50.00	11.40	2.68	2.65	3.38	3.18
	4.67	15.37	11.12	2.91	2.89	3.62	3.42
	5.13	2.68	10.66	3.12	3.12	3.34	3.36
	5.58	0.73	9.75	2.88	2.98	2.90	2.94

Source: MML

Table 3.3: Joint probability of design waves and water levels (in 50 years)

Return period (joint probability) [years]	WL [mOD] (in 50 years)	Extreme Wave Return Period R [yrs]	Tm [s]	Hs (toe) [m] Profile 1	Hs (toe) [m] Profile 2	Hs (toe) [m] Profile 3	Hs (toe) [m] Profile 4
1	3.43	0.45	8.90	2.09	2.02	2.44	2.46
	3.88	0.38	8.50	2.18	2.25	2.20	2.24
	4.34	0.33	8.05	1.92	1.96	1.86	1.89
	4.8	0.28	7.43	1.50	1.52	1.46	1.47
	5.26	0.21	5.92	0.55	0.56	0.55	0.55
10	3.43	2.68	10.66	2.20	2.14	2.88	2.67
	3.88	2.68	10.66	2.44	2.40	3.14	2.93
	4.34	1.93	10.54	2.68	2.66	3.27	3.18
	4.8	1.16	10.23	2.91	2.90	3.09	3.11
	5.26	0.73	9.75	2.88	2.98	2.92	2.95
	5.72	0.35	8.23	1.97	1.99	1.91	1.93
50	3.88	33.30	11.34	2.49	2.46	3.19	2.98
	4.34	28.54	11.31	2.74	2.72	3.45	3.24
	4.8	15.37	11.12	2.98	2.97	3.63	3.49
	5.26	6.11	10.85	3.21	3.21	3.45	3.47
	5.72	1.09	10.17	2.99	3.09	2.98	3.02
	6.17	0.33	8.05	1.83	1.85	1.79	1.80
100	3.88	108.34	11.62	2.52	2.48	3.21	3.01
	4.34	72.22	11.52	2.76	2.74	3.46	3.26
	4.8	50.00	11.40	3.00	2.99	3.71	3.52
	5.26	15.37	11.12	3.23	3.23	3.63	3.65
	5.72	2.68	10.66	3.27	3.38	3.31	3.36
	6.17	0.73	9.75	2.89	2.98	2.87	2.90

Source: MML

3.2 Scenarios

The following scenarios have been considered as part of the wave overtopping assessment (both for present day and in 50 years, including beach drawdown):

- Case 1: Existing structure and foreshore geometry (Baseline) including beach drawdown
- Case 2: Revetment up to existing crest level of seawall
- Case 3: Revetment up to +7.00m OD, promenade at +7.00m OD
- Case 4: Revetment up to +7.50m OD, promenade at +7.00m OD
- Case 5: Revetment up to +7.50m OD with crest and crest wall up to +8.15m OD and promenade at +7.00m OD)

The crest width of the revetment was set at 5m and its slope at 1V to 3H.

3.3 Wave Overtopping Formulae

Overtopping hazards are assessed by determining the volume of water that passes over the crest of the defence. Hazards driven by overtopping can be linked to a number of flow parameters. The outputs of overtopping analysis undertaken utilising the EurOtop Manual 2018 (Van der Meer, et al., 2018) are:

- Mean overtopping discharge (q), defined as the average overtopping volume from all waves, it is estimated in litres per second per metre length of seawall.
- Individual maximum overtopping volume (V_{max}), is defined as the maximum discharge from a single wave in litres per metre length of seawall.

These parameters (q and V_{max}) are checked against defined criteria to establish the performance of differing geometric structure configurations. In the latest EurOtop V_{max} is the preferred parameter to define overtopping hazard as this represents the maximum wave overtopping based on the structure geometry, wave conditions and typical wave distributions. Definition of the criteria for V_{max} are less established and therefore the overtopping assessment will make use of both parameters, refer to Section 3.4.

When defining the required overtopping performance of a structure it is important to consider:

- The frequency of the overtopping event; and,
- The receptors (assets, people…) at risk behind the overtopping point.

The frequency of the overtopping events, assessed by the return periods set in the joint probability analysis should relate to the expectations of the users of the structures, highway and promenade and the requirements of the asset owners/ managers.

The EurOtop Manual gives empirical formulations, or neural net/gaussian interpolation methods, that predict either the best fit to the test data or upper bound. The upper bound values of the predictions were used.

The EurOtop Manual II – 2018 Equations 5.12 & 5.13, as shown below, are used to determine the overtopping discharge on the smooth revetment sections of the scheme (armour slope smoother than 1V to 2H).

Figure 3.1: Equations for overtopping discharge of smooth revetment

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.026}{\sqrt{\tan\alpha}} \gamma_b \cdot \xi_{m-1,0} \cdot \exp\left[-\left(2.5 \frac{R_c}{\xi_{m-1,0} \cdot H_{m0} \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v}\right)^{1.3}\right] \quad 5.12$$

with a maximum of: $$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma^*}\right)^{1.3}\right] \quad 5.13$$

Source: (Van der Meer, et al., 2018).

The following EurOtop Manual II – 2018 Equation 6.6, as shown below, is used to determine the overtopping discharge on the steep revetment sections of the scheme (armour slope equal or steeper than 1V to 2H).

Figure 3.2: Equation for overtopping discharge of steep revetment

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right] \text{ for steep slopes 1:2 to 1:4/3} \quad 6.6$$

Source: (Van der Meer, et al., 2018).

The overtopping discharge at the vertical wall sections of the scheme have been determined by the EurOtop Manual II – 2018 Equation 7.2, as shown below:

Figure 3.3: Equation for overtopping discharge of vertical wall

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot \exp\left[-\left(2.12 \frac{R_C}{H_{m0}}\right)^{1.3}\right] \quad 7.2$$

Source: (Van der Meer, et al., 2018).

Inputs to the calculations comprise the water levels, wave heights and wave periods for each profile that resulted from the joint probability analysis, both at present day and in 50 years, the structure geometry and the beach profile for each of the profiles investigated (including beach drawdown).

The main assumptions for the calculation are as follows:

- Storm duration = 6 hours.
- Roughness of revetment γ_f = 0.55 for two-layer rock armour with impermeable core (EurOtop II)
- Concrete surface of vertical walls
- Waves acting perpendicular to the structure
- No berm
- Bullnose (Return Wall) width Br = 0.5m and height hr = 1m at Access Build-out.

3.4 Wave Overtopping Criteria

The following criteria set out in EurOtop II Manual (Van der Meer, et al., 2018) and in the EurOtop Manual (Pullen, et al., 2007), have been reviewed to assess the level of risk associated with wave overtopping for the different scenarios. The discharge limits act as guidelines to assess the frequency of extreme waves exceeding the level of the proposed sea defences.

Table 3.4: Overtopping limits for structural design of breakwaters, seawalls, dikes

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Rubble mound breakwaters; H_{m0} > 5 m; no damage	1	2,000-3,000
Rubble mound breakwaters; H_{m0} > 5 m; rear side designed for wave overtopping	5-10	10,000-20,000

Source: (Van der Meer, et al., 2018).

Table 3.5: Overtopping limits for people and vehicles (EurOtop II)

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea. H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m H_{m0} < 0.5 m	 0.3 1 10-20 No limit	 600 600 600 No limit
Cars on seawall / dike crest, or railway close behind crest H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m	 <5 10-20 <75	 2000 2000 2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

Source: (Van der Meer, et al., 2018).

Table 3.6: Tolerable discharge comparison between EurOtop Manual I & II

Return Period	Tolerable Discharge	Comment	Reference
1 in 1 year	q< 1 l/s per m V_{max}< 600 l/m.	For people and vehicles - People at seawall / dike crest. Clear view of the sea. H_{m0} = 2m.	EurOtop (2018): Table 3.3
1 in 1 year	q< 1-10 l/s per V_{max}< 500 l/m at low level.	Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jets, low danger of fall from walkway.	EurOtop (2007): Table 3.2
1 in 200 year	-	No limits given for vertical structures or promenades	EurOtop (2018)
1 in 200 year	q< 200 l/s per m	No damage to paved or armoured promenade behind seawall.	EurOtop (2007): Table 3.5

Source: (Van der Meer, et al., 2018).

Table 3.7: Overtopping limits for damage to the defence crest (EurOtop Manual I – 2007)

Hazard type and reason	Mean discharge q (l/s/m)
Embankment seawalls/sea dikes	
No damage if crest and rear slope are well protected	50–200
No damage to crest and rear face of grass covered embankment of clay	1–10
No damage to crest and rear face of embankment if not protected	0.1
Promenade or revetment seawalls	
Damage to paved or armoured promenade behind seawall	200
Damage to grassed or lightly protected promenade or reclamation cover	50

Source: (Pullen, et al., 2007).

Table 3.8: Overtopping limits for people and vehicles (EurOtop Manual I – 2007)

Hazard type and reason	Mean discharge	Max volume(1)
	q (l/s/m)	V_{max} (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

Source: (Pullen, et al., 2007).

In principle the overtopping limits are taken from the latest industry standard guidance, EurOtop Manual 2018 (Van der Meer, et al., 2018) as shown above. However, for areas of promenade and carriageway landward of the crest no limits are given in the current version of the guidance and the limits from the previous version of the guidance have been adopted, as shown in Table 3.9. Those values are defined to ensure that the paved promenade is not damaged during extreme events behind the crest of the revetment/ seawall.

Table 3.9: Recommended discharge limits for assets

Surface	q [l/m/s]	Return period (years)
Paved	200	100
Grass	50	100

For pedestrian and vehicle access near the crest of the structure because the area does not provide essential access, but only amenity access, the overtopping limits will be assessed for the 1 in 1-year and 1 in 10-year wave and water level conditions. The risk for pedestrians and vehicles will be assessed as part of a risk assessment and mitigation measures such as promenade or road closure will be assessed.

Table 3.10: Recommended discharge limits for users

User	Vmax [l/m]	Return period (years)
Pedestrian	600	1 - 10
Vehicle	2,000	1 - 10

Overtopping measurements vary widely even within a single series of tests in physical modelling. It would not be unreasonable to expect the results of a physical model to be between a half and twice the predicted value for the structure. Strict adherence to the specified overtopping limits, particularly as they are upper bound predictions, is not appropriate as in many instances this may result in impractical structures. For instance, if a wave wall was designed as a standard height parapet and the predictions exceeded the limit by 20% that would be deemed acceptable. However, when criteria are relaxed the risk consequences should be fully understood and supported through risk assessment.

3.5 Wave Overtopping Results

The estimated overtopping results are presented in Table 3.11 to Table 3.15 below per return period and profile location. The results cover the different scenarios described in section 3.2 and consider both present day and 50-year situations at each profile, including beach drawdown. The calculations are provided in Appendix A.

Table 3.11: Overtopping results – Case 1

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass (P)/ Exceed (E) criteria
Profile 1	**1**	53	11,852	82	16,596	E
	10	421	43,706	656	52,180	E
	50	683	52,981	918*	55,452*	E
	100	789	54,551	955*	55,789*	E
Profile 2	**1**	125	17,384	194	22,341	E
	10	236	21,581	295*	25,126*	E
	50	275*	22,665*	336**	26,138**	E
	100	287*	22,983*	354**	26,552**	E
Profile 3	**1**	96	20,623	188	33,267	E
	10	689	57,450	948*	62,159*	E
	50	1,071*	61,692*	1,343**	62,130**	E
	100	1,206**	62,725**	**	**	E
Profile 4	**1**	81	17,883	131	23,505	E
	10	590	54,901	869*	49,452*	E
	50	899*	60,195*	1,301**	51,090**	E
	100	935*	60,605*	1,458**	51,435**	E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.12: Overtopping results – Case 2

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	16	141	46	673	P/E
	10	391	1,225	802	18,124	E
	50	772	2,351	1,313*	27,422*	E
	100	860	3,001	1,545*	38,332*	E
Profile 2	**1**	73	179	135	2,683	P/E
	10	784	1,890	1,473*	26,085*	E
	50	1,430*	4,128*	1,669**	39,311**	E
	100	1,461*	4,550*	1,688**	41,343**	E
Profile 3	**1**	67	157	128	2,216	P/E
	10	899	2,392	1,453*	25,621*	E
	50	1,285*	5,350*	1,909**	43,843**	E
	100	1,680*	6,077*	2,067**	48,876**	E
Profile 4	**1**	42	157	85	1,756	P/E
	10	689	2,016	1,206	23,150	E
	50	982	4,192	1,631*	40,335*	E
	100	1,401	5,298	1,979**	44,522**	E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.13: Overtopping results – Case 3

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	0	125	1	423	P
	10	27	709	67	10,329	E
	50	73	1,289	143	17,292	P
	100	95	1,665	229	26,030	P/E
Profile 2	**1**	0	154	1	815	P/E
	10	25	686	76	11,722	E
	50	88	1,508	158	18,659	P
	100	122	1,670	251	28,442	P/E
Profile 3	**1**	0	277	1	443	P
	10	36	867	70	10,729	E
	50	105	2,105	164	22,593	P
	100	140	2,696	237	26,749	P/E
Profile 4	**1**	0	201	1	485	P
	10	37	896	74	11,125	E
	50	95	1,942	167	22,951	P
	100	147	2,405	246	27,455	P/E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.14: Overtopping results – Case 4

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	1	0	89	0	252	P
	10	13	575	35	7,143	P/E
	50	39	958	81	12,520	P
	100	54	1,010	138	19,809	P
Profile 2	1	0	120	0	563	P
	10	12	557	41	8,434	P/E
	50	48	1,122	91	13,574	P
	100	68	1,200	154	22,345	P
Profile 3	1	0	215	0	265	P
	10	18	692	37	7,477	E
	50	60	1,622	98	17,052	P
	100	83	2,077	144	20,478	P
Profile 4	1	0	153	0	294	P
	10	19	714	39	7,810	E
	50	54	1,496	100	17,376	P
	100	86	1,795	150	21,136	P

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.15: Overtopping results – Case 5

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	0	16	0	51	P
	10	3	1,264	8	2,465	E
	50	9	2,945	20	5,437	P
	100	14	4,068	42	8,655	P
Profile 2	**1**	0	25	0	75	P
	10	2	1,194	11	3,160	E
	50	12	3,691	27	5,973	P
	100	17	4,167	53	10,567	P
Profile 3	**1**	0	53	0	109	P
	10	4	1,744	9	2,726	E
	50	17	5,818	36	8,758	P
	100	26	8,012	52	11,919	P
Profile 4	**1**	0	34	0	118	P
	10	4	1,837	10	3,000	E
	50	15	5,200	38	9,117	P
	100	25	6,774	54	12,380	P

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

4 Interpretation of Results and Recommendations

4.1 Interpretation of Results

The initial overtopping results for the existing structures and geometries were presented in Table 3.11 (**Case 1**). For the 1 in 10-year return period, at present day, the maximum mean overtopping discharge q estimated is 689 l/m/s with a maximum overtopping volume V_{max} of 57,450 l/m and flooding occurring in 50 years when considering the sea level rise (Profile 3). These values are significantly higher than the limits proposed by guidelines and impose risk to public health and safety. Existing structures are at high risk of flooding and damage during extreme events as overtopping values significantly exceed the overtopping criteria presented in section 3.4.

Case 1 – Existing structure and foreshore geometry (Baseline) including beach drawdown

- Extremely high wave discharge volumes (both mean and peak)
- Promenade flooded at profiles 2, 3 and 4 from 1 in 10 year events and from 1 in 50 year events at profile 1 (higher crest level).
- Exceeds defined overtopping limits
- Unsafe for the public for all extreme events
- Severe damage to the promenade, the highway and the highway equipment

For Case 2, the mean overtopping discharges are comparable to Case 1 in terms of mean discharge value with a more noticeable reduction in terms of the maximum volume. Those values still pose risks to public health and safety and leave the protected structures at high risk of flooding and damage during extreme events.

Case 2 – Revetment up to existing crest level of seawall

- Extremely high wave discharge volumes (both mean and peak)
- Promenade flooded at profiles 2, 3 from 1 in 10 year events and from 1 in 50 year events at profiles 1 and 4.
- Mean overtopping discharges comparable to Case 1. Maximum overtopping volumes are divided by 13 in average compared to Case 1 at present day.
- Exceeds defined overtopping limits
- Unsafe for the public for all extreme events
- Severe damage to the promenade, the highway and the highway equipment

For **Case 3**, the mean discharges are significantly reduced compared to the existing defence. However, the maximum overtopping volumes remain over the criteria set in section 3.4 with high risks associated to public safety and potential damage to protected structures.

The mean overtopping discharge q remains under the limit for structures of 200 l/m/s (exceeded only for 1 in 100 year events in 50 years' time) and the maximum overtopping volume is reduced under the limit of 600 l/m (pedestrians) for 1 in 1 year events at present day.

Case 3 – Revetment up to +7.00m OD, promenade at +7.00m OD

- Overtopping results are significantly reduced and meet most of the criteria set at present day
- Mean overtopping discharges are reduced by 90% in average compared to Case 1 (Baseline) at present day. Maximum overtopping volumes are reduced by 97% in average compared to Case 1 at present day.
- Exceeds defined mean overtopping discharge limit for assets in 50 years' time for 1 in 100 year events.
- Exceeds maximum overtopping limit for vehicles at present day and just meets limit for pedestrians for 1 in 1 year events in 50 years' time.

For **Case 4**, the mean overtopping discharges are significantly reduced compared to Case 1, with the mean overtopping discharge q remaining under the limit for structures of 200 l/m/s for all cases and the maximum overtopping volume reduced under the limit of 600 l/m (pedestrians) for 1 in 1 year events.

Case 4 – Revetment up to +7.50m OD, promenade at +7.00m OD

- Overtopping results are significantly reduced and meet all the criteria set at present day and in 50 years 'time
- Mean overtopping discharges are reduced by 94% in average compared to Case 1 (Baseline) at present day. Maximum overtopping volumes are reduced by 98% in average compared to Case 1 at present day.
- Meets defined mean overtopping discharge limit for assets in all return periods
- Meets maximum overtopping limit for vehicles at present day and meets limit for pedestrians for 1 in 1 year events in 50 years' time. Exceeds that limit for 1 in 10 year events and beyond.

For **Case 5**, the mean overtopping discharges are significantly reduced compared to Case 1, with the mean overtopping discharge q being under the limit for structures of 200 l/m/s for all cases and reducing the maximum overtopping volume under the limit of 600 l/m (pedestrians) for 1-1 year events, in close range of the 1 in 10 year events.

Case 5 – Revetment up to +7.50m OD with crest and crest wall up to +8.15m OD (with associated promenade at +7.00m OD)

- Overtopping results are significantly reduced and meet the criteria set at present day and in 50 years 'time
- Mean overtopping discharges are reduced by 99% in average compared to Case 1 (Baseline) at present day.
- Meets defined mean overtopping discharge limit for assets in all return periods
- Meets limit for pedestrians for 1 in 1 year events in 50 years' time. Exceeds that limit for 1 in 10 year events and beyond.

4.2 Potential Mitigations and Adaptations

Road Closure

Mitigation measures such as promenade/ road closure during severe storms are required to keep the crest level at a reasonable level. In case of extreme storm events beyond 1 in 10-year return period, road closure might be required. Barriers would be reinstalled to prevent vehicular access to the promenade and an agreed mitigation for baring non-motorised users (pedestrians, cyclists etc) from entering the promenade such as VMS signage or physical barriers.

Climate Resilience

It is recommended that the new promenade proposed be adaptable for the future (beyond 50 years). Considering the effects of sea level rise, it is likely that a raising of the sea defences be required after a certain time. This is judged as a more cost-efficient approach rather than raising the promenade to 120-year design criteria at present day.

This would materialise as a setback distance left in the promenade to build a new crest wall or building a crest wall which can be raised in the future. The crest of the rock revetment has been designed so that it can also be raised in the future as required.

Raising the road and the promenade after 50 years is more challenging, that is why it is recommended to carry out those works at present day as highway infrastructure is less adaptable than the coastal defence.

4.3 Summary

The results for **Case 1 and Case 2** (keeping the existing crest level of the seawall) are well above the defined overtopping limits (section 3.4) and would not be safe for users as well as for the integrity of the promenade, road and embankment. Severe damages would be caused during extreme events, as it is already happening, and the frequency and severity of those damages is likely to increase with sea level rise. The railway embankment is likely to suffer damages when the promenade/road is flooded during the 1 in 50 and 1 in 100-year events.

Case 3 (revetment crest at +7.00m OD) represents a significant improvement compared to **Case 1 and Case 2** as it prevents the promenade from flooding and reduces the overtopping volumes to more reasonable values, particularly for the 1 in 1 year events. However even with the widening of the crest, this scenario is not estimated to be sufficient to meet the defined overtopping criteria in 50 years' time.

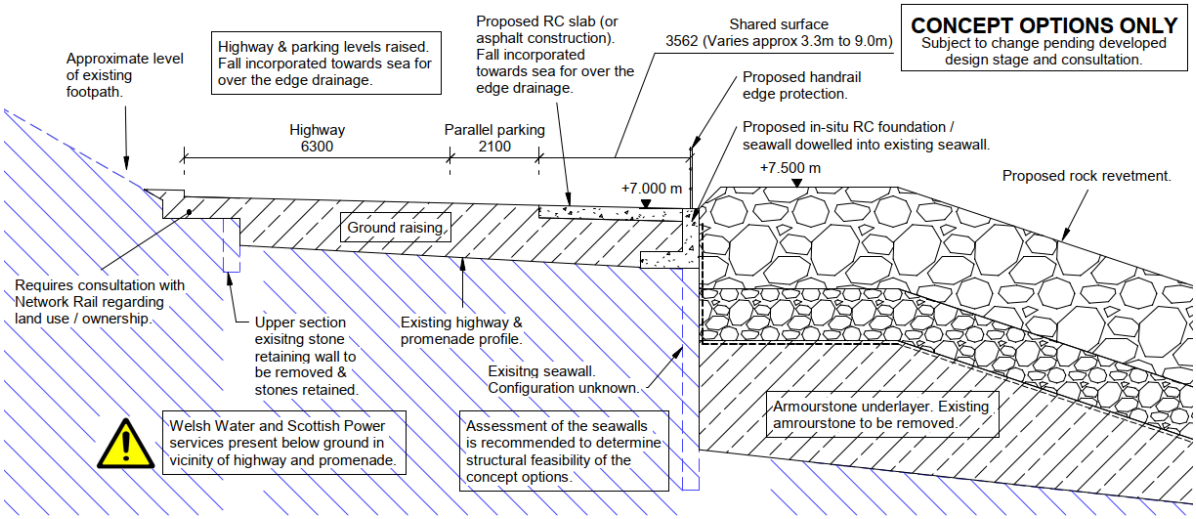
The results for **Case 4 and Case 5** (revetment crest at +7.50m OD, and crest wall at +8.15m OD for **Case 5**) are either within or in close range of the defined overtopping limits at present day and in 50 years' time.

Including certain mitigations (road closure for 1 in 10-year events) and potential for future adaptations, **Case 4** is considered to be the most suitable option to take forward. **Case 4** meets the criteria set for paved assets and generates very significant reduction in wave discharges compared to the existing defences, while still being feasible, cost efficient and adaptable. Crest levels below +7.50m OD are unlikely to meet the defined overtopping criteria which ensure durability of the assets/ structures and the safety of the public.

4.4 Outline Recommended Crest Level and Promenade Level

Based on the results presented and considering the levels of the existing structures at both extremities of the promenade (Porth Eirias and Splash Point), **Case 4** is the recommended design solution to protect the promenade from wave overtopping.

Figure 4.1: Illustration of proposed promenade raising and rock revetment crest



Mitigation measures such as promenade/ road closure are required to keep the crest level at the reasonable level proposed.

Physical modelling studies are recommended to validate the empirical formulae extracted from the EurOtop Manual used in this present study.

5 References

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Appendices

A. Overtopping Calculations

Project				
Colwyn Bay Old Promenade Coastal Defence				
Wave Overtopping Formulae	Dvn/dept	MNC/PCO	Job no/file no	415437
	Calculated by	NS	Date	10/02/2020
	Checked by	FL	Date	15/02/2020

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Wave Overtopping Formulae

Overtopping Discharge for Smooth Revetment:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.026}{\sqrt{\tan\alpha}} \gamma_b \cdot \xi_{m-1,0} \cdot \exp\left[-\left(2.5 \frac{R_c}{\xi_{m-1,0} \cdot H_{m0} \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v}\right)^{1.3}\right] \qquad 5.12$$

with a maximum of: $$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma^*}\right)^{1.3}\right] \qquad 5.13$$

Overtopping Discharge for Steep Revetment:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right] \quad \text{for steep slopes 1:2 to 1:4/3} \qquad 6.6$$

Overtopping Discharge for Vertical Wall:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot \exp\left[-\left(2.12 \frac{R_C}{H_{m0}}\right)^{1.3}\right] \qquad 7.2$$

Parameters:

q	=	wave overtopping discharge (l/m/s)	γ_b	=	influence factor for a berm
g	=	gravitational acceleration constant (m/s^2)	γ_f	=	influence factor for roughness elements on a slope
H_{m0}	=	Offshore Wave Height (m)	γ_β	=	influence factor for oblique wave attack
α	=	angle between overall structure slope and horizontal (°)	γ_v	=	influence factor for a wall at the end of a slope
$\xi_{m-1,0}$	=	Breaker Parameter	γ^*	=	influence factor for non breaking waves for a storm wall on a slope or promenade
R_c	=	crest freeboard of structure (m)			

Project				
Colwyn Bay Old Promenade Coastal Defence				
Wave Overtopping Formulae	Dvn/dept	MNC/PCO	Job no/file no	415437
	Calculated by	NS	Date	10/02/2020
	Checked by	FL	Date	15/02/2020

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Maximum Overtopping Volume (Revetment):

$$V_{\max} = a \cdot [\ln(N_{ow})]^{1/b} \qquad 5.57$$

α, b = parameters of the Weibull distrubution calculated from equations 5.53 & 5.54

Now = given by P_{ov} x N_w calculated from EurOtop II (2018) equations 5.52 & 5.56

Maximum Overtopping Volume (Vertical Wall):

$$V_{max} = a(lnN_{ow})^{1/b} \qquad 7.27$$

Calculated in accordance to EurOtop II (2018) equations 7.24 - 7.33

Reduction factor due to wide crest:

$C_r = 3.06 \exp(-1.5G_c/H_{m0})$ with maximum $C_r = 1$ 6.8

Return wall (Bullnose) reduction factor K_{bn}:

$$k_{bn} = \frac{q_{\text{with\_bullnose}}}{q_{\text{without\_bullnose}}} \qquad 7.23$$

Calculated in accordance to EurOtop II (2018) figures 7.21& 7.23 and equations 7.21 & 7.22

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
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Profile 1 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

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OVERTOPPING CALCULATIONS: PROFILE 1

Existing structure and foreshore geometry - Case 1

Crest Level:	+6.13 mOD	Revetment Crest:	+3 mOD
Toe Level:	+0.89 mOD	Revetment Slope:	1: 5.15 m

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**V_{max} [l/m]**
1	3.29	0	2	2.70	52	9,453
	2.84	36	7,102	2.25	89	16,556
	2.38	53	11,852	1.79	82	16,596
	1.92	27	10,206	1.33	55	9,597
	1.46	1	1,021	0.87	2	1,637
10	3.29	0	4	2.70	78	11,168
	2.84	59	8,744	2.25	168	21,503
	2.38	133	17,959	1.79	316	34,906
	1.92	251	30,364	1.33	522	47,815
	1.46	421	43,706	0.87	656	52,180
	1.00	211	23,388	0.41	27	2,401
50	2.84	70	9,442	2.25	193	22,570
	2.38	156	19,087	1.79	361	36,272
	1.92	295	31,893	1.33	600	49,292
	1.46	497	45,383	0.87	918	55,452
	1.00	683	52,981	0.41	73	3,171
	0.55	20	1,837	-0.04	*	*
100	2.84	75	9,749	2.25	204	23,030
	2.38	164	19,423	1.79	375	36,670
	1.92	311	32,397	1.33	627	49,766
	1.46	520	45,862	0.87	955	55,789
	1.00	789	54,551	0.41	89	3,208
	0.55	59	3,499	-0.04	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	3.29	1	3.54	37	2.70	11	4.05	445
	2.84	5	3.82	132	2.25	37	4.12	1,061
	2.38	16	3.77	141	1.79	46	3.64	673
	1.92	9	2.95	44	1.33	39	2.90	165
	1.46	0	1.20	0	0.87	0	1.19	0
10	3.29	1	4.00	57	2.70	16	4.54	679
	2.84	9	4.41	181	2.25	69	4.93	2,565
	2.38	46	4.78	310	1.79	213	5.30	7,177
	1.92	153	5.09	599	1.33	504	5.59	15,003
	1.46	391	5.35	1,225	0.87	802	5.44	18,124
	1.00	250	3.80	250	0.41	588	3.74	3,933
50	2.84	11	4.61	205	2.25	77	5.14	3,038
	2.38	53	5.02	362	1.79	232	5.54	8,487
	1.92	171	5.37	728	1.33	539	5.88	17,852
	1.46	422	5.68	1,508	0.87	1,031	6.18	30,159
	1.00	772	5.70	2,351	0.41	1,313	5.70	27,422
	0.55	425	3.55	247	-0.04	*	*	*
100	2.84	12	4.70	216	2.25	81	5.23	3,266
	2.38	55	5.09	379	1.79	238	5.61	8,908
	1.92	177	5.46	776	1.33	551	5.97	18,872
	1.46	432	5.77	1,599	0.87	1,047	6.27	31,716
	1.00	860	6.01	3,001	0.41	1,545	6.24	38,332
	0.55	1,094	5.45	2,652	-0.04	*	*	*

* With $R_c < 0$ there is flooding, water level above crest. No overtopping defined.

Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	3.54	10	3.57	0	4.05	165
	3.71	0	3.82	79	3.12	1	4.12	423
	3.25	0	3.77	125	2.66	0	3.64	233
	2.79	0	2.95	20	2.20	0	2.90	41
	2.33	0	1.20	0	1.74	0	1.19	0
10	4.16	0	4.00	17	3.57	0	4.54	239
	3.71	0	4.41	114	3.12	2	4.93	1,031
	3.25	1	4.78	268	2.66	11	5.30	3,310
	2.79	7	5.09	406	2.20	40	5.59	8,058
	2.33	27	5.35	709	1.74	67	5.44	10,329
	1.87	4	3.80	150	1.28	10	3.74	1,502
50	3.71	0	4.61	134	3.12	3	5.14	1,217
	3.25	2	5.02	299	2.66	13	5.54	3,912
	2.79	8	5.37	472	2.20	47	5.88	9,575
	2.33	32	5.68	853	1.74	128	6.18	18,788
	1.87	73	5.70	1,289	1.28	143	5.70	17,292
	1.42	5	3.55	123	0.83	13	3.50	1,593
100	3.71	0	4.70	143	3.12	3	5.23	1,309
	3.25	2	5.09	309	2.66	14	5.61	4,110
	2.79	9	5.46	497	2.20	49	5.97	10,131
	2.33	33	5.77	900	1.74	133	6.27	19,755
	1.87	95	6.01	1,665	1.28	229	6.24	26,030
	1.42	100	5.45	1,413	0.83	193	5.46	18,907

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**
1	4.66	0	3.54	3	4.07	0	4.05	92
	4.21	0	3.82	45	3.62	0	4.12	252
	3.75	0	3.77	89	3.16	0	3.64	129
	3.29	0	2.95	10	2.70	0	2.90	19
	2.83	0	1.20	0	2.24	0	1.19	0
10	4.66	0	4.00	7	4.07	0	4.54	131
	4.21	0	4.41	69	3.62	1	4.93	611
	3.75	0	4.78	240	3.16	5	5.30	2,092
	3.29	3	5.09	379	2.70	20	5.59	5,456
	2.83	13	5.35	575	2.24	35	5.44	7,143
	2.37	1	3.80	142	1.78	4	3.74	819
50	4.21	0	4.61	83	3.62	1	5.14	718
	3.75	1	5.02	268	3.16	6	5.54	2,462
	3.29	4	5.37	425	2.70	24	5.88	6,458
	2.83	16	5.68	672	2.24	73	6.18	13,673
	2.37	39	5.70	958	1.78	81	5.70	12,520
	1.92	2	3.55	107	1.33	5	3.50	834
100	4.21	0	4.70	90	3.62	1	5.23	771
	3.75	1	5.09	277	3.16	7	5.61	2,585
	3.29	4	5.46	442	2.70	26	5.97	6,831
	2.83	17	5.77	705	2.24	76	6.27	14,369
	2.37	52	6.01	1,231	1.78	138	6.24	19,809
	1.92	54	5.45	1,010	1.33	113	5.46	13,986

Project					
Colwyn Bay Old Promenade Coastal Defence					
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437	
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Profile 1 (Beach Drawdown)	Checked by	NC	Date	31/03/2020	5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	3.54	0	4.72	0	4.05	15
	4.86	0	3.82	5	4.27	0	4.12	51
	4.40	0	3.77	16	3.81	0	3.64	21
	3.94	0	2.95	0	3.35	0	2.90	2
	3.48	0	1.20	0	2.89	0	1.19	0
10	5.31	0	4.00	0	4.72	0	4.54	23
	4.86	0	4.41	12	4.27	0	4.93	142
	4.40	0	4.78	86	3.81	1	5.30	591
	3.94	0	5.09	379	3.35	4	5.59	1,821
	3.48	3	5.35	1,264	2.89	8	5.44	2,465
	3.02	0	3.80	88	2.43	0	3.74	151
50	4.86	0	4.61	15	4.27	0	5.14	170
	4.40	0	5.02	106	3.81	1	5.54	703
	3.94	1	5.37	461	3.35	5	5.88	2,175
	3.48	3	5.68	1,505	2.89	20	6.18	5,437
	3.02	9	5.70	2,945	2.43	21	5.70	4,790
	2.57	0	3.55	71	1.98	0	3.50	135
100	4.86	0	4.70	17	4.27	0	5.23	184
	4.40	0	5.09	113	3.81	1	5.61	741
	3.94	1	5.46	495	3.35	6	5.97	2,311
	3.48	4	5.77	1,596	2.89	21	6.27	5,732
	3.02	14	6.01	4,068	2.43	42	6.24	8,655
	2.57	13	5.45	3,297	1.98	30	5.46	5,492

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile 2 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

Sheet no: 1 of 5

OVERTOPPING CALCULATIONS: PROFILE 2

Existing structure and foreshore geometry - Case 1

Crest Level:	+5.5 mOD	Revetment Crest:	+3.3 mOD
Toe Level:	+1.89 mOD	Revetment Slope:	1: 3.85 m

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]
1	2.66	0	17	2.07	95	12,199
	2.21	0	120	1.62	194	22,341
	1.75	125	17,384	1.16	14	1,646
	1.29	5	849	0.70	11	1,094
	0.83	2	1,261	0.24	2	161
10	2.66	0	34	2.07	140	14,069
	2.21	1	246	1.62	295	25,162
	1.75	236	21,581	1.16	40	2,677
	1.29	31	2,408	0.70	65	3,075
	0.83	53	3,021	0.24	90	1,978
	0.37	34	2,362	-0.22	*	*
50	2.21	1	317	1.62	336	26,138
	1.75	275	22,665	1.16	45	2,751
	1.29	37	2,497	0.70	75	3,133
	0.83	62	3,098	0.24	114	1,991
	0.37	92	2,535	-0.22	*	*
	-0.08	*	*	-0.67	*	*
100	2.21	1	354	1.62	354	26,552
	1.75	287	22,983	1.16	47	2,772
	1.29	39	2,525	0.70	78	3,151
	0.83	65	3,119	0.24	118	1,996
	0.37	98	2,551	-0.22	*	*
	-0.08	*	*	-0.67	*	*

* With R_c < 0 flooding occurs, water level above crest. No overtopping can be defined.

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**
1	2.66	2	3.40	47	2.07	34	3.40	1,089
	2.21	18	3.71	120	1.62	135	3.71	2,683
	1.75	73	3.87	179	1.16	176	3.87	1,523
	1.29	52	2.99	54	0.70	189	2.99	475
	0.83	1	1.21	0	0.24	46	1.21	0
10	2.66	4	3.87	76	2.07	47	3.87	1,603
	2.21	28	4.31	182	1.62	175	4.31	5,071
	1.75	122	4.71	382	1.16	469	4.71	12,110
	1.29	354	5.03	881	0.70	962	5.03	21,950
	0.83	784	5.32	1,890	0.24	1,473	5.32	26,085
	0.37	659	3.84	480	-0.22	*	*	*
50	2.21	33	4.51	212	1.62	192	4.51	5,955
	1.75	137	4.95	465	1.16	502	4.95	14,252
	1.29	386	5.32	1,093	0.70	1,013	5.32	26,106
	0.83	830	5.65	2,350	0.24	1,669	5.65	39,311
	0.37	1,430	5.84	4,128	-0.22	*	*	*
	-0.08	*	*	*	-0.67	*	*	*
100	2.21	36	4.60	226	1.62	199	4.60	6,375
	1.75	142	5.02	492	1.16	512	5.02	14,932
	1.29	397	5.41	1,171	0.70	1,031	5.41	27,574
	0.83	846	5.75	2,497	0.24	1,688	5.75	41,343
	0.37	1,461	6.01	4,550	-0.22	*	*	*
	-0.08	*	*	*	-0.67	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	3.40	5	3.57	0	3.40	279
	3.71	0	3.71	55	3.12	1	3.71	815
	3.25	0	3.87	154	2.66	0	3.87	229
	2.79	0	2.99	23	2.20	0	2.99	41
	2.33	0	1.21	0	1.74	0	1.21	0
10	4.16	0	3.87	10	3.57	0	3.87	354
	3.71	0	4.31	88	3.12	2	4.31	1,319
	3.25	1	4.71	246	2.66	10	4.71	3,853
	2.79	6	5.03	385	2.20	39	5.03	8,863
	2.33	25	5.32	686	1.74	76	5.32	11,722
	1.87	4	3.84	158	1.28	10	3.84	1,532
50	3.71	0	4.51	106	3.12	2	4.51	1,516
	3.25	1	4.95	277	2.66	13	4.95	4,479
	2.79	8	5.32	449	2.20	46	5.32	10,432
	2.33	30	5.65	830	1.74	129	5.65	19,839
	1.87	88	5.84	1,508	1.28	158	5.84	18,659
	1.42	5	3.58	129	0.83	13	3.58	1,621
100	3.71	0	4.60	115	3.12	3	4.60	1,614
	3.25	1	5.02	287	2.66	13	5.02	4,687
	2.79	8	5.41	474	2.20	49	5.41	11,009
	2.33	32	5.75	878	1.74	134	5.75	20,837
	1.87	95	6.01	1,662	1.28	251	6.01	28,442
	1.42	122	5.60	1,670	0.83	207	5.60	20,018

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile 2 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

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Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	3.40	1	4.07	0	3.40	154
	4.21	0	3.71	29	3.62	0	3.71	563
	3.75	0	3.87	120	3.16	0	3.87	124
	3.29	0	2.99	12	2.70	0	2.99	19
	2.83	0	1.21	0	2.24	0	1.21	0
10	4.66	0	3.87	4	4.07	0	3.87	209
	4.21	0	4.31	50	3.62	1	4.31	854
	3.75	0	4.71	213	3.16	5	4.71	2,606
	3.29	2	5.03	361	2.70	20	5.03	6,311
	2.83	12	5.32	557	2.24	41	5.32	8,434
	2.37	1	3.84	149	1.78	4	3.84	833
50	4.21	0	4.51	62	3.62	1	4.51	969
	3.75	0	4.95	242	3.16	6	4.95	2,995
	3.29	3	5.32	407	2.70	24	5.32	7,357
	2.83	15	5.65	656	2.24	73	5.65	14,920
	2.37	48	5.84	1,122	1.78	91	5.84	13,754
	1.92	2	3.58	112	1.33	5	3.58	848
100	4.21	0	4.60	69	3.62	1	4.60	1,027
	3.75	1	5.02	251	3.16	6	5.02	3,126
	3.29	4	5.41	424	2.70	25	5.41	7,749
	2.83	16	5.75	689	2.24	77	5.75	15,647
	2.37	52	6.01	1,230	1.78	154	6.01	22,345
	1.92	68	5.60	1,200	1.33	124	5.60	15,020

Project					
Colwyn Bay Old Promenade Coastal Defence					
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437	
Overtopping Assessment	Calculated by	NS	Date	10/02/2020	Sheet no
Profile 2 (Beach Drawdown)	Checked by	NC	Date	31/03/2020	5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	3.40	0	4.72	0	3.95	9
	4.86	0	3.71	2	4.27	0	4.23	75
	4.40	0	3.87	25	3.81	0	3.71	27
	3.94	0	2.99	1	3.35	0	2.93	2
	3.48	0	1.21	0	2.89	0	1.20	0
10	5.31	0	3.87	0	4.72	0	4.44	16
	4.86	0	4.31	7	4.27	0	4.87	117
	4.40	0	4.71	68	3.81	1	5.25	537
	3.94	0	5.03	334	3.35	4	5.57	1,755
	3.48	2	5.32	1,194	2.89	11	5.59	3,160
	3.02	0	3.84	100	2.43	0	3.78	167
50	4.86	0	4.51	10	4.27	0	5.08	143
	4.40	0	4.95	86	3.81	1	5.50	647
	3.94	1	5.32	414	3.35	5	5.86	2,119
	3.48	3	5.65	1,440	2.89	20	6.19	5,486
	3.02	12	5.84	3,691	2.43	27	5.85	5,973
	2.57	0	3.58	80	1.98	0	3.53	148
100	4.86	0	4.60	12	4.27	0	5.17	156
	4.40	0	5.02	92	3.81	1	5.58	685
	3.94	1	5.41	447	3.35	6	5.96	2,260
	3.48	3	5.75	1,533	2.89	21	6.28	5,798
	3.02	13	6.01	4,061	2.43	53	6.41	10,567
	2.57	17	5.60	4,167	1.98	38	5.60	6,629

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile 3 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

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OVERTOPPING CALCULATIONS: PROFILE 3

Existing structure and foreshore geometry - Case 1

Crest Level:	+5.47 mOD	Verticall Wall	
Toe Level:	+0.0 mOD	Beach Slope:	1:51.3

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]
1	2.63	98	16,850	2.04	188	33,267
	2.18	96	20,623	1.59	196	29,461
	1.72	98	17,379	1.13	185	22,762
	1.26	55	9,073	0.67	166	26,220
	0.80	2	1,391	0.21	29	3,534
10	2.63	140	19,207	2.04	246	28,357
	2.18	267	32,226	1.59	571	54,472
	1.72	456	46,975	1.13	825	64,790
	1.26	605	56,421	0.67	948	62,159
	0.80	689	57,450	0.21	**	**
	0.34	373	32,990	-0.25	*	*
50	2.18	302	33,492	1.59	424	37,273
	1.72	517	48,466	1.13	955	64,476
	1.26	802	60,392	0.67	1,343	62,130
	0.80	1,071	61,692	0.21	**	**
	0.34	1,034	43,157	-0.25	*	*
	-0.11	*	*	-0.70	*	*
100	2.18	317	34,033	1.59	524	44,563
	1.72	535	48,897	1.13	**	**
	1.26	836	60,873	0.67	**	**
	0.80	1,206	62,725	0.21	**	**
	0.34	**	**	-0.25	*	*
	-0.11	*	*	-0.70	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

* * Out of equation boundaries. Relatively too large waves

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	2.63	35	4.58	304	2.04	97	4.60	1,788
	2.18	47	4.18	222	1.59	128	4.15	2,216
	1.72	67	3.78	157	1.13	153	3.55	1,376
	1.26	43	2.86	43	0.67	177	2.83	448
	0.80	1	1.18	0	0.21	51	1.18	0
10	2.63	46	5.11	404	2.04	204	5.63	4,141
	2.18	150	5.51	792	1.59	476	6.03	10,273
	1.72	376	5.87	1,627	1.13	853	6.21	18,799
	1.26	645	5.86	2,288	0.67	1,130	5.86	24,585
	0.80	899	5.52	2,392	0.21	1,453	5.50	25,621
	0.34	628	3.71	392	-0.25	*	*	*
50	2.18	163	5.73	913	1.59	503	6.26	11,928
	1.72	403	6.14	1,904	1.13	976	6.66	23,554
	1.26	812	6.48	3,640	0.67	1,565	6.89	36,754
	0.80	1,285	6.56	5,350	0.21	1,909	6.56	43,843
	0.34	1,419	5.76	3,928	-0.25	*	*	*
	-0.11	*	*	*	-0.70	*	*	*
100	2.18	169	5.83	969	1.59	515	6.36	12,697
	1.72	411	6.21	1,992	1.13	989	6.74	24,597
	1.26	827	6.58	3,844	0.67	1,640	7.09	39,848
	0.80	1,419	6.88	6,636	0.21	2,067	6.89	48,876
	0.34	1,680	6.35	6,077	-0.25	*	*	*
	-0.11	*	*	*	-0.70	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
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	Checked by	NC	Date	31/03/2020

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Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	4.58	277	3.57	1	4.60	420
	3.71	0	4.18	193	3.12	1	4.15	443
	3.25	0	3.78	129	2.66	0	3.55	195
	2.79	0	2.86	13	2.20	0	2.83	34
	2.33	0	1.18	0	1.74	0	1.18	0
10	4.16	0	5.11	319	3.57	2	5.63	1,122
	3.71	3	5.51	498	3.12	10	6.03	3,334
	3.25	14	5.87	749	2.66	31	6.21	7,103
	2.79	28	5.86	921	2.20	52	5.86	9,748
	2.33	36	5.52	867	1.74	70	5.50	10,729
	1.87	3	3.71	130	1.28	9	3.66	1,377
50	3.71	4	5.73	537	3.12	12	6.26	3,861
	3.25	16	6.14	842	2.66	42	6.66	9,347
	2.79	52	6.48	1,464	2.20	103	6.89	17,480
	2.33	105	6.56	2,105	1.74	164	6.56	22,593
	1.87	79	5.76	1,387	1.28	142	5.68	17,180
	1.42	4	3.47	108	0.83	12	3.44	1,498
100	3.71	4	5.83	557	3.12	13	6.36	4,113
	3.25	17	6.21	872	2.66	43	6.74	9,768
	2.79	55	6.58	1,538	2.20	114	7.09	19,347
	2.33	140	6.88	2,696	1.74	194	6.89	26,305
	1.87	142	6.35	2,331	1.28	237	6.31	26,749
	1.42	104	5.47	1,452	0.83	189	5.42	18,601

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	4.58	215	4.07	0	4.60	265
	4.21	0	4.18	145	3.62	0	4.15	266
	3.75	0	3.78	93	3.16	0	3.55	106
	3.29	0	2.86	6	2.70	0	2.83	15
	2.83	0	1.18	0	2.24	0	1.18	0
10	4.66	0	5.11	253	4.07	1	5.63	734
	4.21	1	5.51	490	3.62	5	6.03	2,276
	3.75	7	5.87	680	3.16	16	6.21	4,999
	3.29	14	5.86	771	2.70	27	5.86	6,819
	2.83	18	5.52	692	2.24	37	5.50	7,477
	2.37	1	3.71	125	1.78	3	3.66	735
50	4.21	2	5.73	521	3.62	6	6.26	2,623
	3.75	8	6.14	745	3.16	23	6.66	6,668
	3.29	29	6.48	1,177	2.70	62	6.89	13,063
	2.83	60	6.56	1,622	2.24	98	6.56	17,052
	2.37	43	5.76	1,031	1.78	80	5.68	12,420
	1.92	1	3.47	96	1.33	4	3.44	769
100	4.21	2	5.83	535	3.62	7	6.36	2,791
	3.75	9	6.21	766	3.16	24	6.74	6,964
	3.29	30	6.58	1,230	2.70	70	7.09	14,566
	2.83	83	6.88	2,077	2.24	120	6.89	20,233
	2.37	82	6.35	1,738	1.78	144	6.31	20,478
	1.92	56	5.47	1,039	1.33	110	5.42	13,701

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile 3 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

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Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	4.58	53	4.72	0	4.60	109
	4.86	0	4.18	31	4.27	0	4.15	57
	4.40	0	3.78	17	3.81	0	3.55	14
	3.94	0	2.86	0	3.35	0	2.83	1
	3.48	0	1.18	0	2.89	0	1.18	0
10	5.31	0	5.11	74	4.72	0	5.63	501
	4.86	0	5.51	336	4.27	2	6.03	1,559
	4.40	1	5.87	1,123	3.81	7	6.21	3,092
	3.94	3	5.86	1,798	3.35	8	5.86	2,865
	3.48	4	5.52	1,744	2.89	9	5.50	2,726
	3.02	0	3.71	63	2.43	0	3.66	115
50	4.86	0	5.73	385	4.27	3	6.26	1,762
	4.40	2	6.14	1,292	3.81	11	6.66	4,582
	3.94	8	6.48	3,433	3.35	31	6.89	8,854
	3.48	17	6.56	5,818	2.89	36	6.56	8,758
	3.02	10	5.76	3,274	2.43	21	5.68	4,699
	2.57	0	3.47	53	1.98	0	3.44	107
100	4.86	0	5.83	410	4.27	3	6.36	1,861
	4.40	2	6.21	1,349	3.81	12	6.74	4,765
	3.94	8	6.58	3,612	3.35	37	7.09	10,384
	3.48	26	6.88	8,012	2.89	52	6.89	11,919
	3.02	24	6.35	6,492	2.43	46	6.31	9,357
	2.57	14	5.47	3,427	1.98	28	5.42	5,200

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile4 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

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OVERTOPPING CALCULATIONS: PROFILE 4

Existing structure and foreshore geometry - Case 1

Crest Level: +5.75 mOD — Verticall Wall

Toe Level: +1.13 mOD — Beach Slope: 1: 45 m

Return period (joint probability) [yrs]	Present Day: Freeboard R_c [m]	Present Day: q [l/m/s]	Present Day: V_{max} [l/m]	In 50 years (including SLR): Freeboard R_c [m]	In 50 years (including SLR): q [l/m/s]	In 50 years (including SLR): V_{max} [l/m]
1	2.91	54	9,756	2.32	132	21,583
	2.46	79	15,511	1.87	131	23,505
	2.00	81	17,883	1.41	111	16,501
	1.54	40	9,145	0.95	85	10,205
	1.08	0	1,505	0.49	8	1,774
10	2.91	82	11,534	2.32	211	25,882
	2.46	172	21,930	1.87	381	39,981
	2.00	317	35,557	1.41	622	53,510
	1.54	517	49,417	0.95	753	57,692
	1.08	590	54,901	0.49	869	49,452
	0.62	289	27,427	0.03	**	**
50	2.46	197	23,034	1.87	427	41,266
	2.00	363	36,997	1.41	700	54,873
	1.54	595	51,042	0.95	1,050	61,352
	1.08	899	60,195	0.49	1,301	51,090
	0.62	899	54,257	0.03	**	**
	0.17	*	*	-0.42	*	*
100	2.46	209	23,510	1.87	448	41,810
	2.00	377	37,418	1.41	724	55,262
	1.54	622	51,566	0.95	1,092	61,726
	1.08	935	60,605	0.49	1,458	51,435
	0.62	1,122	55,633	0.03	**	**
	0.17	*	*	-0.42	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

* * Out of equation boundaries. Relatively too large waves

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	2.91	11	4.25	212	2.32	63	4.62	1,402
	2.46	28	4.20	217	1.87	85	4.21	1,756
	2.00	42	3.83	157	1.41	93	3.59	1,011
	1.54	22	2.90	43	0.95	94	2.85	289
	1.08	0	1.19	0	0.49	8	1.18	0
10	2.91	16	4.76	268	2.32	98	5.31	2,463
	2.46	67	5.18	466	1.87	271	5.71	6,907
	2.00	204	5.55	949	1.41	604	6.08	15,065
	1.54	478	5.86	1,887	0.95	891	5.89	21,574
	1.08	689	5.55	2,016	0.49	1,206	5.55	23,150
	0.62	435	3.74	318	0.03	859	3.69	5,195
50	2.46	75	5.40	535	1.87	291	5.94	8,068
	2.00	223	5.81	1,118	1.41	639	6.34	17,626
	1.54	513	6.16	2,260	0.95	1,170	6.69	30,593
	1.08	982	6.47	4,192	0.49	1,631	6.59	40,335
	0.62	1,170	5.83	3,475	0.03	1,684	5.74	31,860
	0.17	691	3.50	326	-0.42	*	*	*
100	2.46	79	5.49	567	1.87	299	6.03	8,613
	2.00	229	5.88	1,172	1.41	649	6.42	18,433
	1.54	525	6.26	2,395	0.95	1,188	6.79	32,257
	1.08	998	6.57	4,418	0.49	1,784	6.93	45,225
	0.62	1,401	6.38	5,298	0.03	1,979	6.37	44,522
	0.17	1,506	5.53	3,645	-0.42	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

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Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	4.25	140	3.57	1	4.62	435
	3.71	0	4.20	201	3.12	1	4.21	485
	3.25	0	3.83	143	2.66	0	3.59	211
	2.79	0	2.90	15	2.20	0	2.85	36
	2.33	0	1.19	0	1.74	0	1.18	0
10	4.16	0	4.76	178	3.57	1	5.31	760
	3.71	1	5.18	374	3.12	7	5.71	2,488
	3.25	7	5.55	554	2.66	27	6.08	6,465
	2.79	28	5.86	919	2.20	53	5.89	9,950
	2.33	37	5.55	896	1.74	74	5.55	11,125
	1.87	3	3.74	137	1.28	9	3.69	1,422
50	3.71	2	5.40	404	3.12	8	5.94	2,898
	3.25	9	5.81	621	2.66	31	6.34	7,556
	2.79	33	6.16	1,073	2.20	89	6.69	15,704
	2.33	95	6.47	1,942	1.74	167	6.59	22,951
	1.87	87	5.83	1,487	1.28	147	5.74	17,658
	1.42	4	3.50	113	0.83	12	3.46	1,532
100	3.71	2	5.49	419	3.12	9	6.03	3,096
	3.25	10	5.88	643	2.66	33	6.42	7,909
	2.79	35	6.26	1,129	2.20	93	6.79	16,562
	2.33	99	6.57	2,042	1.74	198	6.93	26,709
	1.87	147	6.38	2,405	1.28	246	6.37	27,455
	1.42	111	5.53	1,542	0.83	194	5.47	18,979

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	4.25	87	4.07	0	4.62	276
	4.21	0	4.20	153	3.62	0	4.21	294
	3.75	0	3.83	108	3.16	0	3.59	115
	3.29	0	2.90	7	2.70	0	2.85	16
	2.83	0	1.19	0	2.24	0	1.18	0
10	4.66	0	4.76	117	4.07	1	5.31	477
	4.21	1	5.18	345	3.62	3	5.71	1,641
	3.75	3	5.55	525	3.16	14	6.08	4,491
	3.29	14	5.86	770	2.70	28	5.89	6,984
	2.83	19	5.55	714	2.24	39	5.55	7,810
	2.37	1	3.74	131	1.78	3	3.69	765
50	4.21	1	5.40	373	3.62	4	5.94	1,903
	3.75	4	5.81	572	3.16	17	6.34	5,230
	3.29	17	6.16	877	2.70	52	6.69	11,530
	2.83	54	6.47	1,496	2.24	100	6.59	17,376
	2.37	47	5.83	1,106	1.78	84	5.74	12,847
	1.92	1	3.50	100	1.33	5	3.46	792
100	4.21	1	5.49	387	3.62	4	6.03	2,030
	3.75	5	5.88	588	3.16	18	6.42	5,471
	3.29	18	6.26	917	2.70	55	6.79	12,155
	2.83	56	6.57	1,568	2.24	123	6.93	20,603
	2.37	86	6.38	1,795	1.78	150	6.37	21,136
	1.92	61	5.53	1,106	1.33	114	5.47	14,053

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Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	4.25	13	4.72	0	4.62	118
	4.86	0	4.20	34	4.27	0	4.21	69
	4.40	0	3.83	21	3.81	0	3.59	16
	3.94	0	2.90	0	3.35	0	2.85	1
	3.48	0	1.19	0	2.89	0	1.18	0
10	5.31	0	4.76	24	4.72	0	5.31	235
	4.86	0	5.18	147	4.27	1	5.71	865
	4.40	1	5.55	596	3.81	5	6.08	2,527
	3.94	3	5.86	1,794	3.35	8	5.89	3,008
	3.48	4	5.55	1,837	2.89	10	5.55	3,000
	3.02	0	3.74	71	2.43	0	3.69	127
50	4.86	0	5.40	173	4.27	1	5.94	992
	4.40	1	5.81	697	3.81	6	6.34	2,914
	3.94	4	6.16	2,108	3.35	23	6.69	6,932
	3.48	15	6.47	5,200	2.89	38	6.59	9,117
	3.02	12	5.83	3,618	2.43	23	5.74	5,095
	2.57	0	3.50	59	1.98	0	3.46	117
100	4.86	0	5.49	187	4.27	1	6.03	1,054
	4.40	1	5.88	732	3.81	7	6.42	3,043
	3.94	4	6.26	2,230	3.35	24	6.79	7,294
	3.48	16	6.57	5,463	2.89	54	6.93	12,380
	3.02	25	6.38	6,774	2.43	50	6.37	10,076
	2.57	15	5.53	3,731	1.98	31	5.47	5,562