Dorothy Birks

Proposed Development at North Beach Road, Barassie

Flood Risk Assessment

30 September 2021

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Document Information and History

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Table of Contents

List of Figures

List of Tables

SEPA CHECKLIST

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019)

This document must be attached within the front cover of any Flood Risk Assessments issued to Local Planning Authorities (LPA) in support of a development proposal which may be at risk of flooding. The document will take only a few minutes to complete and will assist SEPA in reviewing FRAs, when consulted by LPAs. This document should not be a substitute for a FRA.

Development Proposal Summary			
Site Name:	North Beach Barasie, Troon		
Grid Reference:	Easting: 232488	Northing:	632388
Local Authority:	South Ayrshire Council		
Planning Reference number (if known):			
Nature of the development:	Commercial	If residential, state type:	Restaurant / Café
Size of the development site:	0.05 Ha		
Identified Flood Risk:	Source: Coastal	Source name:	
Land Use Planning			
Is any of the site within the functional floodplain? (refer to SPP para 255)	Yes	If yes, what is the net loss of storage?	m^3
Is the site identified within the local development plan?	No	Local Development Plan Name: / Allocation Number / Reference:	Year of Publication:
If yes, what is the proposed use for the site as identified in the local plan?	Select from List	If Other please specify:	
Does the local development plan and/or any pre-application advice, identify any flood risk issues with or requirements for the site.	No	If so, please specify:	
What is the proposed land use vulnerability?	Least Vulnerable	Do the proposals represent an increase in land use vulnerability?	No
Supporting Information			
Have clear maps / plans been provided within the FRA (including topographic and flood inundation plans)?	Yes		
Has sufficient supporting information, in line with our Technical Guidance, been provided? For example: site plans, photos, topographic information, structure information and other site specific information.	Yes		
Has a historic flood search been undertaken?	Yes	If flood records in vicinity of the site please provide details:	
Is a formal flood prevention scheme present?	No	If known, state the standard of protection offered:	
Current / historical site use:	Disused toliet block - now demolished with hardstanding base remaining		
Is the site considered vacant or derelict?	Yes		
Development Requirements			
Freeboard on design water level:	0.6 m		
Is safe / dry access and egress available?	Neither	but no overnight accomodation; Min access/egress level:	m AOD
Design levels:	Ground level: m AOD	Min FFL:	5.45 mAOD (above surrounding ground levels)
Mitigation			
Can development be designed to avoid all areas at risk of flooding?	Yes		
Is mitigation proposed?	Yes		
If yes, is compenstory storage necessary?	No		
Demonstration of compensatory storage on a "like for like" basis?	No		
Should water resistant materials and forms of construction be used?	No		

PAGE 1 of 2

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019)

Hydrology

Is there a requirement to consider fluvial flooding?		No		
Area of catchment:			km²	Is a map of catchment area included in FRA?
Estimation method(s) used (please select all that apply):				If Pooled analysis have group details been included?
				If other (please specify methodology used):
Estimate of 200 year design flood flow:			m³/s	
Qmed estimate:			m³/s	Method:
Statistical Distribution Selected:				Reasons for selection:

Hydraulics

Hydraulic modelling method:				Software used:
				If other please specify:
Number of cross sections:				
Source of data (i.e. topographic survey, LiDAR etc):				Date obtained / surveyed:
Modelled reach length:			m	
Any changes to default simulation parameters?				If yes please provide details:
Model timestep:				
Model grid size:				
Any structures within the modelled length?				Specify, if combination:
Maximum observed velocity:			m/s	
Brief summary of sensitivity tests, and range:				
variation on flow (%)			%	Please specify climate change scenario considered:
variation on channel roughness (%)			%	
blockage of structure (range of % blocked)			%	
boundary conditions:		Upstream		Downstream
(1) type				
	Specify if other			Specify if other:
(2) does it influence water levels at the site?				
Has model been calibrated (gauge data / flood records)?				
Is the hydraulic model available to SEPA?				
Design flood levels:	200 year		m AOD	200 year plus climate change — m AOD
Cross section results provided?				
Long section results provided?				
Cross section ratings provided?				
Tabular output provided (i.e. levels, velocities)?				
Mass balance error:				

Coastal

Is there a requirement to consider coastal / tidal flooding?		Yes		
Estimate of 200 year design flood level:	2021	3.64	m AOD	
Estimation method(s) used:	corected to 2021	CFB		If other please specify methodology used:
Allowance for climate change (m):	2100 (from 2017)	0.85	m	
Allowance for wave action etc (m):	0.4	0.4	m	
Overall design flood level:		4.85	m AOD	

Comments

Any additional comments:

Approved by: M Stewart
Organisation: Kaya Consulting Ltd.
Date: 30-Sep-21

Note: Further details and guidance is provided in 'Technical Flood Risk Guidance for Stakeholders' which can be accesssed here:- CLICK HERE

PAGE 2 of 2

1 Introduction

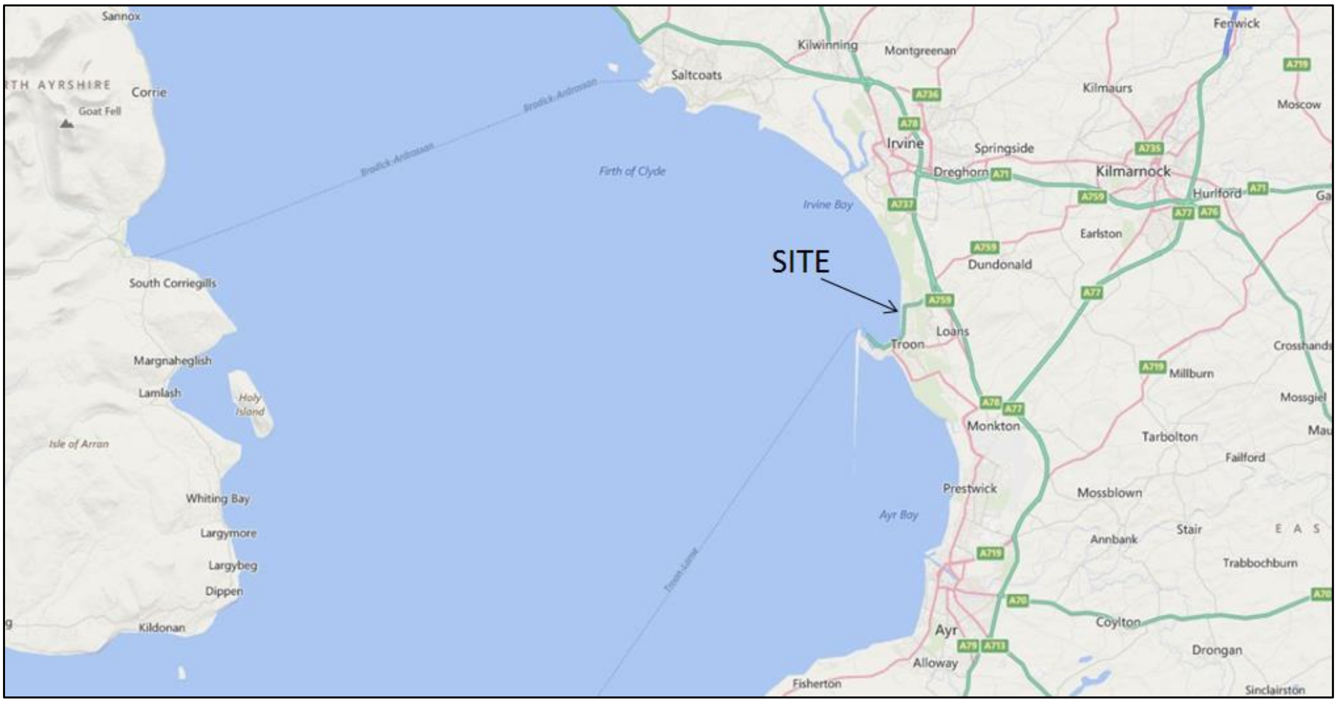
1.1 Background

Kaya Consulting Ltd was originally commissioned in 2014 by Dorothy Birks through CASA Design to undertake an assessment of flooding risk of a proposed development site at North Beach Road, Barassie, north of Troon, South Ayrshire (Figure 1) for planning application REF 14/00587/APP. The planning approvals expired in 2018 and the client has instructed Kaya Consulting Ltd. to update the flood risk assessment (FRA) to meet current standards.

The current report had been updated in September 2021 to meet current guidance and legislation. In particular, coastal flood levels and the uplift for climate change (sea level rise) have changed since 2014.

The site is located on the seaward side of the B746 Beach Road, with Irvine Bay in the Firth of Clyde to the west. The site comprised public toilets (which have now been demolished) and the proposals are to erect a new restaurant/cafe on the same site. A general location plan is shown in Figure 1.

Figure 1: General location plan



There are two watercourses which enter Irvine Bay to the north and south of the site. The Barassie Burn enters the Bay some 450m to the north and the Darley Burn some 450m to the south of the site (see Figure 2). There are no other watercourses near the site. The site is around 70m east of the Mean High Water Springs (MHWS) position on the 1:10,000 Ordnance Survey map. Hence, the main risk of flooding of the site is from the Firth of Clyde. Flood risk from the two watercourses will also be assessed, although given the distance from the site the risk from fluvial flooding is likely to be small. The risk of flooding from surcharging sewer system and groundwater will also be assessed.

The scope of work includes the following:

- Assessing risk of flooding from high tides, storm surges and waves in the Firth of Clyde;
- Assessing risk of flooding from the adjacent watercourses;
- Assessing risk of flooding from surface water runoff, surcharging sewers and groundwater.

Information made available to Kaya Consulting Ltd. for the study includes the following:

- Outline site boundary;
- Proposed development layout plan; and
- 1m LIDAR data purchased for the study.

The work carried out for the assessment and the main findings of the study are summarised in the following sections.

2 Legislative and Policy Aspects

2.1 National Planning Policy

The current version of the Scottish Planning Policy (SPP) was published in June 2014 https://www.gov.scot/publications/scottish-planning-policy/

The SPP sets out national planning policies that includes policies related to the management of flood risk. The key principles of SPP with respect to flooding are that the planning system should promote (Paragraph 255):

- *a precautionary approach to flood risk from all sources, including coastal, water course (fluvial), surface water (pluvial), groundwater, reservoirs and drainage systems (sewers and culverts), taking account of the predicted effects of climate change;*
- *flood avoidance: by safeguarding flood storage and conveying capacity, and locating development away from functional flood plains and medium to high risk areas;*
- *flood reduction: assessing flood risk and, where appropriate, undertaking natural and structural flood management measures, including flood protection, restoring natural features and characteristics, enhancing flood storage capacity, avoiding the construction of new culverts and opening existing culverts where possible; and*
- *avoidance of increased surface water flooding through requirements for Sustainable Drainage Systems (SuDS) and minimising the area of impermeable surface.*

SPP requires that most types of development are not located within the functional floodplain of a watercourse or the coast, defined as an area flooded during a 1 in 200-year event. Development should also take account of the effects of future climate change. Types of development allowed in floodplains are those that are water compatible (e.g., sports pitch) or where there is a small extension or similar development on an existing footprint.

Civil infrastructure may not be suitable for areas at risk of flooding up to a 1 in 1000 year event and some other types of development (e.g., care homes) may need to be protected for a 1 in 1000 year event, depending on the vulnerability of the land use.

SPP requires infrastructure and buildings to be generally designed to be free from surface water flooding for rainfall events greater than the 1 in 200-year event. SPP does not require surface water flooding risk to be considered for events higher than the 1 in 200-year event.

There is a general principle that development should not increase flood risk to others.

There is a presumption against land raising within floodplains. SPP allows this under exceptional circumstances only, where it is shown to have a neutral or better impact on flood risk outside the raised area (with provision of compensatory flood storage). SPP does not specific exceptional circumstances and provides local authorities some interpretation in this area.

2.2 Local Authority Policies and Guidance with Respect to Flood Risk

South Ayrshire Council (SAC) do not have a specific guidance on flooding and flood risk. Their Local Plan was adopted in 2014. The policies relating to flooding have been updated in the Proposed Local Development Plan was published September 2019 (https://www.south-ayrshire.gov.uk/planning/local-development-plans/ldp2/final%20proposed%20ldp2%20(for%20in%20house%20print).pdf) and is currently under review. Relevant policies are described below:

LDP policy: the coast

South Ayrshire Council will support proposals that protect the foreshore from development. Development within the wider coastal area will have to be in line with the Coastal Strategy Diagram and Coastal Development Guidance and the emerging Clyde Regional Marine Plan and must also safeguard the scenic and environmental qualities of the area. Any coastal development should be appropriately sited to avoid effects associated with managing current and predicted flood and erosion risk.

The Coastal Development Guidance and Strategy note that the Barassie site is located on an area classed 'Partly Developed' coastline in Troon. SAC note that very small scale developments which integrate well with existing land uses and which complement the surrounding environment will be encouraged. 'Very small scale' is taken to mean facilities that would not require any substantial building works. Landscaping works may be necessary to ensure that the facilities are suitability integrated into the landscape.

LDP policy: flood and development

Development should avoid areas which are likely to be affected by flooding or if the development would increase the likelihood of flooding elsewhere. SAC will assess development proposals against the Scottish Environmental Protection Agency's (SEPA) publication 'Flood Risk and Land use Vulnerability Guidance' (2018), or subsequent updates.

SAC will not approve land raising (work that permanently raises a site above the functional flood plain of a watercourse, or elsewhere if flooding is an issue), unless the developer can demonstrate that this would have a neutral or mitigating effect on the probability of flooding elsewhere; be linked to the provision of compensatory storage; and not create islands of development.

Areas of impermeable surfaces should be kept to a minimum in all new developments. Development proposals must include Sustainable Urban Drainage Systems (SUDS) which have been designed in line with the SUDS Manual (CIRIAC697). Where possible, SUDS should be designed to maximise the opportunities for habitat restoration and biodiversity and be considered as an integral element of wider visual and landscape design.

2.3 SEPA Guidance

SEPA are a statutory consultee to the planning process with respect to flood risk. To support its role and to give guidance to practitioners and local authorities SEPA have published a series of guidance documents. The key documents with direct relevance to flood risk assessment are;

1. SEPA (2018a), Flood Risk and Land Use Vulnerability Guidance, July 2018. https://www.sepa.org.uk/media/143416/land-use-vulnerability-guidance.pdf
2. SEPA (2019a), Technical Flood Risk Guidance for Stakeholders - SEPA requirements for undertaking a Flood Risk Assessment, May 2019. https://www.sepa.org.uk/media/162602/ss-nfr-p-002-technical-flood-risk-guidance-for-stakeholders.pdf
3. SEPA (2019b), Climate change allowances for flood risk assessment in land use planning, April 2019. https://www.sepa.org.uk/media/426913/lups_cc1.pdf
4. SEPA (2018b), Land Use Planning System, SEPA Development Plan Guidance Note 2a, July 2018. https://www.sepa.org.uk/media/306609/lups-dm-gu2a-development-management-guidance-on-flood-risk.pdf

Reference 1 provides SEPA's assessment of land use vulnerability which allows the identification of the appropriate return period to be considered in any flood risk assessment, based on the type of development proposed.

Reference 2 is a technical guidance document intended to outline methodologies that may be appropriate for hydrological and hydraulic modelling and sets out what information SEPA requires to be submitted as part of a Flood Risk Assessment.

Reference 3 outlines the most recent SEPA guidance in terms of flow, rainfall and sea level uplifts for climate change.

Reference 4 provides additional planning guidance with respect to flood risk.

In addition, The Water Environment (Controlled Activities) (Scotland) Amended Regulations 2011 (CAR) describes requirements for any works at or near watercourses that require licensing. SEPA are responsible for the implementation of the Act, see https://www.sepa.org.uk/media/34800/introduction-to-the-controlled-activities-regulations.pdf for an outline of the regulations and SEPA (2021) for a practical guide to the regulations (https://www.sepa.org.uk/media/34761/car_a_practical_guide.pdf).

With relevance to all developments the Regulations include a requirement that surface water discharge must not result in pollution of the water environment. It also makes Sustainable Drainage Systems (SuDS) a requirement for new development, with the exception of runoff from a single dwelling and discharges to coastal waters.

2.4 Guidance and Policy Constraints with Relevance to Current Site

Based on relevant policies and guidance the following sections outlines the principles and constraints under which the flood risk assessment is undertaken.

2.4.1 Land Use Vulnerability and Design Event

The proposed development is for a new restaurant/café, which is considered a 'Least Vulnerable' Use based on SEPA (2018a). Developments of this type are considered suitable for land outside the 1 in 200-year floodplain according to SEPA (2018a).

Medium to high-risk flood risk areas (>0.5% Annual Probability, i.e., within the 200-year floodplain) are generally not suitable for this type of development unless the following applies "Redevelopment of a previously developed site where it involves the demolition of existing buildings and/or erection of additional buildings within a development site, and the proposed land use is equal or less vulnerable than the existing land use". It is not clear what the vulnerability of the previous buildings on the site (toilet block) were. The site is now a car park/picnic area.

The design event for this development is the 1 in 200-year event.

2.4.2 Constraints on Developable Area

2.4.2.1 Coastal Flooding

Based on SPP housing development is not appropriate within the 1 in 200-year functional 'coastal' floodplain, although the site is fronted by open coastline. Land-raising may be permitted on the open coastline, if it can be shown that the land raising will not increase flooding elsewhere.

The assessment will identify the 1 in 200-year floodplain from coastal flooding.

2.4.2.2 River Flooding

Based on SPP housing development is not appropriate within the 1 in 200-year functional floodplain.

SEPA guidance recommends no development or land raising within the 1 in 200-year floodplain of any watercourse. If the watercourse is impacted by culverting, SEPA will require the floodplain to be mapped with a consideration of culvert blockage. There is no clear guidance on the amount of blockage, but the assessment will consider a realistic amount of blockage that could be expected in a flood event, based on the size of the culvert or bridge opening, land use and professional judgement.

Council guidance is consistent with SPP and the SEPA guidance.

The assessment will identify the 1 in 200-year floodplain from any watercourse impacting the site and identify any constraints on development.

2.4.2.3 Surface Water Flooding

Land affected by surface water flooding can generally be developed assuming the surface water flood risk can be managed through the development of the site drainage system and land drainage to manage surface water entering the site from outside its boundaries. However, in some cases, where sites currently act to store surface water, development could displace surface water and increase flood risk elsewhere. In these cases, there may be a need to leave areas of surface water storage undeveloped and/or provide storage of equivalent volumes of surface water elsewhere in the site.

The assessment will consider surface water flooding risks and identify constraints on development.

2.4.3 Climate Change Considerations

The development should be resilient against the impacts of climate change, such that properties are not predicted to flood for the design event plus climate change.

For coastal flooding, cumulative sea level rise from 2017 to 2100, based on the outputs from UK Climate Projections 2018 (UKCP18) for the Clyde River Basin Region is 0.85m (SEPA, 2019a).

The assessment will consider increases in flow due to climate change based on SEPA guidance and will consider climate change (sea-level rise) for coastal flooding to be +0.85m for the year 2100.

2.4.4 Development Levels and Finished Floor Levels

South Ayrshire Council do not provide specific guidance on Finished Floor Levels or development levels.

SEPA (2019a and 2019b) notes that adequate freeboard should be provided for developments involving the erection of new buildings and in the majority of cases an adequate freeboard allowance would be 600mm above the design flood level (separate to any climate change allowance applied). It is noted that other freeboards can be recommended if supported by appropriate modelling. For re-developments of existing buildings, the freeboard allowance is considered a recommendation and should be applied as far as practicable.

The assessment will consider Finished Floor Levels based on the 1 in 200 year + climate change flood levels + freeboard.

2.4.5 Site Access Considerations

It is important that developments can be accessed and left during flood events, so that developments do not form islands within flooded areas.

SEPA (2019b) requires that provision of a safe and flood free route during the design event for any development that introduces overnight accommodation onto a site, which enables the free movement of people of all abilities (on foot or with assistance) both to and from a secure place that is connected to ground above the design flood level and/or wider area. This refers to river or coastal flooding.

Access requirements with respect to coastal flooding will be considered in this assessment.

2.4.6 Other Flooding Risks

2.4.6.1 Reservoir Flooding

This site is not at significant risk of flooding from reservoir failure upstream of the site.

2.4.6.2 Site Drainage and Sewer Flooding

The design of the site drainage system is not part of this assessment and is being undertaken by others.

2.4.6.3 Existing Flood Defences

SEPA (2019b) provides guidance with respect to development behind flood prevention schemes.

This site is not protected by any existing formal flood defences.

2.4.6.4 Canal Flooding

In Scotland, canals are operated and managed by Scottish Canals. Failures and overtopping of canals are rare and areas at risk are generally known by Scottish Canals who should be consulted for developments located close to any canal.

There aren't any canals within 500m of the site and so the flood risk from canals has not been considered.

2.4.6.5 CAR Licensing

Any crossings or changes to watercourses within the site may require CAR licencing. CAR licences are not required as part of a planning application and are generally conditioned as part of a planning consent. However, during the planning process sufficient information should be provided in a planning application so SEPA can identify whether it is likely that a CAR license would be granted.

There are not considered to be any aspects of the development which requires a CAR licence.

3 Site Location and Description

The proposed development site is located landward of the sandy beach in Barassie between the B746 Beach road and the Firth of Clyde, Figure 2. The site consists of a former toilet block (now demolished) and associated hard standing areas. In 2021, the toilet block has been demolished and the hardstanding base remains.

On the seaward side, the site is fronted by a cycle path, a narrow strip of semi-vegetated sand dunes and then the sand beach. The MHWS mark is located some 70m west of the site. Barassie Burn and Darley Burn enter the Firth of Clyde approximately 450m north and 450m south of the site, respectively, Figure 2.

Figure 2: Site location plan

1m LIDAR data was purchased for the site and surrounding area and the topography of the site is shown in Figure 3. The site gently slopes east to west towards the sea. The level of the B746 road landward the site is approximately 4m AOD. The site slopes from 4m AOD adjacent to the road down to approximately 3.1m AOD at the south-west corner of the site. The cycle path fronting the site is at an elevation of approximately 3.1m AOD. Between the cycle path and the sand beach there is a raised ridge of vegetated sand dunes, with a ridge height of around 3.5 – 3.6 m AOD, Figure 3.

Figure 3: Topography and selected spot levels in the vicinity of the site

A aerial image of the site (from Google Earth) shows the location of the site with respect to the dunes and sand beach, Figure 4. The image shows that the dune ridge is not continous, with paths cutting through the dune ridge for beach-goers to access the beach. There are a number of cars parked landward of the dunes to the south of the site and to the north of the site, cars are parked seaward of the dune ridge, Figure 4.

Several cross-sections of the beach and site were extracted from the LiDAR data, at locations shown in Figure 5 and the profiles are shown in Figure 6. All beach profiles clearly show the dune ridge at an elevation of around 3.5 – 3.6 m AOD, although the exact elevation of the dune ridge varies spatially along the beach; for example at profile 5 the maximum elevation of the beach ridge is only 3.32 m AOD. Landward of the dune ridge there is an area of lower lying land, where the cycle path is located, before the topography rises again towards the B746 road, which is at elevations of around 4.0 – 4.5 m AOD. Most of the profiles show an area of lower ground landward of the road, before the topography rises again to the hinterland.

Profile 4 was extracted across the foreshore and through the site and shows the following features. The foreshore is gently sloping, with a gradient of around 1 in 100 (0.01) below 2 m AOD, and steepens towards the back of the beach up to the dune ridge. The dune ridge is approximately 35 m wide and reaches an elevation of 3.69 m AOD. Landward of the dunes there is an area of lower-lying land at elevations of around 3.1 – 3.2 m AOD (Figure 6), which is currently used as a cycle path (Figure 2). The land steepens landward of the cycle path up to the site at around 3.2 to 4.0 m AOD, with the road landward of the site at around 4.0 - 4.1 m AOD.

Figure 4: Aerial view of site (from Google Earth)

Figure 5: Locations of extracted beach profiles at Barassie

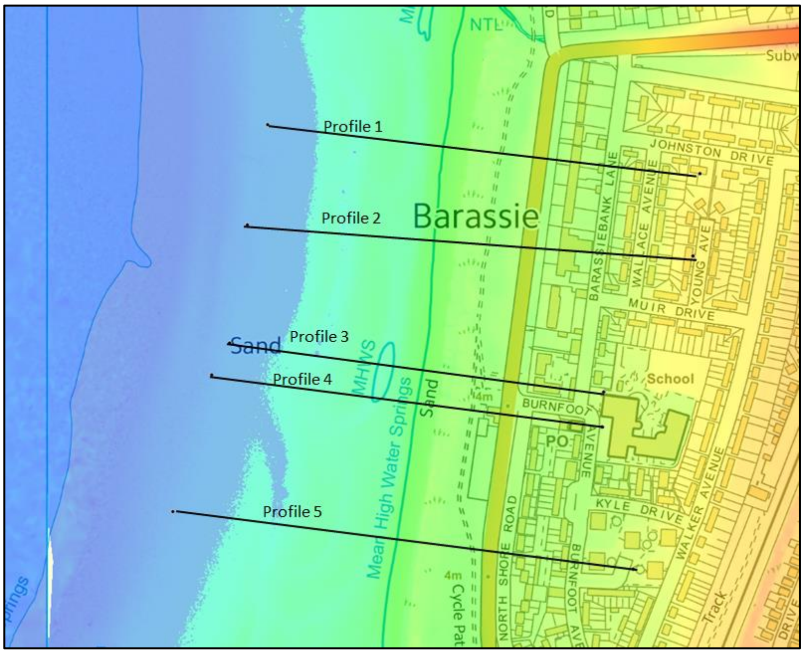
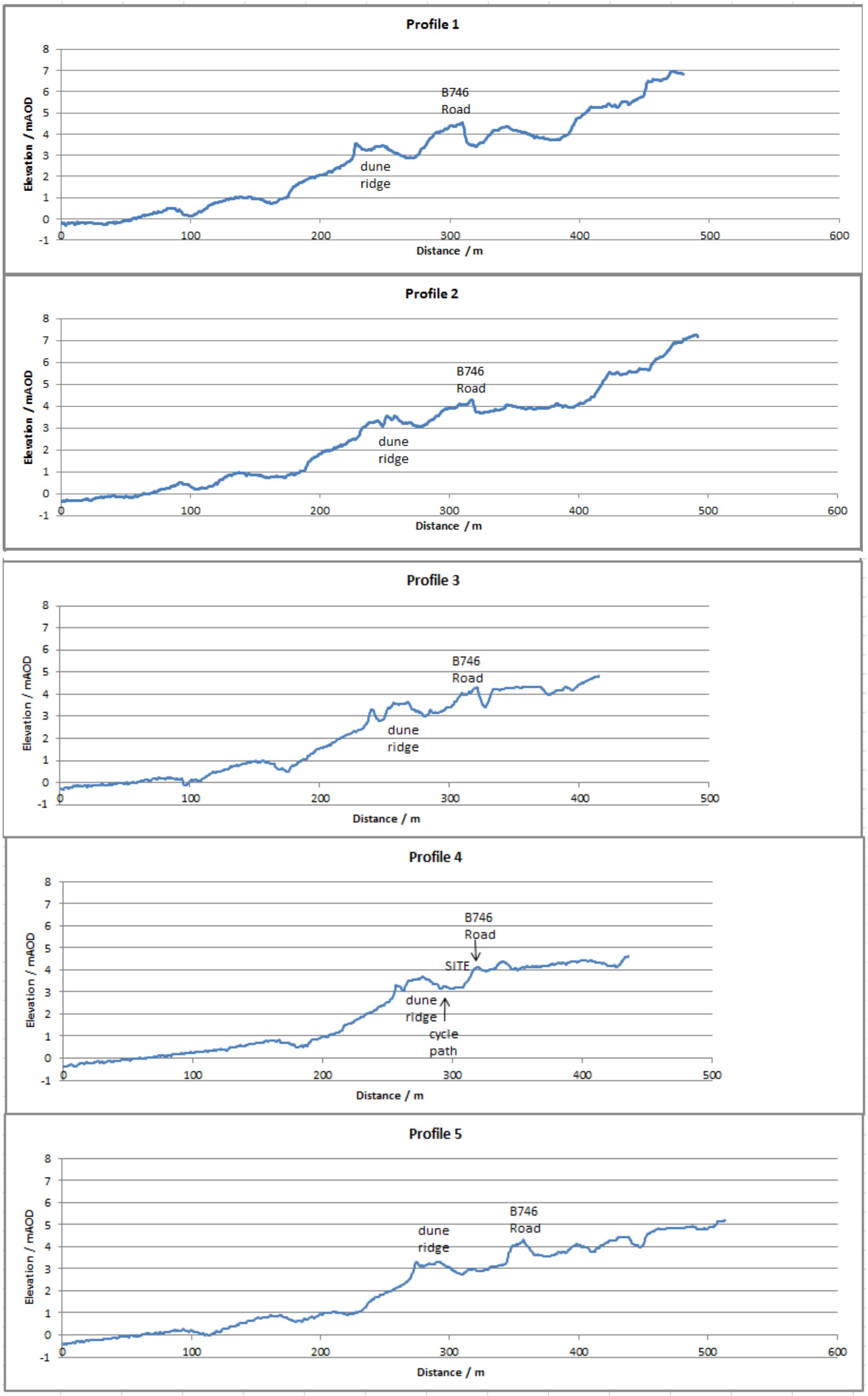


Figure 6: Beach profiles at selected locations, Profile 4 is across site



4 Extreme Sea Levels and Waves

Extreme water levels in the Firth of Clyde are determined by a combination of astronomical tides and storm surges caused by weather conditions offshore. Astronomical tides are created largely by the attraction of the moon and are accurately predictable in advance. Storm surges are caused by meteorological factors (such as winds acting on sea surface and variation in atmospheric pressure), prediction of which is less accurate.

4.1 Present day extreme sea levels

An Environment Agency (2011 and 2019 updated) report and associated data sets have updated the standard POL (1997) method for estimation of extreme sea levels around the UK coast. As part of a joint initiative with the Environment Agency, SEPA have developed Coastal Flood Boundary (CFB) Sea Levels. This data provides peak estimated sea levels for several return periods. The data is represented by points at intervals of between 1km and 2km. The updated data represents data for the year 2017.

The closest data point is Point 1752 (NGR 229409 633330), which is located approximately 3km west of the site. Extreme sea levels for a range of return periods based on CFB data for this location are provided in the table below, with their corresponding confidence range.

Table 1: Extreme Sea levels for Barassie, Troon

Return Period	Extreme Sea Level 2017 (m AOD)[a]	Extreme Sea Level 2021 (m AOD)[b]	Confidence Range 2017 (m AOD)
200-year	3.60	3.64	3.36 – 3.96
1000-year	3.91	3.95	3.55 -4.45

[a] Source: Data from Coastal Design Sea Levels Coastal Flood Boundary Extreme Sea Levels Estuary GIS theme, point 1752, Base year 2017 (EA 2019).
[b] Adjusted to 2021.

4.2 Impact of climate change on sea levels

SEPA have recently published guidance on climate change allowances for flood risk assessment in land use planning (SEPA, 2019a). Cumulative sea level rise from 2017 to 2100, based on the outputs from UK Climate Projections 2018 (UKCP18) for the Clyde River Basin Region is 0.85m, which equates to ~0.01m/year. The 2017 extreme sea level has been adjusted to 2021 using this estimate of sea-level rise. A future 200-year extreme still water level with climate change (i.e., for the year 2100) is **4.45m AOD** at the site (i.e., 3.60 + 0.85 = 4.45m AOD).

DEFRA guidance (2006) provides estimates of the likely consequence of climate change on wave heights over the next century for areas around the UK coastline, see Table 2.

Table 2: Adjustments due to climate change, based on DEFRA (2006)

Component	1990-2025	2025-2055	2055-2085	2085-2115
Increase in extreme wave height	+5%	+5%	+10%	+10%

4.3 Wave Heights

Estimates of wave heights likely to reach the shoreline at Barassie were made using a number of different standard methodologies. The assessment required the calculation of the following parameters;

- Estimation of return period still water levels (See Section 4.1)
- Estimation of Significant Wave Height
    - Estimate Significant Wave Height in Deep Water
    - Estimate Significant Wave Height in Shallow Water

Section 4.4 considers the potential for wave overtopping of the sea front.

The wave assessment considers waves produced by local winds (i.e. from direct fetch lengths across the Firth of Clyde). The assessment does not consider more complex wave process, such as refraction of waves travelling along the Firth of Clyde. Uncertainties associated with these assumptions will be considered in the choice of freeboard.

4.3.1 Estimation of Significant Wave Height

For the prediction of wave overtopping the first key input is the 'incident significant wave height' that approaches the sea defences. There are many definitions of significant wave height. One commonly used definition is the average of the highest third of the waves ($H_{1/3}$). The Eurotop Manual (2018) uses the spectral wave height (H_{mo}) and this is the value that is used in this assessment.

The value of the significant wave height that is required for this assessment is that at the toe of shoreline, once the waves have been impacted by shallow water effects. Hence, two stages are required in the prediction;

- Estimate deep water significant wave height for different return period wind conditions
- Estimate shallow water wave height

<u>Estimation of deep water significant wave height</u>

Predictions of the deep water significant wave height are based on estimated return period wind speeds. Estimates of return period wind conditions were made using the methods outlined in British Standard No. 1699. Using the map provided in BS 1699, the 1 in 50 year wind condition for the Barassie region was estimated to be 25 m/s. This wind speed relates to a south-westerly wind, which is the direction that has the highest wind speed around the British Isles. Wind speeds for different return periods were then estimated using the scaling relationship provided in BS 1699. Wind speeds for different wind directions were predicted using 'Direction Factors' also provided within BS 1699.

Maximum fetch lengths for winds approaching the site were calculated for all directions at 45° segments (as well as other directions with relatively large fetches). Estimates of critical wind speeds for a range of return periods are shown in Table 3.

Table 3: Estimated return period wind speeds for Barassie Shore

		Wind speed for different return periods (m/s)					
Direction	**Fetch Length (m)**	**2**	**5**	**10**	**50**	**100**	**200**
270	27,300	19.2	21.1	22.3	24.8	25.7	26.6
320	55,700	16.5	18.2	19.2	21.3	22.1	22.9
330	36,800	15.9	17.5	18.5	20.5	21.3	22.0

Estimates of the significant wave height in deep water were then made using three different methodologies:

- Wilson's Formula
- ACES (Handbook of Coastal Engineering)
- Coastal Engineering Manual

Calculations were undertaken using wind speeds and fetch length for 270° (i.e. west). These combinations of wind speeds and fetch lengths provided the highest significant wave height values.

A comparison of 1 in 200 year significant wave heights and periods for the three different methods is provided in Table 54. All three methods provided reasonably similar predictions. Each method can be used to predict significant wave heights for a range of different return periods and the values used in the assessment are the averages of the results of the three calculation methods.

Where relevant, and as outlined in DEFRA (2006), deep water wave heights were increased by 10 % to account for the effects of climate change by 2085.

Table 4: Estimation of 1 in 200 year significant wave heights (deep water)

Method	$^aH_{mo}$ (m)	T_m (s)	T_p (s)
Wilson's Formula	2.99	5.0	6.0
ACES (1999)	2.25	4.7	5.6
CEM (2003)	2.61	3.8	4.5
Average	*2.62*	*4.5*	*5.4*

$^aH_{1/3}$ converted to H_{mo} using method given in US Army Corps of Engineers Report EM 1110-2-1614
T_m – average period of waves
T_p – Period of peak waves

Calculation of shallow water wave heights

As waves approach the shore they can shoal and break as the water depth decreases and the wave interacts with the bed. Breaking of waves will tend to limit the maximum wave height that will impact a sea defence. The significant wave height in shallow water depends on a number of parameters including the water depth and the foreshore slope. At the Barassie site, the foreshore slope was estimated using LIDAR topographic data. Downslope of the base of the dune ridge, the foreshore slope is around 0.016 (1 in 62). Estimation of the shallow water wave height (H_{m0}) is dependent on the seabed level that the calculation is made. For the purposes of this assessment the calculations were made at a bed level of 3.5 m OD, which is the approximate elevation of the top of the sand dune, seaward of the site (see Figure 3).

Based on extreme water levels in Table 1, water depths over the sand dune would be expected to be around 0.1 m only. With climate change, the water depth for a 200 year event would be of the order of 0.9 m.

Estimates of wave heights for depth-limited situations can be using methods in the Eurotop Manual. For shallow water depths (<1 m) the calculations typically suggest that wave heights are a percentage (60 – 90 %) of the water depth. This would suggest waves of <0.1 m under present day conditions and waves of around 0.5 to 0.8 m under climate change. For most assessments a detailed joint probability analysis would be considered for different combinations of extreme water level and wave heights. However, given the shallow water depths, we take a conservative approach and consider 200 year water levels with maximum wave heights based on the water depth over the sand dunes. Design water levels based on the extreme sea level and wave heights are shown in Table 5.

These predictions do not take into account the range of processes that could result in sea water reaching elevations higher than predicted for conditions of static sea level and an offshore wave, e.g., wave run-up or overtopping due to impacts with structures or dunes. However, given the relatively small wave heights predicted at the site, wave overtopping is not expected to be a significant risk. The risk from overtopping will be considered through the choice of conservative freeboards for Finished Floor Levels at the site.

Table 5: Design water levels (with estimated depth-limited, shallow water wave heights)

	Still Water		Deep Waves			[a]Shallow Waves	[b]Combined Water Level (m)
Scenario	Return Period (years)	[a]Water Level (m)	Return Period (years)	H_{m0} (m)	T_p (s)	H_{m0} (m)	
200 Year	200	3.64	200	2.62	5.4	0.1	3.69
200 Year + CC	200 + CC	4.45	200	2.62	5.4	0.8	4.85

[a] Based on assessment outlined in report text
[b] Still Water Level + half of shallow wave height

5 Flood Risk Assessment

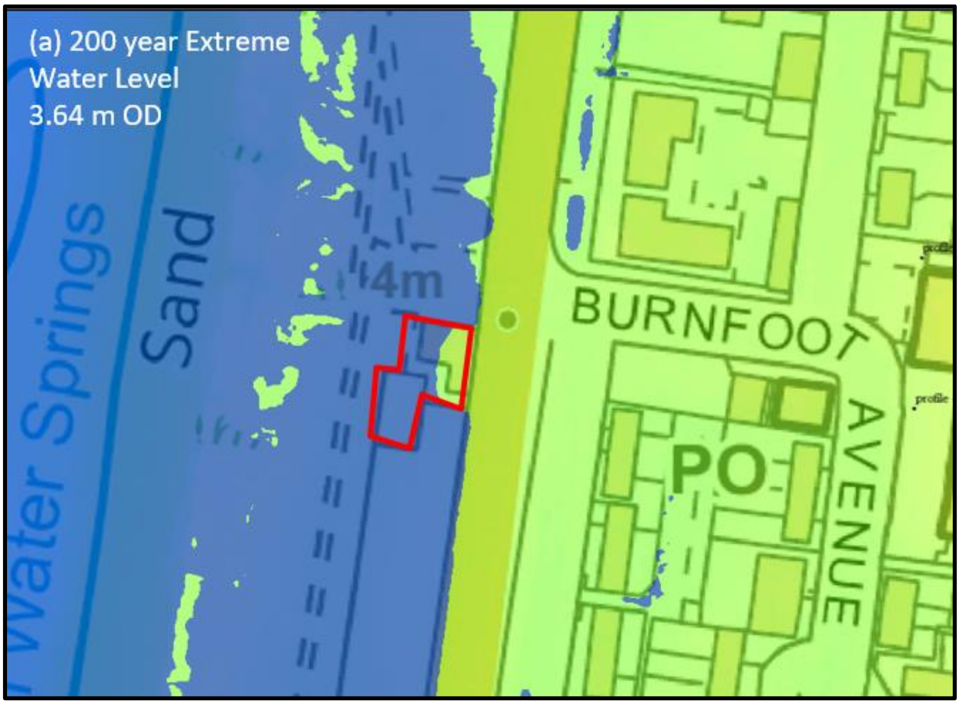
5.1 Risk of flooding from the sea

The site elevation varies between 3.1 m AOD and 4.0 m AOD. The predicted 200 year still water level is 3.64 m AOD (Table 1). This indicates that approximately 70% of the existing site is below the predicted present day 200 year still water level, see Figure 7.

Considering a 200 year event with climate change (4.45m AOD) all of the site is predicted to lie within the 200 year + climate change coastal floodplain.

There is also additional risk from waves reaching the site, particularly with climate change.

Figure 7: Flood inundation maps for present day 200 year extreme sea level



5.2 Flooding risk from Barassie Burn and Darley Burn

The two watercourses enter the sea some 450 m to the north and south of the site and there is considered to be no risk of flooding of the site from the watercourses.

5.3 Flooding risk from surface water runoff and surcharging sewer system

The B746 road in this area is relatively flat and slightly higher than the existing site and excess water on the road would potentially spill onto the site. It is suggested that provision will need to be made in the design of the site for such flows to pass through the site without affecting the development and flow into the sea. If the floor of the site is raised to the level recommended (5.45m AOD), the site would be higher than the road and surface water drainage should be allowed to pass through the site.

Similarly, any excess water from sewer system on the road would potentially spill onto the site and any such flows will need to be managed in the same way as above.

Due to location of the site and general topography in the area, it is unlikely that the site would be at risk of flooding from groundwater.

5.4 Flood Management Measures

For present day extreme sea level and wave height estimates part of the site is predicted to lie within the coastal floodplain, as shown in Figure 7. However, under present day conditions the road to the rear of the site is not predicted to lie within the floodplain. As the site is located within the coastal floodplain only, land raising of the site within the floodplain is likely to be allowed by SEPA and the local council as land raising would not increase flooding risk to others.

We would recommend that Finished Floor Levels for the site are raised above the 1 in 200 year + climate change flood level + a freeboard. As outlined in Table 5 the 1 in 200 year + climate change level (with waves) at the site is predicted to be around 4.85 m AOD. Hence, we would suggest that Finished Floor Levels are set at around 600 mm above this level at 5.45 m AOD. With floor levels at 5.45 m AOD we would not suggest there is a need for additional protection for wave overtopping. However, we would recommend that consideration is given to designing the sea facing side of the development in such a way that it would dissipate wave energy in front of the site, e.g., rip rap on ground or soft landscaping rather than vertical wall facing the sea.

It is noted that for the 1 in 200 year + climate change (plus waves) situation the road to the rear of the site is predicted to be affected by flooding with depths of around 0.7 m to the north and south of the site and 0.8 m directly opposite the site. Hence, it is expected that emergency access to the site may not be possible during extreme conditions. As the proposed development is a restaurant, there will not be overnight accommodation at the site, and we would recommend that the owners sign up to the SEPA Floodline Flood Warning System and that appropriate evacuation measures are taken prior to the arrival of an extreme coastal flood event.

It is noted that the assessment assumes that the sand dunes seaward of the site will remain into the future and will provide some protection to the site in terms of breaking of waves. A detailed geomorphological assessment is not part of this study; however, the long term stability of these dunes may need to be monitored by the council, with appropriate protection measures if there is evidence of increased erosion over time.

Surface water runoff from the development will be made to the sea. Hence, there should be no requirements to attenuate runoff from the site before being discharged to the sea. However, there may be a requirement for treatment of surface water runoff before discharge.

6 Summary and Conclusions

This report describes a flood risk assessment for a proposed residential development site on a site at Barassie, North of Troon located between the B746 Beach Road and Firth of Clyde. The flooding risk to the site is associated with extreme sea levels and waves.

The site elevation is largely below the present day 200 year still water level (i.e., astronomical tide + storm surge) and would also be affected by high water levels combined with high waves. However, as the site is located within the coastal floodplain only, land raising of the site within the floodplain is likely to be allowed by SEPA and the local council as land raising would not increase flooding risk to others.

We would recommend that Finished Floor Levels for the site are raised above 5.45 m OD, which is 600 mm above the 1 in 200 year + climate change flood level plus an allowance for waves.

It is expected that emergency access to the site may not be possible during extreme conditions, with water depths on the road of up to 0.8m. There is not expected to be any overnight accommodation at the proposed development (restaurant). We would recommend that the owners sign up to the SEPA Floodline Flood Warning System and that appropriate evacuation measures are taken prior to the arrival of an extreme coastal flood event.

Design of the site drainage system was not part of this assessment. However, as the final sink for site runoff is the sea, there is no requirement for on-site attenuation as far as flooding risk is concerned.

It is good practice to design finished floor levels an appropriate height above surrounding ground levels and arrange finished ground levels sloping away from buildings. General ground levels should be finished in a way not to allow ponding of surface water within the site where it could increase the risk of flooding of properties.

As with any design, maintenance is an important requirement for an effective drainage system. Regular maintenance programs need to be implemented for all components of the drainage system.

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