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PHASE 1 FLOOD RISK ASSESSMENT REPORT

PREPARED FOR: URBAN VIEW ARCHITECTURE

PROPOSED RESIDENTIAL RE-DEVELOPMENT

SHOPSDAM ROAD, LANCING,
EAST SUSSEX, BN15 8ES

DECEMBER 2009

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SUMMARY

This report presents the findings of a Flood Risk Assessment (FRA) that has been carried out for the proposed residential re-development at Shopsdam Road, Lancing, East Sussex, BN15 8ES. This FRA has been carried out using current best practices, and against the criteria set out in Planning Policy Statement (PPS) 25 - 'Development and Flood Risk'.

The proposed re-development involves the demolition of the existing buildings and the construction of four, two-storey houses; three with under croft parking and one with adjacent parking. The re-development site is currently occupied by a large, two-storey residential property.

Information provided by the EA suggests that the 1:200 year flood level is currently estimated as 4.3 mAOD. This level is expected to increase to 4.7 mAOD by the year 2060 and to 5.5 mAOD by the year 2115.

Sea 'defences' in this area are elevated to between 6.06 and 6.12 mAOD. Based on this, and an analysis of local topography, it is unlikely that a significant quantity of flood water would reach the development site by means of wave overtopping except under the most extreme conditions. However, in order to take a precautionary approach, the developer has agreed to set all ground floor levels at 6.1 mAOD (300 mm above the 2115 flood level of 5.5 mAOD).

At its closest proximity, the development site lies approximately 50 m to the north of the English Channel (at mean high tide) and approximately 2.5 km to the west of the River Adur. According to low detail, national-scale flood mapping created on behalf of the Environment Agency (EA), the proposed development site would appear to lie within Flood Zone 3a ("High Probability of flooding") of the English Channel.

As such, the risk from tidal flooding to the proposed re-development is considered to be of ***low significance***. However, the risk of flooding from overtopping or breach of the tidal defences is considered to be of ***moderate significance*** and ***not significant*** respectively. The risk of fluvial flooding to the proposed re-development is considered to be ***not significant.*** The risks to the proposed development from groundwater, sewer or pluvial flooding are considered to be of ***low significance***. The effect of the development on local catchment hydrology is considered to be ***not significant***.

As such, and given that:

(a) the site lies within an existing developed area;

(b) the re-development site is significantly elevated relative to its surroundings and benefits from comprehensive sea defences.

(c) a safe route of escape can be provided via Shopsdam Road;

(d) in terms of flood resilience, significant betterment can be achieved through the use various flood-proofing measures, including demountable flood barriers;

following guidelines contained within PPS25, the proposed re-development is considered to be **suitable**, assuming appropriate mitigation (including adequate warning and evacuation procedures) can be maintained for the lifetime of the development.

FLOOD RISKS TO DEVELOPMENT					
Source	**Existing**		**Proposed Mitigation**	**Residual (following development)**	
	Risk	**Impact**		**Risk**	**Impact**
TIDAL: 1:200 year design tidal flood level	Low Significance	Moderate Significance	Raised ground floor level, safe route of escape, flood resilient design, subscription to flood warning service	Low Significance	Low Significance
TIDAL: Overtopping of tidal defences	Moderate Significance	Low Significance	Raised ground floor level, safe route of escape, flood resilient design, subscription to flood warning service	Moderate Significance	Low Significance
BREACH: Defence breach under 1:200 year tidal flood level	Not Significant	Moderate Significance	Raised ground floor level, safe route of escape, flood resilient design, subscription to flood warning service	Not Significant	Low Significance
FLUVIAL: 1:100 year design fluvial level: main river	Not Significant	Not Significant	Not Required	Not Significant	Not Significant
FLUVIAL: Non-main river	Not Significant	Not Significant	Not Required	Not Significant	Not Significant
PLUVIAL: Accumulation of surface runoff / overland flow	Low Significance	Moderate Significance	Raised ground floor level, flood resilient design	Low Significance	Low Significance
GROUNDWATER	Low Significance	Low Significance	Raised ground floor level, flood resilient design	Low Significance	Low Significance
SEWER FLOODING	Low Significance	Low Significance	Raised ground floor level, flood resilient design	Low Significance	Low Significance

EFFECT OF DEVELOPMENT ON FLOOD RISK		
Effect	**Impact**	**Mitigation**
Displacement of floodwater	Not significant	Not Required
Increased surface runoff generation	Not significant	Not Required
Hydraulic performance of channels	Not significant	Not Required

Table S1: Summary of flood risks, impacts and proposed flood mitigation measures.
Note: an explanation of the levels of significance use for the Flood Risk Assessment is provided in Appendix C, Table C1.

1 INTRODUCTION

1.1 As part of the planning process it is necessary to demonstrate that new development can be achieved in a sustainable manner, with an acceptable risk of flooding, and that the development does not increase the risk of flooding elsewhere. As such, AMBIENTAL were commissioned to undertake a Flood Risk Assessment (FRA) of the site by Urban View Architecture.

1.2 This FRA relates to a proposed residential re-development at Shopsdam Road, Lancing, East Sussex, BN15 8ES. The proposed re-development is for the demolition of the existing buildings on site and the construction of four, two-storey houses; three with under croft parking and one with adjacent parking. The re-development site is currently occupied by a large two-storey residential property.

1.3 Low detailed J-FLOW flood modelling provided by the EA suggests that the proposed development site lies within the 1:200 year tidal floodplain of the English Channel (see Figure 7). As such, the EA is likely to object to the application until such time as an FRA in compliance with *Planning Policy Statement Note 25*: *Development and Flood risk* (PPS25) has been submitted.

1.4 This report describes the results of the study. It is based on consideration of hydrological, topographical and anecdotal information relating to the surrounding area and information concerning the development as provided by Urban View Architecture.

1.5 The site lies within an existing developed area and consequently the *principle* of development may be acceptable, provided that: (i) appropriate flood mitigation measures are adopted; and, (ii) flood risk elsewhere in the catchment is not increased.

1.6 This report takes into account the recommendations contained within Planning Policy Statement Note 25 (PPS25) 'Development and Flood Risk' and local government policies on flooding and drainage.

2 SITE DESCRIPTION AND PROPOSED DEVELOPMENT

Site Description & Location

2.1 The proposed development site is located at Shopsdam Road, Lancing, East Sussex, BN15 8ES. The wider site area covers approximately 800 m^2.

2.2 Figures 1, 2 and 3 below show the site location in relation to proximal watercourses. At its closest proximity, the development site lies approximately 50 m to the north of the English Channel (at mean high tide) and approximately 2.5 km to the west of the River Adur.



Figure 1: Wider location plan (development site circled in red). *(Source: Multimap)*

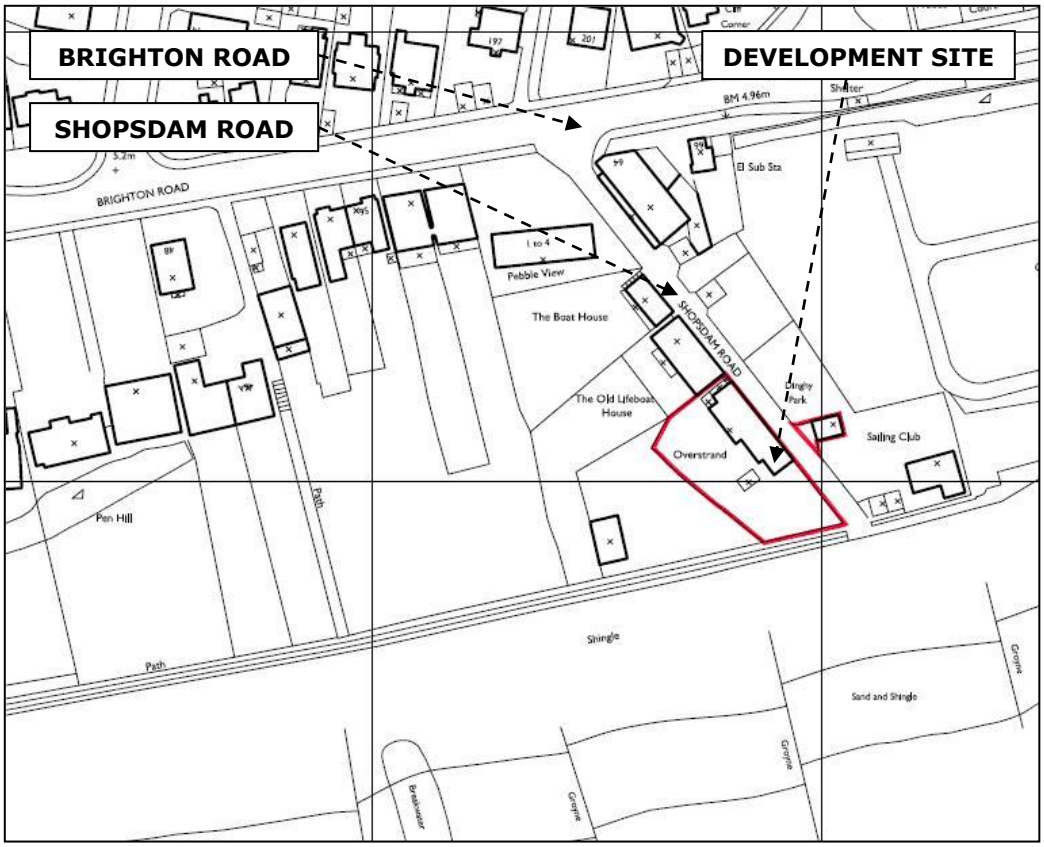


Figure 2: Location of the site boundary (in red) in relation to Shopsdam Road and Brighton Road. *(Source: Urban View Architecture)*



Figure 3: Aerial view of the existing properties. Red outline denotes the site boundary. *(Source: Microsoft Virtual Earth)*

2.3 Existing structures on the development site consist of a large, two-storey residential property, a log cabin (concrete base), a greenhouse and a shed.

2.4 Opposite the main property, directly across Shopsdam Road is a garage (concrete block).

2.5 The existing buildings on site have an aggregate footprint area of approximately 235 m^2.

Proposed Re-development

2.6 The proposed re-development is residential and is for the demolition of the existing buildings (excluding the garage, opposite) and the construction of four, two-storey houses; three with under croft parking and one with adjacent parking. The existing garage opposite the main site on Shopsdam Road is to be retained for use.

2.7 The proposed site layout can be seen below in Figure 4.

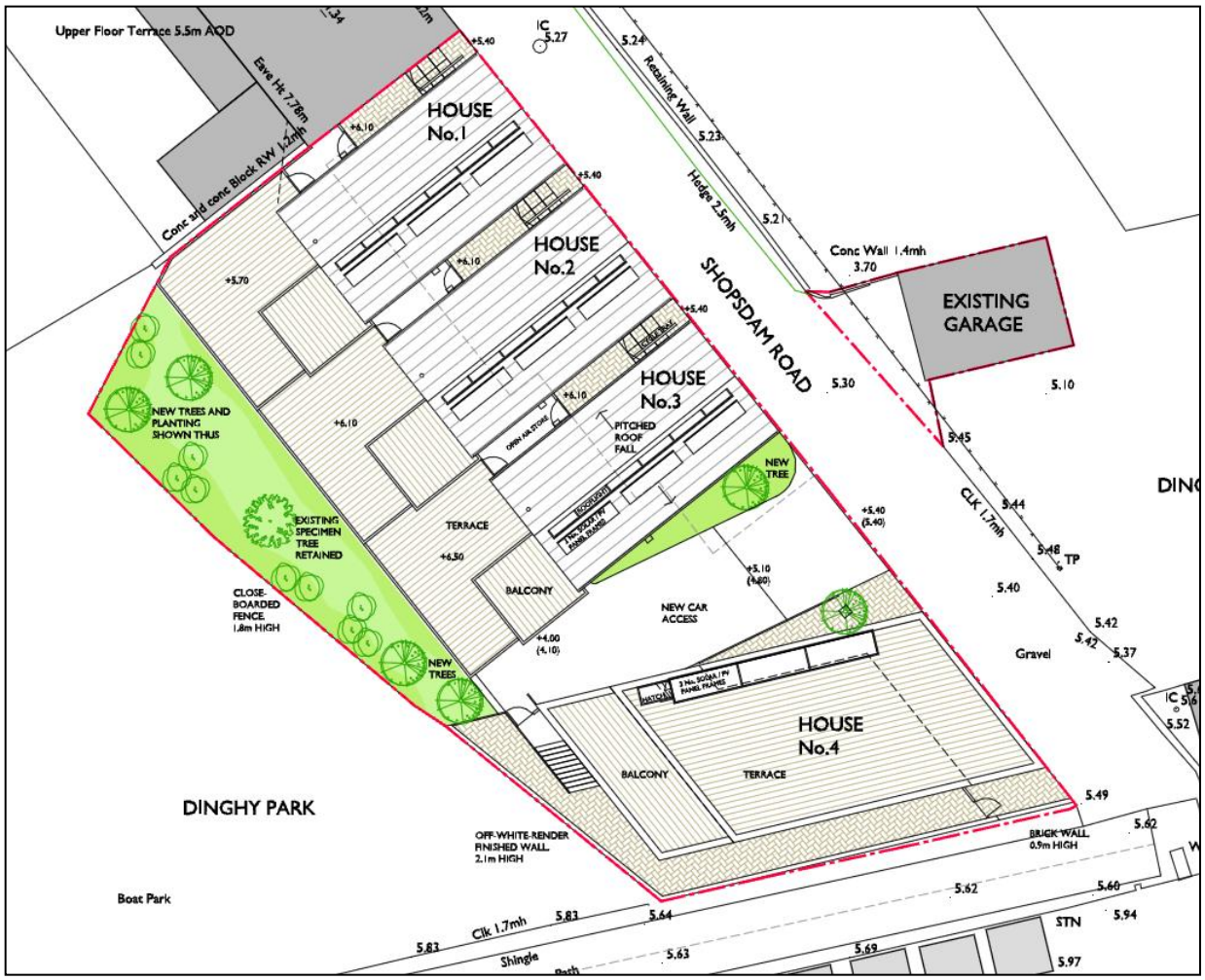


Figure 4: Extract from the proposed development plans for Shopsdam Road.
(Source: Urban View Architecture)

2.8 Ground floor levels will be raised to that of Shopsdam Road, with a ground floor design level of 5.3 mAOD. Please refer to architects drawings for building and context elevations.

2.9 Vehicular access to the site is currently via Shopsdam Road. Under the new proposals, this would remain (See Appendix A, Drawing No. 1117-P-202).

Site Survey

2.10 A topographical survey of the site provided by Urban View Architecture (November 2006) shows that topographic levels on site range between approximately 2.88 mAOD and 5.52 mAOD. The existing lower floor level of the property is 3.30 mAOD. An extract from the topographic survey is shown in Figure 5 below. A copy of the wider area topographic survey is included in Appendix A (Drawing No. 1117-P-201).

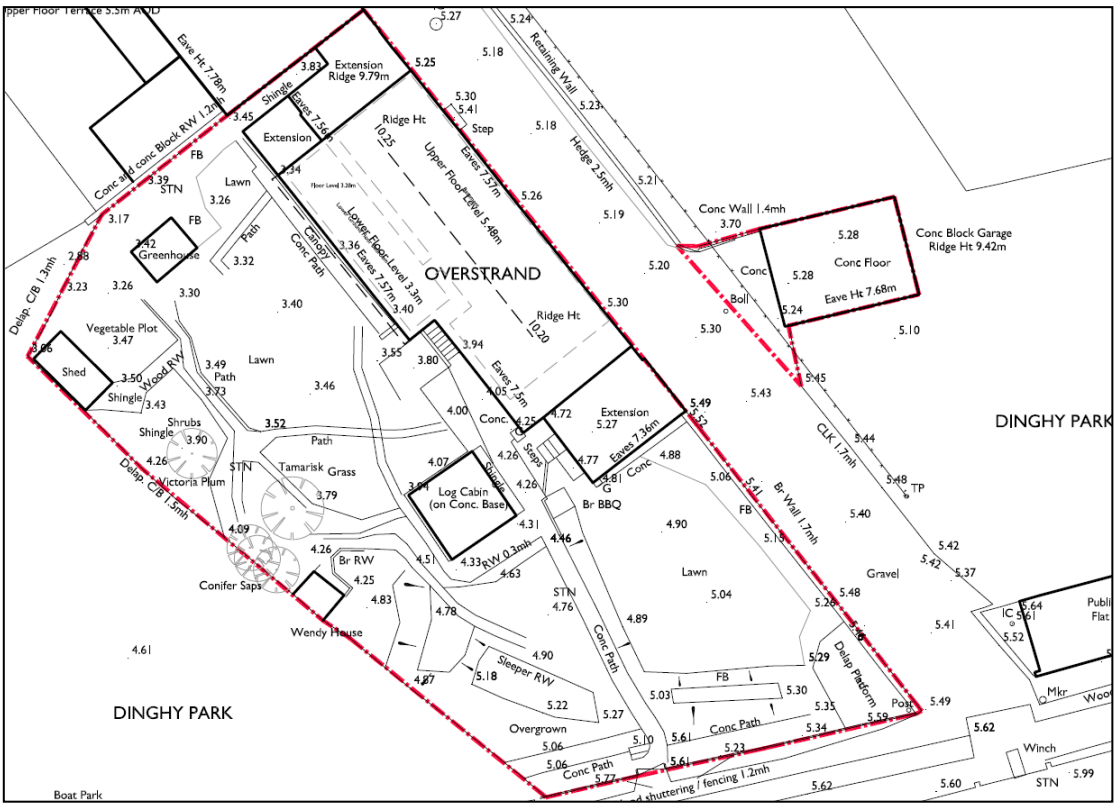


Figure 5: Extract from topographic survey showing levels on site and existing building footprint. *(Source: Urban View Architecture)*

2.11 The topographical survey (Drawing No. 1117-P-201) shows that the development site is gently sloping from the southeast of the property at the junction of Shopsdam Road and the seafront downwards towards the northwest of the site, to the rear of the proposed properties.

2.12 Levels taken north and south along Shopsdam Road in close proximity to the site generally range between 5.18 mAOD to the north and 5.41 mAOD to the south.

3 FLUVIAL/TIDAL FLOOD RISK

Potential Flood Sources

3.1 The proposed re-development site lies approximately 50 m to the north of the English Channel (at mean high tide).

3.2 Based on communication with the EA and analysis of the EA Flood Map data provided, the River Adur is the most proximal watercourse to the site and is, therefore, likely to be the principle source of fluvial flood risk to the development site. The River Adur is classified as a 'main river' and as such the EA has statutory powers of repair and inspection.

3.3 However, along this reach of the channel the River Adur has a strong tidal influence. Therefore, given the distance from the site to the non-tidal River Adur, the risk of fluvial flooding to the re-development can be considered to be ***not significant***.

3.4 Given that there are no other non-main rivers, ordinary watercourses or drainage ditches in the surrounding area, the risk of non-main river fluvial flooding is considered to be ***not significant.***

EA Flood Zones

3.5 Initial communication with the EA revealed that part of the proposed development site lies within Flood Zone 3a (i.e. 'High Probability' of flooding at the 1:200 year level). This is supported by EA flood risk map information (Figure 7) which has been produced using JFLOW - a relatively coarse, national-scale flood modelling strategy (see Appendix D for description of JFLOW). These maps indicate the potential spatial extent of a fluvial flood event which has a magnitude that is, on average, likely to occur once in every two hundred years (i.e. the 1:200 year tidal floodplain). It is important to note that only the *potential* fluvial floodplain is shown; **the mitigating effects of any flood defences currently in place are not considered**.

3.6 For reference, the definition of PPS25 flood risk zones is included below in Table 1.

	Description
Zone 1	**Low Probability**. This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).
Zone 2	**Medium Probability**. This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% – 0.1%) in any year.
Zone 3a	**High Probability**. This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
Zone 3b	**The Functional Floodplain**. This zone comprises land where water has to flow or be stored in times of flood. SFRA's should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

Table 1: Definition of PPS25 Flood Zones. Shaded cells indicate relevance to the site. *(Source: EA)*

3.7 As can be seen below in Figure 6, according to the JFLOW derived flood map, the site lies in Flood Zone 3a ('High Probability').



Figure 6: EA JFLOW derived floodmap. Red circle denotes the re-development site. Blue area represents EA Flood Zones 3a. *(Source: EA)*

Modelled Flood Levels

3.8 Flows and water levels associated with very extreme events can only be estimated using detailed hydrodynamic modelling. The aforementioned, low detail, JFLOW modelling strategy cannot be used to derive extreme river or tide levels.

3.9 Communication with the EA revealed that detailed tide level information for extreme storm events is available for this area. It is understood that these levels are based on modelling carried out as part of the report untitled *Extreme Sea levels: Kent, Sussex, Hampshire & Isle of Wight* produced by JBA consulting (2004) for the Environment Agency.

3.10 'The study has involved extensive work in identifying sources of data, abstracting sea levels in a digital format and quality checking of the data [and] the evaluation of the available techniques for the extrapolation of data to provide sea levels up to a 1,000-year return period (0.1% probability of occurrence per year) and for interpolation between analysed sites to provide estimates at any point on the coastline' (JBA Consulting, 2004).

3.11 The modelled levels presented in this section are derived from the detailed modelling along this stretch of the English Channel. Water levels associated with extreme flood events have been estimated by JBA Consulting at different locations in close proximity to the site. The most relevant point was found to be Shoreham Harbour. Figure 7 shows this location in relation to the re-development site.



Figure 7: Position of the re-development site in relation to the model extraction point. *(Source: Multimap)*

3.12 The modelled levels presented in Table 2 relate to the location of those modelled points in close proximity to the site. The levels provided represent the 1 in 200 year tidal flood event with an allowance for raised sea levels and storm intensity as a result of potential climate change by 2060 and 2115. These levels have been estimated by the EA based on current predictions regarding climate change and its resultant potential effect on sea level in the area.

	1:200/1:1000 YEAR FLOOD EVENT MODELLED LEVELS (mAOD)		
YEAR	**2000**	**2060**	**2115**
Littlehampton	4.1/4.3	4.5/4.7	5.4/TBC
Shoreham Harbour	4.3/4.4	4.7/4.8	5.5/TBC
Newhaven	4.3/4.4	4.7/4.8	5.5/TBC

Table 2: Modelled extreme sea levels for the English Channel. Highlighted cells correspond to the model extraction point closest to the site. *(Source: EA/JBA Consulting)*

3.13 As can be seen in Table 2, modelled 1:200 year flood levels range from 4.3 mAOD to 5.5 mAOD depending on the impacts of potential climate change. Using the guidance found within PPS25, for the purposes of this FRA, modelled levels for Shoreham Harbour have been used.

Flood Alleviation

3.14 Communication with the EA suggests that there are no formal flood defences/alleviation schemes within the vicinity of the site *per se*. However, the shingle beach acts as a raised embankment between the property and the sea, which is significantly higher (between 6.06 mAOD and 6.12 mAOD) than either that of the property (5.4 mAOD) or that of the 1:200 year flood level plus allowance for climate change (5.5 mAOD).

3.15 Figure 8 below shows the existing primary and secondary lines of flood defences in the area. The first line of defence is elevated at between 6.06 mAOD and 6.12 mAOD in close proximity to the site. The modelled level for the 1:200 year event (with allowance for climate change up to 2115) for Shoreham Harbour is 5.5 mAOD. Given the nature of tidal flooding, it is expected that in the event of such a high tide, some waves would exceed that level.

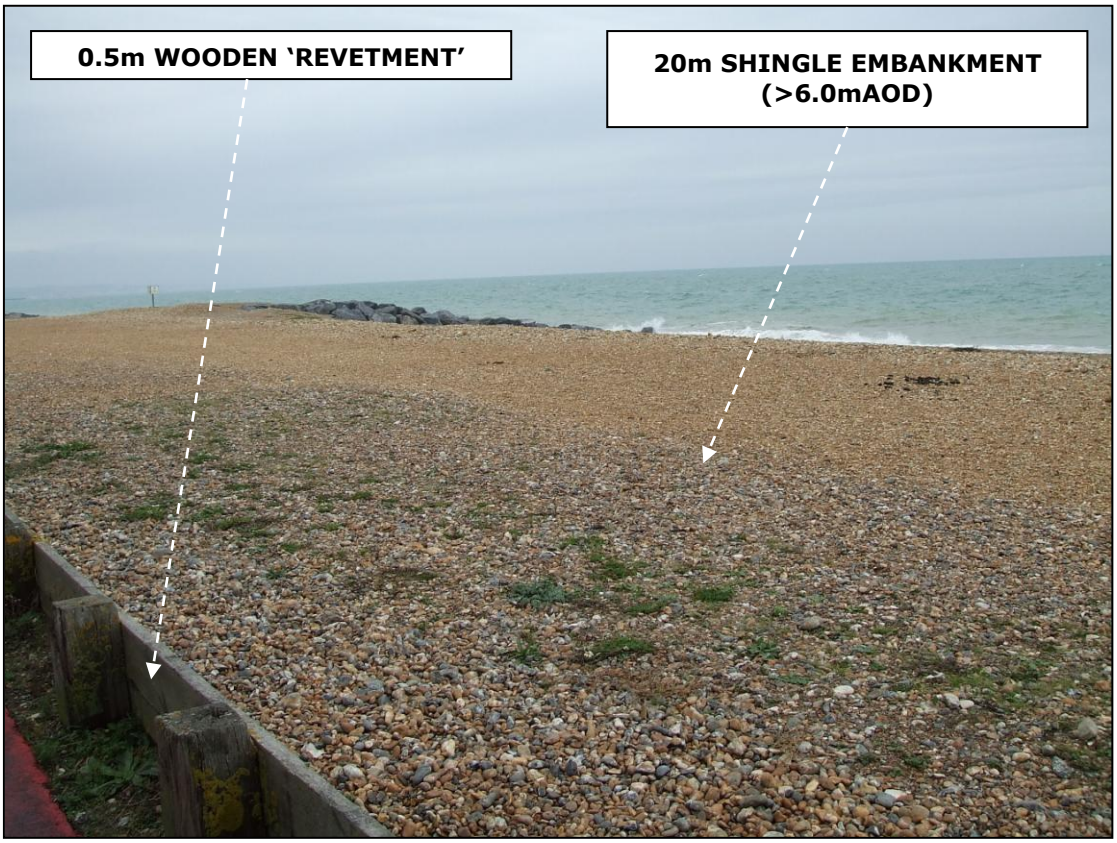


Figure 8: Likely path of water following overtopping of the existing defences derived from the topographic survey of the site. *(Source: Appendix A, Drawing No. 1117-P01)*

Overtopping and Defence Breach

3.16 Further to the above and following a request from EA Development Control, a quantitative assessment of overtopping was undertaken at the site. The calculations are shown in full in Appendix E.

3.17 The assessment analysed overtopping rates using the methodology specified in EA R&D Technical Report W178. A joint-probability analysis was then applied to these calculations so as to establish the worst-case scenario at this location for the design return period (1:200 year). It should also be noted that, as required by PPS25, the calculations include an allowance for climate change upto 2110.

3.18 The parameters used (based on topographic survey information) were:

- A top shingle level of 6.0mAOD;
- A shingle berm of 20.0m*, and;
- A small wave wall at the rear of the berm of 0.5m high.

* Further to previous communication with EA Development Control, the berm was reduced in width by 75% (to 5.0m) to reflect the possible accelerated erosion of the defence whist under extreme conditions.

3.19 The conclusions of the study are summarised below:

- If the berm is assumed to be maintained at 20.0m throughout the design event, there is no significant overtopping;
- With the berm reduced to 5.0m, greater levels of overtopping occur;
- The worst overtopping occurred during the joint-probability event which linked the highest wave heights with the lowest mean water level;
- The 'worst-case scenario' 1:200 year event (including a 75% breach in proximal defences) results in a flood level of 5.12mAOD.

3.20 Considering the above and the topography of the site's surroundings, if overtopping of defences resulted in a significant volume of water in the vicinity of the development site, this water would likely pond in the lower elevated land to the east or west of Shopsdam road.

3.21 Given that the development site benefits from both (i) the presence of defences elevated significantly above the 1:200 year flood level (allowing for potential climate change) and (ii) an area of high ground exists between the defences and the development site, the risk of tidal flooding at the 1:200 year level is considered to be of ***low significance***.

3.22 However, given (i) the potential effects of climate change on raising extreme tide levels, and (ii) the fact that some wave heights may exceed the tide level, it is possible that some water may be conveyed over the flood defences. As such, given that the quantity of water is likely to be low in all but the most extreme of events, the risk of tidal flooding via overtopping of defences at the 1:200 year level is considered to be of ***moderate significance***.

3.23 Grant Moffatt, EA Development Control Engineer, has confirmed that given the nature of the topography in the area, the complete failure/breaching of tidal flood defences is not a scenario which is required to be considered. As such, the risk to the site from tidal defence breach flooding is considered to be ***not significant***.

3.24 Given the very low ground floor level of the existing property and based on the above, the impact of tidal flooding to the existing site via any mechanism would be expected to be of ***moderate significance***.

The Sequential Test

3.25 Under PPS25, all new planning applications must undergo a *Sequential Test*. This test must be implemented by local planning authorities with a view to locating particularly vulnerable new developments (e.g. residential, hospitals, mobile homes etc.) outside of the floodplain. The test refers to the EA Flood Zones described in Table 2. For reference, the PPS25 *Sequential Test* is reproduced below:

Flood Risk Vulnerability Classification		Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test Required	✓	✓
	Zone 3a	Exception Test Required	✓	×	Exception Test Required	✓
	Zone 3b (functional floodplain)	Exception Test Required	✓	×	×	×

Table 4: The Sequential Test as specified by Planning Policy Statement 25. Shaded cells denote the proposed re-development. Please note: ✓ means development is appropriate; × means the development should not be permitted.
(Source: PPS25)

3.26 Using the principles of the Sequential Test outlined above, the proposed re-development is for residential properties (i.e. 'more vulnerable') and is almost entirely located in Flood Zone 3a (as defined by the EA).

3.27 Residential developments located within Flood Zone 3a are required to pass the *exception test* under PPS25. For the exception test to be passed, the proposed development must meet the following criteria:

- it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh the flood risk, as informed by a Strategic Flood Risk Assessment;
- the development is on developable or previously developed land, or, if it is not on previously developed land, that there are no alternative sites;
- a Flood Risk Assessment demonstrates that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

(Source: PPS-25: Planning and Flood Risk)

3.28 As such, and in order to address these requirements, the planning application submitted by Urban View Architects is required to be accompanied by an FRA which shows that the re-development can be achieved in a sustainable manner, with an overall reduction of flood risk to the site and surrounding area.

4 SURFACE WATER FLOOD RISK

Definition

4.1 PPS25 defines surface water flooding as: "*Intense rainfall, often of short duration, that is unable to soak into the ground or enter drainage systems* [and that] *can run quickly off land and result in local flooding. In developed areas, this flood water can be polluted with domestic sewage where foul sewers surcharge and overflow. Local topography and built form can have a strong influence on the direction and depth of flow. The design of development down to a micro-level can influence or exacerbate this. Overland flow paths should be taken into account in spatial planning for urban developments. Flooding can be exacerbated if development increases the percentage of impervious area.*"

4.2 New or re-developments must therefore incorporate management of surface water, as an essential element of reducing future flood risk to both the site and its surroundings.

Existing Risk

4.3 Neither Southern Water nor the EA hold records suggesting that the site has been previously affected by surface water flooding and as such, this suggests that the risk from this source of flooding is relatively low.

4.4 As such, the existing risk to the site from pluvial flooding is considered to be of ***low significance***.

4.5 At present, the lower floor levels of the existing dwelling are set at approximately 3.3 mAOD. Given this, in the event that pluvial flooding occurs at this location, the impact to the existing site would be expected to be of ***moderate significance***.

5 GROUNDWATER FLOOD RISK

Definition

5.1 Groundwater flooding can occur when water levels in the ground rise above surface elevations. This is most likely to occur in low-lying areas, underlain by permeable geology (usually referred to as *aquifers*). These may be extensive, regional aquifers, comprising chalk or sandstone, or may be localised sands or river gravels in valley bottoms underlain by less permeable rocks.

5.2 Water levels below the ground rise during wet winter months, and fall again in the summer as water flows out into rivers. During very wet periods, rising water levels may lead to the flooding of normally dry land, as well as reactivation of flow in *bournes* (intermittent streams), when groundwater levels are high. Chalk aquifers show some of the largest seasonal variations in groundwater level, and represent the most extensive source of potential groundwater flooding. Groundwater flooding may take weeks or months to dissipate because groundwater flow is much slower than surface flow and water levels thus take much longer to fall.

Existing Risk

5.3 The bedrock on which the re-development site is located is 'chalk including red chalk' (Source: British Geological Society). Figure 9 below shows the underlying geological deposits within this part of south-east England.

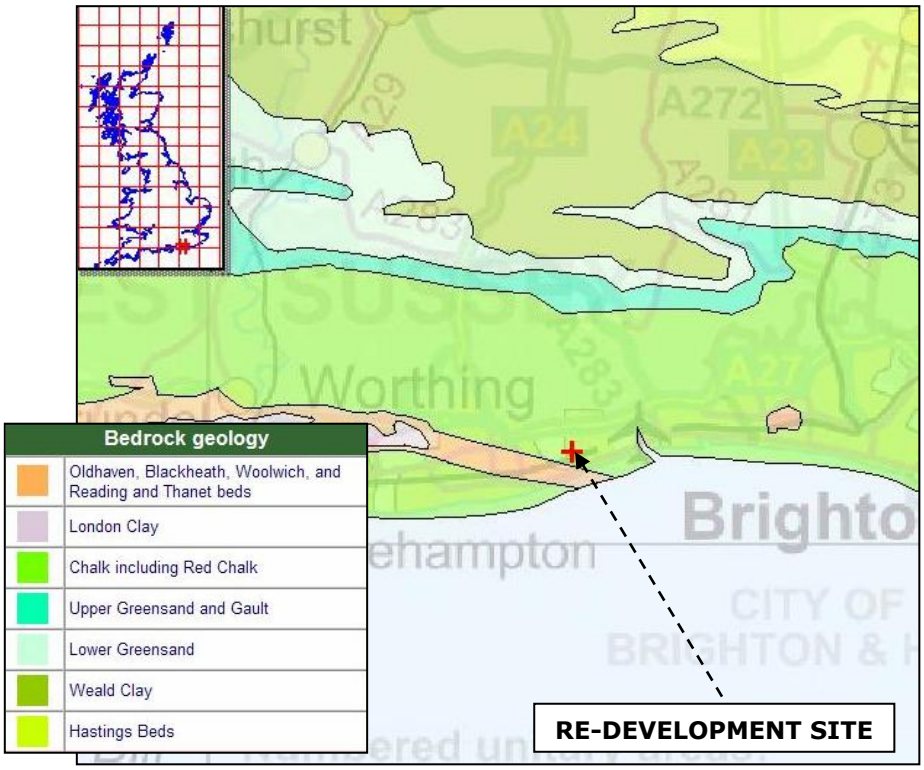


Figure 9: Geological deposits in and around Lancing. *(Source: British Geological Society)*

5.4 Although chalk is highly permeable, given the elevated topographic levels on site, the risk of groundwater flooding at this site can be considered to be of ***low significance***.

5.5 Given the extremely low risk in this area, the impact to the existing site from groundwater flooding would be expected to be of ***low significance***.

6 SEWER FLOOD RISK

Definition

6.1 In urban areas, rainwater is frequently drained into surface water sewers or sewers containing both surface and waste water known as 'combined sewers'. Flooding can result when the sewer is overwhelmed by heavy rainfall, becomes blocked or is of insufficient capacity, and will continue until the water drains away. When this happens to combined sewers, there is a high risk of land and property flooding with water contaminated with raw sewage as well as pollution of rivers due to discharge from combined sewer overflows.

Existing Risk

6.2 Communication with Southern Water has revealed that no incidents of flooding as a result of surcharging of sewers in the vicinity of the site have been recorded. As such, given that there is no indication to suggest that the site may have flooded previously, the risk of flooding due to overflowing surface and/or foul water sewers can be considered to be of ***low significance***.

6.3 Given the above and considering the existing usage of the site; in the event of sewer surcharging, the impact to the site would be expected to be of ***low significance***.

7 FLOOD RISK ASSESSMENT

Existing Risk Summary

7.1 The site is currently at risk from a number of sources of flooding:

- **Tidal** – Overtopping of tidal defences *(Moderate significance);*
- **Pluvial** – On-Site *(Low significance)*;
- **Groundwater** – On-Site *(Low significance)*;
- **Sewer** – Adjacent Road *(Low significance)*.

7.2 In its existing state, the site is particularly vulnerable to flooding for a number of reasons:

- The lower floor levels of the property are currently set at approximately 3.3 mAOD (2.2 m below the expected 1:200 year level in 2115);
- The existing building design does not incorporate effective flood proofing measures and as such, is particularly vulnerable to flooding;
- It is understood that there is currently no formal evacuation plan for the existing property.

Effects of the proposed development on flood risk on-site, and in the surrounding area

7.3 This proposal aims primarily to reduce the risk of flooding where possible, and to significantly reduce the impact of flooding to the structures on site. This proposal aims to alleviate the vast majority of these risks.

7.4 Current EA policy regarding new or re-development states that under PPS25, new developments should be set above the modelled 200-year flood level with allowance for climate change (Source: EA). Communication with the EA has suggested that a freeboard of 600 mm should be added to this level for residential developments. As such, **the ground floor design level for this site has been set at 6.1 mAOD (5.5 mAOD + 600 mm)**.

7.5 This raise in ground floor levels would effectively situate the replacement dwelling outside of EA Flood Zone 3a.

7.6 Given that there is a small intensification of use at the site, there could be an increase in development discharge flows. As such, so as to minimise the effect of the proposal on local drainage systems, it is suggested that Thames Water are consulted at the detailed design stage.

7.7 To further reduce the potential impact of flooding at the site, these proposals involve the inclusion of flood proofing measures within the building design (see section 8).

7.8 Given the location of this re-development, the significant betterment in terms of reduced impact that can be achieved relative to the existing development and that the site appears to be relatively well protected from the 1:200 year floodplain (with allowance for climate change), ***it can be concluded that the development should not increase flood risk elsewhere in the catchment as there would not be a significant reduction in on-site floodplain storage capacity or restriction of flood flow routes (as per PPS25)***.

7.9 However, although the proposals should not increase flood risk elsewhere in the catchment, in the event that tidal flows enter the site, it is necessary to ensure that flood risk to the new development is reduced to an acceptably low level. Further, should floodwaters ingress, it is necessary to minimise the associated damage and risk to life. The incorporation of wet and dry proofing, other flood mitigation methods and the formulation of emergency (evacuation) procedures would help to ensure this (see Section 8 for recommendations regarding mitigation measures).

Assessment of speed of onset, duration and impact

7.10 Information derived from the EA Flood Map suggests that the majority of the site lies within an area at a high risk of flooding (i.e. EA Flood Zone 3a). As such, it is understood that an escape route to more elevated areas, away from the main source of flood risk (i.e. The English Channel) should be provided. Based on information collected from the detailed topographic survey of the site (Appendix A, Drawing No. 1117-P-201), Ordnance Survey data and the EA JFLOW derived flood map (Figure 6) a proposed evacuation route is shown below in Figure 10.

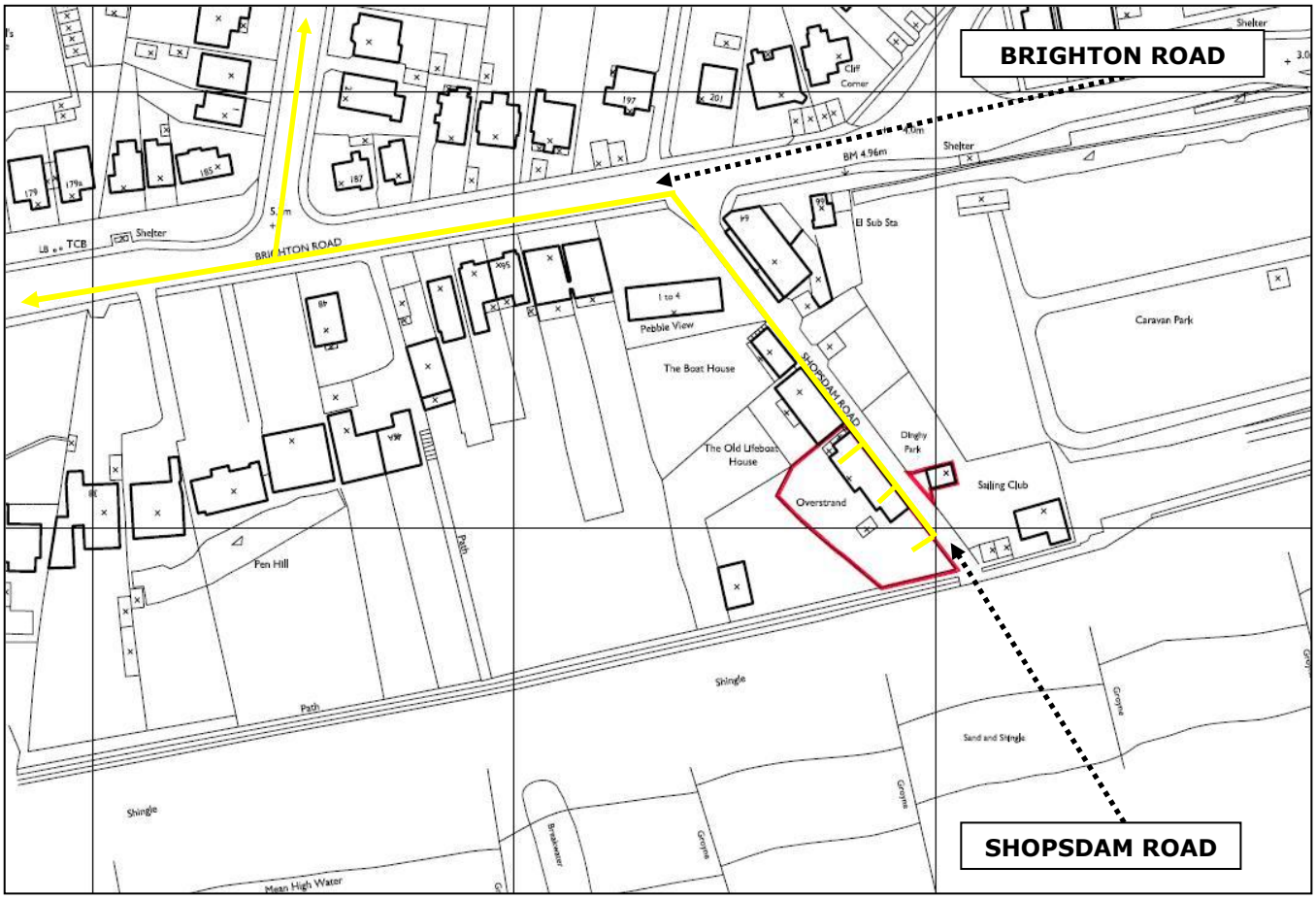


Figure 10: Extract from Ordnance Survey data for the area denoting a potential safe escape route in the event of an extreme fluvial flood. Yellow arrows show potential escape route. The site is outlined in red.

7.11 Assuming overtopping of tidal defences occurs during the 1:200 year design event, given that:

(i) the maximum level estimated within the joint-probability analysis was found to be 5.12mAOD, which remains at least 8 mm below the lowest section of Shopsdam Road (adjacent to the site). It is worth noting that whilst Topographic levels on Shopsdam Road drop to below 5.0mAOD at the confluence with Brighton Road, there is no conceivable flow-path to this location (see topographic survey).

(ii) given the above, a safe escape route can be followed northwest up Shopsdam Road then west along Brighton Road (Flood Zone 1);

(iii) the ground floor level of the buildings will be raised to 6.1 mAOD, and;

(iv) significant flood proofing measures shall be incorporated within the development design;

under these proposals, the impact of flooding following this development would be expected to be of ***low significance***.

Assessment of probability and extent of flooding

7.12 Based on a comparison of modelled flood levels and existing topographic levels, following the definitions set out in PPS25, both the proposed and existing dwellings appear to be well protected against the expected high tide level of a 1:200 or 1:1000 year storm event. Based on this, the site has an annual probability of flooding of less than 0.1% from the sea (ignoring wave action). As such, following the definitions set out in PPS25, if defences are acknowledged, the development can be considered to be at a 'low risk' of flooding from tidal sources.

Assessment of existing and proposed drainage

7.13 Southern Water has confirmed that they do not hold records of sewer flooding in this area.

7.14 It is understood that all surface/foul waters from the proposed development would be discharged into the existing foul water drainage system, which is maintained by Southern Water.

7.15 Given that foul water discharge is unlikely to significantly increase with the proposed development (as there is little intensification of use); the current drainage capacity may suffice. However, communication with Southern Water regarding drainage capacity and design is recommended at the detailed design stage.

Impacts to fluvial geomorphology and longer term sustainability

7.16 Given that the channel itself will not be altered as part of the development, and assuming adoption of the mitigation measures outlined in Section 8, there will be no significant impacts (either positive or negative) to local fluvial morphology and longer-term sustainability.

8 SCOPE FOR MITIGATION

8.1 The risk to the site from tidal flooding post-development will remain of ***low significance***. The risk from overtopping or breaching of tidal defences will remain of ***moderate significance*** and ***not significant*** respectively. The risks from groundwater, sewer and pluvial flooding are considered to be of ***low significance***. The effect of the development on local catchment hydrology will remain ***not significant***.

8.2 However, given that:

(i) the EA Flood Map considers the development site to be located within the 1:200 year floodplain (EA Flood Zone 3a), and;

(ii) climate change could result in increased sea levels in the English Channel;

the following recommendations are provided:

8.3 To minimise local flood risk from such future occurrences as tidally-induced flooding, blocked road gullies, overflowing sewers and burst water mains, the developer has agreed to raise slab levels above surrounding ground levels and above the ground levels of the exiting development. Following EA recommendations, finished ground floor levels within the new development should be set a minimum of 600 mm (due to potential model inaccuracy) above the 200-year modelled flood level (with allowance for climate change).

8.4 The developer has therefore agreed that the minimum finished ground floor level will be set at 6.1 mAOD

8.5 Following this mitigation, the impact of tidal flooding on the proposed development and its inhabitants is considered to be of ***low significance***.

8.6 Flood-proofing measures and flood resistant designs should also be incorporated into the new development. In addition to raising slab levels, additional protection measures to be included into the building design include:

- bringing down electrical services from ceilings;
- wiring, power outlets, switches, etc. installed above the maximum floodwater level;
- air brick protection (where appropriate – if airbricks are used, protection will be provided);
- solid (i.e. concrete) floors.

Flood Warning and Emergency Evacuation

8.7 It is recommended that the site owner and individual property owners subscribe to the Environment Agency's Flood Warning Service. The site owner should ensure that this service is made available to all occupants of the proposed development.

8.8 The EA operates a 24-hour telephone service on 0845 988 1188 that provides frequently updated flood warnings and associated floodplain information. Further information can be found on www.environment-agency.gov.uk/floodline. Floodline Warnings Direct is a free service operated by the EA that provides flood warnings direct to occupants by telephone, mobile phone, fax or pager.

8.9 To minimise local flood risk from such occurrences as river-induced flooding, blocked road gullies, overflowing sewers and burst water mains in the future, the developer has agreed to maintain a safe, unobstructed escape route from the properties (see *7.10*/*7.11*). This route should be communicated to residents of the property so as to enable evacuation to a safe location following an early flood warning and/or during a flood event.

8.10 As such, egress from the site during a flood warning / flood event should be via the front of the properties onto Shopsdam Road (heading north-west) and then onto Brighton Road heading west/north, away from the flood source (see Figure 11).

8.11 The creation of a raised ground floor would also mean that, in the event that evacuation is not possible during a catastrophic flood event and / or rapid inundation occurs, occupants could remain in relative safety within their properties.

9 CONCLUSIONS

9.1 This report has presented the findings of a Flood Risk Assessment that has been carried out for the proposed residential re-development at Shopsdam Road, Lancing, BN15 8ES, East Sussex. The proposed re-development involves the demolition of the existing buildings and the construction of four, two-storey houses; three with under croft parking and one with adjacent parking. The assessment has been carried out using current best practices, and against the criteria set out in PPS25.

9.2 The risk from tidal flooding to the proposed re-development is considered to be of ***low significance*** as the site resides behind effective flood defences. The risk from overtopping of these tidal defences is considered to be of ***moderate significance***, whilst the risk of defence breach flooding is considered to be ***not significant***. The risk to the site from fluvial flooding is also considered to be ***not significant***. The risks to the proposed development from groundwater, pluvial or sewer flooding are considered to be of ***low significance***. The effect of the development on local catchment hydrology is considered to be ***not significant***.

9.3 Following a detailed comparison of modelled tidal flood levels and topographic levels, it would appear that the entire site is well protected from the 1:200 year floodplain, although according to the EA Flood Map, resides within EA Flood Zone 3a. As such, following the definitions provided within PPS25, if flood defences are disregarded, the development site has an annual probability of flooding of at least 0.5% from tidal sources. However, if flood defences are taken into consideration then the development site has an annual probability of flooding of less than 0.1% from tidal sources (ignoring wave-action).

9.4 The EA estimates that the associated 1:200 year flood level, allowing for the potential impact of climate change on peak flows, is 4.7 mAOD (2060) and 5.5 mAOD (2115).

9.5 The proposed development includes a number of design features and flood alleviation measures which would significantly improve the situation with regard to flood risk. Measures include:

- the raising ground floor levels to 6.1 mAOD;
- provision of a safe escape route;
- inclusion of flood proofing techniques.

9.6 To mitigate against residual flood risk and resultant impacts in the future, additional recommendations were provided including:

- Subscription to the Environment Agency's Flood Warning Service, and;
- incorporation of adequate surface / foul water drainage facilities with attenuation at the detailed design stage in consultation with Southern Water Utilities.

9.7 As such, and following an analysis of EA flood risk maps, recorded / modelled river level, topographic and anecdotal information, **it can be concluded that the risk and impact of tidal flooding can be reduced following re-development of this site.**

9.8 Given that: (a) the site lies within an existing developed area; (b) significant betterment can be achieved through the techniques and methods outlined within this report; and (c) a safe route of escape can be provided as part of the re-development, following guidelines contained within PPS25, the proposed development type is considered to be ***suitable*** assuming appropriate mitigation (including adequate warning and evacuation procedures) can be maintained for the lifetime of the development.

The findings and recommendations of this report are for the use of the client who commissioned the assessment, and no responsibility or liability can be accepted for the use of the report or its findings by any other person or for any other purpose.

Dr. J. B. Butler

B.Sc., M.Phil., PhD.

Ambiental Technical Solutions Ltd. December 2009

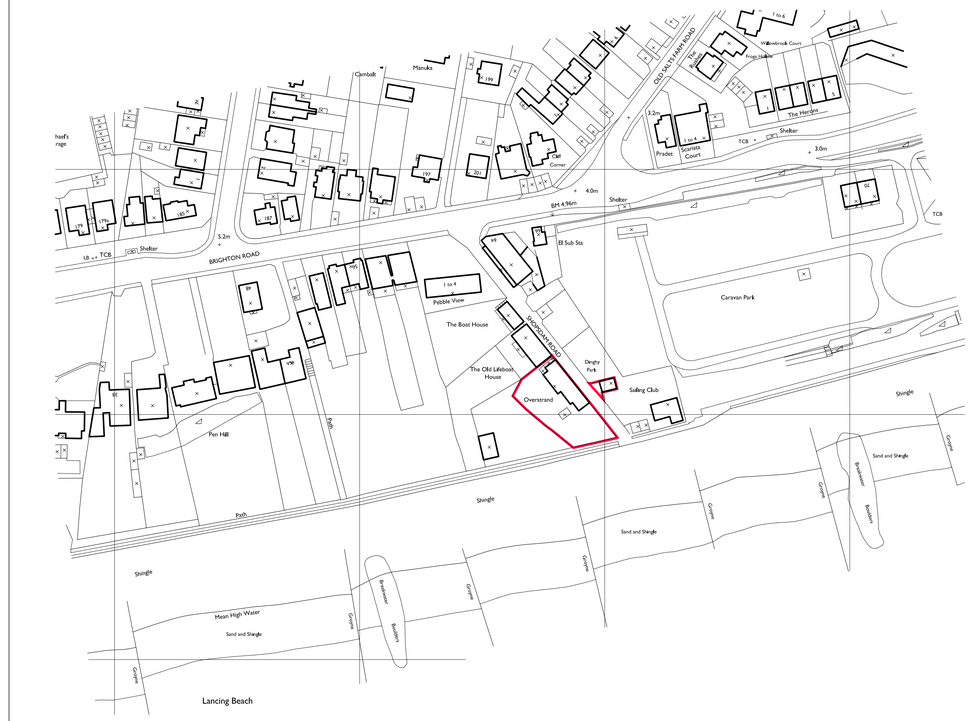
APPENDIX A - SUPPORTING INFORMATION

Drawing Numbers:

1. 1117-P-201 – Topographic Survey
2. 1117-P-202 – Proposed Site Plan
3. 1117-P-203 – Floor Plans



EXISTING SURVEY, 1:250 @ A1, 1:500 @ A3 (CHECK SCALE BAR)



OS BLOCK PLAN, 1:1250 @ A1, 1:2500 @ A3

NOTE:

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Project
OVERSTRAND,
SHOPSDAM ROAD,
LANCING.

Drawing Title
PLANNING:
EXISTING SITE
SURVEY AND
OS BLOCK PLAN

Scale: AS SHOWN
Drawn by: DB
Date: 16/12/09
Checked by: HD
Drawing Number: 1117-P-201
Revision: -

THE BOAT HOUSE
Upper Floor Terrace 5.5m AOD
Ridge Ht 11.35
Eave 7.98
Eaves 7.8m
Ridge Ht 11.34
Eave Ht 7.78m
THE OLD LIFEBOAT HOUSE
Upper Floor Terrace 5.5m AOD
Ridge Ht 11.34
Eaves 7.82m
Eave Ht 7.78m
Conc and conc Block RW 1.2m
Gravel
Conc Wall
Conc Wall 1.1mh (on .18mh plinth)
TP
IC
Retaining Wall
Hedge 2.5mh
Conc Wall 1.4mh
EXISTING GARAGE
SHOPSDAM ROAD
CARAVAN PARK
DINGHY PARK
Eave Ht 11.6m
Upper Ridge 13.99m
Lower Ridge 12.36m
SAILING CLUB
Deck Level 6.20
Decking
Public Toilets
Flat Roof 7.95m
Lawn
Deck Level
HOUSE No.1
HOUSE No.2
HOUSE No.3
HOUSE No.4
TERRACE
BALCONY
OPEN AIR STORE
SKYLIGHT
3 No. SOLAR PV PANEL FRAMES
HATCH
PITCHED ROOF FALL
NEW TREE
NEW TREES AND PLANTING SHOWN THUS
EXISTING SPECIMEN TREE RETAINED
CLOSE-BOARDED FENCE, 1.8m HIGH
NEW TREES
NEW CAR ACCESS
OFF-WHITE-RENDER FINISHED WALL. 2.1m HIGH
BRICK WALL 0.9m HIGH
Flat Roof 7.35m
Boat Park
Beach Huts
Ridge 8.41 Eave 7.82
Ridge 8.30 Eave 7.63
Ridge 8.30 Eave 8.00
Ridge 8.54 Eave 8.00
Ridge 8.65 Eave 8.00
Ridge 8.42 Eave 8.06
Ridge 8.2 Eaves 7.69
Ridge 8.2 Eaves 7.79
Ridge 8.21 Eaves 7.79
Ridge 8.31 Eaves 7.63
Ridge 8.48 Eaves 7.85
Ridge 8.29 Eaves 7.65
Clk 1.7mh
Wood shuttering 0.3mh
Shingle
Conc Path
Conc
Mkr
Winch
STN
NORTH
0 5m 10m 25m

PLAN, 1:125 @ A1, 1:250 @ A3 (CHECK SCALE BAR)

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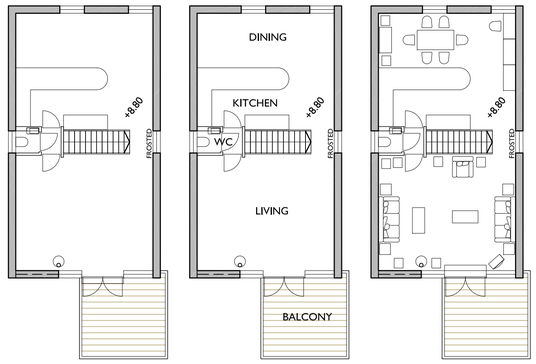
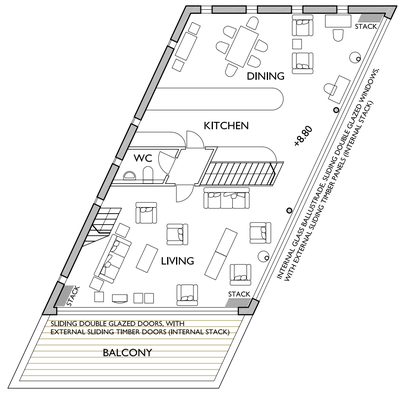
Project
OVERSTRAND, SHOPSDAM ROAD, LANCING.

Drawing Title
PLANNING: PROPOSED SITE PLAN

Scale: AS SHOWN
Drawn by: DB
Date: DEC 09
Checked by: HD
Drawing Number: 1117-P-202
Revision: -

FIRST FLOOR PLAN

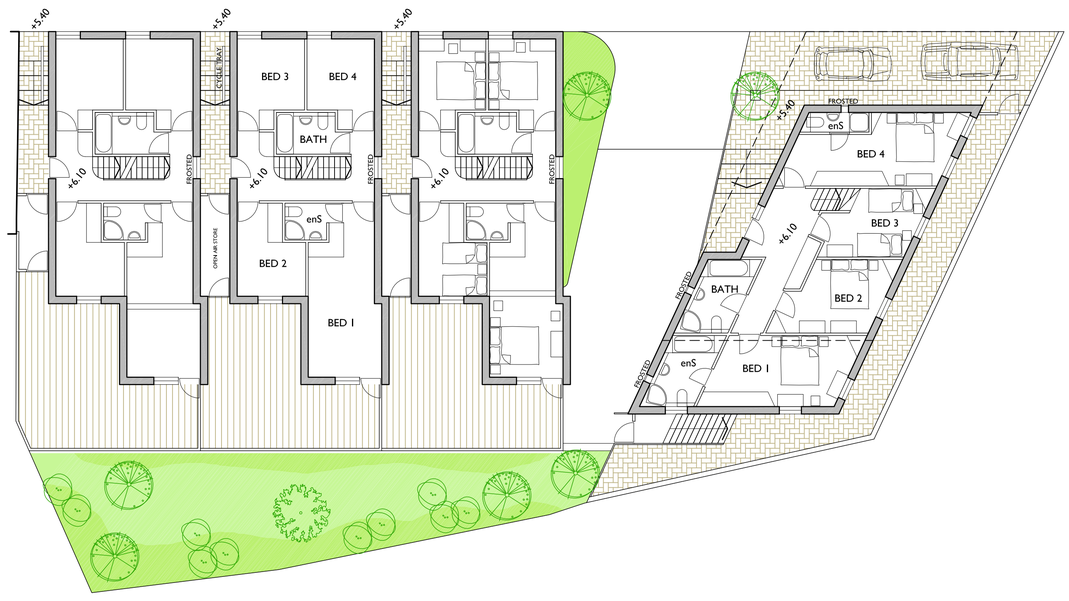




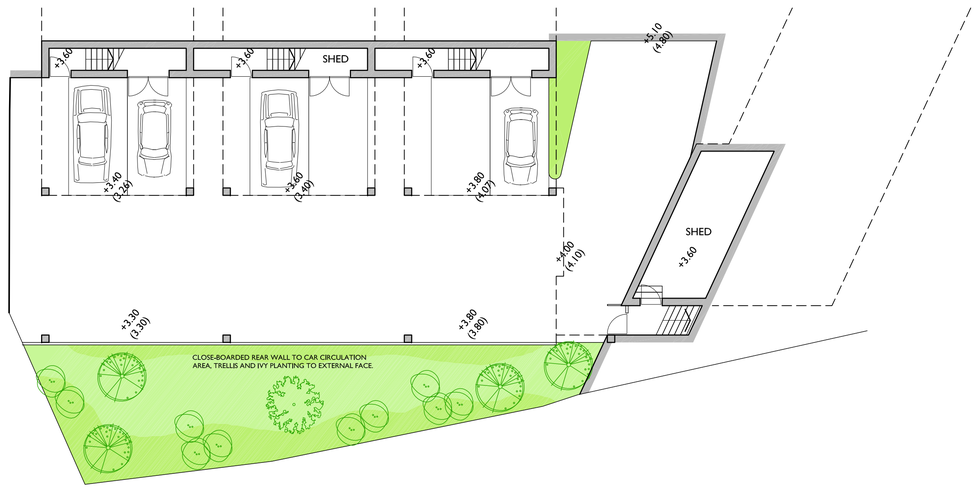




GROUND FLOOR PLAN



LOWER GROUND FLOOR PLAN



PLANS, 1:125 @ A1, 1:250 @ A3 (CHECK SCALE BAR)

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Drawing Title
PLANNING: PROPOSED FLOOR PLANS

Scale	Drawn by
AS SHOWN	DB
Date	Checked by
DEC 09	HD
Drawing Number	Revision
1117-P-203	-

APPENDIX B – INFORMATION RELATING TO JFLOW

JFLOW and flood outlines (Source: EA)

Flood Zones have been produced using JFLOW, a nationally consistent model. JFLOW has been used to produce the 1% (1 in 100 year) and 0.1% (1 in 1000 year) flood outlines.

The flood outlines have been developed by applying flow and tide models to a 3D ground level map of England and Wales, known as a Digital Terrain Model (DTM). This is created by flying an aircraft over the whole of the country using radar to record and create a contoured model of the land. This DTM is used as the basis of a grid of cells which is used to estimate the extent of flooding in a flood of a given return period or probability.

The size of the flood event (1 in 100 or 1 in 100 year) is determined by the inflows to the JFLOW model, which are calculated using statistical techniques from the Flood Estimation Handbook. The technique used is based upon catchment descriptors and data transfer, the details of these can be found in the Flood Estimation Handbook volume 3. The Flood Estimation Handbook provides a consistent technique for estimating inflows to the national model and its methods are widely accepted.

The methodology is a raster-based approach, driven by an underlying Digital Elevation Model (DEM).

- Each cell has a ground level and water depth
- Water can move to any of surrounding 8 cells where the water level is lower
- Water will pond in low spots until the water level is high enough to spill
- The velocity of movement depends on water surface slope and surface roughness

The above points describe the basic principles of the model. The two underlying principles are:

- Mass conservation within each cell
- Calculation of the fluxes between the cells

Each grid cell is treated as a small storage area. Mass conservation is applied to each grid cell. The flux between cells is calculated using a form of the generalised weir equation.

Efficient coding is achieved by keeping a list of all currently wet cells and a list of newly wet cells. This avoids having to search through each cell in the ground grid.

For whole catchment modelling, the hydrographs used as inflow boundary conditions represent the whole hydrograph at that inflow location and a simple conceptual method has been derived to account for the amount of flow within the channel banks. A simple solution was therefore sought which would approximately account for the proportion of flow contained within the channel without requiring further information about the channel.

The simple conceptual method used involves two assumptions:

1. That bankfull flow (Q_b) is equal to QMED as calculated by the Flood Estimation Handbook (FEH) methods. QMED has a return period of 2 years. This assumption derives from the concept of dominant discharge in fluvial geomorphology (Wolman and Leopold, 1957; Wolman and Miller, 1960) where the cross-section shape is assumed to be formed by a discharge with a recurrence interval of 1-2years.

2. That the additional channel flow (Q_c) scales with both Q_b and depth above bankfull (d).

The basis of the current model is that each grid cell acts as a small flood cell and the links to each of the surrounding cells are automatically calculated. It is therefore capable of simulating the inundation extent at a level of detail equal to the underlying DEM. It is fundamentally volume conservative and so, in a given time period, will simulate the peak water levels across the floodplain depending on the volume of water that has entered the floodplain. This approach is a half-way house between the common 1D hydrodynamic models and a 2D hydrodynamic model.

Limitations

JFLOW was used to produce flood maps for the whole of England and Wales for all catchments greater than 3 sq km in a consistent manner. The method is therefore very generalised and therefore cannot take account of information that may be very significant locally. This might include:

1 Effects of bridges and other structures including flood defences are not taken into account.
2 Errors in the DTM, caused by trees and buildings for example.
3 The effect of reservoirs and urban drainage and other man made influences on the flow regime can only be taken into account in a very general sense in JFLOW.
4 The channel is assumed to be able to take the 2 year flow. This may not be true especially in those modified by man.
5 Hydraulic roughness is assumed to be the same everywhere in JFLOW, but of course it is not.

For these and many other reasons, the flood outlines produced by JFLOW can only be taken as a rough guide, showing where more detailed flood risk assessments are essential. Flood risk assessments should also be undertaken near small watercourses whose catchments are too small to have been included in the JFLOW modelling

APPENDIX C – ADDITIONAL INFORMATION

Table C1: Explanation of the levels of Significance used for the Flood Risk Assessment.

Significance	Risk of flooding of proposed development following completion	Impact of proposed development on both local and catchment hydrology
Not significant	Proposed development is not located in a 1:100 year fluvial or 1:200 year tidal floodplain. Flooding as a result of the accumulation of surface runoff either on-site, or elsewhere in the catchment is highly unlikely.	Proposed development does not affect the quantity/quality of surface runoff and does not alter surface/groundwater flow locally or elsewhere within the catchment.
Low significance	Proposed development is located in a 1:100 year fluvial/1:200-year tidal floodplain, although no mitigation measures are required due to regional flood defences. Existing local drainage measures are sufficient to ensure that the accumulation of surface runoff does not result in flooding on-site or increase the risk of flooding elsewhere within the catchment.	Proposed development has a minor affect on the quantity/quality of surface runoff or surface/groundwater flow either locally or elsewhere within the catchment. Such changes may be sustainable without mitigation measures.
Moderately significant	Proposed development is located in a 1:100 year fluvial/1:200-year tidal floodplain and mitigation measures are required to reduce flood risk to an acceptable level. Surface runoff attenuation methods may be required to ensure that the accumulation of surface runoff does not result in flooding on-site or increase the risk of flooding elsewhere within the catchment.	Proposed development has a notable affect upon the quantity/quality of surface runoff and has a discernable impact upon surface/groundwater flow either locally or elsewhere within the catchment. Mitigation measures may be required in order for the development to be sustainable throughout the duration of its intended lifetime.
Moderate-high significance	Proposed development is located in a 1:100 year fluvial/1:200-year tidal floodplain and significant mitigation measures are required to reduce flood risk to an acceptable level. A range of surface runoff attenuation methods will be required to ensure that the accumulation of surface runoff does not result in flooding on-site or increase the risk of flooding elsewhere within the catchment.	Proposed development has a large affect on the quantity/quality of surface runoff and has a considerable impact upon surface/groundwater flow either locally or elsewhere within the catchment. A primary commitment to successful mitigation measures will be required in order for the development to be sustainable throughout the duration of its intended lifetime.
Highly significant	The proposed development is considered to be particularly susceptible to either tidal or fluvial flooding or a combination of both. Resultant changes in the rates of surface runoff as a result of the development will increase flood risk both on-site and elsewhere in the catchment. The incorporation of even a wide range of practicable mitigation measures may not ensure that the development remains sustainable in terms of flood risk for the duration of its intended lifetime.	Proposed development has a major affect on the quantity/quality of surface runoff and has a severe impact upon surface/groundwater flow locally or elsewhere within the catchment. The incorporation of even a wide range of practicable mitigation measures may not ensure that the development remains sustainable throughout the duration of its intended lifetime.

APPENDIX D – OVERTOPPING (JOINT PROBABILITY) ANALYSIS

Overtopping Rates

Sea Defences - Golden Sands

Reference: Wave Overtopping of Sea Walls
Sponsor EA, R&D Technical Report W178
Author HR Wallingford Ltd

Profile Box 3.6 Wave Return Wall on Permeable Slopes
Top level of shingle = 6m ODN
Bottom of Wave Wall 6m ODN, top of Wave Wall = 6.5m ODN

		Berm Reduced to 5m wide				Current Berm width 20m wide			
		2060	2060	2060	2060	2060	2060	2060	2060
Ac*		0.047064666	0.046976	0.050227	0.054652	0.047064666	0.04697592	0.050227408	0.054651719
Ac		1.3	1.41	2.04	2.51	1.3	1.41	2.04	2.51
Height to bottom of wave return wall		6	6	6	6	6	6	6	6
Surge Tide Water Level		4.7	4.59	3.96	3.49	4.7	4.59	3.96	3.49
Mean wave period, Tm	seconds	5.6	5.8	6.5	6.8	5.6	5.8	6.5	6.8
g	m/s2	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81
Significant Wave Height,Hs	metres	2.48	2.73	3.98	4.65	2.48	2.73	3.98	4.65
(gHs)^.5		4.932423339	5.175065	6.248504	6.753999	4.932423339	5.175065217	6.248503821	6.753998816
Qb*		0.00060292	0.000606	0.00049	0.000367	0.00060292	0.00060643	0.000490244	0.000367051
A		0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131
B		55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6
Ac*		0.047064666	0.046976	0.050227	0.054652	0.047064666	0.04697592	0.050227408	0.054651719
r		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
-BAc*/r		-3.07858286	-3.072778	-3.285463	-3.574865	-3.07858286	-3.072777809	-3.285463426	-3.5748654
Q	m3/s/m	0.082142603	0.094198	0.124417	0.113857	0.082142603	0.094197743	0.124416533	0.113856506
	l/s/m	82.14260335	94.19774	124.4165	113.8565	82.14260335	94.19774301	124.4165331	113.8565059
Width of top of Berm , Cw		5	5	5	5	20	20	20	20
Cw/Hs		2.02	1.83	1.26	1.08	8.06	7.33	5.03	4.30
(-1.5Cw/Hs)		-3.024193548	-2.747253	-1.884422	-1.612903	-12.09677419	-10.98901099	-7.537688442	-6.451612903
Exp((-1.5Cw/Hs)		0.048596997	0.064104	0.151917	0.199308	5.57748E-06	1.68862E-05	0.000532627	0.001577975
Cr		0.14870681	0.196157	0.464865	0.609883	1.70671E-05	5.16719E-05	0.00162984	0.004828603
Qc*		8.96583E-05	0.000119	0.000228	0.000224	1.02901E-08	3.13354E-08	7.9902E-07	1.77235E-06
Q	m3/s/m	0.012215164	0.018478	0.057837	0.069439	1.40193E-06	4.86738E-06	0.000202779	0.000549768
	l/s/m	12.21516447	18.47759	57.83695	69.43914	0.001401934	0.004867378	0.202779022	0.549767921
Value for Ac*		Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
Wh = height of wave return wall	metres	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
W*		0.384615385	0.35461	0.245098	0.199203	0.384615385	0.354609929	0.245098039	0.199203187
Df (from Figure 3.10)		0.08	0.1	0.25	0.5	0	0	0.001	0.04
Q = Qc x Df	m3/s/m	0.000977213	0.001848	0.014459	0.03472	0	0	2.02779E-07	2.19907E-05
	l/s/m	0.977213158	1.847759	14.45924	34.71957	0	0	0.000202779	0.021990717

The mean wave period has been obtained from a correlation between wind speed, maximum wave heights and significant wave periods produced by Derbyshire & Draper

Profile Box 3.6

		Berm Reduced to 5m wide				Current Berm width 20m wide			
		2110	2110	2110	2110	2110	2110	2110	2110
Ac*		0.018101795	0.020989	0.033731	0.041805	0.018101795	0.020989241	0.033731152	0.041805299
Ac		0.5	0.63	1.37	1.92	0.5	0.63	1.37	1.92
Height to bottom of wave return wall		6	6	6	6	6	6	6	6
Surge Tide Water Level		5.5	5.37	4.63	4.08	5.5	5.37	4.63	4.08
Mean wave period, Tm	seconds	5.6	5.8	6.5	6.8	5.6	5.8	6.5	6.8
g	m/s2	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81
Significant Wave Height,Hs	metres	2.48	2.73	3.98	4.65	2.48	2.73	3.98	4.65
(gHs)^.5		4.932423339	5.175065	6.248504	6.753999	4.932423339	5.175065217	6.248503821	6.753998816
Qb*		0.004009	0.003319	0.001442	0.00085	0.004009	0.001873127	0.00057514	0.000272165
A		0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131
B		55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6
Ac*		0.018101795	0.020989	0.033731	0.041805	0.018101795	0.020989241	0.033731152	0.041805299
r		0.85	0.85	0.85	0.85	0.85	0.6	0.6	0.6
-BAc*/r		-1.184070331	-1.372943	-2.206414	-2.734558	-1.184070331	-1.945002975	-3.125753398	-3.873957724
Q	m3/s/m	0.546191328	0.515548	0.366019	0.263814	0.546191328	0.29095571	0.145961823	0.084423569
	l/s/m	546.1913275	515.5482	366.0187	263.8144	546.1913275	290.9557099	145.9618231	84.42356857
Width of top of Berm , Cw		5	5	5	5	20	20	20	20
Cw/Hs		2.02	1.83	1.26	1.08	8.06	7.33	5.03	4.30
(-1.5Cw/Hs)		-3.024193548	-2.747253	-1.884422	-1.612903	-12.09677419	-10.98901099	-7.537688442	-6.451612903
Exp((-1.5Cw/Hs)		0.048596997	0.064104	0.151917	0.199308	5.57748E-06	1.68862E-05	0.000532627	0.001577975
Cr		0.14870681	0.196157	0.464865	0.609883	1.70671E-05	5.16719E-05	0.00162984	0.004828603
Qc*		0.000596166	0.000651	0.00067	0.000519	6.84219E-08	9.67881E-08	9.37387E-07	1.31418E-06
Q	m3/s/m	0.08122237	0.101129	0.170149	0.160896	9.32189E-06	1.50342E-05	0.000237894	0.000407648
	l/s/m	81.22236974	101.1286	170.1494	160.8959	0.009321889	0.01503424	0.237894395	0.407647937
Value for Ac*		Equation not Valid	Valid	Valid	Valid	Equation not Valid	Valid	Valid	Valid
Wh = height of wave return wall	metres	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
W*		1	0.793651	0.364964	0.260417	1	0.793650794	0.364963504	0.260416667
Df (from Figure 3.10)		0.01	0.035	0.3	0.5	0	0	0.001	0.01
Q = Qc x Df	m3/s/m	0.000812224	0.00354	0.051045	0.080448	0	0	2.37894E-07	4.07648E-06
	l/s/m	0.812223697	3.539501	51.04483	80.44795	0	0	0.000237894	0.004076479

Table 1

Joint Probability Combination for Lancing
Using amended Static Water Levels: 2060

Water level (mOD)	Significant wave height (m) (3 hourly)																	
	Joint return period (years)																	
	0.1	1				3				10				100				200
	0° - 360°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°
2.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.35	1.85	3.51	1.47	2.09	3.4	3.86	1.75	2.44	3.79	4.21	2.03	2.79	4.2	4.9	2.49	3.39	4.89	5.12
3.39	1.54	3.26	1.22	1.79	3.12	3.61	1.56	2.2	3.53	3.98	1.86	2.57	3.94	4.67	2.34	3.2	4.66	4.85
3.49	-	3.03	0.98	1.55	2.86	3.39	1.36	1.97	3.27	3.77	1.69	2.36	3.7	4.46	2.21	3.02	4.45	4.65
3.65	-	2.74	0.5	1.14	2.52	3.1	1.07	1.63	2.94	3.51	1.47	2.09	3.4	4.21	2.03	2.79	4.2	4.44
3.85	-	2.46	-	0.68	2.23	2.85	0.72	1.3	2.66	3.26	1.23	1.81	3.12	3.98	1.86	2.57	3.94	4.2
3.96	-	-	-	-	-	2.61	0.27	1.07	2.38	3.03	0.97	1.54	2.86	3.77	1.69	2.36	3.7	3.98
4	-	-	-	-	-	2.48	-	0.7	2.25	2.91	0.81	1.4	2.74	3.67	1.6	2.26	3.58	3.86
4.07	-	-	-	-	-	-	-	-	-	2.73	0.5	1.14	2.53	3.51	1.47	2.09	3.4	3.76
4.19	-	-	-	-	-	-	-	-	-	2.48	0	0.71	2.24	3.26	1.25	1.84	3.12	3.5
4.59	-	-	-	-	-	-	-	-	-	-	-	-	-	2.48	-	0.71	2.25	2.73
4.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.48

Table 2

Revised Joint Probability Combination for Lancing
Using amended Static Water Levels: 2115

Water level (mOD)	Significant wave height (m) (3 hourly)																	
	Joint return period (years)																	
	0.1	1				3				10				100				200
	0° - 360°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°	0° - 90°	90° - 180°	180° - 270°	0° - 360°
2.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.92	1.85	3.51	1.47	2.09	3.4	3.86	1.75	2.44	3.79	4.21	2.03	2.79	4.2	4.9	2.49	3.39	4.89	5.12
3.97	1.54	3.26	1.22	1.79	3.12	3.61	1.56	2.2	3.53	3.98	1.86	2.57	3.94	4.67	2.34	3.2	4.66	4.85
4.08	-	3.03	0.98	1.55	2.86	3.39	1.36	1.97	3.27	3.77	1.69	2.36	3.7	4.46	2.21	3.02	4.45	4.65
4.27	-	2.74	0.5	1.14	2.52	3.1	1.07	1.63	2.94	3.51	1.47	2.09	3.4	4.21	2.03	2.79	4.2	4.44
4.50	-	2.46	-	0.68	2.23	2.85	0.72	1.3	2.66	3.26	1.23	1.81	3.12	3.98	1.86	2.57	3.94	4.2
4.63	-	-	-	-	-	2.61	0.27	1.07	2.38	3.03	0.97	1.54	2.86	3.77	1.69	2.36	3.7	3.98
4.68	-	-	-	-	-	2.48	-	0.7	2.25	2.91	0.81	1.4	2.74	3.67	1.6	2.26	3.58	3.86
4.76	-	-	-	-	-	-	-	-	-	2.73	0.5	1.14	2.53	3.51	1.47	2.09	3.4	3.76
4.9	-	-	-	-	-	-	-	-	-	2.48	0	0.71	2.24	3.26	1.25	1.84	3.12	3.5
5.37	-	-	-	-	-	-	-	-	-	-	-	-	-	2.48	-	0.71	2.25	2.73
5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.48