# 1 INTRODUCTION

Fairhurst was appointed by Riverside Inverclyde to carry out a Flood Risk Assessment (FRA) for the proposed Gourock Pierhead development, Inverclyde.

The site is located on land which is to be reclaimed from the sea, land along the coastline and also in areas of existing development. A location plan of the site is provided in Figure 1 below.


**Figure 1 - Development Site Location Plan**

The site (including reclaimed land) is spread over an area of approximately 2.5ha around Kempock Point at Gourock Pierhead. Part of the site is already developed as a road and car parking area, which is to be reconfigured as part of the proposals. The site is on the coast and is bounded along one side by the Firth of Clyde.

Flood risk has therefore been assessed in relation to the Firth of Clyde. Other potential sources of flooding have also been considered.

# 2 PLANNING POLICY

## 2.1 National planning policy

In consideration of planning applications, planning authorities require to be satisfied that due account has been taken of Scottish Planning Policy (SPP) and Planning Advice Note 69 (PAN69): Planning and Building Standards Advice on Flooding. It is necessary to show that adequate protection against flooding exists or can be provided for the proposed development and that the development does not increase any existing flood risk to persons or property upstream and downstream.

Flood risk has been categorised as High, Medium and Low based on the probability of inundation. Extracts from the Flood Risk Matrix set out in the SPP document highlight the likely planning response in the context of flood risk.

**RISK FRAMEWORK**

**Little or No Risk** – annual probability of watercourse, tidal or coastal flooding is less than 0.1% (1:1000)

- No constraints due to watercourse, tidal or coastal flooding.

**Low to Medium Risk Area** – annual probability of watercourse, tidal or coastal flooding in the range 0.1% - 0.5% (1:1000 – 1:200)

- These areas will be suitable for most development. A flood risk assessment may be required at the upper end of the probability range (i.e. close to 0.5%) or where the nature of the development or local circumstances indicate heightened risk. Water resistant materials and construction may be required depending on the flood risk assessment. Subject to operational requirements, including response times, these areas are generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots etc. Where such infrastructure must be located in these areas or is being substantially extended it should be capable of remaining operational and accessible during extreme flooding events.

**Medium to High Risk** – annual probability of watercourse, tidal or coastal flooding greater than 0.5% (1:200)

- Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots etc., schools, care homes, ground-based electrical and telecommunications equipment unless subject to an appropriate long term flood risk management strategy. The policy for development on functional flood plains applies. Land raising may be acceptable.
- If built development is permitted, appropriate measures to manage flood risk will be required and the loss of flood storage capacity mitigated to produce a neutral or better outcome.
- Within built up areas, medium to high risk areas may be suitable for residential, institutional, commercial and industrial development provided flood prevention measures to the appropriate standard already exist, are under construction or are planned as part of a long term development strategy. In allocating sites, preference should be given to those areas already defended to required standards. Water resistant materials and construction should be used where appropriate.
- In undeveloped and sparsely developed areas, medium to high risk areas are generally not suitable for additional development. Exceptions may arise if a location is essential for operational reasons, e.g. for navigation and water based recreation uses, agriculture, transport or some utilities infrastructure and an alternative lower risk location is not achievable. Such infrastructure should be designed and constructed to remain operational during floods. These areas may also be suitable for some recreation, sport, amenity and nature conservation uses provided adequate evacuation procedures are in place. Job-related accommodation (e.g. caretakers and operational staff) may be acceptable. New caravan and camping sites should not be located in these areas. If built development is permitted, measures to manage flood risk are likely to be required and the loss of flood storage capacity minimised. Water resistant materials and construction should be used where appropriate.

**Figure 2 - Extract from the SPP Flood Risk Framework**

SPP states that new development should not take place if it would be at significant risk of flooding from any source or would materially increase the probability of flooding elsewhere. In general, the storage capacity of floodplains should be safeguarded and works to elevate the level of the site by landraising should not lead to a loss of floodwater storage capacity.

The Scottish Environment Protection Agency (SEPA) has a duty to give advice to planning authorities as to flood risk under the Flood Risk Management Act 2009, Section 72. SEPA considers this to include professional and expert interpretation of data or records.

The Secretary of State for Scotland's guidance requires SEPA to take a holistic approach to the protection and enhancement of the environment. Planning authorities must consider SEPA's views on the merits of any proposals involving carrying out works or operations in the bed or on the banks of rivers and streams.

The SEPA/Planning Authority Protocol on Development at Risk of Flooding: Advice and Consultation issued in September 2000 presents principles to be followed by the authorities regarding advice and consultation on flood risk issues. It also presents generic guidance on the requirements for undertaking flood risk assessments.

## 2.2 Local planning policy

The Inverclyde Local Plan (the Plan), adopted on 31st January 2006, outlines Inverclyde Council's land use planning policies and emphasises their commitment to achieving sustainable development. In terms of flooding, the Plan reinforces the requirements of SPP7. Policy UT4 – Reducing Flood Risk, *'…seeks the incorporation of protection against a 1 in 200yr flood event in all new developments, or a justification as to why such a level of protection is not required'*.

Specifically, Policy UT4 requires:

'…*Clyde waterfront and coastal development to be protected against coastal flooding to a level of 5m above the ordnance datum'.* Consideration must also be given to '…*predicted climate change and sea level changes in the period to 2050.'*

Whilst there is no explicit guidance on varying levels of protection for different elements of the development infrastructure indications are given to suggest that the design standard will depend on the type of development proposed.

It is stated in the Inverclyde Local Plan Monitoring and Update Report 2009 that policy UT4 will "*require to be updated to reflect the new flood risk management planning regime introduced in the Flood Risk Management (Scotland) Act once it comes into force and the new statement on insurance provision made by the ABI".* As of February 2012, there has been no further update to this and it can be assumed that policy UT4 as outlined in the Plan (2006) still stands.

# 3 DEVELOPMENT SITE

## 3.1 Existing Site Conditions

### *3.1.1 General Background & Desk Study*

The site is located within Gourock town centre, to the rear of Kempock Street and extends around the area of foreshore / beach directly to the west of Gourock Railway Station.

The main components of the site are two areas of car parking (the first at the railway station and the second between the buildings on the north side of Kempock Street and the Firth of Clyde). There is an area of rough, apparently previously developed land to the north of the station car park, between the car park itself and the Firth of Clyde.

The station car park is currently accessed via a junction with Shore Street, and the western car park is currently accessed via a junction with Albert Road, at the western end of Kempock Street.

Separating these two areas is a stretch of rough ground and intertidal foreshore / beach, situated on the Firth of Clyde below buildings at the east end of Kempock Street.

There are areas of the public highway included in the site, such as along Kempock Street and the junctions which will be remodelled as part of the proposals.

The site is bounded by the Firth of Clyde, Kempock Street and Gourock Railway Station/Station Road. The site's surroundings are a combination of established residential areas, commercial floor space along Kempock Street and the railway station. Albert Road, Kempock Street and Shore Street provide the main arterial routes to, from and through Gourock.

The only water feature present on or around the site is the Firth of Clyde which is predominantly tidal at Gourock. The wave climate in the local area is complex, as there are a number of deep lochs nearby (Holy Loch, Loch Long and Gare Loch).

Topography across the site is generally flat, being part of an existing development. Levels vary from a maximum of 6.09mAOD to a minimum of 4.19mAOD. In some areas there are proposed levels, to tie in with those on the reclaimed land.

### *3.1.2 Historic Land Use*

Readily available historic mapping for the area has been examined from 1858 to the present day in order to identify changes in land use on the site and throughout the local area which may be relevant to flood risk.

Since the second half of the 19$^{th}$ century, there has always been settlement along the coastline at Kempock Point in Gourock. The harbour has always been present, suggesting that the wave climate around Gourock is suitable for shipping. A railway station was constructed in the 1890s to compliment the harbour. Throughout the 20$^{th}$ century there are no further major changes that would affect the water environment, with the only major change being that the area becomes increasingly urbanised.

### *3.1.4 Other Sources of Information*

A topographic survey of the site was carried out and existing levels have been provided by Hirst Landscape Architects (shown in Appendix A). Fairhurst have also applied for the Marine License Consent, which required bed levels around the bay area which have been used in the flood risk assessment.

Admiralty Charts have been used to determine bed depths; the chart in particular which has been used is "Scotland – West Coast. Approaches to the River Clyde, 1:15,000 scale"

The SEPA/EA Coastal Flood Boundary Conditions project data has been used to determine extreme sea levels at Gourock.

BS 6399 Part 2: Loading for buildings: Code of practice for wind loads has been used to determine wind speeds around Gourock.

## 3.2 Proposed Development

The proposed development masterplan is shown on drawing 1194/46/B in Appendix A.

The proposed development will comprise of the following aspects:

- Streetscape improvements along the south side of Kempock Street;
- Realigned pedestrian and vehicular access junctions to the train station and Kempock Street car parks;
- A new vehicular access junction to the station car park at the south east edge of the site;
- Environmental improvements, soft landscaping and hard landscaping throughout the site;
- Reconfiguration of the two car parks;
- A new area of open space / public realm at the northern corner of the station car park;
- A new link road on 'reclaimed land', supported by rock revetments, across the existing beach area. This will join the two car parks, extend the Kempock Street car park and create a one way traffic movement system in the town centre; and
- A new slipway for recreational access to the sea.

## 3.3 SEPA indicative Flood Map

SEPA's Indicative Flood Map (http://www.sepa.org.uk/flooding/mapping/) provides predictive guidance on the possible extent of functional floodplain (1 in 200yr flood extent) for catchments greater than 3km$^2$. It also provides predictive guidance on areas which are at risk of flooding from the sea, or at risk from combined action of fluvial flooding and the sea.

Areas of the the site and surrounding coastline are identified at risk of flooding from the sea by the SEPA flood map.. Whilst the flood map is a useful tool in initially establishing whether a site might be at risk of flooding, the following caveat is attached to its use:

> *"The Indicative River & Coastal Flood Map (Scotland) is designed to be used as a national strategic assessment of flood risk to support planning policy in Scotland. It has been developed to give an indication of whether a general area, not individual properties or specific location, may be affected by flooding".*

More detailed analysis is required to fully understand flood risk to the development site.

# 4 POTENTIAL SOURCES OF FLOOD RISK

At this location there are several potential sources of flooding that may require to be considered:

- **Coastal flooding:** Flooding from the sea can occur where extreme sea levels are higher than the corresponding level on shore causing inundation of the area surrounding the coastline. It can also occur as a result of the action of wave overtopping during storm events when high winds combined with deep water produce waves of high enough energy to break at the coastline or on coastal defences and have water overtop onto land.

- **Overland flow:** Overland flow occurs when the infiltration capacity of the ground is exceeded in a storm event. This could result in water travelling as sheet flow overland or excess water being conveyed from one location to another via local road networks.

- **Sewer flooding:** If the capacity of sewers is exceeded in an extreme event, or a blockage occurs, surcharging of the network can result in surface flooding.

The following potential sources of flood risk have been discounted:

- **Fluvial Flows:** No open or culverted watercourses have been identified on or in the vicinity of the development site.

- **Infrastructure failure:** No infrastructure conveying a watercourse has been identified on or in the vicinity of the development site.

- **Groundwater:** By nature of its location the site is not considered to be vulnerable to groundwater flooding.

# 5 SEA LEVEL, WAVES AND OVERTOPPING

## 5.1 Objectives

Gourock Pierhead is subject to flood risk from the sea. An extreme sea level, wave and overtopping assessment has been conducted to predict the risk from a 0.5% annual probability event, taking all factors surrounding coastal flood risk into consideration.

## 5.2 Extreme Sea Levels

Extreme sea levels alone can cause flooding in coastal areas where they are high enough to inundate low lying areas of land, and thus must first be checked to predict whether the site is at risk directly from sea levels.

Furthermore, extreme sea levels are required (along with wind speed) in order to be able to predict wave height. Therefore levels for several different return period events have been retrieved in order to be able to find the 200 year joint probability for wind and extreme sea level through a joint probability analysis.

Extreme sea levels have been retrieved from the SEPA/EA Coastal Flood Boundary Conditions data. This data set gives predicted extreme sea levels (and associated confidence intervals) for points along the coastline of Scotland in GIS format, along with the locations of estuary boundaries beyond which the data is not considered reliable. Drawing 87097/WS/001 in Appendix A shows the location of the data point which has been used for Gourock Pierhead. While this point is not directly opposite the development site, it is considered suitable given that it is approximately 4km away – which is equal to the spacing of the points. The sea at the development site is also within the area where the results are considered acceptable for use.

Table 1 below shows the extreme sea level values extracted from the data set.

**Table 1 - Extreme Sea Levels at Gourock**

| Return Period (Years) | Extreme Sea Level (mAOD) |
|---|---|
| **2** | 2.79 |
| **5** | 2.94 |
| **10** | 3.08 |
| **20** | 3.22 |
| **50** | 3.40 |
| **100** | 3.54 |
| **200** | 3.69 |

## 5.3 Wind Speed

Wind speed is required for input to the joint probability analysis. Ultimately this analysis will provide an estimate of the 200 year joint probability wind speed and extreme sea level for a wave height analysis.

Wind speed has been based on data given in BS6399 Part 2and adjusted for local conditions using the method outlined in "Floods and Reservoir Safety 3rd Edition".

This method is for use where wind will generate waves over a reservoir, loch or large body of water. This is appropriate for the analysis because the wind which will generate waves at Gourock will come over either a loch or some other large body of water which is not open sea.

Within the area surrounding Gourock Pierhead, there are a number of directions from which wind may originate uninterrupted over open water. In addition to this, wave action is to be examined at three different points across the development site. Given the number of possible directions from which the wind may originate and locations to which the waves may arrive, combined with the varying bottom profile (see section 5.6) across the area, a number of fetch lengths have initially been chosen for wind speed analysis. The eight initially identified fetch lengths have been looked at from the start, but the number of lengths considered decreases as the analysis progresses and it becomes clearer which fetch lengths are the most critical. A drawing showing the fetch directions, along with the three site locations used are provided in Appendix A.

Table 2 below shows the final wind speeds for each of the eight different fetch lengths which have been identified.

**Table 2 - Wind Speeds (m/s) Around Gourock**

| Return Period (Years) | Fetch 1 | Fetch 2 | Fetch 3 | Fetch 4 | Fetch 5 | Fetch 6 | Fetch 7 | Fetch 8 |
|---|---|---|---|---|---|---|---|---|
| **2** | 23.86 | 21.66 | 18.40 | 25.81 | 22.02 | 25.17 | 18.47 | 19.02 |
| **5** | 25.67 | 23.31 | 19.79 | 27.77 | 23.70 | 27.08 | 19.87 | 20.46 |
| **10** | 27.18 | 24.68 | 20.96 | 29.40 | 25.09 | 28.68 | 21.04 | 21.67 |
| **20** | 28.69 | 26.05 | 22.12 | 31.04 | 26.49 | 30.27 | 22.21 | 22.87 |
| **50** | 30.20 | 27.42 | 23.29 | 32.67 | 27.88 | 31.86 | 23.38 | 24.08 |
| **100** | 31.40 | 28.52 | 24.21 | 33.68 | 28.99 | 33.13 | 24.32 | 25.04 |
| **200** | 32.61 | 29.62 | 25.15 | 35.28 | 30.11 | 34.41 | 25.25 | 26.01 |

## 5.4 Joint Probability Analysis

The joint probability analysis brings together the above presented results for extreme sea level and wind speed to result in a set of 200 year joint probability values. The joint probability analysis is based on the method outlined in DEFRA Report FD2308/TR2 "*Use of Joint Probability Methods in Flood Management*". The spreadsheet to accompany the report has been used to aid the analysis.

The 200 year joint probability extreme sea level and wind speed is required; therefore the most appropriate dependence measure is that for wave height (a function of wind speed) and sea level (related to extreme sea level). The value of rho around Gourock, as outlined in Figure 1 in DEFRA Report FD2308/TR02 is 0.55, showing that there is strong dependence between the two variables at this location.

The joint probability analysis has been carried out for each of the eight fetch lengths and produces a number of possible combinations for the 200 year extreme sea level and wind speed for each fetch length. The combinations that lead to the critical wave height for overtopping are presented below in Table 3.

**Table 3 - Joint Probability Results, Critical Combinations**

| Fetch | Extreme Sea Level (mAOD) | Wind Speed (m/s) |
|---|---|---|
| **1** | 2.83 | 28.69 |
| **2** | 3.69 | 17.27 |
| **3** | 3.69 | 14.68 |
| **4** | 3.69 | 20.58 |
| **5** | 3.69 | 17.55 |
| **6** | 3.69 | 20.07 |
| **7** | 3.69 | 14.73 |
| **8** | 3.69 | 15.17 |

## 5.5 Bottom Profile

The bottom profile is essential for input to the wave height analysis as wave heights can be limited by water depth.

In this case, data for the bottom profile has come from three different sources:

- **Admiralty Charts** which show the bed profile at and around the site. The chart which has been used – *"Approaches to the River Clyde"* – also extends into the surrounding lochs.
- **Ordnance Survey mapping** which shows the level at which the water meets land and has been used to complete part of the bottom profile that extends into Loch Long for which the Admiralty Charts are incomplete. The lack of detailed bottom profile is considered insignificant for the stretch which is interpolated between the last point on Admiralty Charts and the OS mapping because it is at the very start of the fetch where the wave is only beginning to gain energy from the wind.
- **Development proposal drawings** which show some levels at a more detailed scale than the Admiralty Charts around Gourock Pierhead, and have been used to supplement the other information to obtain as accurate as possible a prediction of wave height at the shore.

Overall, 16 bottom profiles have been produced – 8 for site locations 1 and 2, and a further 8 for location 3 (one for each wind fetch length).

## 5.6 Wave Height Analysis

In order to determine the near shore wave height at the toe of the coastal defences at Gourock Pierhead, a wave propagation model for the transitions from deep water to shallow water was constructed using the SwanOne wave propagation modelling software.

This software takes the results of the joint probability analysis along with the bottom profile as its input and reports wave height at various (user-defined) locations across the bed profile. In this case, the height at the toe of the defences has been extracted in the output for use in overtopping analysis.

Wave height as a result of each of the eight fetch lengths is analysed at each of the three selected locations at the development site. The critical wave height at each location leading to critical overtopping rate is shown below in Table 4.

**Table 4 - Wave Height Results, Summary**

| Location | Wave Height (m) | Wave Period (s) |
|---|---|---|
| **1** | 2.06 | 4.37 |
| **2** | 2.06 | 4.37 |
| **3** | 1.11 | 3.64 |

## 5.7 Wave Overtopping Analysis

Wave overtopping analysis has been carried out to determine the rate of overtopping along the proposed coastal defences as part of the development. This has been carried out in line with the guidance set out in EurOtop – Wave overtopping of Sea Defences and Related Structures, Assessment Manual.

The proposed finished level at the site at the top of the revetment (not including the small wall) as shown in Drawing 87097/7201-A is 5.5mAOD**.** The proposed revetment slope fits the standard empirical calculation for *'Armoured Composite Slope with Crest Berm'* in EurOtop. The slope has been extended to a height of 6.0mAOD to take into account the additional 0.5m height provided by the small wall.

Therefore, a run has been carried out for each of the wave heights resulting from the joint probability/wave height analyses at each of the three selected locations at the development site. The outcome of this analysis is a critical value of overtopping rate at each of the three locations on the site. These values are shown below in Table 5:

**Table 5 - Overtopping Analysis Results**

| Location | Overtopping Rate (l/s/m) |
|---|---|
| **1** | 0.69 |
| **2** | 0.69 |
| **3** | 0.08 |

## 5.8 Climate Change

There is growing evidence of global climate change across the world. The UK Climate Impacts Programme (UKCIP) is funded by the Department of the Environment to investigate the potential impacts of climate change in the United Kingdom. The UKCIP has produces assessments of the potential impacts based on rates of increase in global greenhouse gas emissions consistent with the projections of the Intergovenmental Panel on Climate Change (IPCC)

The design life of the development has been taken as 50 years in line with the design life of the revetment. Other parts of the development may have a shorter design life, and thus the approach which has been taken is considered conservative. The effects of potential future climate change on extreme still water levels and significant wave heights have therefore been considered up to the year 2062.

UKCP09 provides relative sea level changes at a 25km grid resolution. The relative sea level changes combine absolute sea levels rise together with estimate of future land level change. For year 2062 under a high emission scenario, 50%ile figure, the relative sea level change for Gourock Pierhead is +0.166m (relative to the 2011 value,).

This provides an estimate of the 200 year extreme still water level in 2062 of **3.86mAOD**.

Changes in expected peak wind speed are also considered with regards to potential future climate change. The UKCIP has produced an assessment of possible future wind speed along with a report which outlines the methodology employed. This report explains that there are several different models by different organisations which have produced varying results. These results vary so widely that it is considered the models are either missing a key element that describes climate, or an inaccurate assumption has been made in order to produce model results. The range of results which the UKCIP have published in their report for the area around Gourock Pierhead predict a change of between -0.1 and +0.1m/s by 2062. Given that the average of these values is zero, and that the uncertainties are so great in the results it is considered sensible to assume zero change in wind speed due to climate change until further studies indicate otherwise.

Using the updated values for extreme sea level (adding 0.166m to current values), the joint probability, wave height and overtopping analyses were re-run to obtain a prediction for overtopping rate taking climate change into account and the critical results are shown below in Table 6.

**Table 6 - Overtopping Analysis Results, Climate Change**

| Location | Overtopping Rate (l/s/m) |
|---|---|
| **1** | 0.72 |
| **2** | 0.93 |
| **3** | 0.18 |

# 6 FLOOD RISK ANALYSIS

The potential sources of flooding identified in Section 4 are discussed below.

## 6.1 Coastal Flood Risk

No part of the site is at risk from the 1 in 200 year extreme sea level. The level which has been retrieved from the SEPA/EA data is 3.69mAOD for the 200 year return period, which gives a generous 1.81m freeboard between the water level and the finished ground levels at the development.

The results of the overtopping analysis show the overtopping rates due to a 1 in 200 year joint probability event.

It can be seen that locations 1 and 2 at the development site have much higher values of overtopping rate in comparison to location 3. At location 3 there is a steady bed gradient for two reasons:

- Location 3 is located in an area which is more sheltered from waves and as such processes of deposition are more acute here.
- Locations 1 and 2 are next to and on where the land for a new car park is to be reclaimed, respectively.

The result of this steady bed gradient at location 3 is that the overtopping rate (as a result of the waves' energy being damped as they approach the shore) is much lower than at the rest of the site.

The overtopping value of 0.69 l/s/m is considered hazardous to pedestrians according to the EurOtop overtopping manual, but is well within the limits for driving at moderate speed and for the presence of trained personnel who are prepared to get wet. However, it has been noted that during the storm event which causes such an overtopping rate, the wind speed is over 32m/s (approximately 73mph) and for safety reasons the car parking area would likely have to be temporarily closed as a result of the entire storm event regardless. This value may also cause some minor damage to building structure elements and landscaping around the coastline.

The lesser value of 0.08 l/s/m around Kempock Point and the railway station is not considered hazardous to pedestrians.

The results due to climate change show an increase in overtopping rate as a result of the predicted increase in global sea levels. This shows that the wave climate around Gourock may be particularly sensitive to future sea level changes. There is no certainty on which of the climate change scenarios (as defined by the IPCC) will play out in the future. Therefore, attention should be given to the changing climate and the possibility that the sea level rise, and associated effects, as predicted in this report is likely to change with revised data from the IPCC in the future.

## 6.2 Overland Flow

Upslope development in the town of Gourock limits the amount of overland flow which can be generated and the local road network along with defined watercourses would tend to intercept flows from remote areas before they reach the site.

Given that the area is of an urban nature and flow may be generated from within the development itself due to pluvial action on impermeable surfaces, it is recommended that an appropriate drainage

network be in place to prevent any ponding of flows on road and car park surfaces. However, flood volumes are likely to be limited and the risk of inundation to property can generally be mitigated by profiling development ground levels to route water around and away from buildings.

## 6.3 Sewer Flooding

Scottish Water records indicate that there is a combined sewer running through the site. In the event of flooding from this sewer, water will naturally flow to low points throughout the site, which in this case are the link road and new car parking area. As recommended in relation to the risk from overland flow, the risk of inundation to property can be mitigated by profiling development ground levels to route water around and away from buildings, and an appropriate drainage network should be in place to prevent ponding of water on impermeable surfaces.

# 7 CONCLUSIONS

Potential flood risk at the development site comes from the sea. Consideration has been made with regard to the risk from the sea by analysis of extreme sea levels and also by the action of waves on the coastal defences which are proposed as part of the development.

An average rate of wave overtopping during the 200 year joint probability event varies across the site from 0.08l/s/m to 0.69 l/s/m. The latter rate is considered hazardous for pedestrians, but not for personnel who have been trained to work in such an environment, or for driving at moderate speed. These overtopping rates occur as a result of high wind action on waves, and therefore will only occur during extreme storm events where the the likelihood of pedestrian presence is low.

The 200 year joint probability overtopping rate is expected to increase in the future in line with expected climate change effects. Climate change models are constantly being updated and the predictions which are currently made by the IPCC and UKCIP are likely to change in the future.

Other potential sources of flooding include overland flow and sewer flooding. Ground should be profiled to route water away from structures and an appropriate drainage network should be installed to ensure the efficient passage of water away from impermeable areas of the site.

## REFERENCES

1. Inverclyde Council, *Inverclyde Local Plan*, 2006. http://www.inverclyde.gov.uk/planning-and-the-environment/planning/development plan/adopted-inverclyde-local-plan-2005

2. Inverclyde Council, *Inverclyde Local Plan 2005, Monitoring and Update Report*, 2009. http://www.inverclyde.gov.uk/planning-and-the-environment/planning/development-plan/monitoring-update-report-2009

3. Scottish Government, *Scottish Planning Policy*, February 2010. http://www.scotland.gov.uk/Publications/2010/02/03132605/0

4. Institution of Civil Engineers, *Floods and Reservoir Safety: 3rd Edition*, 1996.

5. SEPA/Environment Agency, *Coastal Flood Boundary Conditions for the UK Mainland and Islands*, 2011.

6. Hydrographic Office, *Scotland West Coast: Approaches to the River Clyde*, 1979.

7. Archive for Research and Technology on the North Sea and Baltic Coast, *EurOtop Overtopping Manual*, 2007. http://www.overtopping-manual.com/index.html

8. DEFRA, *Use of Joint Probability Methods in Flood Management*, 2005.