
# FLOOD RISK ASSESSMENT FOR THE PROPOSED RE-DEVELOPMENT OF THE CASTLE BUILDINGS, EARL DE GREY PUBLIC HOUSE AND A NEW HOTEL BUILDING, CASTLE STREET, HULL

**PROJECT NO. JAG/AD/JF/39388-Rp001**

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## APPENDICES

# 1.0 INTRODUCTION

## 1.1 Background

1.1.1 Alan Wood & Partners were commissioned by Castle Buildings LLP to prepare a Flood Risk Assessment for the proposed re-development of the Castle Buildings, reconstruction of the Earl De Grey Public House and erection of a hotel at Castle Street, Hull.

1.1.2 A Flood Risk Assessment (FRA) for the proposed development is required to assess the development's risk from flooding.

1.1.3 This report should be read in conjunction with the Drainage Impact Assessment (DIA) which has been prepared for the development (ref: 39388-Rp002 DIA, Prop'd Re-Dev't of the Castle Buildings Site, Castle St, Hull).

## 1.2 Layout of Report

1.2.1 Section 1 provides an introduction to the FRA, explains the layout of this FRA and provides an introduction to flood risk and the latest guidance on development and flood risk in England.

1.2.2 Section 2 provides an introduction to the site. The site description is based upon a desktop study and information provided by the developer. In order to obtain further information on flood risk, consultation was undertaken with the Environment Agency.

1.2.3 Section 3 of this report details the information gathered through the consultation.

1.2.4 Section 4 of this report details the development proposals, and considers the development proposals in relation to the current planning policy on development and flood risk in England (and what type of development is considered appropriate in different flood risk zones). National Planning Policy Framework (NPPF): and its associated Technical Guidance (Communities and Local Government, March 2012) is the current planning policy on flood risk in England, and an introduction to NPPF is provided below.

1.2.5 Section 5 considers the drainage arrangements for the proposed development.

1.2.6 Section 6 of this report considers the flood risk to site, and the potential for the development proposals to impact on flood risk. The assessment of flood risk is based on the latest planning policy and utilises all the information gathered in the preparation of the report.

1.2.7 Section 7 of this report provides details of any recommendations for further work to mitigate against possible flooding.

1.2.8 Section 8 of this report provides a summary of the report.

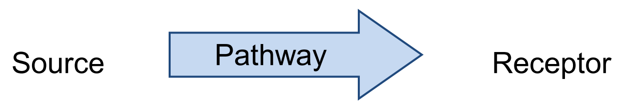
**1.3 Flood Risk**

1.3.1 Flood risk takes account of both the probability and the consequences of flooding.

1.3.2 Flood risk = probability of flooding x consequences of flooding

1.3.3 Probability is usually interpreted in terms of the return period, e.g. 1 in 100 and 1 in 200 year event, etc. In terms of probability, there is a 1 in 100 (1%) chance of one or more 1 in 100 year floods occurring in a given year. The consequences of flooding depends on how vulnerable a receptor is to flooding.

The components of flood risk can be considered using a source-pathway-receptor model.




1.3.4 Sources constitute flood hazards, which are anything with the potential to cause harm through flooding (e.g. rainfall extreme sea levels, river flows and canals). Pathways represent the mechanism by which the flood hazard would cause harm to a receptor (e.g. overtopping and failure of embankments and flood defences, inadequate drainage and inundation of floodplains). Receptors comprise the people, property, infrastructure and ecosystems that could potentially be affected should a flood occur.

## 1.4 National Planning Policy Framework

### 1.4.1 General

1.4.1.1 NPPF and its associated Technical Guidance replaces Planning Policy Statement 25 and provides guidance on how to evaluate sites with respect to flood risk.

1.4.1.2 A summary of the requirements of NPPF is provided below.

### 1.4.2 Sources of Flooding

1.4.2.1 NPPF requires an assessment to flood risk to consider all forms of flooding and lists six forms of flooding that should be considered as part of a flood risk assessment. These forms of flooding are listed in Table 1, along with an explanation of each form of flooding.

**Table1: Forms of Flooding**

| **Flooding From Rivers (Fluvial Flooding)** |
|---|
| Watercourses flood when the amount of water in them exceeds the flow capacity of the river channel. Flooding can either develop gradually or rapidly, depending on the characteristics of the catchment. Land use, topography and the development can have a strong influence on flooding from rivers. |
| **Flooding From the Sea (Tidal Flooding)** |
| Flooding to low-lying land from the sea and tidal estuaries is caused by storm surges and high tides. Where tidal defences exist, they can be overtopped or breached during a severe storm, which may be more likely with climate change. |
| **Flooding from Land (Pluvial Flooding)** |
| Intense rainfall, often of short duration, that is unable to soak into the ground or enter drainage systems 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. |

| **Flooding from Groundwater** |
|---|
| Groundwater flooding occurs when groundwater levels rise above ground levels (i.e. groundwater issues). Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks (aquifers). Chalk is the most extensive source of groundwater flooding. |
| **Flooding from Sewers** |
| In urban areas, rainwater is frequently drained into sewers. Flooding can occur when sewers are overwhelmed by heavy rainfall, and become blocked. Sewer flooding continues until the water drains away. |
| **Flooding from Other Artificial Sources (i.e. reservoirs, canals, lakes and ponds)** |
| Non-natural or artificial sources of flooding can include reservoirs, canals and lakes. Reservoir or canal flooding may occur as a result of the facility being overwhelmed and /or as a result of dam or bank failure. |

### 1.4.3 Flood Zones

1.4.3.1 For river and sea flooding, NPPF uses four Flood Zones to characterise flood risk. These Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences, and are detailed in Table 2.

**Table 2: Flood Zones**

| Flood Zone | Definition |
|---|---|
| **1** | Low probability (less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1%). |
| **2** | Medium probability (between 1 in 100 and 1 in 1,000 annual probability of river flooding (1%-0.1%) or between 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5%-0.1%) in any year). |
| **3a** | High probability (1 in 100 or greater annual probability of river flooding (>1%) in any year or 1 in 200 or greater annual probability of sea flooding (>0.5%) in any given year). |
| **3b** | This zone comprises land where water has to flow or be stored in times flood. Land which would flood with an annual probability of 1 in 20 (5%), or is designed to flood in an extreme flood (0.1%) should provide a starting point for discussions to identify functional floodplain. |

### 1.4.4 Vulnerability

1.4.4.1 NPPF classifies the vulnerability of developments to flooding into five categories. These categories are detailed in Table 3.

**Table 3: Flood Risk Vulnerability Classification**

| Flood Risk Vulnerability Classification | Examples of Development Types |
|---|---|
| **Essential Infrastructure** | - Essential utility infrastructure including electricity generating power stations and grid and primary substations<br>- Wind turbines |
| **Highly Vulnerable** | - Police stations, ambulance stations, fire stations, command centres and telecommunications installations required to be operational during flooding.<br>- Emergency dispersal points.<br>- Basement dwellings.<br>- Caravans, mobile homes and park homes intended for permanent residential use. |
| **More Vulnerable** | - Hospitals.<br>- Residential institutions such as residential care homes, children’s homes, social services homes, prisons and hostels.<br>- Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels.<br>- Non-residential uses for health services, nurseries and educational establishments.<br>- Sites used for holiday or short-let caravans and camping. |
| **Less Vulnerable** | - Building used for shops, financial, professional and other services, restaurants and cafes, hot foot takeaways, offices, general industry, storage and distribution, non-residential institutions not included in “more vulnerable” and assembly and leisure.<br>- Land and buildings used for agriculture and forestry. |
| **Water Compatible** | - Docks, marinas and wharves.<br>- Water based recreation (excluding sleeping accommodation).<br>- Lifeguard and coastguard stations.<br>- Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. |

1.4.4.2 Based on the vulnerability of a development, NPPF states within what Flood Zones(s) the development is appropriate. The flood risk vulnerability and Flood Zone 'compatibility' of developments is summarised in Table 4.

**Table 4: Flood Risk Vulnerability and Flood Zone Compatibility**

| Flood Risk Vulnerability Classification | | Essential Infrastructure | Water Compatible | Highly Vulnerable | More Vulnerable | Less Vulnerable |
|---|---|---|---|---|---|---|
| Flood Zone | 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 2 | ✓ | ✓ | Exception Test | ✓ | ✓ |
| | 3a | Exception Test | ✓ | x | Exception Test | ✓ |
| | 3b | Exception Test | ✓ | x | x | x |

### 1.4.5 The Sequential Test, Exception Test and Sequential Approach

1.4.5.1 The Sequential Test is a risk-based test that should be applied at all stages of development and aims to steer new development to areas with the lowest probability of flooding (Zone 1). This is applied by the Local Planning Authority by means of a Strategic Flood Assessment (SFRA).

1.4.5.2 The SFRA and NPPF may require the Exception Test to be applied to certain forms of new development. The test considers the vulnerability of the new development to flood risk and, to be passed, must demonstrate that:

- There are sustainability benefits that outweigh the flood risk and;
- The new development is safe and does not increase flood risk elsewhere.

1.4.5.3 The Sequential Approach is also a risk based approach to development. In a development site located in several Flood Zones or with other flood risk, the sequential approach directs the most vulnerable types of development towards areas of least risk within the site.

### 1.4.6 Climate Change

1.4.6.1 This is a planning requirement to account for climate change in the proposed design. The recommended allowances should be based on the most relevant guidance from the Environment Agency and the Lead Local Flood Authority.

### 1.4.7 Sustainable Drainage

1.4.7.1 The key planning objectives in NPPF are to appraise, manage and where possible, reduce flood risk. Sustainable Drainage Systems (SuDS) provide an effective way of achieving some of these objectives, and NPPF and Part H of the Building Regulations (DTLR 2002) direct developers towards the use of SuDS wherever possible.

# 2.0 EXISTING SITE DESCRIPTION

## 2.1 Location

2.1.1 The site is located to the north of Castle Street (A63), to the south east of Waterhouse Lane and to the west of the Princes Quay car park.

2.1.2 An aerial photograph and location plan are included in Figures 1 and 2 below.


*Figure 1: Aerial Photograph*

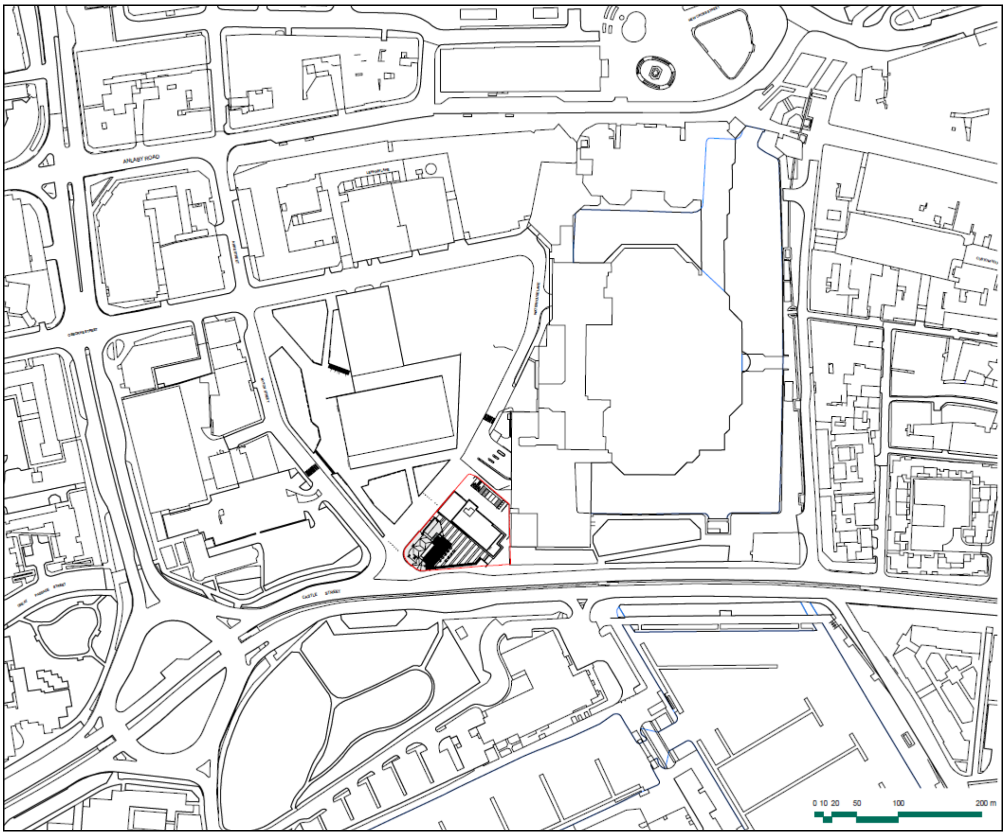


*Figure 2: Site Location Plan*

2.1.3 The Ordnance Survey grid reference for the centre of the site is approximately 509515, 428490.

## 2.2 Existing Site Description

2.2.1 The area of the development currently comprises the Castle Buildings, the Earl De Grey public House and a car park.

2.2.2 The total area of the development has been calculated at 2475m².

## 2.3 Surrounding Features

2.3.1 To the north of the development site lies Waterhouse Lane and the Bonus Arena development.

2.3.2 Immediately to the east of the site is the southern extremity of the Princes Quay retail and multi-storey car park development.

2.3.3 To the south of the development is Castle Street (A63), beyond which is a hotel and Hull Marina.

2.3.4 To the west of the site is Myton Street, beyond which is a car park and retail development.

## 2.4 Topography

2.4.1 A topographic survey of the development site has been undertaken, which shows that existing ground levels over the area of the site vary from approximately 3.08m to 3.64m OD(N).

2.4.2 Road levels along Castle Street fronting the site were found to vary from approximately 2.78m to 3.09m OD(N).

2.4.3 Road levels on Myton Street adjacent to the site were found to vary from approximately 3.07m to 3.18m OD(N).

2.4.4 Road levels on Waterhouse Lane adjacent to the site were found to vary from approximately 3.13m to 3.17m OD(N).

2.4.5 A copy of the topographic survey drawing is included in Appendix A.

## 2.5 Ground Conditions

2.5.1 A desktop study of the British Geological Survey map reveals the local geology to comprise superficial deposits of Tidal Flat Deposits – Clay and Silt overlaying bedrock comprising Burnham Chalk Formation – Chalk.

2.5.2 Local borehole records show that the glacial clays extend to a minimum depth of 4m below ground level.

2.5.3 The ground conditions are therefore considered to be unsuitable for the disposal of surface water run-off to soakaways/infiltration trenches.

2.5.4 A study of the groundwater maps shows that the site overlays a Principal Aquifer but does not lie within a Groundwater Vulnerability Zone.

## 3.0 CONSULTATION

3.1 Consultation has taken place with the Design Team in order to obtain relevant information pertaining to the proposed development.

3.2 Consultation has taken place with the Environment Agency in order to obtain relevant information in respect of flood mapping and flood data.

3.3 Consultation has taken place with Hull City Council in respect of relevant flood information within the Hull Strategic Flood Risk Assessment and disposal of surface water run-off from the development.

## 4.0 PROPOSED DEVELOPMENT

4.1 The development involves the re-development of the existing Castle Buildings and Earl De Grey public house adjacent land to include the following:-

- Refurbishment and extension to the existing 2/3-storey Castle Buildings.
- Dismantling and partial relocation of the existing 3-storey Earl De Grey public house.
- Construction of a new 9-storey hotel building.
- External paved area.
- External area of car parking.
- Landscaping works.
- New service supplies.

4.2 Layout drawings of the proposed development are included in Appendix B.

4.3 In terms of flood risk vulnerability, drinking establishments and hotels are classed as 'More Vulnerable' development, whilst offices and restaurants are classed as 'Less Vulnerable' development (Table 3).

4.4 In terms of flood zone compatibility, the construction of 'More Vulnerable' development in Flood Zone 3a requires an Exception Test, whilst the construction of 'Less Vulnerable' development is considered to be appropriate (Table 4).

# 5.0 DRAINAGE ASSESSMENT

## 5.1 General

5.1.1 For a more detailed analysis of the drainage proposals for the development, refer to separate document (ref: 39388-Rp002 DIA, Prop'd Re-Dev't of Castle Buildings Site, Castle St, Hull).

## 5.2 Surface Water Drainage

5.2.1 From the aerial photograph included in Figure 3 below, it can be seen that the area of the development is currently impermeable, in the form of roof areas and external paving, which are positively drained.

*Figure 3: Aerial Photograph*

5.2.2 The 2 year 60 minute storm discharge rate from the existing site, with an impermeable area of 2475m$^2$, has been calculated at approximately 8.5 litres per second.

5.2.3 In order to provide a degree of improvement to the existing drainage network, the discharge from the new development will need to provide a 50% reduction from the current situation.

5.2.4 On this basis the permissible discharge would reduce to approximately 4.3 litres per second and consequently this discharge rate has been used as the basis for the surface water drainage design.

5.2.5 Requirement H3 of the Building Regulations establishes a preferred hierarchy for disposal of surface water disposal. Consideration should firstly be given to soakaway, infiltration, watercourse and sewer in that priority order.

5.2.6 Ground conditions in the area of the development are considered unsuitable for the disposal of surface water run-off from the development into soakaways or infiltration trenches.

5.2.7 The second preferred option would be to discharge the surface water run-off from the development to a watercourse.

5.2.8 Investigations have revealed that there are no watercourses in the vicinity of the development which could be used to discharge surface water run-off from the site.

5.2.9 It is therefore proposed that the surface water run-off from the new development is discharged into the public sewer network via the existing outfall pipes from the site.

5.2.10 In order to ensure the development does not pose a risk of flooding to other properties, it will be necessary to attenuate the drainage by restricting the discharge to the agreed rate and provide storage as required.

5.2.11 The current design requirements will need to be based upon the 100 year storm event with an allowance of 30% for climate change resulting from global warming.

5.2.12 The required storage volume for the 1 year and 30 year storm events must be stored within the drainage network below ground to prevent flooding.

5.2.13 The additional storage volume required to accommodate the 100 year storm event plus climate change can be stored above ground providing it remains within the confines of the site and does not pose a risk of flooding to the development or to other parties beyond the development site.

5.2.14 Alternatively, this storage volume can be accommodated within an appropriate storage tank below ground.

5.2.15 Based upon the above design criteria, calculations have been undertaken to assess the volume of storage which will need to be provided.

5.2.16 A summary of the calculations is set out in Table 5 below.

**Table 5: Volume of Surface Water Storage Required**

| **Storm Event** | **30 Year Storm** | **100 Year Storm + 30%** |
|---|---|---|
| **Storage Volume Required ($m^3$)** | $50m^3$ | $103m^3$ |
| **Additional Storage Volume Required ($m^3$)** | Nil | $53m^3$ |

5.2.17 Copies of the surface water storage calculations are included in Appendix C.
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## 6.0 FLOOD RISK ASSESSMENT

### 6.1 Flood Zone

6.1.1 A copy of the Environment Agency Flood Map for Planning is included in Figure 4 below, which identifies the development site to be located within an area designated as Flood Zone 3, (high probability of flooding), comprising land assessed as having a 1 in 100 or greater annual probability of river flooding or a 1 in 200 year or greater annual probability of flooding from the sea.

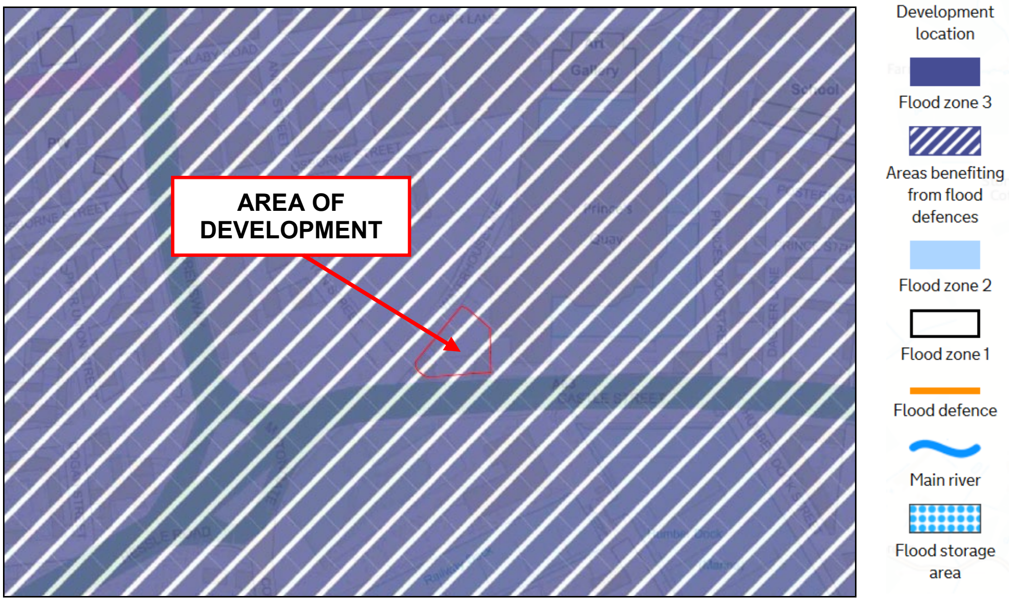



*Figure 4: Environment Agency Flood Map for Planning dated March 2019*

6.1.2 A revised strategic Flood Risk Assessment has been prepared for the city of Hull (2016), which has categorized areas of the city into likely flood depth areas.

6.1.3 An abstract from Figure 14 of the Hull SFRA is included in Figure 5 below, which indicates that the site lies in an area  which varies from Flood Zone 3aii (Medium 1) to Flood Zone 3aiii (Medium 2).

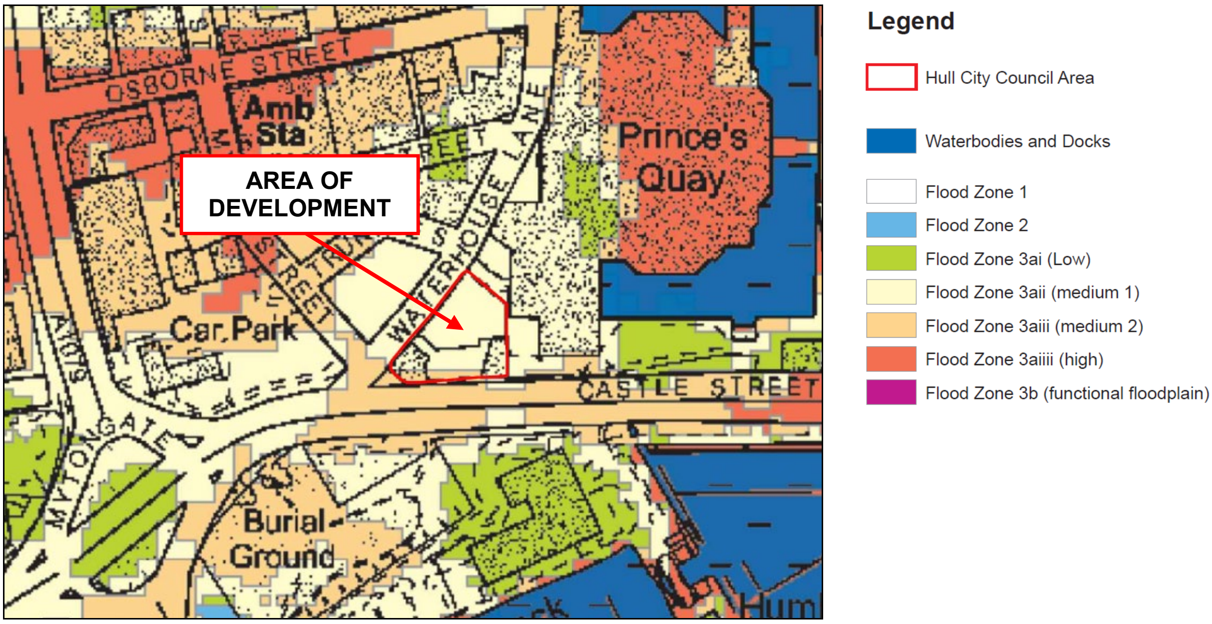



*Figure 5: Abstract from Hull SFRA (2016) Figure 14 Flood Zone Map*

## 6.2 Tidal Flooding – River Humber

6.2.1 A copy of the flood map showing the extent of flooding from rivers or the sea produced by the Environment Agency is included in Figure 6 below. This shows the site lies in an area classed as varying from "Very Low Risk" to "Medium Risk" from flooding.

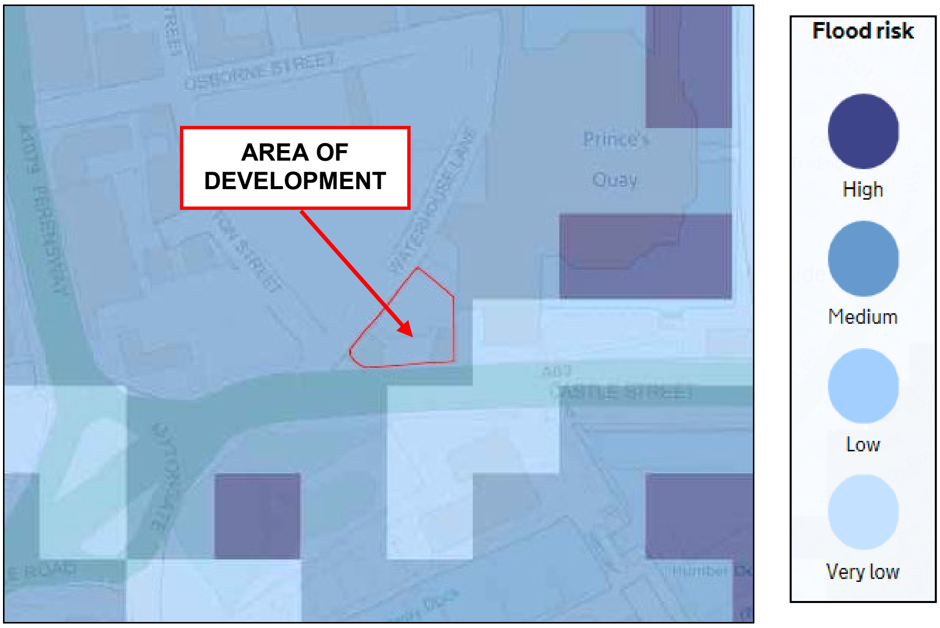



*Figure 6: Environment Agency Map Showing The Extent of Flooding from Rivers or the Sea dated March 2019*

6.2.2 Flood data has been obtained from the Environment Agency in respect of the development site. An abstract of the data received is included in Appendix D.

6.2.3 The 1 in 200 year predicted high water level for the River Humber in the region of the development has been calculated at 5.72m OD(N) by the Environment Agency.

6.2.4 An allowance needs to be made for climate change resulting from global warming, which is expected to result in increased global sea levels.

6.2.5 For commercial developments with a design life of 50 years, the anticipated sea level rise in this region is approximately 415mm. This would project the predicted high water level to approximately 6.14m OD(N).

6.2.6 In addition to the high water level, there is the likelihood of wave action on the River Humber which historically has been at a maximum height of approximately 1.1m. However, at a distance of approximately 500m from the coastline, we consider that wave action can be discounted.

6.2.7 The river defences to the banks of the River Humber in proximity to the site are generally of steel sheet piled construction, which are generally maintained at a level of approximately 5.85m OD(N).

6.2.8 With a predicted water level of 6.14m, it is likely that the existing defences would be overtopped during periods of high tidal levels.

6.2.9 An abstract from Figure 0 of the Hull SFRA (2016) is included in Figure 7 below which provides an indication of ground levels.

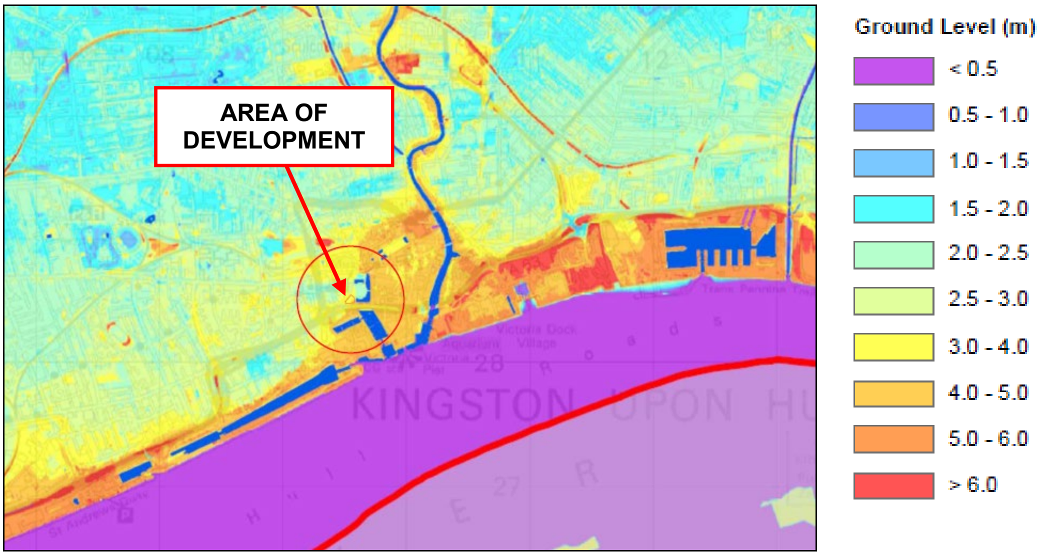



*Figure 7: Abstract from Hull SFRA (2016) Figure 0 showing Indicative Ground Levels*

6.2.10 A study of the local topography shows that flood waters would gravitate northwards towards the lower-lying land where ground levels over a large area of the city are at approximately 2m OD(N) and the land further to the north at below 0.5m OD(N).

6.2.11 The flood waters will dissipate as they flow northwards, generally channelling along the road network, spreading out and reducing in depth as the flood extends from the source of the flooding.

6.2.12 However, with ground levels over the site being in the region of 3m OD(N), the site could be affected by a significant depth of flood water. Consequently, flood mitigation measures will need to be considered in order to minimise the risk of flood damage occurring. Details of such measures are included in Section 7 of this report.

6.2.13 The mapping received from the Environment Agency shows the likely depth of flooding to the site would be between 0.5-1m up to 1-2m for a breach scenario and a maximum depth of 1-2m for an overtopping scenario.

## 6.3 Fluvial Flooding – River Hull

6.3.1 The development site is located approximately 700m to the west of the River Hull to the north of the River Hull Tidal Barrier and is consequently not influenced by water levels within the River Humber, assuming the barrier will be in place during a major flood event.

6.3.2 The Environment Agency have advised that the highest predicted water level for a 1 in 200 year event has been determined at 4.27m OD(N) for a defended scenario and 5.24m OD(N) for an undefended scenario.

6.3.3 The risk to the development from the River Hull would be from the existing river defences to the north of the tidal barrier being overtopped during a period when the flow rate and water level in the River Hull are high due to high levels of surface water run-off into the watercourse upstream, coincidental with the barrier being closed due to high tidal levels within the River Humber.

6.3.4 Flood waters overtopping the defences would then spread outwards and we have therefore investigated the likely depth of water which could affect the site.

6.3.5 We have examined the defences along the western bank of the River Hull to the north of the tidal barrier and have identified that there are currently several isolated low spots in the defences over a distance of approximately 250m from the site which are below the required defence level. These total approximately 30m in length and are an average of 200mm below the defence level.

6.3.6 During a flood situation, we have considered the effect that overtopping of these defences will have on the development.

6.3.7 Taking normal tidal cycles into account, overtopping could be expected to commence approximately 15 minutes prior to maximum flood level being reached and would continue for a further 15 minutes after the highest tide level.

6.3.8 The river wall will act as a sharp crested weir and, subsequently, the rate at which the water floods can be derived from the formula below:

$Q = 2/3 \times B \times \sqrt{(2g)}\, H^{3/2}$

6.3.9 Using this to calculate the rate of discharge over the defences, we estimate this to amount to approximately 40m$^3$/sec, which would lead to a total flood volume of approximately 72,300m$^3$ of water over one tidal cycle.

6.3.10 It can be seen from Figure 7 that a large area of Hull is substantially lower than the river defence level. The flood waters resulting from a breach of the defences would gravitate towards the lowest ground levels which lie to the north of the development, where ground levels are as low as 2.0m OD(N) and would spread out over a large area of the surrounding land.

6.3.11 Any flood waters would consequently flow northwards rather than accumulating at any significant depth at the location of the development, ponding where the land is at the lowest level.

6.3.12 With the site lying at a distance of approximately 700m from this potential flood source the likelihood of the site being affected by flooding is considered to be low and acceptable.

6.3.13 The defences along the River Hull are currently being brought up to the required level of flood defence and therefore any risk to the development from this flood source should only be short term.

### 6.4 Tidal & Fluvial Combined Flooding

6.4.1 An abstract from the Hull SFRA (2016) Figure 6B is included in Figure 8 below, which shows the anticipated depth of flood waters over the area of the development.

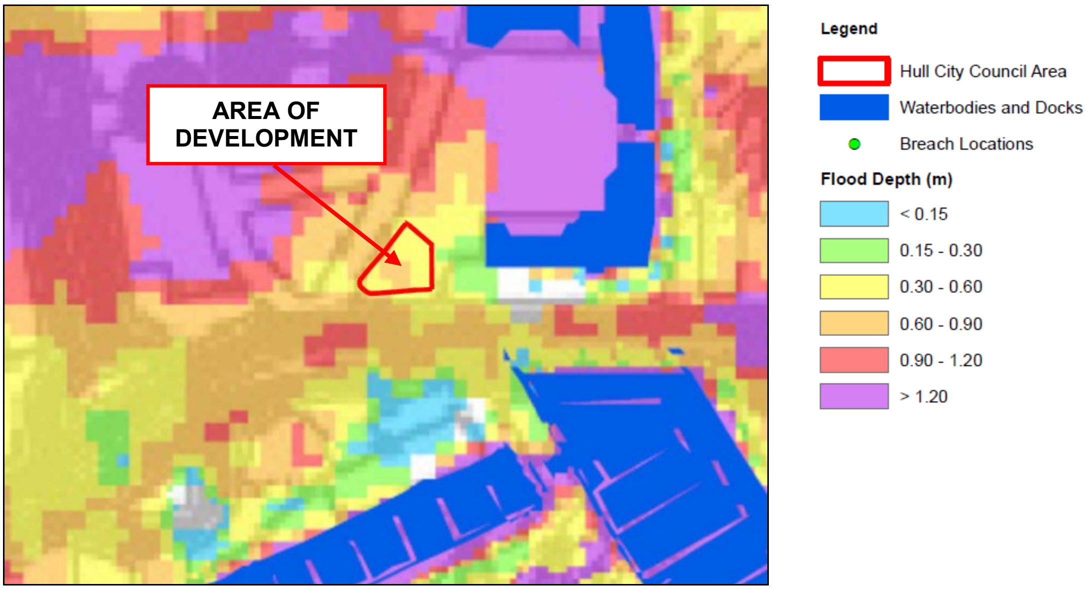



*Figure 8: Abstract from Hull SFRA (2016) Figure 6B Flood Depth Map*

6.4.2 This indicates a likely depth of flooding varying from 0.15m to 0.3m up to 0.60 to 0.90m over the site.

6.4.3 An abstract from the Hull SFRA (2016) Figure 7 is included in Figure 9 below, which indicates a likely velocity of flood waters to vary from 0.10 to 0.30 m/s up to 0.50 to 1.00 m/s over the site.

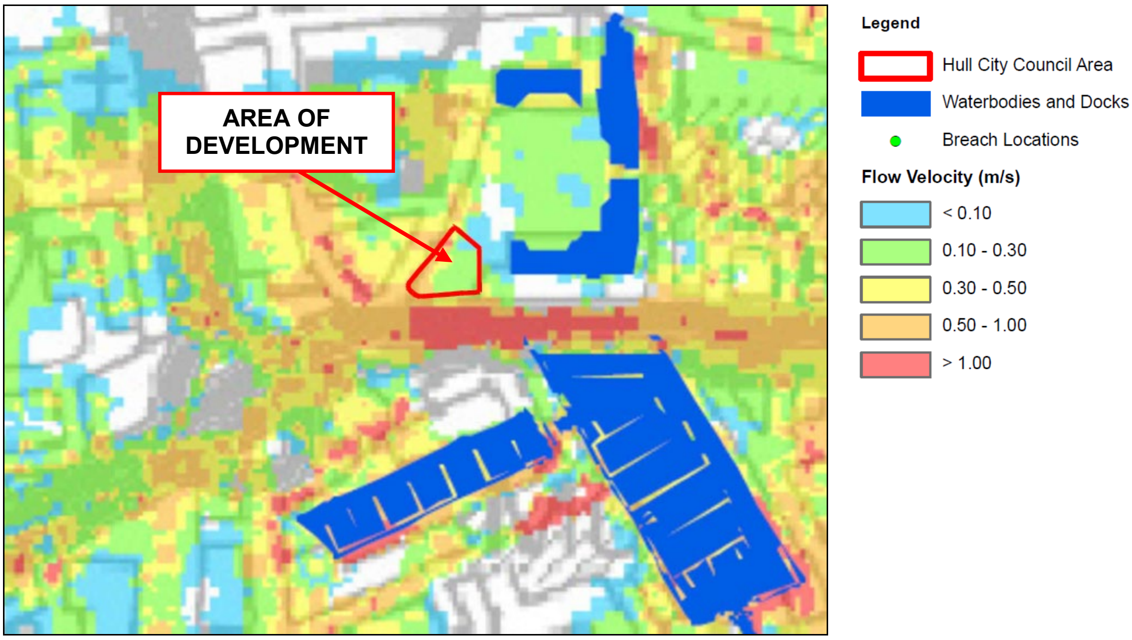



*Figure 9: Abstract from Hull SFRA (2016) Figure 7 Velocity of Flood Waters*

6.4.4 An abstract from the Hull SFRA (2016) Figure 8 Flood Hazard map is included in Figure 10 below. This identifies the development site to be located in an area in which the hazard of flooding is considered to be vary from “low” to “moderate”.

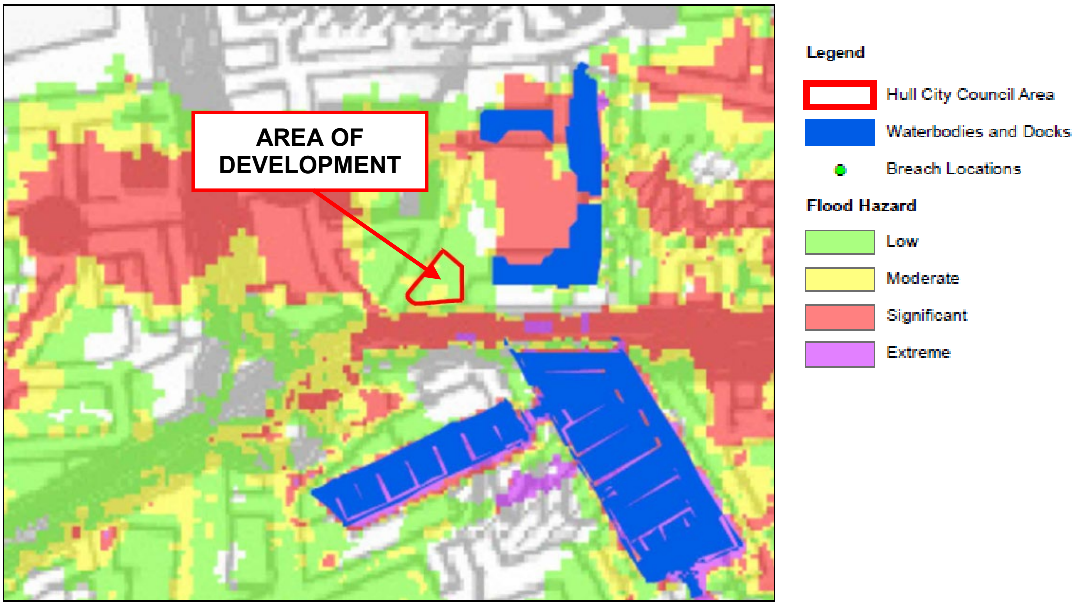



*Figure 10: Abstract from Hull SFRA 2016 Figure 8 Flood Hazard Map*

## 6.5 Exception Test Information

6.5.1 An abstract from the Hull SFRA (2016) Figure 13 is included in Figure 11 below, which indicates that the site is in an area likely to flood to a depth varying from 0m - 0.3m up to 0.6m - 0.9m accounting for accumulated flood events.


*Figure 11: Abstract from Hull SFRA 2016 Figure 13 Exception Test Information*

6.5.2 Flood mitigation measures will need to be incorporated in the design of the development to reduce the likelihood of damage occurring should the development be affected by flood waters.

6.5.3 Such measures are incorporated in Section 7 of this report.

## 6.6 Surface Water Flooding

6.6.1 A copy of the Environment Agency map showing the extent of flooding from surface water is included in Figure 12 below.

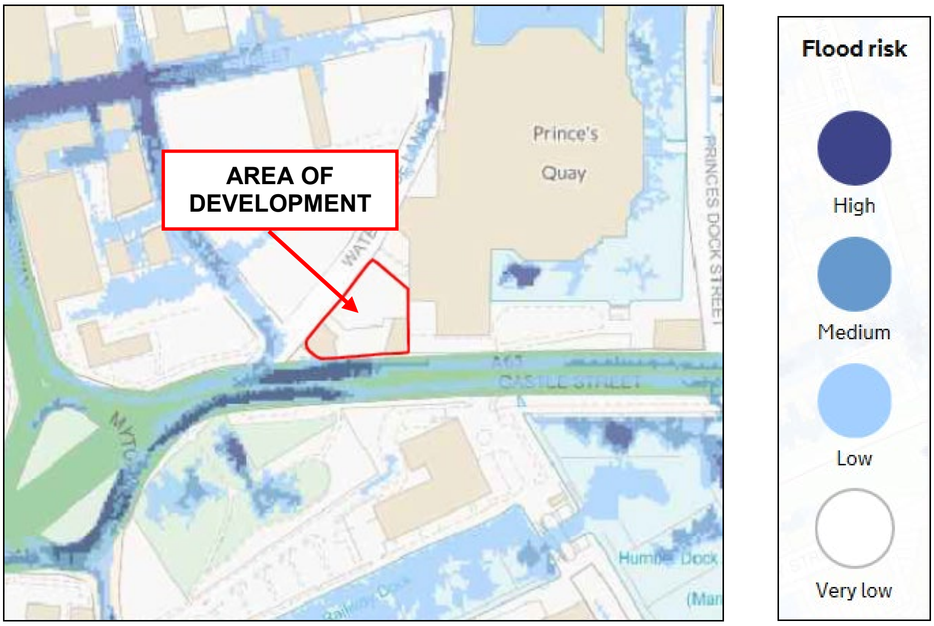



*Figure 12: Environment Agency Map dated March 2019 Showing the Extent of Flooding from Surface Water*

6.6.2 The map indicates that the risk of surface water flooding to the areas of the development are considered to be very low, with a likelihood of some flooding on the adjacent roadway.

6.6.3 An abstract from the Hull SFRA (2016) Figure 10 showing the likely depth of surface water flooding is included in Figure 13 below.

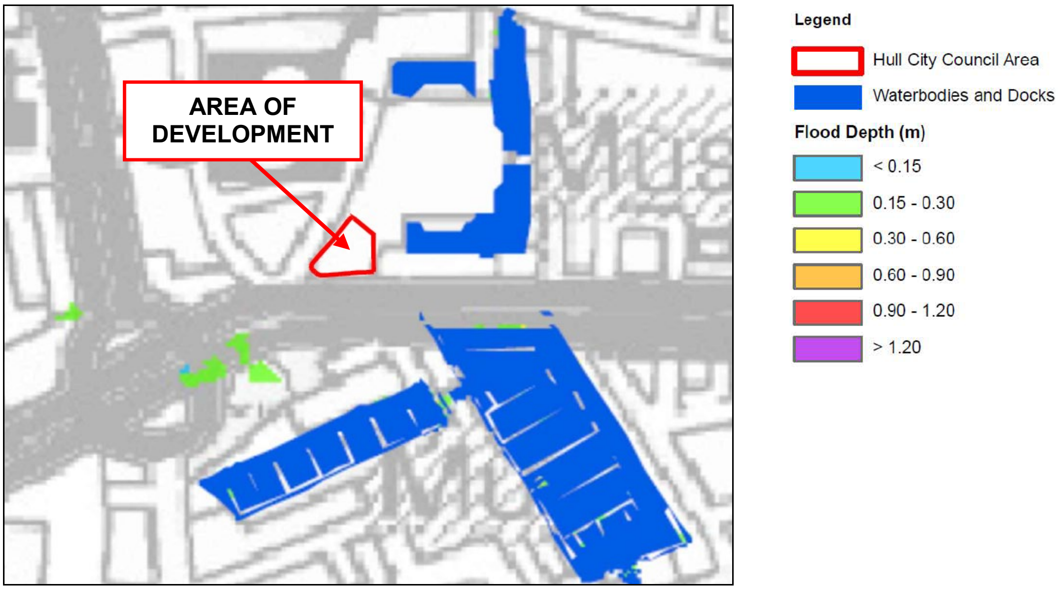



*Figure 13: Abstract from Hull SFRA (2016) Figure 10 Likely Depth of Surface Water Flooding Map*

6.6.4 The map shows that the site is not considered to be at risk.

6.6.5 Based upon the above information the risk to the development from surface water flooding is considered to be low and acceptable.

## 6.7 Flooding from Open Drainage Ditches

6.7.1 There are no open drainage ditches located in the vicinity of the development site.

6.7.2 The risk of flooding from this source is therefore considered to be low and acceptable.

## 6.8 Groundwater Flooding

6.8.1 Groundwater flooding can occur when the sub-surface water levels are high and emerges above ground level.

6.8.2 The site overlays a Principal Aquifer but does not lie within a groundwater vulnerability zone.

6.8.3 However, the construction works will not involve excessive deep excavation works and consequently the risk to the development from this potential flood source is considered to be low and acceptable.

## 6.9 Flood Risk from Water Mains

6.9.1 There are existing water mains present within the adjacent developments and within the public highways.

6.9.2 There are no known issues with the condition of any such water mains.

6.9.3 The risk to the development from this potential flood source is therefore considered to be low and acceptable.

## 6.10 Flood Risk from Existing Drainage Services

6.10.1 There are existing drainage services present within the adjacent developments and within the public highways.

6.10.2 There are no known issues with regard to the capacity or condition of the existing drainage services.

6.10.3 The risk of flooding to the development from this potential source is considered to be low and acceptable.

## 6.11 Flooding from Reservoirs, Canals and Other Artificial Sources

6.11.1 The Hull Marina is located approximately 150m to the south of the development site.

6.11.2 Levels in the marina are controlled by lock gates and consequently the marina is not considered to pose any risk of flooding to the development.

6.11.3 Any flooding of the marina would occur as a consequence of tidal flooding from the River Humber (considered in Section 6.2 of this report).

6.11.4 A copy of the map produced by the Environment Agency showing the extent of flooding from reservoirs is included in Figure 14 below.

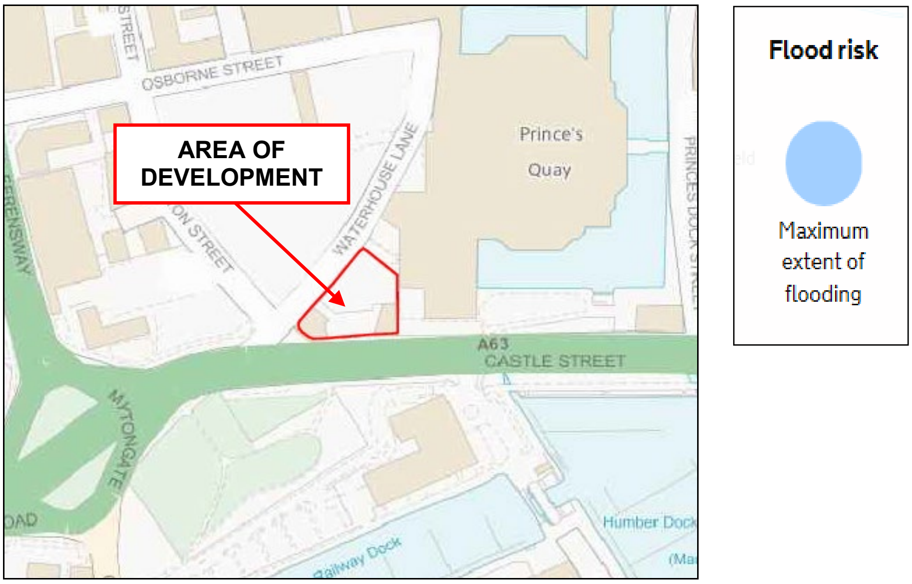



*Figure 14: Environment Agency map dated March 2019 showing the Extent of Flooding from Reservoirs*

6.11.5 The map shows that the development site is not considered to be at risk.

# 7.0 FLOOD MITIGATION MEASURES

## 7.1 Passive Flood Protection Works

7.1.1 With the development lying in an area shown to incorporate land considered to be at high risk of flooding and subject to a high velocity of flood water, flood protection measures will need to be incorporated into the design of the development.

7.1.2 For new developments within Flood Zone 3 the normal requirement is to elevate the ground floor to a minimum height of 600mm above the existing ground level, adjacent road level or predicted flood level, whichever is the higher.

7.1.3 An overlay of the topographic survey levels onto the Sequential Test map (Figure 13) of the SFRA has been carried out in order to assess the likely flood level over the site.

7.1.4 For the local area shown to be prone to flooding to a depth of 0.3 to 0.6m, the survey identifies the lowest ground level to be at approximately 3.28m OD(N) and the highest ground level to be at approximately 3.47m OD(N).

7.1.5 The calculated flood levels over this area would consequently vary from approximately 3.77m OD(N) (3.47m + 0.3m) to 3.88m OD(N) (3.28m + 0.6m).

7.1.6 For the local area shown to be prone to flooding to a depth of 0.6 to 0.9m, the survey identifies the lowest ground level to be at approximately 2.80m OD(N) and the highest ground level to be at approximately 3.47m OD(N).

7.1.7 The calculated flood levels over this area would consequently vary from approximately 3.70 OD(N) (2.80m + 0.9m) to 3.97m OD(N) (3.337m OD(N) + 0.6m).

7.1.8 We consider it would be prudent to assume the upper end scenario forms the basis for the required flood mitigation measures, which would result in a predicted flood level of 3.97m OD(N).

7.1.9 In order to minimise the risk of the buildings being affected by flood waters, the ground floor construction level should be elevated by 600mm above this likely flood level.

7.1.10 This would consequently result in a ground floor construction level of 4.57m OD(N) for the new buildings.

7.1.11 The adjacent paving in proximity to the entrance to the relocated public house has been identified at approximately 3.38m OD(N) on the topographic survey.

7.1.12 In order to provide compliant DDA access to the building, it is considered that the highest ground floor construction level which can be achieved for this building is approximately 3.38m OD(N).

7.1.13 The adjacent paving in proximity to the entrance to the new hotel building has been identified at approximately 3.38m OD(N) on the topographic survey.

7.1.14 In order to provide compliant access to the hotel building, it is considered that the highest ground floor construction level which can be achieved is approximately 3.40m OD(N).

7.1.15 The existing ground floor construction level of the Castle Buildings has been identified at approximately 3.20m OD(N).

## 7.2 Flood Resilience

7.2.1 For new developments which lie within the flood zone it is a requirement to provide an additional 300mm of flood resilience above the elevated ground floor construction level in order to minimise any flood damage and provide ease of reconstruction, should flood waters enter the building.

7.2.2 For this development, this would equate to a flood resilience level of 4.87m OD(N) (flood level of 4.57m + 0.3m).

7.2.3 It will not be possible to raise the ground floor level of the new hotel building up to the required flood protection level due to access restrictions and DDA compliant access requirements.

7.2.4 In order to provide the required level of flood protection, it will therefore be necessary to increase the height of flood resilience within the building. To achieve a flood protection level of 4.87m OD(N) (4.57m + 0.3m) the height of flood resilience would need to be 1470mm.

7.2.5 At this height it is not possible to provide a water-tight structure due to the resultant water pressure on the external fabric of the building and an "open door" policy is recommended, allowing flood waters to enter the building.

7.2.6 For the new hotel building, the following measures should therefore be adopted within the new construction:-

- The ground floors should be of solid concrete or an appropriate precast concrete flooring system incorporating a waterproof membrane.
- The external walls should be of water-resistant construction up to 1470mm above ground floor level.
- There should be no voids within the external walls, other than doorways and windows within 1470mm of finished floor level which would allow flood waters to enter the building.
- All partition walls constructed at ground floor level should be of suitable robust construction or metal stud partitions fixed with plasterboard, with the lower boarding laid horizontally for ease of replacement.
- All electrical apparatus or other flood sensitive equipment should be elevated to a minimum of 1470mm above finished floor level to prevent damage occurring should flood waters enter the buildings.
- All cables should be routed at high level with vertical drops to the fittings.
- The ground floor electric circuits should be suitable isolated such that the upper floors of the development can remain in operation should the ground floor electrical installation become damaged.
- Floor finishes provided at ground floor level should be suitable for ease of cleaning after flooding, should this situation occur.

7.2.7 For the existing Castle Buildings the existing ground floor construction level has been identified to be at approximately 3.20m OD(N).

7.2.8 It will not be possible to raise the ground floor level up to the required flood protection level due to DDA access requirements and because the building is Grade II listed (the works would result in significant alteration of historic fabric).

7.2.9 In order to provide the required level of flood protection it will therefore be necessary to increase the height of flood resilience within the building. To achieve a flood protection level of 4.87m OD(N) (4.57m + 0.3m) the height of flood resilience would need to be 1670mm.

7.2.10 At this height it is not possible to provide a water-tight structure due to the resultant water pressure on the external fabric of the building and an "open door" policy is recommended, allowing flood waters to enter the building.

7.2.11 For the refurbished Castle Buildings the following measures should therefore be adopted within the new construction:-

- There should be no voids within the external walls, other than doorways within 1670mm of finished floor level which would allow flood waters to enter the buildings.
- All new partition walls constructed at ground floor level should be of suitable robust construction or metal stud partitions fixed with plasterboard, with the lower boarding laid horizontally for ease of replacement.
- All electrical apparatus or other flood sensitive equipment should be elevated to a minimum of 1670mm above finished floor level to prevent damage occurring should flood waters enter the buildings.
- All cables should be routed at high level with vertical drops to the fittings.
- The ground floor electric circuits should be suitable isolated such that the upper floor of the development can remain in operation should the ground floor electrical installation become damaged.
- Floor finishes provided at ground floor level should be suitable for ease of cleaning after flooding, should this situation occur.

7.2.12 For the new Earl de Grey building, with a ground floor construction level of 3.38m OD(N), the required height of flood resilience would need to be 1490mm.

7.2.13 For this building the following measures should therefore be adopted within the new construction:-

- The external walls should be of water-resistant construction up to 1490mm above ground floor level.
- There should be no voids within the external walls, other than doorways and windows within 1490mm of finished floor level which would allow flood waters to enter the buildings.
- All partition walls constructed at ground floor level should be of suitable robust construction or metal stud partitions fixed with plasterboard, with the lower boarding laid horizontally for ease of replacement.
- All electrical apparatus or other flood sensitive equipment should be elevated to a minimum of 1490mm above finished floor level to prevent damage occurring should flood waters enter the buildings.
- All cables should be routed at high level with vertical drops to the fittings.
- The ground floor electric circuits should be suitable isolated such that the upper floor of the development can remain in operation should the ground floor electrical installation become damaged.
- Floor finishes provided at ground floor level should be suitable for ease of cleaning after flooding, should this situation occur.

## 7.3 Safe Refuge

7.3.1 It is a requirement for safe refuge to be provided within new developments at a minimum level of 7.25m OD(N) in this area of the city to ensure that there will be no requirement for evacuation measures by the emergency services.

7.3.2 The development incorporates three-storey and nine-storey construction and consequently safe refuge will be available on the upper floors of the buildings, on the third floor level and above, which can be accessed by the internal staircases and passenger lifts in an emergency situation.

7.3.3 The requirement for safe refuge provision has therefore been satisfied.

## 7.4 Management

7.4.1 The development should be connected to the Environment Agency's early 'Flood Direct' warning service to ensure there is sufficient time available for ground floor, first floor and second floor accommodation to be vacated should the need arise.

7.4.2 Each building within the development should have a Flood Risk Evacuation Plan in place. Suitable notices should be positioned in common areas to ensure all occupants understand the procedures in place in the event of a flood situation and where to escape to safety, should this prove necessary.

## 7.5 Access/Egress

7.5.1 Safe access or egress from the development could be restricted during the peak time of a major flood scenario. However, adequate warning will be given and the timescale of the flood will be limited due to tidal conditions. Safe access and egress will therefore be predominantly available.

7.5.2 Safe refuge is provided and there should therefore be no requirements for evacuation of occupants of the development by the Emergency Services during a major flood situation.

## 8.0 SUMMARY

8.1 The report has been prepared to assess the flood risk implications for the redevelopment of the Castle Buildings and the Earl De Grey public house together with the construction of a new hotel building at Castle Street, Hull.

8.2 The site falls in Flood Zone 3a (high flood risk) on the Environment Agency maps and in an area shown to be subject to flooding to a depth varying from 0-0.3m to 0.6-0.9m on the latest Hull SFRA maps. The proposals are considered to be 'More Vulnerable' development.

8.3 The primary risk to the site is from tidal flooding from the River Humber resulting from the river defences being breached or overtopped during an extreme flood event.

8.4 The primary focus for flood risk assessment is to protect life, and then consideration should be given to buildings, contents, operation and re-use. As the scheme is progressed the design should consider exceedance and routing of flows away from the buildings.

8.5 Mitigation works are proposed which we consider will reduce the risk to the development from flooding down to an acceptable level.

8.6 This report has considered other potential sources of flooding to the site, including groundwater, surface water, existing sewers, water mains and other artificial sources.

8.7 Overall, this report demonstrates that the flood risk to the development is reasonable and acceptable providing the recommended mitigation measures are adopted.

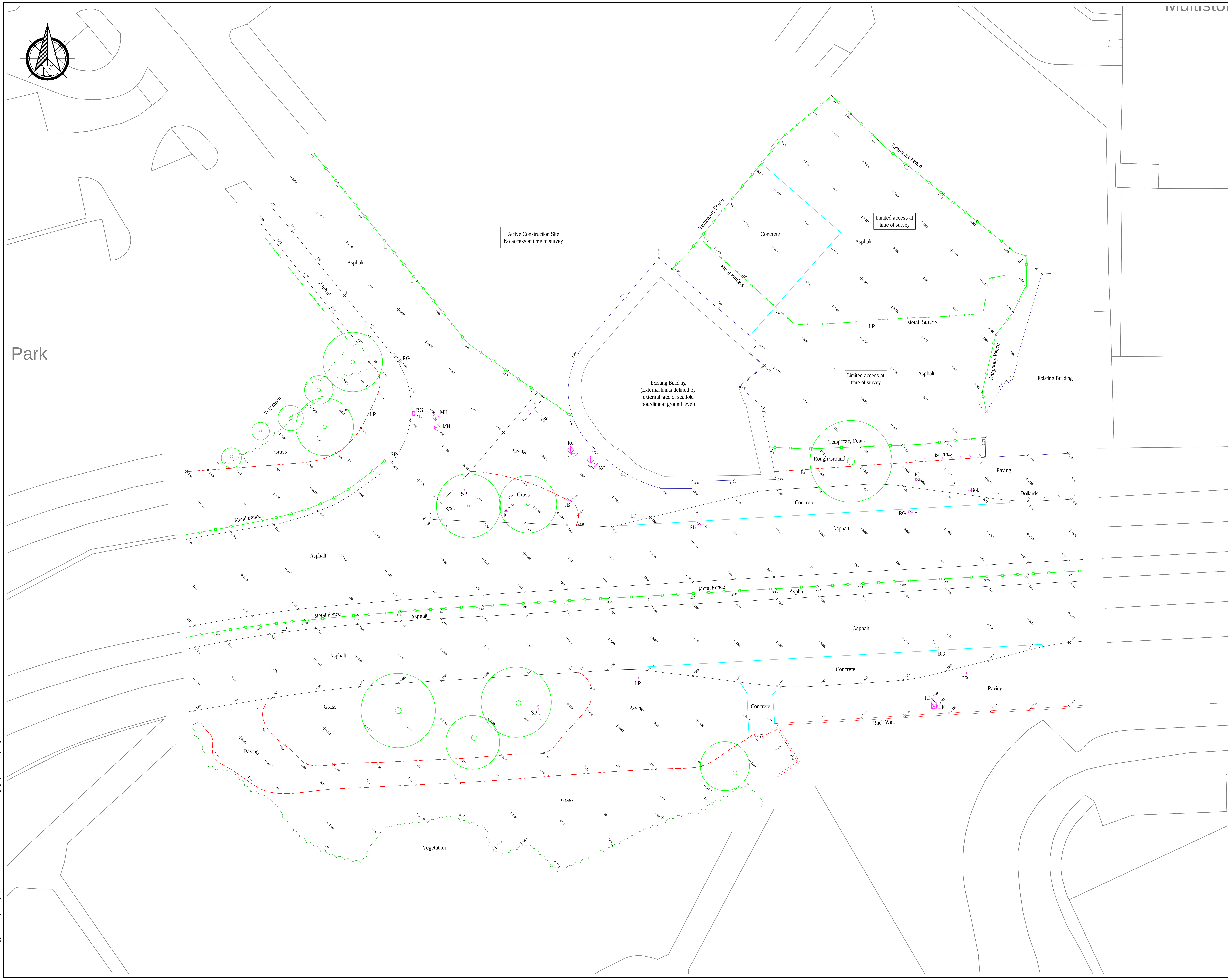
8.8 It is our opinion that the development is fully compliant with the updated Hull SFRA 2016 Standing Advice.

Alan Wood & Partners

# APPENDIX A

**Topographic Survey Drawing**

Version 3.0



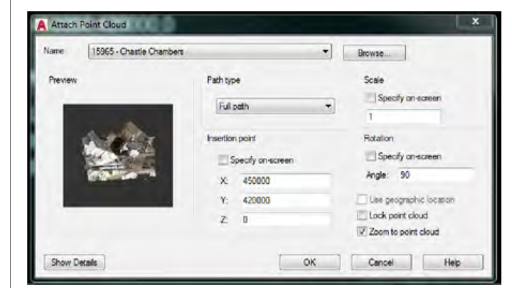

NOTES:

This drawing is subject to copyright and must not be reproduced, stored or transmitted in any form without prior permission from Mason Clark Associates.

All topographical data collected using a Faro M-Series scanner. Integral mean scan point tension <2.0mm.

All levels to O.S. Datum. Levels on Stations S1-3 established using Leica Smartnet RTK Corrective GPS. Minimum of 100 RTK corrections per measurement.

To insert Recap point cloud to correct O.S. position insert at 450000,420000,0 (as shown below)




Key:

| | |
|---|---|
| LP | Lamp Post |
| IC | Inspection Cover |
| RG | Road Gully |
| Bol. | Bollard |
| MH | Manhole |
| JB | Junction Box |
| KC | Telecoms Cover |

| Rev | Details | By | Date |
|---|---|---|---|
| P1 | Preliminary Issue | MT | 08.12.2017 |

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Hull, HU5 2DW
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Client.

Wykeland

Project.

Castle Chambers

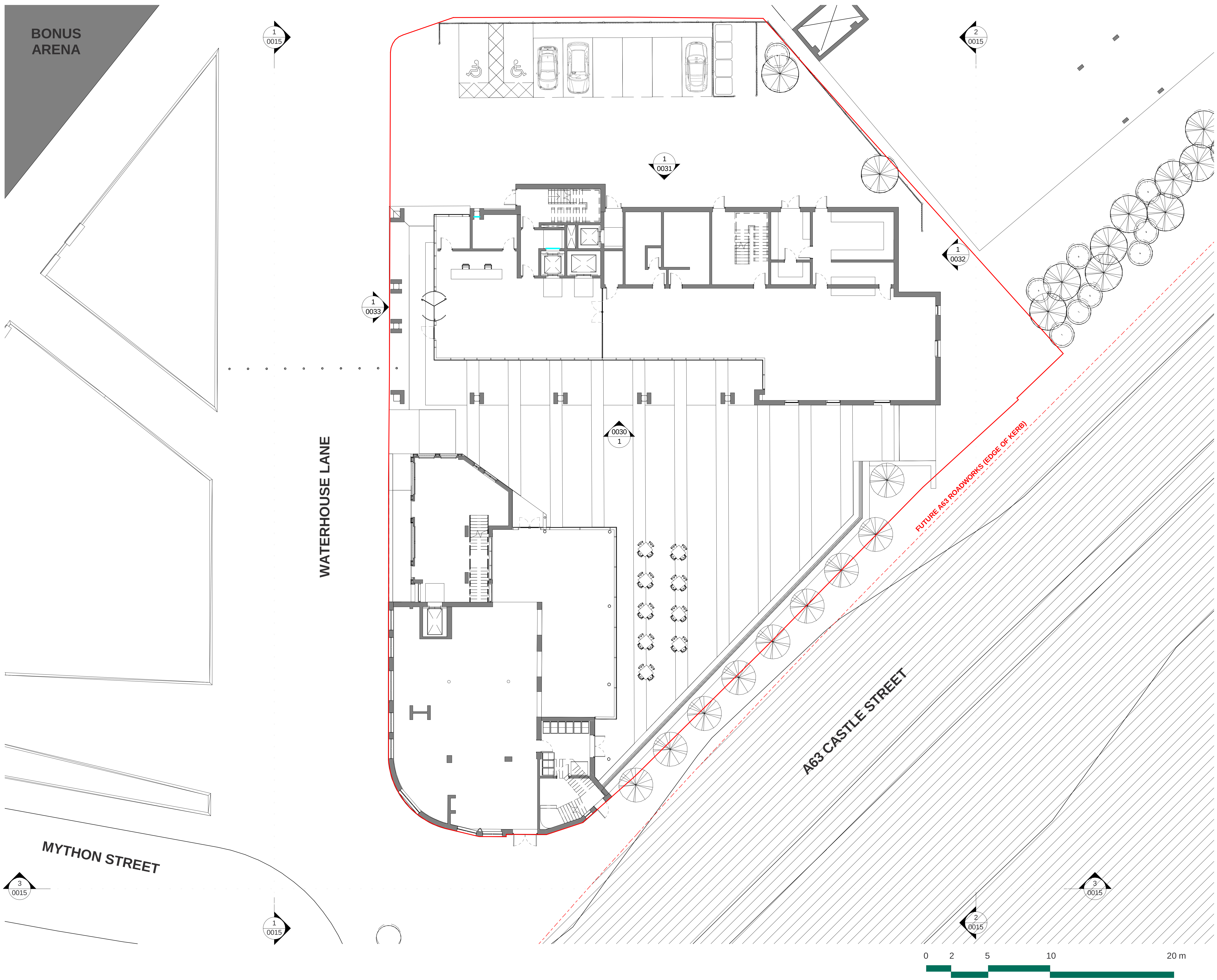
Title.

Topographical Survey

| | | |
|---|---|---|
| Drawn: MT | Checked: ND | Date: Dec 2017 |
| Scale @ A1 : 1/200 | | |
| Drawing No : 15965-01 | | Rev: P1 |

# APPENDIX B

## Layout Drawings




DLA DESIGN

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ARCHITECTURE

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PROJECT
PRINCES QUAY, HULL

TITLE
PROPOSED SITE PLAN

SCALE
1 : 200 @ A2

DATE
13/02/19

DLA REF
2016-223

DRAWN
VP

REVIEWED
JO

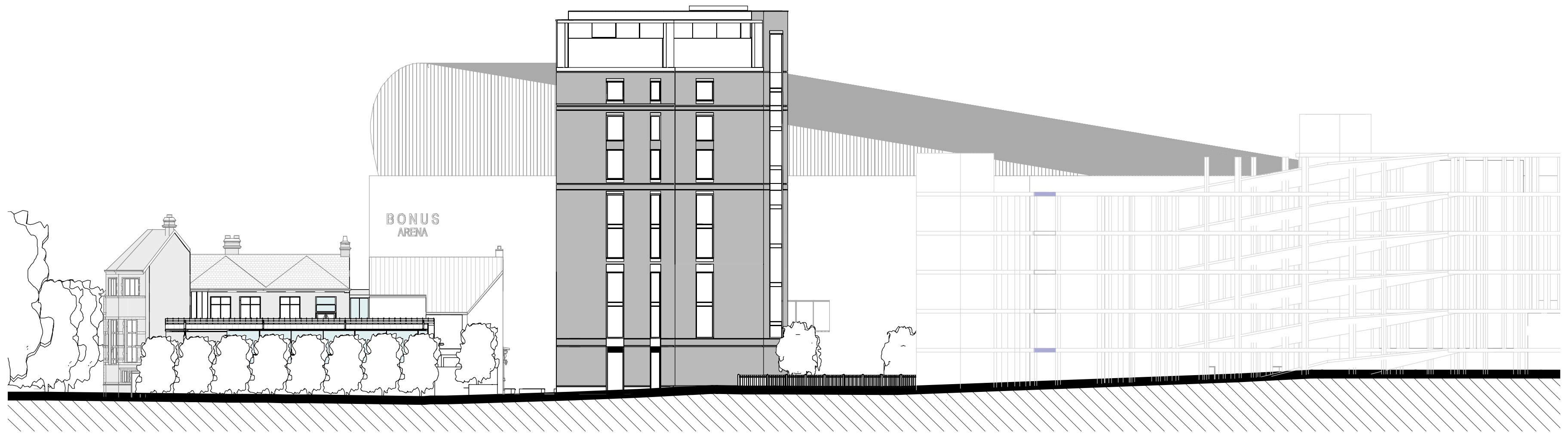
DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
|---|---|---|---|---|---|---|
| | DLA | | | | | 0012 |

STATUS
SUITABILITY DESCRIPTION
FOR PLANNING

REVISION
REVISION DESCRIPTION


## SITE SECTION 1
1 : 500




## SITE SECTION 2
1 : 500

## SITE SECTION 3
1 : 500

VIEW OF PROPOSED BUILDINGS AND PUBLIC REALM

APPROACH FROM A63 WEST

APPROACH FROM HULL MARINA - VIEW OF PROPOSED BUILDINGS

APPROACH FROM HULL MARINA AND PROPOSED NEW PEDESTRIAN

AERIAL VIEW OF PROPOSAL IN THE CONTEXT OF HULL BONUS ARENA, HULL MARINA, HULL MINSTER, THE OLD TOWN AND PROPOSED NEW

0 5 10 20 50 m

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PRINCES QUAY, HULL

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| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
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| | DLA | | | | | 0015 |

STATUS

SUITABILITY DESCRIPTION
FOR PLANNING

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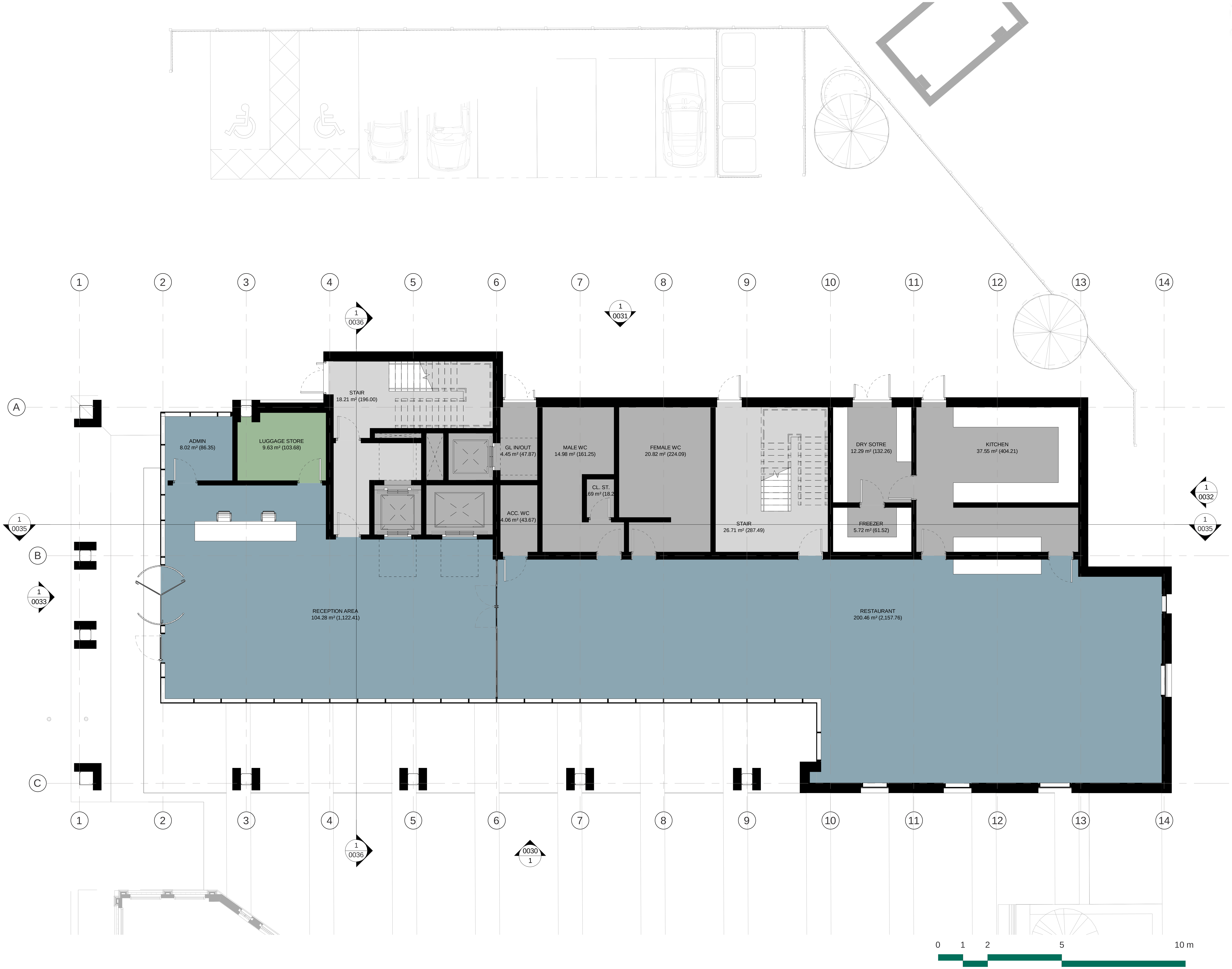
REVISION DESCRIPTION




DLA DESIGN

REVISIONS

| No. | DESCRIPTION | DATE |
|---|---|---|

By Department Legend

- ANCILLARY
- CIRC
- BOH
- NET AREA

NORTH

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PROJECT
PRINCES QUAY, HULL

TITLE
GA GROUND FLOOR PLAN
HOTEL

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| DLA REF | DRAWN | REVIEWED |
|---|---|---|
| 2016-223 | VP | JO |

DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
|---|---|---|---|---|---|---|
| | DLA | | | | | **0020** |

| STATUS | SUITABILITY DESCRIPTION |
|---|---|
| | **FOR PLANNING** |

| REVISION | REVISION DESCRIPTION |
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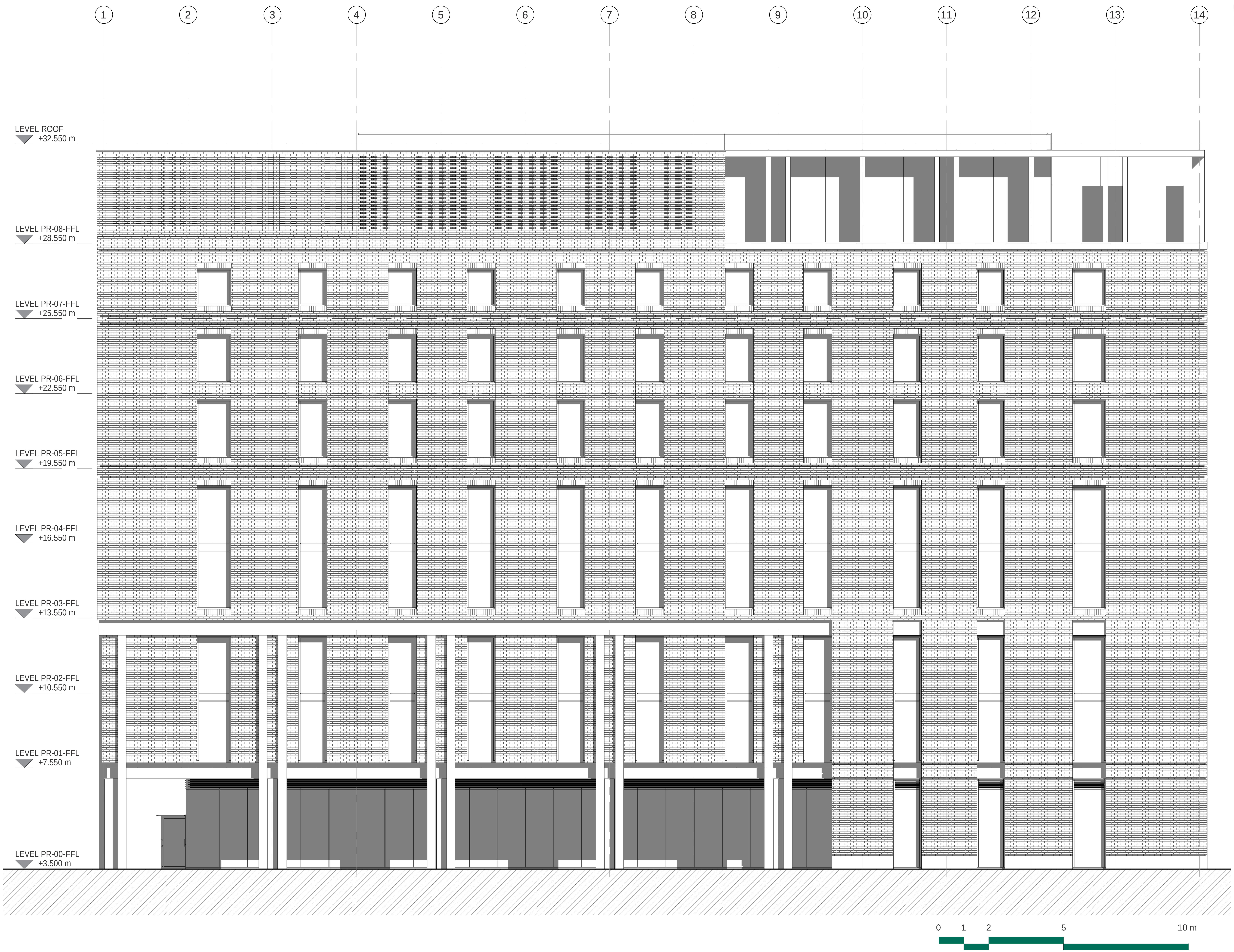


DLA DESIGN

REVISIONS

| No. | DESCRIPTION | DATE |
|---|---|---|

ARCHITECTURE

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PROJECT
PRINCES QUAY, HULL

TITLE
GA SOUTH ELEVATION
HOTEL

SCALE
1 : 100 @ A2

DATE
13/02/19

DLA REF
2016-223

DRAWN
VP

REVIEWED
JO

DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
|---|---|---|---|---|---|---|
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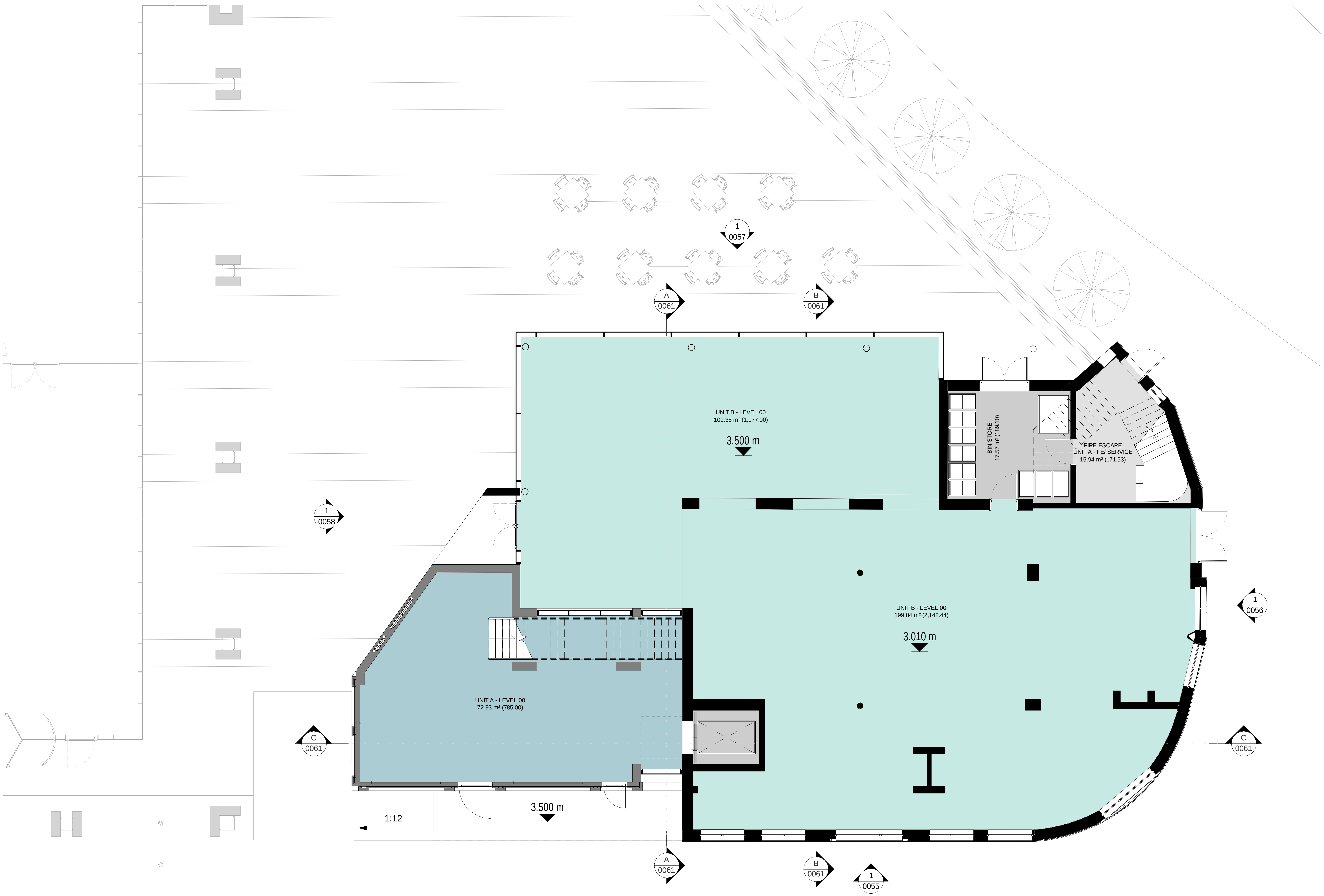
STATUS

SUITABILITY DESCRIPTION
FOR PLANNING

REVISION

REVISION DESCRIPTION




## GROSS EXTERNAL AREA:

| Level | Area (m) | Area (ft) |
|---|---|---|
| 00 | 458 | 4930 |
| 01 | 301 | 3240 |
| 02 | 43 | 463 |
| Total | 802 | 8633 |

## NET INTERNAL AREA:

| Name | Department | Area (m) | Area (ft) |
|---|---|---|---|
| BIN STORE | SERVICE | 17.57 m² | 189 ft² |
| UNIT A - CIRC. | CIRCULATION | 2.52 m² | 27 ft² |
| UNIT A - FE/ SERVICE | CIRCULATION | 15.94 m² | 172 ft² |
| UNIT A - FE/ SERVICE | CIRCULATION | 25.79 m² | 278 ft² |
| UNIT A - LEVEL 00 | UNIT A | 72.93 m² | 785 ft² |
| UNIT A - LEVEL 01 | UNIT A | 157.61 m² | 1696 ft² |
| UNIT A - LEVEL 01A | UNIT A | 53.38 m² | 575 ft² |
| UNIT A - LEVEL 02 | UNIT A | 27.09 m² | 292 ft² |
| UNIT A - LIFT | SERVICE | 4.68 m² | 50 ft² |
| UNIT A TERRACE | CIRCULATION | 23.38 m² | 252 ft² |
| UNIT B - LEVEL 00 | UNIT B | 199.04 m² | 2142 ft² |
| UNIT B - LEVEL 00 | UNIT B | 109.35 m² | 1177 ft² |
| | | 709.27 m² | 7635 ft² |

0 1 2 5 10 m

DLA DESIGN

REVISIONS

| No. | DESCRIPTION | DATE |
|---|---|---|

By Department Legend

- CIRCULATION
- UNIT A
- SERVICE
- UNIT B

NORTH

ARCHITECTURE


No. 55 | St Paul's Street | Leeds | LS1
0113 887 3100 www.dla-


PROJECT
PRINCES QUAY, HULL

TITLE
PR GA GROUND FLOOR PLAN
CAS. BUILD. & EARL DE GREY

SCALE 1 : 100 @ A2 | DATE 13/02/19

DLA REF 2016-223 | DRAWN VP | REVIEWED JO

DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
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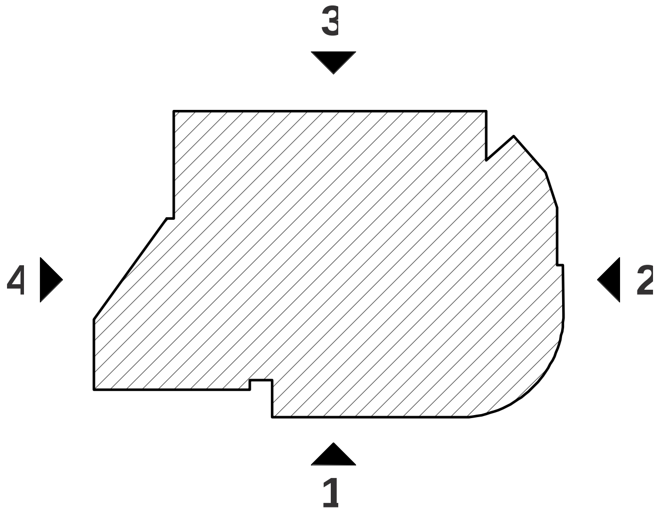
| | DLA | | | | | 0050 |

STATUS | SUITABILITY DESCRIPTION FOR PLANNING

REVISION | REVISION DESCRIPTION


## KEY PLAN ELEVATIONS

1 : 500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|---|---|---|

ARCHITECTURE


No. 55 | St Paul's Street | **Leeds** | **LS1 2TE**

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PROJECT
PRINCES QUAY, HULL

TITLE
PROPOSED ELEVATION 1
CAS. BUILD. & EARL DE GREY

| SCALE | DATE | |
|---|---|---|
| As indicated @ A3 | 13/02/19 | |
| DLA REF | DRAWN | REVIEWE |
| 2016-223 | VP | JO |

DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
|---|---|---|---|---|---|---|
| | **DLA** | | | | | **0055** |

| STATUS | SUITABILITY DESCRIPTION |
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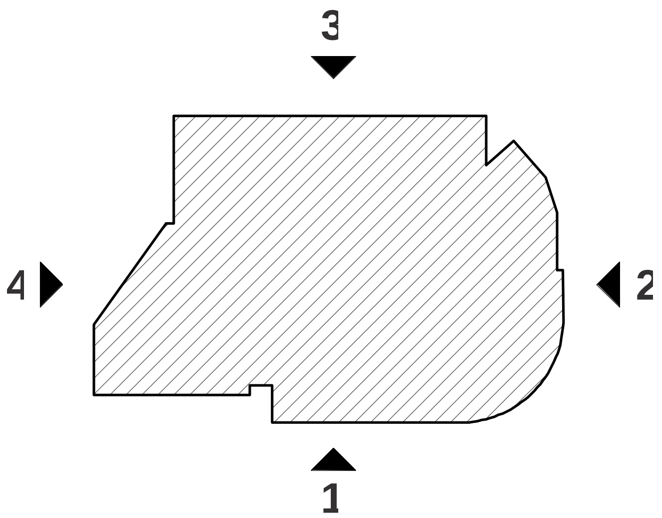
| | **FOR PLANNING** |
| REVISION | REVISION DESCRIPTION |




KEY PLAN ELEVATIONS

1 : 500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|---|---|---|

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PROJECT
PRINCES QUAY, HULL

TITLE
PROPOSED ELEVATION 3
CAS. BUILD. & EARL DE GREY

| SCALE | DATE | |
|---|---|---|
| As indicated @ A3 | 13/02/19 | |
| DLA REF | DRAWN | REVIEWE |
| 2016-223 | VP | JO |

DRAWING NAME

| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
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| STATUS | SUITABILITY DESCRIPTION |
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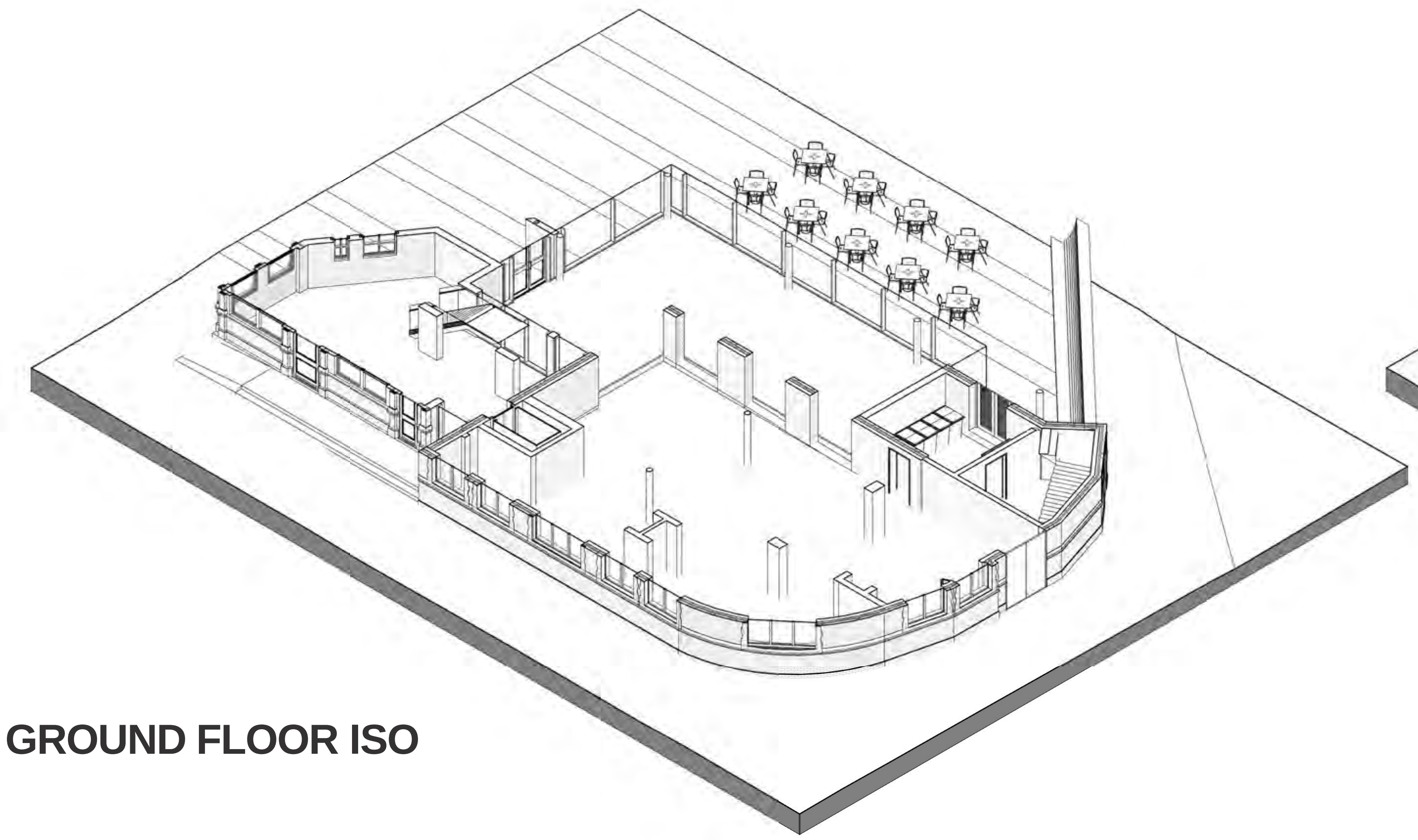
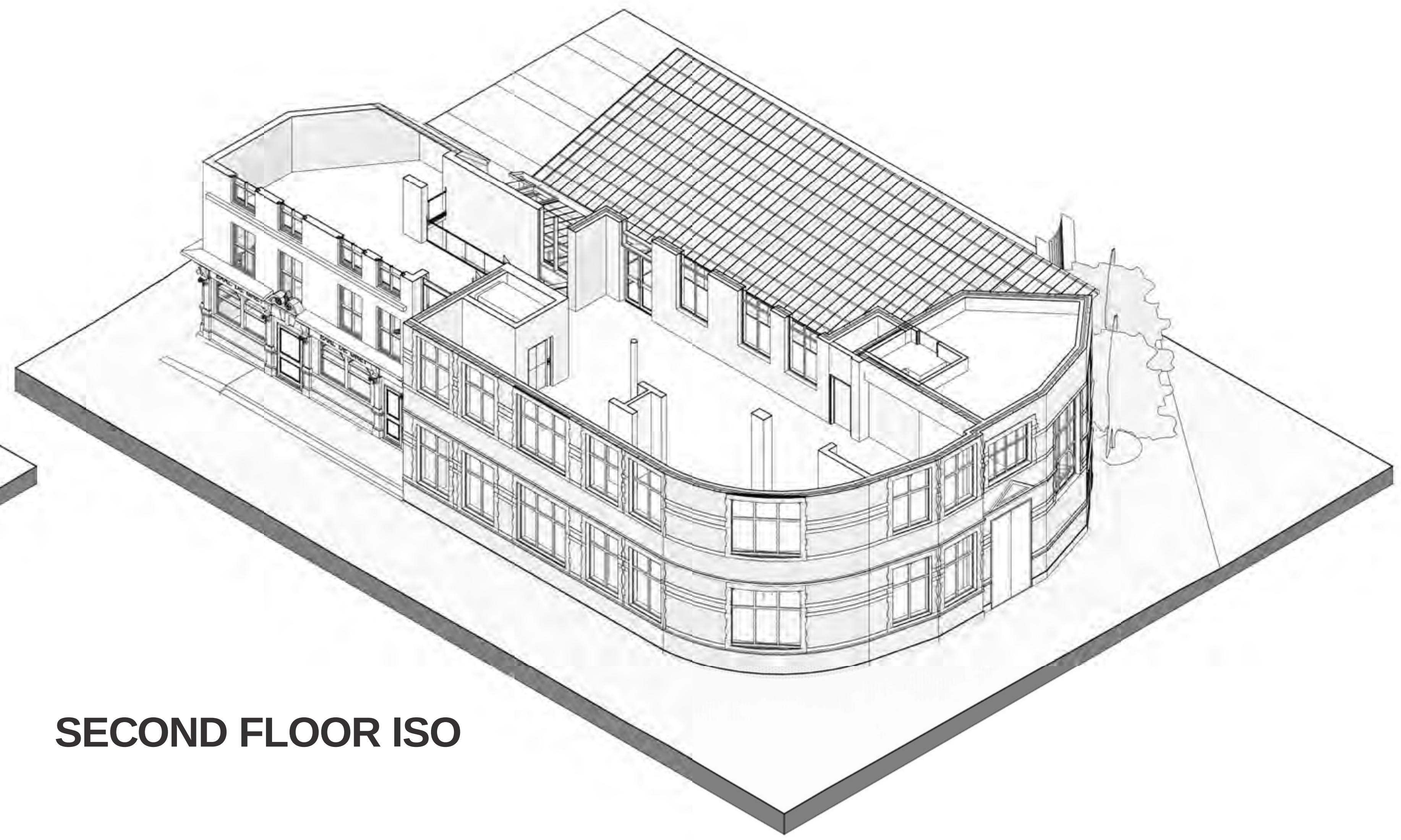
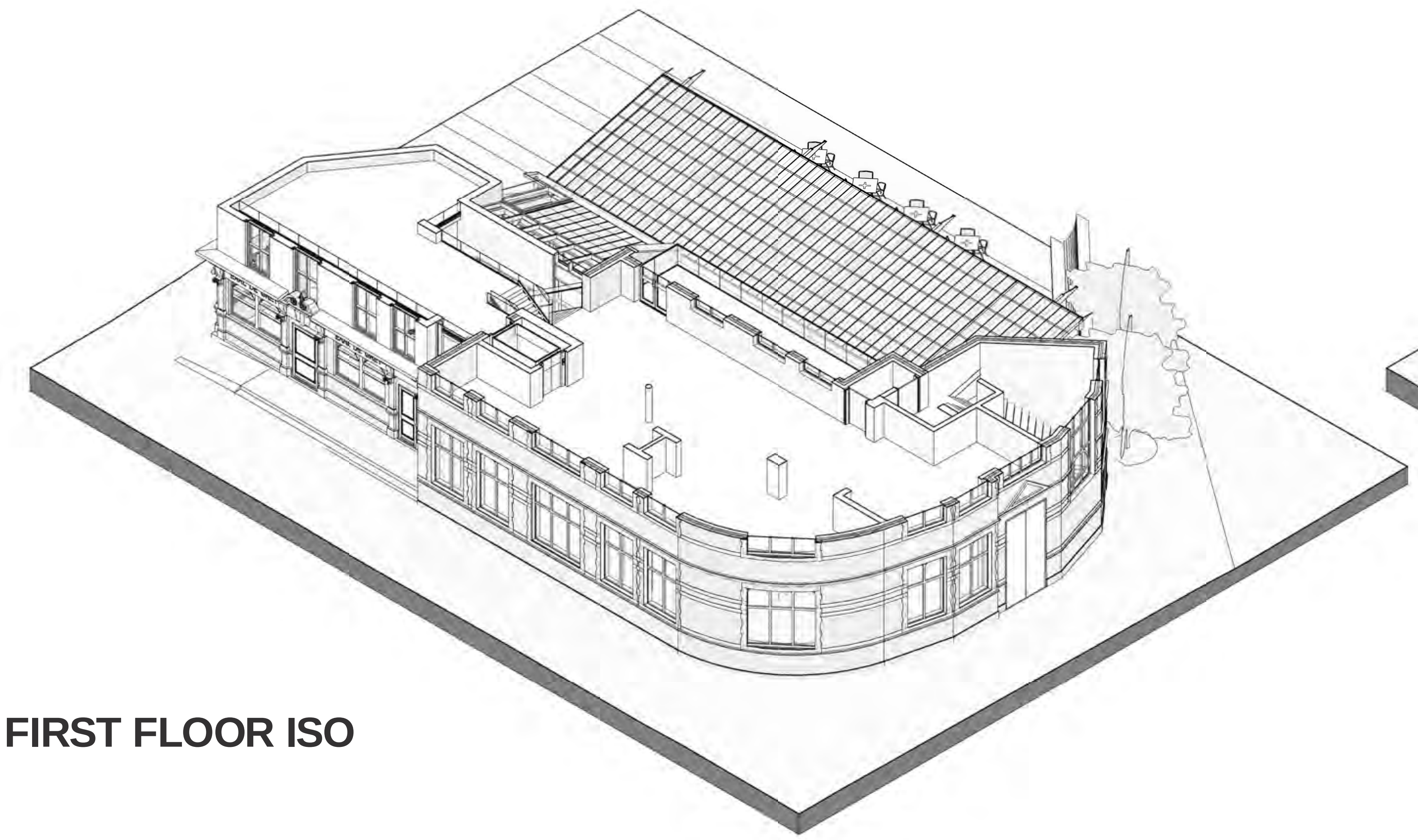
| REVISION | REVISION DESCRIPTION |



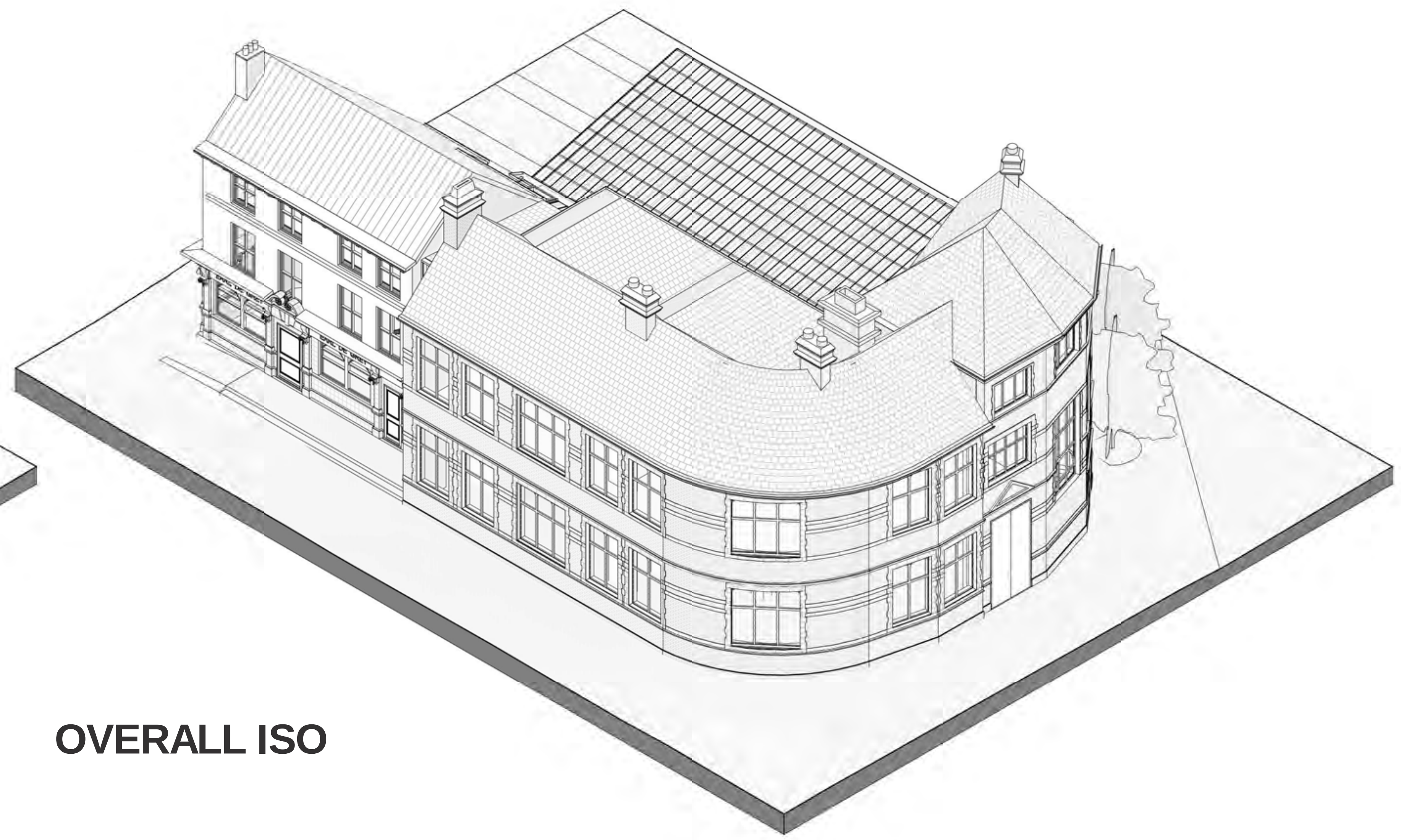
GROUND FLOOR ISO



SECOND FLOOR ISO



FIRST FLOOR ISO



OVERALL ISO

DLA DESIGN

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PROJECT
PRINCES QUAY, HULL

TITLE
PROPOSED GA - ISOMETRICS
CAS. BUILD. & EARL DE GREY

SCALE
@ A2

DATE
13/02/19

DLA REF
2016-223

DRAWN
VP

REVIEWED
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| PROJECT | ORIGINATOR | ZONE | LEVEL | TYPE | ROLE | NUMBER |
| --- | --- | --- | --- | --- | --- | --- |
| | DLA | | | | | 0060 |

STATUS

SUITABILITY DESCRIPTION
FOR PLANNING

REVISION

REVISION DESCRIPTION

# APPENDIX C

## Surface Water Storage Calculations

## Summary of Results for 30 year Return Period

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 15 min Summer | 10.592 | 0.592 | 4.3 | 29.6 | O K |
| 30 min Summer | 10.741 | 0.741 | 4.3 | 37.0 | O K |
| 60 min Summer | 10.839 | 0.839 | 4.3 | 41.9 | O K |
| 120 min Summer | 10.855 | 0.855 | 4.3 | 42.7 | O K |
| 180 min Summer | 10.832 | 0.832 | 4.3 | 41.6 | O K |
| 240 min Summer | 10.798 | 0.798 | 4.3 | 39.9 | O K |
| 360 min Summer | 10.722 | 0.722 | 4.3 | 36.1 | O K |
| 480 min Summer | 10.640 | 0.640 | 4.3 | 32.0 | O K |
| 600 min Summer | 10.548 | 0.548 | 4.3 | 27.4 | O K |
| 720 min Summer | 10.471 | 0.471 | 4.3 | 23.6 | O K |
| 960 min Summer | 10.348 | 0.348 | 4.3 | 17.4 | O K |
| 1440 min Summer | 10.200 | 0.200 | 4.2 | 10.0 | O K |
| 2160 min Summer | 10.117 | 0.117 | 3.7 | 5.9 | O K |
| 2880 min Summer | 10.095 | 0.095 | 3.0 | 4.7 | O K |
| 4320 min Summer | 10.074 | 0.074 | 2.2 | 3.7 | O K |
| 5760 min Summer | 10.064 | 0.064 | 1.8 | 3.2 | O K |
| 7200 min Summer | 10.057 | 0.057 | 1.5 | 2.9 | O K |
| 8640 min Summer | 10.053 | 0.053 | 1.3 | 2.6 | O K |
| 10080 min Summer | 10.049 | 0.049 | 1.2 | 2.5 | O K |
| 15 min Winter | 10.671 | 0.671 | 4.3 | 33.5 | O K |
| 30 min Winter | 10.840 | 0.840 | 4.3 | 42.0 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 15 min Summer | 70.267 | 0.0 | 32.6 | 18 |
| 30 min Summer | 45.948 | 0.0 | 42.7 | 32 |
| 60 min Summer | 28.763 | 0.0 | 53.5 | 60 |
| 120 min Summer | 17.497 | 0.0 | 65.1 | 100 |
| 180 min Summer | 12.951 | 0.0 | 72.2 | 132 |
| 240 min Summer | 10.419 | 0.0 | 77.5 | 166 |
| 360 min Summer | 7.627 | 0.0 | 85.1 | 236 |
| 480 min Summer | 6.113 | 0.0 | 90.9 | 306 |
| 600 min Summer | 5.147 | 0.0 | 95.7 | 366 |
| 720 min Summer | 4.470 | 0.0 | 99.7 | 426 |
| 960 min Summer | 3.576 | 0.0 | 106.4 | 542 |
| 1440 min Summer | 2.608 | 0.0 | 116.4 | 766 |
| 2160 min Summer | 1.900 | 0.0 | 127.2 | 1104 |
| 2880 min Summer | 1.517 | 0.0 | 135.4 | 1468 |
| 4320 min Summer | 1.103 | 0.0 | 147.6 | 2200 |
| 5760 min Summer | 0.879 | 0.0 | 156.9 | 2936 |
| 7200 min Summer | 0.737 | 0.0 | 164.5 | 3640 |
| 8640 min Summer | 0.638 | 0.0 | 170.9 | 4400 |
| 10080 min Summer | 0.565 | 0.0 | 176.4 | 5104 |
| 15 min Winter | 70.267 | 0.0 | 36.5 | 18 |
| 30 min Winter | 45.948 | 0.0 | 47.8 | 32 |

## Summary of Results for 100 year Return Period (+30%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume ($m^3$) | Status |
|---|---|---|---|---|---|
| 15 min Summer | 10.503 | 0.503 | 4.3 | 51.8 | O K |
| 30 min Summer | 10.650 | 0.650 | 4.3 | 66.9 | O K |
| 60 min Summer | 10.777 | 0.777 | 4.3 | 80.1 | O K |
| 120 min Summer | 10.856 | 0.856 | 4.3 | 88.1 | O K |
| 180 min Summer | 10.860 | 0.860 | 4.3 | 88.6 | O K |
| 240 min Summer | 10.847 | 0.847 | 4.3 | 87.2 | O K |
| 360 min Summer | 10.807 | 0.807 | 4.3 | 83.1 | O K |
| 480 min Summer | 10.766 | 0.766 | 4.3 | 78.9 | O K |
| 600 min Summer | 10.725 | 0.725 | 4.3 | 74.7 | O K |
| 720 min Summer | 10.683 | 0.683 | 4.3 | 70.3 | O K |
| 960 min Summer | 10.587 | 0.587 | 4.3 | 60.5 | O K |
| 1440 min Summer | 10.426 | 0.426 | 4.3 | 43.9 | O K |
| 2160 min Summer | 10.265 | 0.265 | 4.3 | 27.3 | O K |
| 2880 min Summer | 10.176 | 0.176 | 4.1 | 18.1 | O K |
| 4320 min Summer | 10.110 | 0.110 | 3.5 | 11.3 | O K |
| 5760 min Summer | 10.089 | 0.089 | 2.8 | 9.2 | O K |
| 7200 min Summer | 10.077 | 0.077 | 2.4 | 8.0 | O K |
| 8640 min Summer | 10.070 | 0.070 | 2.1 | 7.2 | O K |
| 10080 min Summer | 10.065 | 0.065 | 1.8 | 6.6 | O K |
| 15 min Winter | 10.567 | 0.567 | 4.3 | 58.4 | O K |
| 30 min Winter | 10.733 | 0.733 | 4.3 | 75.5 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume ($m^3$) | Discharge Volume ($m^3$) | Time-Peak (mins) |
|---|---|---|---|---|
| 15 min Summer | 118.224 | 0.0 | 54.7 | 18 |
| 30 min Summer | 78.014 | 0.0 | 72.3 | 33 |
| 60 min Summer | 49.114 | 0.0 | 91.2 | 62 |
| 120 min Summer | 29.915 | 0.0 | 111.2 | 120 |
| 180 min Summer | 22.100 | 0.0 | 123.2 | 170 |
| 240 min Summer | 17.728 | 0.0 | 131.8 | 198 |
| 360 min Summer | 12.895 | 0.0 | 143.8 | 262 |
| 480 min Summer | 10.296 | 0.0 | 153.1 | 332 |
| 600 min Summer | 8.640 | 0.0 | 160.6 | 402 |
| 720 min Summer | 7.484 | 0.0 | 166.9 | 470 |
| 960 min Summer | 5.960 | 0.0 | 177.2 | 600 |
| 1440 min Summer | 4.318 | 0.0 | 192.6 | 840 |
| 2160 min Summer | 3.123 | 0.0 | 209.1 | 1188 |
| 2880 min Summer | 2.479 | 0.0 | 221.3 | 1528 |
| 4320 min Summer | 1.788 | 0.0 | 239.3 | 2204 |
| 5760 min Summer | 1.416 | 0.0 | 252.9 | 2936 |
| 7200 min Summer | 1.182 | 0.0 | 263.7 | 3672 |
| 8640 min Summer | 1.019 | 0.0 | 272.7 | 4400 |
| 10080 min Summer | 0.898 | 0.0 | 280.5 | 5136 |
| 15 min Winter | 118.224 | 0.0 | 61.3 | 18 |
| 30 min Winter | 78.014 | 0.0 | 81.0 | 32 |

Summary of Results for 100 year Return Period (+30%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 60 min Winter | 10.880 | 0.880 | 4.3 | 90.6 | O K |
| 120 min Winter | 10.979 | 0.979 | 4.3 | 100.8 | O K |
| 180 min Winter | 10.994 | 0.994 | 4.3 | 102.3 | O K |
| 240 min Winter | 10.976 | 0.976 | 4.3 | 100.6 | O K |
| 360 min Winter | 10.924 | 0.924 | 4.3 | 95.2 | O K |
| 480 min Winter | 10.868 | 0.868 | 4.3 | 89.4 | O K |
| 600 min Winter | 10.809 | 0.809 | 4.3 | 83.3 | O K |
| 720 min Winter | 10.747 | 0.747 | 4.3 | 77.0 | O K |
| 960 min Winter | 10.606 | 0.606 | 4.3 | 62.5 | O K |
| 1440 min Winter | 10.362 | 0.362 | 4.3 | 37.3 | O K |
| 2160 min Winter | 10.173 | 0.173 | 4.1 | 17.8 | O K |
| 2880 min Winter | 10.112 | 0.112 | 3.6 | 11.5 | O K |
| 4320 min Winter | 10.083 | 0.083 | 2.6 | 8.5 | O K |
| 5760 min Winter | 10.070 | 0.070 | 2.1 | 7.2 | O K |
| 7200 min Winter | 10.063 | 0.063 | 1.7 | 6.4 | O K |
| 8640 min Winter | 10.057 | 0.057 | 1.5 | 5.9 | O K |
| 10080 min Winter | 10.053 | 0.053 | 1.3 | 5.5 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 60 min Winter | 49.114 | 0.0 | 102.2 | 62 |
| 120 min Winter | 29.915 | 0.0 | 124.5 | 118 |
| 180 min Winter | 22.100 | 0.0 | 138.0 | 174 |
| 240 min Winter | 17.728 | 0.0 | 147.6 | 224 |
| 360 min Winter | 12.895 | 0.0 | 161.0 | 278 |
| 480 min Winter | 10.296 | 0.0 | 171.4 | 356 |
| 600 min Winter | 8.640 | 0.0 | 179.8 | 434 |
| 720 min Winter | 7.484 | 0.0 | 186.9 | 512 |
| 960 min Winter | 5.960 | 0.0 | 198.5 | 654 |
| 1440 min Winter | 4.318 | 0.0 | 215.7 | 882 |
| 2160 min Winter | 3.123 | 0.0 | 234.2 | 1192 |
| 2880 min Winter | 2.479 | 0.0 | 247.8 | 1496 |
| 4320 min Winter | 1.788 | 0.0 | 268.0 | 2204 |
| 5760 min Winter | 1.416 | 0.0 | 283.2 | 2936 |
| 7200 min Winter | 1.182 | 0.0 | 295.3 | 3640 |
| 8640 min Winter | 1.019 | 0.0 | 305.5 | 4400 |
| 10080 min Winter | 0.898 | 0.0 | 314.2 | 5120 |

## Rainfall Details

| | | | |
|---|---|---|---|
| Rainfall Model | FSR | Winter Storms | Yes |
| Return Period (years) | 100 | Cv (Summer) | 0.750 |
| Region | England and Wales | Cv (Winter) | 0.840 |
| M5-60 (mm) | 18.700 | Shortest Storm (mins) | 15 |
| Ratio R | 0.391 | Longest Storm (mins) | 10080 |
| Summer Storms | Yes | Climate Change % | +30 |

## Time Area Diagram

Total Area (ha) 0.248

| **Time From:** | **(mins) To:** | **Area (ha)** |
|---|---|---|
| 0 | 4 | 0.248 |

## Model Details

Storage is Online Cover Level (m) 12.000

## Tank or Pond Structure

Invert Level (m) 10.000

| Depth (m) | Area (m²) | Depth (m) | Area (m²) | Depth (m) | Area (m²) |
|---|---|---|---|---|---|
| 0.000 | 103.0 | 1.000 | 103.0 | 1.001 | 0.0 |

## Hydro-Brake® Optimum Outflow Control

| | |
|---|---|
| Unit Reference | MD-SHE-0098-4300-1000-4300 |
| Design Head (m) | 1.000 |
| Design Flow (l/s) | 4.3 |
| Flush-Flo™ | Calculated |
| Objective | Minimise upstream storage |
| Application | Surface |
| Sump Available | Yes |
| Diameter (mm) | 98 |
| Invert Level (m) | 10.000 |
| Minimum Outlet Pipe Diameter (mm) | 150 |
| Suggested Manhole Diameter (mm) | 1200 |

| Control Points | Head (m) | Flow (l/s) |
|---|---|---|
| Design Point (Calculated) | 1.000 | 4.3 |
| Flush-Flo™ | 0.298 | 4.3 |
| Kick-Flo® | 0.636 | 3.5 |
| Mean Flow over Head Range | - | 3.7 |

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

| Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) |
|---|---|---|---|---|---|---|---|
| 0.100 | 3.2 | 1.200 | 4.7 | 3.000 | 7.2 | 7.000 | 10.7 |
| 0.200 | 4.2 | 1.400 | 5.0 | 3.500 | 7.7 | 7.500 | 11.1 |
| 0.300 | 4.3 | 1.600 | 5.3 | 4.000 | 8.2 | 8.000 | 11.4 |
| 0.400 | 4.2 | 1.800 | 5.6 | 4.500 | 8.7 | 8.500 | 11.8 |
| 0.500 | 4.1 | 2.000 | 5.9 | 5.000 | 9.1 | 9.000 | 12.1 |
| 0.600 | 3.7 | 2.200 | 6.2 | 5.500 | 9.6 | 9.500 | 12.4 |
| 0.800 | 3.9 | 2.400 | 6.5 | 6.000 | 10.0 | | |
| 1.000 | 4.3 | 2.600 | 6.7 | 6.500 | 10.4 | | |

## Summary of Results for 30 year Return Period

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 60 min Winter | 10.960 | 0.960 | 4.3 | 48.0 | O K |
| 120 min Winter | 10.985 | 0.985 | 4.3 | 49.2 | O K |
| 180 min Winter | 10.953 | 0.953 | 4.3 | 47.6 | O K |
| 240 min Winter | 10.905 | 0.905 | 4.3 | 45.3 | O K |
| 360 min Winter | 10.791 | 0.791 | 4.3 | 39.6 | O K |
| 480 min Winter | 10.670 | 0.670 | 4.3 | 33.5 | O K |
| 600 min Winter | 10.523 | 0.523 | 4.3 | 26.1 | O K |
| 720 min Winter | 10.408 | 0.408 | 4.3 | 20.4 | O K |
| 960 min Winter | 10.248 | 0.248 | 4.3 | 12.4 | O K |
| 1440 min Winter | 10.118 | 0.118 | 3.8 | 5.9 | O K |
| 2160 min Winter | 10.087 | 0.087 | 2.8 | 4.4 | O K |
| 2880 min Winter | 10.074 | 0.074 | 2.2 | 3.7 | O K |
| 4320 min Winter | 10.060 | 0.060 | 1.6 | 3.0 | O K |
| 5760 min Winter | 10.053 | 0.053 | 1.3 | 2.6 | O K |
| 7200 min Winter | 10.047 | 0.047 | 1.1 | 2.4 | O K |
| 8640 min Winter | 10.044 | 0.044 | 0.9 | 2.2 | O K |
| 10080 min Winter | 10.041 | 0.041 | 0.8 | 2.0 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 60 min Winter | 28.763 | 0.0 | 59.9 | 60 |
| 120 min Winter | 17.497 | 0.0 | 72.9 | 112 |
| 180 min Winter | 12.951 | 0.0 | 80.9 | 140 |
| 240 min Winter | 10.419 | 0.0 | 86.8 | 180 |
| 360 min Winter | 7.627 | 0.0 | 95.3 | 256 |
| 480 min Winter | 6.113 | 0.0 | 101.9 | 332 |
| 600 min Winter | 5.147 | 0.0 | 107.2 | 392 |
| 720 min Winter | 4.470 | 0.0 | 111.7 | 448 |
| 960 min Winter | 3.576 | 0.0 | 119.2 | 556 |
| 1440 min Winter | 2.608 | 0.0 | 130.4 | 748 |
| 2160 min Winter | 1.900 | 0.0 | 142.5 | 1100 |
| 2880 min Winter | 1.517 | 0.0 | 151.6 | 1464 |
| 4320 min Winter | 1.103 | 0.0 | 165.4 | 2188 |
| 5760 min Winter | 0.879 | 0.0 | 175.8 | 2928 |
| 7200 min Winter | 0.737 | 0.0 | 184.2 | 3672 |
| 8640 min Winter | 0.638 | 0.0 | 191.4 | 4288 |
| 10080 min Winter | 0.565 | 0.0 | 197.6 | 5136 |

## Rainfall Details

| | | | |
|---|---|---|---|
| Rainfall Model | FSR | Winter Storms | Yes |
| Return Period (years) | 30 | Cv (Summer) | 0.750 |
| Region | England and Wales | Cv (Winter) | 0.840 |
| M5-60 (mm) | 18.700 | Shortest Storm (mins) | 15 |
| Ratio R | 0.391 | Longest Storm (mins) | 10080 |
| Summer Storms | Yes | Climate Change % | +0 |

## Time Area Diagram

Total Area (ha) 0.248

| **Time From:** | **(mins) To:** | **Area (ha)** |
|---|---|---|
| 0 | 4 | 0.248 |

## Model Details

Storage is Online Cover Level (m) 12.000

## Tank or Pond Structure

Invert Level (m) 10.000

| Depth (m) | Area (m²) | Depth (m) | Area (m²) | Depth (m) | Area (m²) |
|---|---|---|---|---|---|
| 0.000 | 50.0 | 1.000 | 50.0 | 1.001 | 0.0 |

## Hydro-Brake® Optimum Outflow Control

| | |
|---|---|
| Unit Reference | MD-SHE-0098-4300-1000-4300 |
| Design Head (m) | 1.000 |
| Design Flow (l/s) | 4.3 |
| Flush-Flo™ | Calculated |
| Objective | Minimise upstream storage |
| Application | Surface |
| Sump Available | Yes |
| Diameter (mm) | 98 |
| Invert Level (m) | 10.000 |
| Minimum Outlet Pipe Diameter (mm) | 150 |
| Suggested Manhole Diameter (mm) | 1200 |

| Control Points | Head (m) | Flow (l/s) |
|---|---|---|
| Design Point (Calculated) | 1.000 | 4.3 |
| Flush-Flo™ | 0.298 | 4.3 |
| Kick-Flo® | 0.636 | 3.5 |
| Mean Flow over Head Range | - | 3.7 |

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

| Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) | Depth (m) | Flow (l/s) |
|---|---|---|---|---|---|---|---|
| 0.100 | 3.2 | 1.200 | 4.7 | 3.000 | 7.2 | 7.000 | 10.7 |
| 0.200 | 4.2 | 1.400 | 5.0 | 3.500 | 7.7 | 7.500 | 11.1 |
| 0.300 | 4.3 | 1.600 | 5.3 | 4.000 | 8.2 | 8.000 | 11.4 |
| 0.400 | 4.2 | 1.800 | 5.6 | 4.500 | 8.7 | 8.500 | 11.8 |
| 0.500 | 4.1 | 2.000 | 5.9 | 5.000 | 9.1 | 9.000 | 12.1 |
| 0.600 | 3.7 | 2.200 | 6.2 | 5.500 | 9.6 | 9.500 | 12.4 |
| 0.800 | 3.9 | 2.400 | 6.5 | 6.000 | 10.0 | | |
| 1.000 | 4.3 | 2.600 | 6.7 | 6.500 | 10.4 | | |

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