Flood Risk Assessment

Kingmoor Energy Recovery Facility, Kingmoor Park, Carlisle

Quality Management

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Executive Summary

This FRA demonstrates that the Proposal would be operated with minimal risk from flooding, would not increase flood risk elsewhere and is compliant with the requirements of the NPPF.

The proposal should not therefore be precluded on the grounds of flood risk.

The primary flood risk to the Application Site is from surface water (pluvial) flooding due to the direct rainfall onto the site exceeding the infiltration capacity of the soils rather than overland flow from adjacent areas. It is understood that ponding occurs at the location of topographical lows on the site. The Application Site has no other history of flooding.

Using a conservative estimate of water velocity of 0.00m/s and a maximum water depth of 0.50m any flooding would result in a 'moderate' flood hazard with a dangerous for some (i.e. children) - "danger: Flood zone with deep or fast flowing water". Therefore, the risk of flooding from surface water flooding is considered to be of **low significance**.

A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

- Fluvial Flooding
- Groundwater Flooding

The flooding sources will only inundate the site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the Proposal site.

The risk from fluvial sources will be further mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the site.

The Proposal is classified as 'less vulnerable', 'less vulnerable' uses are appropriate within Flood Zone 1 after the completion of a satisfactory FRA.

In conclusion, the development will be situated in Flood Zone 1, with a low annual probability of flooding and from all sources. The chance of flooding from all sources each year is **low or not significant**.

The SUDS Strategy ensures that a sustainable drainage solution can be achieved which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the site. The SUDS Strategy takes into account the following principles:

- No increase in the volume or runoff rate of surface water runoff from the site.
- No increase in flooding to people or property off-site as a result of the development.
- No surface water flooding of the site.
- The proposals take into account a 40% increase in rainfall intensity due to climate change.

In line with adopting a 'management train' it is recommended that water is managed as close to source as possible. This will reduce the size and cost of infrastructure further downstream and also shares the maintenance burden more equitably. It is therefore recommended that the site provides its own attenuation. This will be in the form of:

- Settlement of solids will be promoted by the SUDS measures, by using a pond/lagoon.
- For larger events storage in other areas such as landscaping, provided that it will not cause damage or prevent access.
- Where required correctly sized oil interceptors/separators will be installed before discharge to the pond/lagoon.

For all development, a hierarchical approach to surface water management is promoted. This approach has been adopted within this SUDS Strategy. Infiltration will not be possible therefore surface water runoff from the site will be discharged to Cargo Beck at the QBAR runoff rate after attenuation within a pond/lagoon.

The size of the pond/lagoon has been calculated such that the Proposal has the capacity to accommodate the 1 in 100 year rainfall event including a 40% increase in rainfall intensity that is predicted to occur as a result of climate change. Consequently, all areas drained have been designed to accommodate a 100 year (+40% climate change) storm event.

The remainder of the site that is not formally drained, i.e. landscaped areas, will be permeable (grass). The majority of rainwater falling on these areas will soak into the ground. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

Surface water runoff from all hard surfaces will receive an appropriate level of treatment in accordance with the SUDS Manual which will minimise the risk of pollution to the River Eden SSSI, River Eden SAC and off site locations. The surface water runoff will be directed to the north east of the site and impact on the stability of the West Coast Main Railway Line or RAF MU14 landfill site (Site 8E – Glory Hole).

This restriction in surface water runoff will also provide significant flood mitigation benefits to existing third party property and land downstream of the site that may be potentially at risk from flooding.

The flooding sources will be managed on the site by using a number of mitigation strategies to manage and reduce the overall flood risk at the site and will ensure the development will be safe. Measures used:

Minimum Floor Level: There is no minimum finished floor level proposed as a result of fluvial flooding; however, it is recommended that all buildings are located above the back of the footway of the adjacent carriageway by 150mm to enable the full capacity of any secondary flood conveyance to be utilised.

Buffer Strip: A buffer strip adjacent to the top of Cargo Beck will be maintained for maintenance purposes. This will be free of buildings and permanent structures as per the terms of The Environmental Permitting (England and Wales) (Amendment) (No.2) Regulations 2016 and the Flood risk activities set out in Paragraph 3 Part 1 of Schedule 23ZA, the prior written consent of the Environment Agency may be required for any works in, over, under or within 8m of the 'main river', or 16m if tidal or within 8 metres of a flood defence structure/ culvert, 16m if tidal.

The buffer strip will also mitigate the impact of flooding from this source should the Cargo Beck overtop its banks.

Flood Resilience and Resistance: The development of the layout should always consider that the site is potentially at risk from an extreme event and as such the implementation of flood resilience and resistance methods should be assessed.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from buildings can be easily and economically incorporated into the development of the site.

Access and Egress: The site and surrounding area is located within Flood Zone 1 therefore a permanently safe and dry access can be maintained.

SUDS Strategy: The surface water runoff produced by the site during a rainfall event is restricted which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the site.

Designing for Local Drainage System Failure: The landscaped areas will include preferential flow paths that convey water away from buildings. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

There will not be an extensive sewerage network on the Proposal site and therefore any potential exceedance flooding would be from the public sewers located within the vicinity of the site. An exceedance or blockage event of the sewers would not affect the proposed property because finished floor levels will be above surrounding ground levels, ensuring any exceedance flooding would not affect the building. Exceedance flows would be contained within the highways surrounding the buildings.

The Sequential Test will not need to be undertaken as part of this planning application as the site is located within Flood Zone 1. Applications located within Flood Zone 1 are not subject to the Exception Test.

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1 Introduction

1.1 Background

This Flood Risk Assessment has been prepared by Hydrogeo Ltd to support a planning application for the Proposal at Kingmoor Park, Carlisle, CA6 4SJ. This FRA includes an assessment of the existing and proposed surface water drainage of the site.

This FRA has been carried out in accordance with guidance contained in the National Planning Policy Framework (NPPF)[1] and associated Planning Practice Guidance[2]. This FRA identifies and assesses the risks of all forms of flooding to and from the development and demonstrates how these flood risks will be managed so that the development remains safe throughout the lifetime, taking climate change into account.

It is recognised that developments which are designed without regard to flood risk may endanger lives, damage property, cause disruption to the wider community, damage the environment, be difficult to insure and require additional expense on remedial works. The development design should be such that future users will not have difficulty obtaining insurance or mortgage finance, or in selling all or part of the development, as a result of flood risk issues.

1.2 National Planning Policy Framework (NPPF)

One of the key aims of the NPPF is to ensure that flood risk is taken into account at all stages of the planning process; to avoid inappropriate development in areas at risk of flooding and to direct development away from areas of highest risk.

It advises that where new development is exceptionally necessary in areas of higher risk, this should be safe, without increasing flood risk elsewhere, and where possible, reduce flood risk overall.

A risk based approach is adopted at stages of the planning process, applying a source pathway receptor model to planning and flood risk. To demonstrate this, an FRA is required and should include:

- whether a proposal is likely to be affected by current or future flooding from all source;
- whether it will increase flood risk elsewhere;
- whether the measures proposed to deal with these effects and risks are appropriate;
- if necessary provide the evidence to the LPA that the Sequential Test can be applied; and
- whether the development will be safe and pass part c) of the Exception Test if this is appropriate.

[1] Department for Communities and Local Government (2012) National Planning Policy Framework.

[2] Department for Communities and Local Government (2014) Planning Practice Guidance - Flood Risk and Coastal Change.

1.3 Report Structure

This FRA has the following report structure:

- Section 2 details the sources of information that have been consulted;
- Section 3 describes the location area, the Application Site and the Proposal;
- Section 4 outlines the flood risk to the Proposal;
- Section 5 details the proposed surface water drainage for the site and assesses the potential impacts of the Proposal on surface water drainage;
- Section 6 outlines the required mitigation measures;
- Section 7 details the sequential and exception tests; and
- Section 8 presents a summary and conclusions.

2 Sources of Information

2.1 Discussion with Regulators

Consultation and discussions with the relevant regulators have been undertaken during the preparation of this FRA including with the Environment Agency, the Local Planning Authority (LPA), the Lead Local Flood Authority (LLFA) and Sewerage Undertakers.

2.1.1 Environment Agency

The Flood and Water Management Act 2010 gives the Environment Agency a strategic overview role for all forms of flooding and coastal erosion. They also have direct responsibility for the prevention, mitigation and remediation of flood damage for main rivers and coastal areas. The Environment Agency is the statutory consultee with regards to flood risk and planning.

Environment Agency Flood Risk Standing Advice for England, the NPPF and the Planning Practice Guidance to the NPPF has been consulted and reviewed during this FRA. This has confirmed the level of FRA required and that a surface water drainage assessment is to be undertaken.

Information regarding the current flood risk at the Application Site, local flood defences and flood water levels has been obtained from the Environment Agency. The Environment Agency has made the following comments:

- With reference to section 5.133 of the Scoping Report, it should be understood that the Flood Zone 1 designation is a 'default' designation, in the absence of any flood modelling at this location. This is because the catchment upstream of the development site is below the 3 km^2, that we would normally model.
- The site is lower than the developed part of the site on the right bank of Cargo Beck. Water leaving the Kingmoor Central site must pass via the West Coast Main Line siphon culvert, which has limited capacity.
- Cargo Beck has been engineered to provide some degree of online storage. However, this is not finite and all proposed development sites in undeveloped Kingmoor Park Central need to have regard for the critical importance of flood and storm water storage on the site.
- The watercourses on the Kingmoor Park Central area were configured to both convey and store water because of the constraints. Any proposals at this location therefore need to be subject to a full Flood Risk Assessment (FRA) to ensure the development does not flood or increase flood risk elsewhere. Any FRA produced will have to have regard for the revised climate change allowances.
- Our understanding is that at present when channel capacity is exceeded, water will flood onto the development site, as the current land levels are generally lower than developed land on the right bank. Furthermore, flood related studies are required as part of the EIA, to demonstrate a better understanding of the hydrological regime to ensure that any proposals recognise and can mitigate any impacts through design. This may include landform manipulation to make space for water and the use of Sustainable Drainage Techniques (SUDS).

- Cargo Beck is designated 'Main River'. Therefore, under the terms of The Environmental Permitting (England and Wales) (Amendment) (No.2) Regulations 2016 and the Flood risk activities set out in Paragraph 3 Part 1 of Schedule 23ZA, the prior written consent of the Environment Agency may be required for any works in, over, under or within 8m of the 'main river', or 16m if tidal or within 8 metres of a flood defence structure/ culvert, 16m if tidal.

- The Permitting for Flood Risk Activities (PfFRA) will control works in, over, under or adjacent to main rivers (including any culverting).

- Your application must demonstrate that:

    1. there is no increase in flood risk either upstream or downstream;

    2. access to the main river network and sea/tidal defences for maintenance and improvement is not prejudiced;

    3. works are carried out in such a way as to avoid unnecessary environmental damage.

- Mitigation is likely to be required to control off site flood risk and we will not be able to issue our permits until this has been demonstrated.

2.1.2 Cumbria County Council

Cumbria County Council is the LPA for minerals and waste developments and the Lead Local Flood Authority (LLFA) and has responsibilities for ‘local flood risk’, which includes surface runoff, groundwater and ordinary watercourses. Planning guidance written by Cumbria County Council regarding flood risk was consulted to assess the mitigation policies in place. The Cumbria County Council Preliminary Flood Risk Assessment (PFRA) which covers the site has been reviewed.

Cumbria County Council has confirmed the following:

- A Flood Risk Assessment is required as part of the Environmental Statement due to the scale of the development. Consideration should also be given to ensure there would be no risk of flooding onto adjacent sites or increase run off which may affect the stability of the West Coast Main Railway Line or RAF MU14 landfill site (Site 8E – Glory Hole).

- Cumbria County Council agrees with the assessment set out in para 5.145 of the Scoping Opinion to assess impact of flood risk especially surface water flooding to the area; assess the impacts of the proposal on flooding to the study area with consideration of drainage and flood storage compensation measures where required; assessment of existing surface water run-off regime and determination of the potential impacts of the development on peak run-off rates and flow; identify public and private drinking water supplies in the area any risks to the quality or quantity would be assessed; develop a mitigation strategy including outline surface water system to manage both water flow and water quality.

- There are a number of watercourses and drainage ditches in the area which connect into the River Eden which runs into the Solway Firth. The River Eden is designated as a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC). The Solway Firth has a number of designations namely Ramsar - Upper Solway Flats and Marshes; SAC - Solway Firth and SSSI – Upper Solway Flats and Marshes. There is potential that the proposed development could impact on the European Protected sites.

2.1.3 Carlisle City Council

Planning guidance written by Carlisle City Council regarding flood risk was consulted to assess the mitigation policies in place. The Carlisle City Council Strategic Flood Risk Assessment (SFRA) which covers the site has been reviewed.

2.1.4 United Utilities

United Utilities is responsible for the disposal of waste water and supply of clean water for this area. Information with regards to sewer and water main flooding contained within the Carlisle City Council SFRA and the Cumbria County Council PFRA has been consulted. All Water Companies have a statutory obligation to maintain a register of properties/areas which are at risk of flooding from the public sewerage system, and this is shown on the DG5 Flood Register.

2.1.5 Network Rail

Network Rail is responsible for the culvert (WCM1 @ 2.1295) on the Cargo Beck which is located to the west of the site. Correspondence has been undertaken with Network Rail and a reply from the drainage team at Network Rail is currently outstanding.

3 Location & Development Description

3.1 Site Location

The Application Site is located within the Kingmoor Park Industrial Estate approximately 3.8km to the north east of Carlisle city centre (see Drawing 1). The approximate National Grid Reference (NGR) is 338085, 559225. The Application Site area is 4.05 hectares (ha) or 40,588m^2.

A number of industrial buildings are located to the north and south of the Application Site. A pond/lagoon is also located to the south of the Application Site. Cargo Beck runs along the northern boundary of the Application Site and leads to a culvert below the West Coast Mainline. The West Coast Mainline is located approximately 100m to the west of the Application Site and an area of low lying semi-improved grassland is located immediately to the east. Located between the site and the West Coast Mainline is an embankment of over 20m in height (RAF MU14 landfill site, Site 8 – Glory Hole).

The wider area is generally industrial or agricultural in nature and a large railway siding and a timber processing and storage facility is located to the north west of the Application Site.

3.2 Existing Development

The Application Site consists of low lying land accommodating scrub and grassland. No noteworthy trees or permanent waterbodies are located on the site, although there are areas of standing water at certain times of the year.

3.3 The Proposal

The Proposal involves the construction of an Energy Recovery Facility (ERF) at the Application Site (see Appendix 1). The Proposal will comprise of the following physical elements:

- A fuel reception hall, also including offices and welfare facilities and storage for all required waste and fuel;
- Boiler House;
- Flue stack, 70m in height;
- An air cooled condenser building, for the cooling of water for re-use in steam boilers attached to the Boiler House;
- 4No. silos, for the storage of ash and reagents for the Flue Gas Treatment system;
- Car parking;
- Gatehouse;
- Housing for electrical and utility connections; and
- Weighbridges.

In addition, the Proposal involves the construction of a new section of road from Kings Drive to the south to the Application Site. The facility will be designed to process up to 250,000 tonnes of refuse derived fuel, sourced from waste management facilities.

The ERF operation will be operated on a 24 hours, 7 days a week basis. Up to 40 full time staff would be employed on the site, with 10 to 16 staff working at the site at any one time.

3.4 Ground Levels

A topographical survey of the Application Site and surrounding area has recently been undertaken (see Appendix 2). The site and surrounding area is relatively flat with a gently slope from north to south. However, the Application Site is approximately 1.00m lower than the adjacent areas to the north.

The Application Site ground levels vary from 14.30 metres Above Ordnance Datum (mAOD) to 14.50mAOD. The topographical survey highlights low spots near the centre of the site.

3.5 Catchment Hydrology

The existing surface water features are shown in Drawing 2. Cargo Beck is located adjacent to the northern boundary of the Application Site flowing from east to west (see Figure 3-1). Cargo Beck is designated as a 'Main River' by the Environment Agency. Therefore, under the terms of The Environmental Permitting (England and Wales) (Amendment) (No.2) Regulations 2016 and the Flood risk activities set out in Paragraph 3 Part 1 of Schedule 23ZA, the prior written consent of the Environment Agency may be required for any works in, over, under or within 8m of the 'main river', or 16m if tidal or within 8 metres of a flood defence structure/ culvert, 16m if tidal.

Approximately 170m upstream from the Application Site, below the roundabout, Cargo Beck discharges from a circular pipe of approximately 1.20m in diameter (see Figure 3-1). A number of other pipes and culvert of varying size discharge into Cargo Beck below the roundabout. It is understood that these are surface water discharges from nearby swales, hardstanding areas and the adjacent highway.

Cargo Beck, adjacent to the northern boundary of the Application Site, is located within a recently man made trapezoidal channel (see Figure 3-2). According to the available topographical survey of the Application Site, Cargo Beck (trapezoidal section with a minimum bottom base of 1.00m, minimum top base of 2.00m, a minimum height of 1.00m, average bottom slope of 0.002, and estimated Manning's n roughness coefficient of 0.03) can easily convey significant discharge. During the site visit there were low water levels within Cargo Beck of less than 500mm, this was after periods of heavy rainfall throughout November 2015 to March 2016.

Near the north west corner of the Application Site Cargo Beck flows through a trash screen (see Figure 3-3) after which the watercourse flows through a concrete lined channel with a metal grid roof (see Figures 3-4 to 3-5). The Cargo Beck then flows in a southerly direction within the concrete lined channel before turning west and discharging through the railway embankment of the West Coast Main Line within a culvert (see Figure 3-6). The Environment Agency has confirmed that the culvert is of a siphon type. Located between the Application Site and the railway culvert is an embankment of over 20m in height (RAF MU14 landfill site, Site 8E – Glory Hole).

Cargo Beck flows to the north west before discharging into the River Eden approximately 800m downstream from the Application Site. The River Eden then discharges into the

Solway Firth. The River Eden is designated as a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC). The Solway Firth has a number of designations namely Ramsar - Upper Solway Flats and Marshes; SAC - Solway Firth and SSSI – Upper Solway Flats and Marshes. It is therefore, understood that Cargo Beck is classified as drainage sensitive.

A pond/lagoon is also located to the south of the Application Site. It is understood that this acts an attenuation pond/lagoon for the nearby industrial units with discharge to the adjacent watercourse.

From the site walkover it is evident, from the location of inspection chambers (see Figure 3-7) on the ground surface, that there is a sewer/pipe which flows from north to south and then turns west under the Application Site before discharging through the adjacent embankment which is located to the west of the Application Site. On Drawing 1 the location of the sewer/pipe is shown as a watercourse, this is not correct as there is no surface watercourse at this location.

It is understood that this sewer/pipe was the outfall for a pumping station which has been removed. It is most likely that the sewer/pipe is disused although it was flooded with water during the site visit.

The geology and hydrogeology of the catchment combines with the topography resulting in rivers with water levels that rise quickly after rainfall. A short response to rainfall will lead to a rapid increase in river levels. The existing site drains by gravity to Cargo Beck will a smaller proportion draining via infiltration into the soil substrate.

Figure 3-1 Upstream culvert on Cargo Beck

Figure 3-2 Looking west along Cargo Beck

Figure 3-3 Trash screen on Cargo Beck to the north west of the Application Site

Figure 3-4 Concrete lined channel with metal grid roof to the north west of the Application Site

Figure 3-5 Concrete lined channel with metal grid roof to the north west of the Application Site

Figure 3-6 Culvert below railway embankment to the west of the Application Site

Figure 3-7 Inspection chamber located on the Application Site

3.6 Geology

The geology of the site has been determined from the British Geological Survey (BGS) Special Sheet: Solway East, 1:50,000 (2006).

In summary the site is located upon the Gretna Till Formation (Superficial Deposits) which formed up to 2 million years ago in the Quaternary Period. These deposits were formed in cold periods with Ice Age glaciers scouring the landscape and depositing moraines of till with outwash sand and gravels. The deposits are generally found to comprise reddish brown, sandy, silty, clayey Diamicton with clasts of greywacke, red sandstone, siltstone and grey granodiorite.

The solid geology underlying the Gretna Till Formation is the Mercia Mudstone Group which formed approximately 200 to 251 million years ago in the Triassic Period. The Mercia Mudstone Group comprises mudstone layers with interbedded sandstone, gypsum and anhydrite.

Underlying the Mercia Mudstone Group is the Kirklington Sandstone Formation which is shown to outcrop at or close to the surface approximately 4km to the east of the site. The Kirklington Sandstone Formation formed in the Triassic Formation and is generally found to comprise fine to medium grained red, locally white, strongly cross bedded sandstone.

Hydrogeo have assessed the July 2002 report “Desk Study, Plots 1-5, West Kingmoor park, Carlisle” produced by Shepard Gilmour Environment Limited to assess the ground conditions of the Application Site. This report provided a summary of works conducted in the late 1990s and early 2000s.

Topsoil is generally present to a depth of 0.30m across the Kingmoor Park site. Made ground was encountered in a number of exploratory holes. Glacial till appears to be approximately 11.50 to 12.40m thick.

Solid geology consisting of mudstone representing the Mercia Mudstone Group is present between depths of 11.50 to 12.50m.

3.7 Groundwater

The site is underlain by the Gretna Till Formation which is classified by the Environment Agency as unproductive strata. These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

The underlying Mercia Mudstone Group are classified by the EA as a Secondary B Aquifer which predominantly comprise lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

The Kirklington Sandstone Formation, which underlies the Mercia Mudstone Group beneath the site, is classified by the EA as a Principal Aquifer. Principal Aquifers are layers of rock that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. The majority of rainfall onto the site surface will be directed to surface runoff and surface watercourses due to the low permeability of the Gretna Till Formation. The low permeability of the Mercia Mudstone Group mudstones will also inhibit rainfall recharge to the underlying Kirklington Sandstone aquifer. The Kirklington Sandstone aquifer will therefore be recharged where it outcrops at or close to the surface approximately 4km to the east of the site. Groundwater discharge is considered to be 2.5km to the north-east of the site providing baseflow to the River Eden.

Previous reports indicate that there is a shallow perched water table within the glacial till on site. Seepages were noted from the side walls of trial pits excavated within the glacial till from horizons *“…one metre to several metres below ground level”,* mainly issuing from sand and gravel horizons within the till. It was proposed that the groundwater flow was from east to west across the Application Site, albeit at a very slow rate.

The groundwater levels recorded during the groundwater monitoring have been recorded at a minimum of 0.44 metres Below Ground Level (mBGL).

3.8 Source Protection Zone

The Application Site is not located within an Environment Agency Source Protection Zone.

3.9 Soil

Information from the National Soil Resource Institute details the Application Site area as being situated on slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils with impeded drainage. The Flood Studies Report WRAP soil map classification is Type 4: Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

3.10 Permeability/Infiltration Rate

In determining the future surface runoff from the Application Site, the potential of using infiltration devices has been considered. An overview of the general ground conditions (see Sections 3.5 to 3.9) may be used to gauge if there is potential for their application. The general ground conditions suggest that the permeability and infiltration rate of the Application Site will be low and is unsuitable for infiltration drainage. Only limited amounts of infiltration drainage would be possible.

4 Flood Risk

4.1 Climate Change

Projections of future climate change in the UK indicate more frequent, short-duration, high intensity rainfall and more frequent periods of long duration rainfall. Guidance included within the NPPF recommends that the effects of climate change are incorporated into FRA. Recommended precautionary sensitivity ranges for peak rainfall intensities and peak river flows are outlined in the associated Planning Practice Guidance to the NPPF[3].

Table 4.1 shows peak river flow allowances by river basin district and Table 4.2 shows the anticipated changes in extreme rainfall intensity in small and urban catchments.

Table 4-1 Peak River Flow Allowances by River Basin District (use 1961 to 1990 baseline)

River Basin District	Allowance category	2015 to 2039	2040 to 2059	2060 to 2115
North West	Upper end	+20%	+35%	+70%
	High central	+20%	+30%	+35%
	Central	+15%	+25%	+30%

Table 4-2 Peak Rainfall Intensity Allowance in Small and Urban Catchment (use 1961 to 1990 baseline)

Allowance category	2015 to 2039	2040 to 2059	2060 to 2115
Upper end	+10%	+20%	+40%
Central	+5%	+20%	+20%

4.2 Sources of Flooding

All sources of flooding have been considered, these are; Fluvial (river) Flooding, Tidal (coastal) Flooding, Groundwater Flooding, Surface Water (pluvial) Flooding, Sewer Flooding and Flooding from Artificial Drainage Systems/Infrastructure Failure.

The key consequences of flooding are death/personal injury, extensive damage to property, properties uninhabitable for long periods, properties cannot be sold, insurance unavailable or too expensive, expense of installing flood resilience measures and business interruptions.

3 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#high-allowances.

4.2.1 Fluvial (river) Flooding

The Cargo Beck is located adjacent to the northern boundary of the Application Site flowing from east to west. Therefore, Cargo Beck poses the primary flood risk to the Application Site.

Cargo Beck has been engineered to provide some degree of online storage. However, it is important to understand the hydrological nature of Cargo Beck due to its implications on fluvial flood risk at the Application Site. Such an investigation was undertaken using 'industry standard' techniques such as the Centre for Ecology and Hydrology (CEH) Flood Estimation Handbook (FEH) webservice and the Revitalised Rainfall Runoff Method version 2 (ReFH2). This method is based on robust hydrological modelling techniques and is described in the Flood Estimation Handbook (FEH). The Institute of Hydrology Report 124 method (IoH124)[4] has also been used.

Catchment descriptors from the FEH CD-ROM v3.0 can be used to infer the physical nature of the catchment and its possible response to a rainfall event. Table 4-1 sets out the relevant catchment descriptors for the study catchment upstream of the Application Site at NGR 338050, 559100 (see Figure 4-1). The catchment boundary has been checked against the OS mapping and no changes are necessary. See Appendix 3 for the full catchment descriptors. A definition of each can be found at http:www.environment-agency.gov.uk/hiflows/97768.aspx.

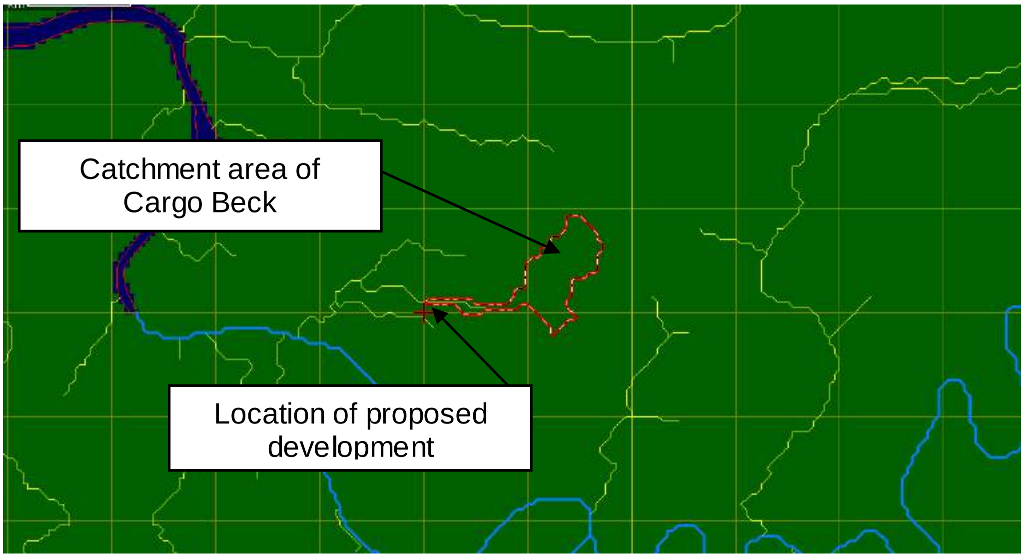
The catchment area is small at 0.55km^2, the SPRHOST value (Standard Percentage Runoff) is high at 39.69 and indicates an impermeable catchment. Approximately 39.69% of the rainfall will contribute to direct runoff rather than be stored and this indicates an impermeable catchment. The BFIHOST value (Baseflow Index) is high at 0.378 indicating a responsive catchment to rainfall with the majority of baseflow being runoff derived i.e. rainfall sources. The catchment is urbanised and the SAAR (Standard Average Annual Rainfall) value is moderate at 820.

Table 4-3 FEH Webservice Key Catchment Descriptors

Catchment Descriptor	Value
Catchment Area	0.55km^2
BFIHOST (Baseflow Index)	0.378
SAAR1961-90 (Standard Average Annual Rainfall)	820
SPRHOST (Standard Percentage Runoff)	39.69
URBEXT1990	0.4129
PROPWET	0.62
Design Rainfall Parameters	**Value**
C	-0.027
D1	0.312
D2	0.447
D3	0.391
E	0.282
F	2.345

[4] Institute of Hydrology (1994) Flood estimation for small catchments. Report no 124.

Figure 4-1 Cargo Beck as shown on the FEH webservice



The nature of the underlying geology, the low permeability of soils and the gentle land gradient (the runoff does not discharge downstream rapidly) of the Application Site and surrounding area means that there can be excessive surface water runoff. The catchment is impermeable, responsive to rainfall and a large majority of rainfall will not infiltrate into the soil substrate generating surface water runoff. The number of surface water features within the surrounding area confirms this. Localised urbanisation will contribute and increase the surface water runoff.

The complicated pattern of drainage ditches in this area has been developed to intercept the surface water runoff and discharge the water safely away from the area ultimately discharging into the Cargo Beck and the River Eden downstream of the Application Site.

Table 4-4 shows that the peak flows for Cargo Beck calculated using the ReFH) Method and the IoH124 Method. It is normal that these methods may differ in their calculated peak flows. Tables 4-4 shows that the peak flows for Cargo Beck range from 0.26m^3/s for the 1 in 2 year event up to 1.46m^3/s for the 1 in 1000 year event (see Appendix 4).

Climate change allowances must be taken into account over the whole lifetime of the development. Therefore, the peak river flows for the 1 in 100 year event have been increased by 40% to account for the effects of climate change in accordance with the Planning Practice Guidance to the NPPF. During the 1 in 100 year (+40%) event the peak flow has been calculated to be 0.99m^3/s.

Table 4-4 Peak Flows for Cargo Beck

Return Period (yrs)	Peak Discharge (m^3/s)	
	ReFH Method	IoH124 Method
2	0.26	0.28
20	0.50	N/A
100	0.71	0.59
100 + 40%	0.99	0.83
200	N/A	0.67

Return Period (yrs)	Peak Discharge (m^3/s)	
	ReFH Method	**IoH124 Method**
1000	1.46	N/A

According to the available topographical survey of the Application Site, Cargo Beck (trapezoidal section with a minimum bottom base of 1.00m, minimum top base of 2.00m, a minimum height of 1.00m, average bottom slope of 0.002, estimated Manning's n roughness coefficient of 0.03) can easily convey significant discharge. The bankfull capacity of the channel has been calculated using the following Manning's equation (see Appendix 5):

$$\boxed{V = \frac{R^{0.67} x S^{0.5}}{n}}$$

Where:

V = velocity (m/s)
R = (Cross Sectional Area of channel)/ (Wetted Perimeter)
S = Slope
n = Manning's Coefficient of Roughness

Table 4-5 shows that the minimum bankfull capacity of Cargo Beck is approximately 1.34m^3/s (see Appendix 5). When comparing the bankfull capacity of the Cargo Beck (see Table 4-5) with the flood flows generated within the Cargo Beck catchment (see Table 4-4) it can be seen that the Cargo Beck has a bankfull capacity of greater than the 1 in 100 year (+40%) event. However, any event greater than the bankfull capacity of 1.34m^3/s may cause localised flooding such as during the 1 in 1000 year event.

Table 4-5 Bankfull Capacity (Manning's Equation)

Bottom Width (m)	Top Width (m)	Depth (m)	Slope	Manning's *n*	Bankfull Capacity (m^3/s)
1.00	2.00	1.00	0.002	0.03	1.34

It should also be taken in consideration that the flow within Cargo Beck adjacent to the Application Site is restricted and controlled by the pipe/culvert upstream of the Application Site, below the roundabout. Cargo Beck discharges from a 1200mm pipe approximately 170m to the north east of the Application Site.

It likely that the pipe will attenuate and restrict the water flowing down Cargo Beck adjacent to the Application Site and therefore, reduce the amount of water that could potential flow out of bank within the vicinity of the Application Site.

Near the north west corner of the Application Site Cargo Beck flows through a general type trash screen (see Figure 3-3) after which the watercourse flows through a concrete lined channel with a metal grid roof (see Figures 3-4 to 3-5). The trash screen reduces the amount of trash and debris entering the culvert (where it could cause a blockage) therefore, reducing flood risk.

Table 4-6 shows that the maximum capacity of the trash screen entrance calculated using the using the Colebrook-White equation, is 1.77m^3/s. When comparing the culvert capacity (see Table 4.6) with the peak flood flows generated within the watercourse catchment (see Table 4.4) it can be seen that culvert has the capacity of well in excess of the 1 in 100 year event. However, any event greater than the capacity of 1.77m^3/s may cause localised flooding.

Table 4-6 Trash Screen Entrance Capacity (Colebrook-White Equation)

Bottom Width (m)	Depth (m)	Slope	Roughness (Ks)	Capacity (m^3/s)
1.00	0.90	0.002	0.15	1.77

Cargo Beck then flows under the railway embankment in a culvert (see Figure 3-6). Due to access and health and safety issues it has not been possible to obtain measurement of the culvert.

The Environment Agency has confirmed that the siphon culvert under the railway line can pass 3.00m^3/s. From site observations it can be concluded that the culvert can easily convey significant discharge

When comparing the capacity of the culvert of 3.00m^3/s with the flood flows generated within the Cargo Beck catchment (see Table 4-4) it can be seen that the culvert has capacity of greater than the 1 in 1000 year event. Due to the large size of this culvert it is unlikely that the maximum flows for drainage ditch will surcharge at the culvert entrance. However, any event greater than the capacity may cause localised flooding.

An assessment of the residual flood risk of failure or blockage (complete or partial) of railway culvert has been undertaken. Blockage of such a feature can occur through a number of different mechanisms:

Large debris in watercourse

If large pieces of rubbish or natural debris are allowed to collect in the channel these can be washed downstream during episodes of high flow and then become lodged either in the bridge entrance of internally within a bridge. This in itself will reduce the culvert capacity, but would also allow smaller pieces of debris to become trapped and then further reduce the bridge capacity.

The potential for this mechanism to be realised depends upon the availability of debris and the frequency with which the watercourse is cleared. In this case there is a smaller sized pipe upstream of the Application Site on which any large debris is likely to become lodged and the availability of suitable sized debris is limited due to the nature of the catchment.

The debris within Cargo Beck is general debris (anything from branches/plants to armchairs and oil drums). The general debris may be deposited within the Beck accidently (such as wind-blown debris) but may also arise through a deliberate act (e.g. disposal of household waste such as old carpets, furniture, garden cuttings).

The Environment Agency's Trash and Security Screen Guide therefore recommends that a general debris trash screen should be installed at the inlet to the culvert which has occurred. Subject to compliance with the Environment Agency's guidance, there is limited potential for a blockage of this type to occur at the culvert.

Sedimentation

Long periods of natural sedimentation, combined with additional sediment loading and other geomorphological changes caused by human actions, can result in siltation with bridges that will then reduce the bridge capacity. There is no reason to expect significant sediment loading in this case. It should also be noted that such problems typically impact smaller culverts and due to the large size of the railway culvert it is unlikely that sedimentation will significantly impact conveyance in this case.

Culvert or channel collapse

A collapse of the culvert would block flows and could lead to water backing up and flooding areas of the Application Site. This is likely to occur where bridges are old and in poor repair however, the culvert is not in need of repair and is regularly maintained. If a partial blockage or failure of the bridge were to occur the capacity of the culvert would be exceeded and localised flooding may occur. However, this will be of a minor nature due to the low flows and topography of the area.

The culvert is large, well maintained and is structurally sound therefore the probability of a culvert collapsing and/or a blockage is low. Due to the large size of this culvert it is unlikely that the maximum flows for drainage ditch will surcharge at the culvert entrance.

If a partial blockage or failure of the culvert were to occur, it is unlikely that the capacity of the culvert would be exceeded. If a complete blockage or failure of the culvert were to occur, which is highly unlikely, flooding of the drainage ditch would occur. However, this will be of a minor nature due to the low flows and topography of the area. Therefore, it can be seen that flooding of the Application Site from surcharging of the culvert is unlikely especially due to the large capacity of the culvert.

On the rare occasion that the capacity of the culvert is exceeded, the water then spills from the culvert inlet and follows the contours of the surrounding area. Water would travel south and flood areas to the south of the Application Site. It is very unlikely that floodwater would back up Cargo Beck and flood the Application Site. There is a large earth embankment of over 20m in height between the culvert and the Application Site. The culvert is located approximately 160m downstream from the Application Site which makes it very unlikely that floodwater would back up and flood the Application Site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the Application Site are approximately 1.00m above the normal water level of the culvert.

The Environment Agency surface water flood map is representative of the fluvial flood risk from the Cargo Beck. The medium risk surface water flood outline is representative of the 1 in 100 year flood event and the low risk surface water flood outline is representative of the 1 in 1000 year event as shown in Drawing 3 The surface water flood map assumes that the channel capacity of the beck is 1 in 2 years. Therefore, the flood map is highly conservative. The majority of floodwater is contained within the watercourse channel. Areas at risk of fluvial flooding are predominantly located along the mapped watercourses and a low spot within the site. The majority of the surface water flood risk posed to the Application Site is from direct rainfall onto the Application Site which then cannot infiltrate into the soil substrate rather than overland flow from adjacent areas (see Section 4.1.4).

Any flooding would result in shallow water depths of less than 300mm and water velocities of over 0.25m/s. Using a conservative estimate of water velocity of 0.25m/s and a maximum water depth of 0.30m any flooding would result in a ‘low’ flood hazard with a caution hazard with a flood zone with shallow flowing or deep standing water as per the

Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose - Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD/2321/TR1. It should be noted that this is the most conservative estimate of flood risk posed by surface water flooding.

The flooding will only inundate the Application Site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the Application Site. The actual risk of flooding caused by overtopping of the river bank during a fluvial flood event on the Cargo Beck will be very limited.

The actual flood risk posed to the Application Site is low each year with a chance of less than 1 in 1000 (0.1%) years. The risk of fluvial flooding will be further managed and mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the Application Site (see Section 6.0). Therefore, the risk of flooding from fluvial flooding is considered to be of **low significance**.

4.1.2 Tidal (coastal) Flooding

The Application Site is not located within the vicinity of tidal flooding sources and the risk of tidal flooding is considered to be **not significant**. Therefore, flooding from this source has not been considered further within this FRA.

4.1.3 Groundwater Flooding

Groundwater flooding is defined as the emergence of groundwater at the ground surface or the rising of groundwater into man-made ground under conditions where the normal range of groundwater levels is exceeded.

Groundwater flooding tends to occur sporadically in both location and time. When groundwater flooding does occur, it tends to mostly affect low-lying areas, below surface infrastructure and buildings (for example, tunnels, basements and car parks) underlain by permeable rocks (aquifers).

The Carlisle City Council SFRA shows that the Application Site and surrounding may be susceptible to groundwater flooding (see Figure A.5 of the SFRA). These areas are predominately within the river gravels of the River Eden and its tributaries.

BGS data shows that the Application Site is at risk of superficial deposit groundwater flooding. This is associated with shallow unconsolidated sedimentary aquifers which overlie unproductive aquifers. The highest susceptibility is potential at the surface with a moderate confidence.

However, there are no historical records of groundwater flooding at or within the vicinity of the Application Site. Previous reports indicate that there is a shallow perched water table within the glacial till on the Application Site.

The risk of groundwater flooding will be further managed and mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the Application Site (see Section 6.0). Therefore, the risk of flooding from groundwater flooding is considered to of **low significance**.

4.1.4 Surface Water (pluvial) Flooding

Surface water flooding tends to occur sporadically in both location and time. The Application Site is not situated on and adjacent to areas of permeability and areas with geology which may result in surface water flooding.

The Environment Agency Surface Water flood map shows that the majority of the Application Site has a low risk of surface water flooding with a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%) years (see Drawing 3). This would result in water depths of less than 300mm and water velocities of less than 0.25m/s.

However, a small proportion of the Application Site has a medium to high risk of surface water flooding with a chance from 1 in 100 (1%) and to less than 1 in 30 (3.3%) years. This would result in water depths of 300 to 900mm and water velocities of less than 0.25m/s. It is understood that during the flood events of December 2015 that ponding of a depth of 300mm occurred on the Application Site (see Figure 4-2).

Figure 4-2 Ponding on the Application Site during December 2015

The Areas Susceptible to Surface Water Flooding (AStSWF) map shows that the Application Site has an intermediate susceptibility to surface water flooding during the 1 in 200 year rainfall event (see Figure A.7 of the SFRA).

The Flood Map for Surface Water (FMfSW) maps shows that a very small proportion of the Application Site may experience surface water flooding of less than 0.30m during the 1 in 30 year and 1 in 200 year rainfall events (see Figure A.8 of the SFRA).

The majority of the surface water flood risk posed to the Application Site is from direct rainfall onto the Application Site which then cannot infiltrate into the soil substrate rather than overland flow from adjacent areas. This has been confirmed within Drawing 3, Figures A.7 and A.8 of the SFRA. Very little overland flow from adjacent higher areas and low velocities associated with standing water occurs. Deeper areas of floodwater are due to the low spots within the Application Site topography and predominantly located along mapped watercourses with very little running or flowing water.

Using a conservative estimate of water velocity of 0.00m/s and a maximum water depth of 0.50m any flooding would result in a 'moderate' flood hazard with a dangerous for some (i.e. children) - "danger: Flood zone with deep or fast flowing water" as per the Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose - Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD/2321/TR1. It should be noted that this is the most conservative estimate of flood risk posed by surface water flooding.

The risk from this source will be further mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the Application Site (see Section 6.0). The risk of flooding from surface water flooding is considered to be of **low significance**.

4.1.5 Sewer Flooding

Sewer flooding occurs when urban drainage networks become overwhelmed and maximum capacity is reached. This can occur if there is a blockage in the network causing water to back up behind it or if the sheer volume of water draining into the system is too great to be handled. Sewer flooding tends to occur sporadically in both location and time such flood flows would tend to be confined to the streets around the development.

The Carlisle City Council SFRA shows that there have been no incidents of sewer flooding within the vicinity of the Application Site (see Figure A.4 of the SFRA).

From the site walkover it is evident, from the location of inspection chambers (see Figure 3-7) on the ground surface, that there is a sewer/pipe which flows from north to south and then turns west under the Application Site before discharging through the adjacent embankment which is located to the west of the Application Site. On Drawing 1 the location of the sewer/pipe is shown as a watercourse, this is incorrect; there is no surface watercourse at this location.

The risk from this source will be further mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the Application Site (see Section 6.0). The risk of flooding from surface water flooding is considered to be **not significant**. Therefore, flooding from these sources has not been considered further within this FRA.

4.1.6 Flooding from Artificial Drainage Systems/Infrastructure Failure

There are no other nearby artificial water bodies, reservoirs, water channels and artificial drainage systems that could be considered a flood risk to the Application Site. Drawing 4 shows that the Application Site is not at risk of flooding from reservoir failure and the Carlisle City Council SFRA shows that the Application Site is not at risk of flooding from a reservoir breach (see Figure A.6 of the SFRA).

The risk of flooding from artificial drainage systems/infrastructure failure is considered to be **not significant**. Therefore, flooding from these sources has not been considered further within this FRA.

4.3 Historic Flooding

The Environment Agency does not have any records of flooding from Cargo Beck at this location.

Anecdotal evidence suggests that the Application Site can become waterlogged in inclement weather rather than flooding from watercourses etc. During the site visit it was noted that small areas of the Application Site where waterlogged to a maximum depth of 150mm. Figure 4-2 shows small areas of the Application Site were waterlogged during the storms of December 2015. These areas of waterlogging are associated with low spots within the Application Site topography.

The Carlisle City Council SFRA shows that the Application Site has not historically flooded (see Figure A.1 of the SFRA). The British Hydrological Society "Chronology of British Hydrological Events" has no information on flooding within the vicinity of the Application Site. No other historical records of flooding for the Application Site have been recorded.

The most significant flood event in recent years occurred in January 2005, when flooding of property and other assets were reported throughout the region. The recorded flow of 1520m³/s at the Sheepmount Gauging Station in Carlisle was the highest on record for the catchment. From the flood records for Eden Bridge, which include the flood marks and a staff gauge maintained by Carlisle City Council between about 1850 and the 1930s, the 2005 flood also appears to be the highest recorded. It was more than 1m higher than the notable floods of 1771, 1822, 1856, 1925 and 1968. The estimated return period for the 2005 event on the River Eden was 0.57 - 0.50% Annual Exceedance Probability (AEP) (i.e. 1 in 175 to 200 year event). In comparison the 1968 event on the River Eden was estimated as a 1.33% (1 in 75 year) AEP event.

Therefore, the Application Site should not flood during a flood event of a similar magnitude i.e. 1 in 175 to 200 year event. It has been concluded that small areas of the Application Site can become waterlogged during heavy rainfall events rather than being inundated with floodwater.

4.4 Existing and Planned Flood Defence Measures

The Application Site is not protected against flood by existing or planned flood defence measures. However, Cargo Beck has been engineered to provide some degree of online storage which will provide some protection to the Application Site against flooding.

Further risk management measures will be used to protect the Application Site from flooding these are discussed in Section 6.0.

4.5 Environment Agency Flood Zones

A review of the Environment Agency's Flood Zones indicates that the Application Site is located within Flood Zone 1 and therefore has a 'low probability' of fluvial/tidal flooding, with less than a 1 in 1000 annual probability of river or sea flooding in any year (<0.1%) (see Drawing 5).

The Flood Zones are the current best information on the extent of the extremes of flooding from rivers or the sea that would occur without the presence of flood defences, because these can be breached, overtopped and may not be in existence for the lifetime of the development. The Flood Zones show the worst case scenario.

The Environment Agency Flood Zones and acceptable development types are explained in Table 4-7. Table 4-7 shows that all development types are generally acceptable in Flood Zone 1.

4.6 Flood Vulnerability

Planning Practice Guidance identifies appropriate uses for the Flood Zones. Applying the Flood Risk Vulnerability Classification in the Planning Practice Guidance, the Application Site is classified as 'less vulnerable'.

Table 4-8 of this report and the Planning Practice Guidance state that 'less vulnerable' uses are appropriate within Flood Zone 1 after the completion of a satisfactory FRA.

Table 4-7 Environment Agency Flood Zones and Appropriate Land Use

Flood Zone	Probability	Explanation	Appropriate Land Use
Zone 1	Low	Less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%)	All development types generally acceptable
Zone 2	Medium	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	Most development type are generally acceptable
Zone 3a	High	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	Some development types not acceptable
Zone 3b	'Functional Floodplain'	Land where water has to be flow or be stored in times of flood. SFRAs should identify this 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)	Some development types not acceptable

Table 4-8 Flood Risk Vulnerability and Flood Zone 'Compatibility'

Flood Risk Vulnerability Classification	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception test required	✓	✓
Zone 3a	Exception test required	✓	×	Exception test required	✓
Zone 3b 'Functional Floodplain'	Exception test required	✓	×	×	×

Key:

✓*: Development is appropriate,* ×*: Development should not be permitted.*

4.7 Site Specific Flood Risk Assessment

A summary of the sources of flooding and a review of the risk posed by each source at the Application Site is shown in Table 4-9.

Table 4-9 Risk Posed by Flooding Sources

Sources of Flooding	Potential Flood Risk	Potential Source	Probability/Significance
Fluvial (river) Flooding	Yes	Cargo Beck	Low
Tidal (coastal) Flooding	No	None Reported	Not significant
Groundwater Flooding	Yes	Groundwater	Low
Surface Water (pluvial) Flooding	Yes	Poor Permeability	Low
Sewer Flooding	No	None Reported	Not significant
Flooding from Artificial Drainage Systems/Infrastructure Failure	No	None Reported	Not significant

The Application Site is unlikely to flood except in extreme conditions. The primary, but unlikely, flood risk to the Application Site is from surface water (pluvial) flooding due to the direct rainfall onto the Application Site exceeding the infiltration capacity of the soils rather than overland flow from adjacent areas. It is understood that ponding occurs at the location of topographical lows on the Application Site. The Application Site has no other history of flooding.

Using a conservative estimate of water velocity of 0.00m/s and a maximum water depth of 0.50m any flooding would result in a 'moderate' flood hazard with a dangerous for some (i.e. children) - "danger: Flood zone with deep or fast flowing water". Therefore, the risk of flooding from surface water flooding is considered to be of **low significance**.

A number of secondary flooding sources have been identified which may pose a **low significant** risk to the Application Site. These are:

- Fluvial Flooding
- Groundwater Flooding

The flooding sources will only inundate the Application Site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the Application Site.

The risk from fluvial sources will be further mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the Application Site.

The Proposal is classified as 'less vulnerable', 'less vulnerable' uses are appropriate within Flood Zone 1 after the completion of a satisfactory FRA.

In conclusion, the development will be situated in Flood Zone 1, with a **low** annual probability of flooding and from all sources. The chance of flooding from all sources each year is **low or not significant**.

5 Surface Water Drainage

5.1 Surface Water Management Overview

It is recognised that consideration of flood issues should not be confined to the floodplain. The alteration of natural surface water flow patterns through developments can lead to problems elsewhere in the catchment, particularly flooding downstream. For example, replacing vegetated areas with roofs, roads and other paved areas can increase both the total and the peak flow of surface water runoff from the Application Site. Changes of land use on previously developed land can also have significant downstream impacts where the existing drainage system may not have sufficient capacity for the additional drainage.

A SUDS Strategy for the Application Site has been developed to manage and reduce the flood risk posed by the surface water runoff. An assessment of the surface water runoff rates has been undertaken, in order to determine the surface water options and attenuation requirements for the Application Site. The assessment considers the impact of the development compared to current conditions. Therefore, the surface water attenuation requirement for the Application Site can be determined and reviewed against existing arrangements.

The requirement for managing surface water runoff from developments depends on the pre-developed nature of the site. If it is an undeveloped greenfield site, then the impact of the development will need to be mitigated so that the runoff from the site replicates the natural drainage characteristics of the pre-developed site. In the case of brownfield sites, drainage proposals will be measured against the existing performance of the site, although it is preferable for solutions to provide runoff characteristics that are similar to greenfield behaviour.

The surface water drainage arrangements for any development site should be such that the volumes and peak flow rates of surface water leaving a developed site are no greater than the rates prior to the Proposal, unless specific off-site arrangements are made and result in the same net effect.

It should be acknowledged that the satisfactory collection, control and discharge of surface water runoff are now a principle planning and design consideration. This is reflected in recently implemented guidance and the recently released National Sustainable Drainage Systems (SUDS) Standards. At this stage it is necessary to demonstrate that the surface water from the Proposal can be discharged safety and sustainably.

5.2 Site Areas

The Application Site currently is in a greenfield state with an area of 4.53ha or 45,264m^2. It is understood that the existing drainage infrastructure at the Application Site efficiently and effectively manages surface water runoff generated at the Application Site. The existing Application Site drains by gravity to Cargo Beck will a smaller proportion draining via infiltration into the soil substrate.

Table 5-1 shows that the pre-development Application Site is constructed from 4.53ha (100%) of permeable surfaces with 0.00ha (0%) impermeable surfaces. The post-development site will be constructed from 2.16ha (48%) of impermeable surfaces with 2.37ha (52%) of permeable surfaces. The Proposal will increase the impermeable area by 2.16ha (+48%) generating higher surface water runoff rates and volumes post-development. This will increase the risk of flooding to the Application Site and off-site locations if the surface water runoff is not attenuated.

Table 5-1 Site Areas (ha)

Element	Pre-application	Post-application	Difference
Permeable Surfaces	4.53 (45,264m^2)	2.22 (23,648m^2)	- 2.16 (21,616m^2)
Impermeable Surfaces	0.00 (00,000m^2)	2.16 (21,616m^2)	+ 2.16 (21,616m^2)
Total	**4.53 (45,264m^2)**	**4.53 (45,264m^2)**	------

5.3 Surface Water Runoff Rates and Volumes

In order to quantify any potential increase in surface water runoff, the pre- and post-development runoff rates and volumes from the Application Site must be determined. The rates of runoff have been determined using the ReFH 2 Method.

Table 5-2 below shows a comparison of surface water runoff rates and volumes pre- and post-development (see Appendix 6). Climate change allowances must be taken into account over the whole lifetime of the development (see Table 4.2). Therefore, the runoff rates for the 1 in 100 year event have been increased by 20% and 40% to account for the effects of climate change in accordance with the Planning Practice Guidance to the NPPF.

The Proposal would result in increasing the peak runoff from the Application Site if the surface water runoff from the developed site is not attenuated. QBAR (rural) has been calculated to be 23.27l/s using the Institute of Hydrology Report 124 method (IoH124) (see Appendix 7).

Currently the majority of rainfall and surfaces water runoff discharges from the Application Site either directly into the Cargo Beck in an uncontrolled manner, with a smaller proportion draining via infiltration into the soil substrate. The current surface water runoff from the Application Site is uncontrolled, untreated, unmanaged and unmitigated. This may cause flooding and pollution of offsite locations as well as the wider water environment.

By utilising a SUDS Strategy, the post-development site will generate lower surface water runoff volumes and rates, which will in turn decrease the risk of flooding to the Application Site and off-site locations.

Table 5-2 Pre-application and Post-application Peak Flows and 6 hour Volumes

Return Period (years)	Pre-application		Post-application		Difference	
	Runoff (l/s)	Volume (m^3)	Runoff (l/s)	Volume (m^3)	Runoff (l/s)	Volume (m^3)
1	20.16	312	36.09	477	+15.93	+165
2	22.73	354	40.68	536	+17.95	+182
30	49.30	740	86.11	1079	+36.81	+339
100	65.25	965	111.81	1380	+46.56	+415
100 + 20%	78.30	1158	134.17	1656	+55.87	+498
100 + 40%	109.62	1621	187.84	2318	+78.22	+697

5.4 Opportunities for Discharge of Surface Water

There are three possible options to discharge the surface water runoff in accordance with requirement H3 of the Building Regulations 2010, this hierarchy is also promoted within the NPPF. Rainwater shall discharge to one of the following, listed in order of priority:

- an adequate soakaway or some other adequate infiltration system; or, where that is not reasonably practicable,
- a watercourse; or where that is not reasonably practicable,
- a sewer.

It is necessary to identify the most appropriate method of controlling and discharging surface water. The design should seek to improve the local runoff profile by using systems that can either attenuate runoff and reduce peak flow rates or positively impact on the existing surface water runoff.

5.3.1 Soakaway/Infiltration System

The general ground conditions suggest that the permeability and infiltration rate of the Application Site will be low and is unsuitable for infiltration drainage. Only limited amounts of infiltration drainage would be possible.

5.3.2 Watercourse

Should infiltration be found to be unsuitable, the next option is discharge to a watercourse. All runoff that cannot be discharged via infiltration will be managed on site and discharged to Cargo Beck.

The topography of the area indicates that a gravity connection could be made to Cargo Beck located to the north of the Application Site. An outfall into Cargo Beck would be made near to the Application Site. Discharge to Cargo Beck would be at greenfield runoff rates.

Therefore, it would be possible to discharge surface water runoff from the Application Site into a watercourse. At this stage it is anticipated that the surface water from the Application Site will be discharged into Cargo Beck at greenfield runoff rates. This option should be explored further.

5.3.3 Sewer

In the event that discharge of surface water via infiltration or discharge to a watercourse is deemed unsuitable, then discharge to the public sewer may be possible. All surface water runoff that cannot be discharged via infiltration or to a watercourse will be managed on site and then discharged to a surface water sewer or combined sewer. Discharge to the sewers would be at greenfield runoff rates.

If required, it should be confirmed with United Utilities if they have the capacity to accept any discharge of surface water from the Application Site. If so, it may be possible to discharge to the public sewers, at a point adjacent to the Application Site. If required, this option should be explored further.

5.4 SUDS and Water Quality

Current guidance promotes sustainable water management through the use of SUDS. SUDS measures should be used to control the surface water runoff from the Application Site therefore, managing the flood risk to the Application Site and surrounding areas from surface water runoff.

One of the aims of the NPPF is to provide not only flood risk mitigation but also to maximise additional gains such as improvements in runoff quality and provision of amenity and bio-diversity. Systems incorporating these features are often termed SUDS and it is the requirement of NPPF that these are considered as the primary means of collection, control and disposal for storm water as close to source as possible.

A hierarchy of techniques is identified[5]:

1. Prevention – the use of good site design and housekeeping measures on individual sites to prevent runoff and pollution (e.g. minimise areas of hard standing).
2. Source Control – control of runoff at or very near its source (such as the use of rainwater harvesting, permeable paving, soakaways and/or green roofs).
3. Site Control – management of water from several sub-catchments (including routing water from roofs and car parks to one/several large soakaways for the whole site, swales and/or infiltration trenches).
4. Regional Control – management of runoff from several sites, typically in a detention pond, basins, tanks and/or wetland.

It is generally accepted that the implementation of SUDS as opposed to conventional drainage systems, provides several benefits by:

- reducing peak flows to watercourses or sewers and potentially reducing the risk of flooding downstream;
- reducing the volumes and frequency of water flowing directly to watercourses or sewers from developed sites;
- improving water quality over conventional surface water sewers by removing pollutants from diffuse pollutant sources;
- reducing potable water demand through rainwater harvesting;
- improving amenity through the provision of public open spaces and wildlife habitat; and
- replicating natural drainage patterns, including the recharge of groundwater so that base flows are maintained.

The most appropriate attenuation system will need to satisfy three main characteristics, firstly, provide the required volume of storage, secondly, minimise the loss of developable land and thirdly, where possible provide local amenity.

The application of the SUDS Manual requires that the runoff from sites is not only restricted to meet the Greenfield runoff characteristics but also that SUDS systems are utilised to improve the quality of the runoff prior to outfall to watercourses.

The SUDS Manual and Environment Agency guidance applies a sustainability hierarchy to the various types of SUDS systems, this is summarised in Table 5-1.

[5] CIRIA (2004) Report C609, Sustainable Drainage Systems – Hydraulic, Structural and Water Quality advice.

Table 5-1 Sustainability Hierarchy

Most Sustainable	SUDS Technique	Flood Reduction	Pollution Reduction	Landscape & Wildlife
	Living Roofs	✓	✓	✓
↑	**Basins and ponds** - Constructed wetlands - Balancing ponds - Detention basins - Retention ponds	✓	✓	✓
	Filter strips and swales	✓	✓	✓
	Infiltration Devices - soakaways	✓	✓	✓
↓	**Permeable Surfaces and Filter Drains** - Gravelled areas - Solid paving blocks - Permeable paving	✓	✓	
Least Sustainable	**Tanked systems** - Over-sized pipes/tanks - Cellular storage	✓		

Systems at the top of the hierarchy provide a combination of attenuation, treatment and ecology and are deemed the most sustainable options. There are always specific scenarios where systems are more suitable than others and at this stage it is not possible to guide the development towards a particular strategy.

In addition to the above hierarchy the SUDS Manual (Table 5.6) identifies the number of treatment trains or SUDS devices through which flow should pass from various point sources of runoff (see Table 5-4). This is designed to ensure that the receiving environments are not put at risk of pollution by new development.

The usual approach is to consider the 'SUDS train' where each of the above options are considered in turn until a suitable solution is found. Thus source control techniques such as soakaways, rainwater harvesting and/or infiltration trenches, if suitable on a site, are considered preferable to permeable conveyance and passive treatment systems such as tanks or ponds. The various options are considered in outline below.

This volume of attenuation storage could be provided by a variety of means these methods are discussed below.

Table 5-4 Number of Treatment Train Components

Runoff Catchment Characteristic	Receiving Watercourse Sensitivity		
	Low	**Medium**	**High**
Roof only	1	1	1
Residential roads Parking areas Commercial zones	2	2	3
Refuse collection Industrial areas Loading bays Lorry parks Highways	3	3	4

5.4.1 Source Control

(i) Soakaways

Soakaways are buried rings or tanks filled with rubble or stone and allow gradual infiltration of collected runoff from impermeable areas into the surrounding soil. They require relatively permeable strata below a site to allow percolation and the reduction in runoff is achieved by the volume of percolation and the available storage volume. An assessment of their suitability requires the characteristics of the sub-soils or the geology to confirm the infiltration rate or vertical permeability.

The Application Site is unsuitable for soakaway drainage; only limited amounts of infiltration drainage would be possible. Therefore, SUDS methods such as soakaways may not provide an adequate means of surface water discharge for the Application Site (see Section 3.10).

(ii) Permeable Paving

The use of permeable paving can often be considered for pedestrian or car parking areas but not for heavy traffic areas such as roadways where the heavy loading could damage the paving infrastructure. Permeable paving also depends on having permeable underlying strata. The permeable paving can either discharge via infiltration or discharge to cellular storage.

Permeable paving will provide storage for the first 5mm (interception storage) as a minimum. It is should be noted that any permeable paving system to be installed by a developer must have an infiltration rate of at least 30mm/hr (0.03m/hr) to avoid ponding on the surface before it reaches the natural soil (permeable paving systems generally would have an infiltration rate in excess of 30mm/hr).

These systems also encourage biological treatment of flow and extraction of oils and heavy metals from the run-off. Land take is reduced as storage is located under car parks and access roads. However, maintenance is potentially a long term issue and the possibility of the paving being damaged, dug up and not properly reinstated or not regularly swept could lead to compromising the future capacity of the system.

This system will negate the need for a separate collection system such as kerbs and gullies. It will also assist in reducing the flood profile of the Application Site by significantly attenuating the run-off from the development within the sub base material.

There is no specific amenity provided by the system other than enabling other areas to be utilised for development rather than potentially sterilizing areas with an easement for a sewer or stand-off for a basin.

The Application Site is unsuitable for soakaway drainage; only limited amounts of infiltration drainage would be possible. Therefore, SUDS methods such as permeable paving may not provide an adequate means of surface water discharge for the Application Site (see Section 3.10).

(iii) Rainwater Harvesting

The reuse of water from roofed areas to provide grey (non-potable) water for flushing WCs within buildings can reduce storm runoff without the need for treatment or oil separators since the risk of spillage or contamination is low. Such a facility could be practical depending on the available water volumes. Over the course of a year a grey water system will reduce the volume of water entering the storm water disposal system and could be considered.

Such a system would require one or more tanks at roof level and under optimum conditions these would be kept as near as full as possible to ensure a reliable water supply. For the purposes of a worst case design scenario it is assumed that the tanks would be full at the start of an extreme rainfall event and hence all storm rainfall would enter the surface water drainage system rather than grey water storage. Whilst there may be merit in including such a scheme in the overall designs these are not considered appropriate in the SUDS assessment.

(iv) Green Roofs

A green roof is a multi-layered system that covers the top of a building with soil and vegetation and which can provide a degree of rain storm attenuation and a reduction in site runoff. These can either be extensive roofs which are low maintenance with a 25-125mm soil layer in which a variety of hardy drought tolerant low plants are grown, or intensive roofs with trees and planters which impose a greater load on the roof structure but are more suitable in certain circumstances. Green roofs can be used to reduce the volume and rate of runoff so that other SUDS techniques in the scheme can be significantly reduced in size. This is not a practical option and is therefore not considered further.

5.4.2 Site Control - Permeable Conveyance Systems

Permeable conveyance systems can take the form of infiltration trenches, swales or filter strips at road margins where surface runoff from roads, car parking areas and also roof drainage can be directed. Used to collect water directly from linear systems, percolate the flow, attenuate and then discharge the flow to either a traditional system or a secondary SUDS device.

The use of these systems is more suited to linear applications such as roads as the typical cross section is relatively small and longer runs are required to provide attenuation volume. Land take can be relatively small in comparison to other systems and both types perform well in improving water quality. They are also ideally suited for disposal of water via secondary infiltration.

It is likely that these features could be utilised as the first treatment train and as part of the site collection and conveyance system.

(i) Infiltration Trench/Swales/Filter Strips/French Drains

These are essentially linear soakaways which allows water to infiltrate into the soils as it is transported to a disposal point. Infiltration techniques such as infiltration trenched/swales/filter strips/french drains may provide a suitable option at the Application Site.

5.4.3 Passive Treatment Systems

Where ground conditions prevent the use of infiltration, such as on ground that may be impermeable or contaminated, SUDS methods that are designed not to infiltrate can be considered. Passive treatment systems can include a pond, wetland, tank or a basin on the lower parts of a site. These will reduce peak flows, but not the volume of runoff, and slow down flows before disposal to a surface water drainage system. These may provide a suitable SUDS solution for the Application Site and options are therefore considered in outline below.

(i) Ponds/Basins and Lagoons

The nature of these systems is such that the runoff from the development can be treated by biological action and stilling to significantly improve the quality of water discharged from the system.

They also provide large areas of open space that can be developed for recreational uses or as new habitats for wildlife. Both systems do, however, take up significant amounts of developable land and have residual maintenance and liability issues attached to their implementation.

A pond/lagoon located in the north east of the Application Site will be used to attenuate the surface water runoff from the Application Site (see Appendix 1). Discharge from the pond/lagoon will be to Cargo Beck at greenfield runoff rates.

(ii) Storage Tanks

Hard engineered tank storage systems have traditionally been used for attenuation structures for the past decade and are often specified where large volumes of storage are required (>200m^3) and available space is an issue. These could be located underneath the roads and paved areas.

These systems have no inherent water treatment properties bar potential sedimentation of the attenuated flow and offer no additional amenity benefits. In some cases, the easement to the tank or culvert is such that a significant portion of land area is sterilized from development and certain planting.

There are also significant costs associated with these systems in production, transportation and installation. However, once installed the long term maintenance of the system is relatively low. With a proven record of successful installation, tanks and culverts are regularly adopted by water authorities across the country, albeit with a large associated easement that will sterilise that portion of the Application Site.

It has been concluded that storage tanks will work at the Application Site and can be used to attenuate the surface water runoff.

(iii) Oversized Drainage Network

A further option on storage and attenuation would be the use of an oversized drainage network designed to act as inline storage, rather than a tank or pond, to provide the required storage volume underground. These could be located underneath the roads and paved areas.

As the diameter of larger pipes readily available is limited the applicability of these types of systems is more suited to <200m^3 of attenuation. Above this volume the length of pipe required is excessive and difficult to suitably fit into a normal site layout.

There is no intrinsic amenity provided by the use of this system neither is there any specific level of run-off treatment over and above that of a standard pipe and gully system. However, due to their traditional nature, the adoption of these types of systems by water authorities is straightforward and does not require any specialist input. The pipes are generally available direct from suppliers with little or no lead in time and the satisfactory long term performance of these systems is well documented.

This option could be used in combination with other SUDS elements to provide the required storage volume. It has been concluded that oversized drainage networks will work at the Application Site and can be used to attenuate the surface water runoff.

(iv) Cellular Storage

Large volumes of storage can be provided under grassed and lightly trafficked areas by using proprietary plastic cellular systems. This will maximise the developable area of the Application Site. These could be located underneath the roads and paved areas. There is no specific mechanism within the system designed to treat flow but extended detention times will allow sedimentation reducing the suspended solids within the discharge.

There is no creation of amenity by the installation of these types of systems, indeed by maintaining access to the system small areas may need to be reserved. If the developable footprint is tight then these systems may be advantageous however to ensure adoptability it is recommended that the use of these systems is discussed with the adopting authority as they are not always preferred.

There would be room to install cellular storage under the drive way areas to provide the storage volume required. This will require the new drainage network to divert flow from the impermeable buildings and parking areas to this cellular storage facility. This could also be drained via permeable pavement surfaces.

It has been concluded that cellular storage will work at the Application Site and can be used to attenuate the surface water runoff.

(v) Surface Storage

The use of roads, public areas and even landscaped areas as additional storage is becoming a widely accepted form of attenuation.

Water spilling from drainage systems can be collected via roads and kerbs and channelled to lower lying areas where it would be stored until the capacity in the existing system returns. These systems have the advantage of requiring little additional infrastructure merely detailing of the proposed roads and grassed areas.

As these systems will only be used in extreme events when the adopted drainage system is exceeded (>1 in 30 years), they provide a very efficient way of catering for these events rather than providing permanent capacity.

There is no inherent water treatment capability in this system or any particular increase in amenity; however, the costs associated with this provision are relatively small. It is recommended that these systems are only used in emergency circumstances (e.g. for events greater than the 1 in 30 year event).

5.5 Site Storage Volumes

The provision of suitable storage on site to mitigate the flood risk resulting from the development of the Application Site will be a key factor in the evolution of the site development layout. The provision of large volumes of attenuation can be achieved by a number of methods; however, not all systems can be assessed in direct comparison.

One of the aims of the NPPF is to provide not only flood risk mitigation but also to maximise additional gains such as improvements in runoff quality and provision of amenity and bio-diversity. Systems incorporating these features are often termed SUDS and it is the requirement of the NPPF that these are considered as the primary means of collection, control and disposal for storm water as close to source as possible.

The principle applied in the design of storage is to limit the discharge rate of surface water runoff from the developed site for events of similar frequency of occurrence to the same peak rate of runoff as that which takes place from a greenfield site prior to development. QBAR (rural) has been calculated to be 23.27l/s.

Due to the sensitive nature of Cargo Beck and the River Eden an allowance of 40% for climate change has been provided for within the calculations. Table 5-5 shows the volume of storage required for the Proposal estimated using the Masterdrain Drainage Software using the FEH catchment descriptors with a winter profile for the 1 in 100 year event with a 40% allowance for climate change (increase in peak rainfall) assuming the proposed 21,616m^2 of impermeable area with 23.27l/s used as the limiting discharge rate (see Appendix 8). A storage volume of 1,195m^3 is required.

It is proposed that the impermeable areas of the Application Site will be discharged to passive treatment systems/attenuation storage which will entail a pond/lagoon located to the north east of the Application Site before discharge to the Cargo Beck at a restricted runoff rate of 23.27l/s . The discharge level will also be set to ensure that a free capacity of 1,195m^3 is always maintained in case of excess rainfall. The discharge mechanism will always be set below a maximum discharge rate of 23.27l/s, to adhere to the greenfield runoff rate or QBAR (rural).

Table 5-5 Storage Volumes

Return Period (years)	Limiting Discharge Rate (l/s)	Volume (m^3)
100 +40%	23.27	1,195

5.6 SUDS Strategy

The objective of this SUDS Strategy is to ensure that a sustainable drainage solution can be achieved which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the Application Site. The SUDS Strategy takes into account the following principles:

- No increase in the volume or runoff rate of surface water runoff from the site.
- No increase in flooding to people or property off-site as a result of the development.
- No surface water flooding of the site.
- The proposals take into account a 40% increase in rainfall intensity due to climate change.

In line with adopting a 'management train' it is recommended that water is managed as close to source as possible. This will reduce the size and cost of infrastructure further downstream and also shares the maintenance burden more equitably. It is therefore recommended that the site provides its own attenuation. This will be in the form of:

- Settlement of solids will be promoted by the SUDS measures, by using a pond/lagoon.
- For larger events storage in other areas such as landscaping, provided that it will not cause damage or prevent access.
- Where required correctly sized oil interceptors/separators will be installed before discharge to the pond/lagoon.

For all development, a hierarchical approach to surface water management is promoted (see Section 5.2). This approach has been adopted within this SUS Strategy. Infiltration will not be possible therefore, surface water runoff from the Application Site will be discharged to Cargo Beck at the QBAR runoff rate after attenuation within a pond/lagoon.

The size of the pond/lagoon has been calculated such that the Proposal has the capacity to accommodate the 1 in 100 year rainfall event including a 40% increase in rainfall intensity that is predicted to occur as a result of climate change. Consequently, all areas drained have been designed to accommodate a 100 year (+40% climate change) storm event.

The remainder of the Application Site that is not formally drained, i.e. landscaped areas, will be permeable (grass). The majority of rainwater falling on these areas will soak into the ground. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

The design of the system will allow any silt and debris from the development an opportunity to settle. Vegetation within the pond/lagoon will naturally filter potentially suspended solids contained in the surface water runoff from any hardstanding.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for the Application Site. These preliminary considerations are based on the outline development scheme provided and hence the design purposes.

The adoption of a SUDS Strategy for the Application Site represents an enhancement from the current conditions as the current surface water runoff from the Application Site is uncontrolled, untreated, unmanaged and unmitigated.

Where SUDS are to be used it must be established that these options are feasible, can be adopted and properly maintained and would not lead to any other environmental problems with a maintenance schedule or the lifetime of the facility and these issues should be considered at the detailed design stage.

In adopting these principles, it has been demonstrated that a scheme can be developed that does not increase the risk of flooding to adjacent properties and development further downstream.

5.7 Designing for Local Drainage System Failure/Design Exceedance

When considering residual risk, it is necessary to make predictions as to the impacts of a storm event that exceeds the design event, or the impact of a failure of the local drainage system. The SUDS Strategy applies a safe and sustainable approach to discharging rainfall runoff from the Application Site and this reduces the risk of flooding however, it Is not possible to completely remove the risk. This section of the FRA is therefore associated with the way the residual risk is managed.

As part of the SUDS Strategy it must be demonstrated that the flooding of property would not occur in the event of local drainage system failure and/or design exceedance. It is not economically viable or sustainable to build a drainage system that can accommodate the most extreme events. Consequently, the capacity of the drainage system may be exceeded on rare occasions, with excess water flowing above ground[6].

The attenuation requirements have been designed to accommodate the 1 in 100 year storm event plus climate change (+40%). The design of the site layout provides an opportunity to manage this local drainage system failure/exceedance flow and ensure that indiscriminate flooding of property does not occur.

There will not be an extensive sewerage network on the Application Site and therefore any potential exceedance flooding would be from the sewers located within the vicinity of the Application Site. Exceedance flows would be contained within the highways.

In particular, the landscaped areas will include preferential flow paths that convey water away from buildings. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

When considering the impacts of a storm event that exceeds the 1 in 100 year (+ 40%) event, there is safety factor for passive treatment systems/attenuation storage (e.g. basin/ponds/lagoons,), even under the design event conditions. Consequently, if this event were to be exceeded there is additional capacity with the system to accommodate this. If this freeboard was to be exceeded the consequences would be similar, if not less than for the local drainage system failure. The pipework and manholes will provide additional water storage and provide betterment. Consequently, the impact of an exceedance event is not considered to represent any significant flood hazard.

The above manages and mitigates the flood risk from surface water runoff to the proposed buildings from surface water runoff generated by the site development and to offsite locations as well the risk from surface water runoff generated offsite.

[6] CIRIA (2006) Designing for exceedance in urban drainage – good practice.

5.5 Off-Site Impacts

The proposed SUDS Strategy is designed to attenuate surface water runoff to the QBAR rural runoff rate for all events up to and including the 1 in 100 year (40%) event.

Surface water runoff will discharge through a pond/lagoon. The design of the system will allow any silt and debris from the development an opportunity to settle. Vegetation within the attenuation drainage ditch will naturally filter potentially suspended solids contained in the surface water runoff from any hardstanding.

Surface water runoff from all hard surfaces will receive an appropriate level of treatment in accordance with the SUDS Manual which will minimise the risk of pollution to the River Eden SSSI, River Eden SAC and off site locations. The surface water runoff will be directed to the north east of the Application Site and impact on the stability of the West Coast Main Railway Line or RAF MU14 landfill site (Site 8E – Glory Hole).

This restriction in surface water runoff will also provide significant flood mitigation benefits to existing third party property and land downstream of the Application Site that may be potentially at risk from flooding.

6 Risk Management

6.1 Introduction

The flood risk at this location is considered suitable for 'less vulnerable' developments within the NPPF. In this flood zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout, form of the development and the use of flood mitigation measures including SUDS techniques.

The flooding sources have been mitigated on the Application Site by using a number of techniques, and mitigation strategies to manage and reduce the overall flood risk at the Application Site. This will ensure the development will be safe and there is:

- Minimal risk to life;
- Minimal disruption to people living and working in the area;
- Minimal potential damage to property;
- Minimal impact of the Proposal on flood risk generally; and;
- Minimal disruption to natural heritage.

The flood risk at the Application Site will be reduced by property level protection measures these are discussed in more detail below.

6.2 Minimum Floor Level

There is no minimum finished floor level proposed as a result of flooding. However, it is recommended that all buildings are located above the back of footway of the adjacent carriageway by 150mm to enable the full capacity of any secondary flood conveyance to be utilised.

6.3 Buffer Strip

A buffer strip adjacent to the top of Cargo Beck will be maintained for maintenance purposes. This will be free of buildings and permanent structures as per the terms of The Environmental Permitting (England and Wales) (Amendment) (No.2) Regulations 2016 and the Flood risk activities set out in Paragraph 3 Part 1 of Schedule 23ZA, the prior written consent of the Environment Agency may be required for any works in, over, under or within 8m of the 'main river', or 16m if tidal or within 8 metres of a flood defence structure/ culvert, 16m if tidal.

The buffer strip will also mitigate the impact of flooding from this source should the Cargo Beck overtop its banks.

6.4 Flood Resilience and Resistance

The development of the layout should always consider that the Application Site is potentially at risk from an extreme event and as such the implementation of flood resilience and resistance methods should be assessed.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from buildings can be easily and economically incorporated into the development of the Application Site.

6.5 Access and Egress

The Application Site and surrounding area is located within Flood Zone 1 therefore a permanently safe and dry access can be maintained.

6.6 SUDS Strategy

The surface water runoff produced by the Application Site during a rainfall event is restricted which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the Application Site (see Section 5.0).

6.7 Designing for Local Drainage System Failure

The landscaped areas will include preferential flow paths that convey water away from buildings. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

There will not be an extensive sewerage network on the Application Site and therefore any potential exceedance flooding would be from the public sewers located within the vicinity of the Application Site. An exceedance or blockage event of the sewers would not affect the proposed property because finished floor levels will be above surrounding ground levels, ensuring any exceedance flooding would not affect the building. Exceedance flows would be contained within the highways surrounding the buildings.

6.8 Flooding Consequences

The mitigation measures detailed above show that the flood risk can be effectively managed and therefore the consequences of flooding are acceptable.

In conclusion, the flood risk to the Application Site can be considered to be limited; the Application Site is situated in Flood Zone 1, with a low annual probability of flooding and from all sources. The Application Site is unlikely to flood except in very extreme conditions.

7 Sequential Approach

7.1 Sequential Test

The risk-based Sequential Test in accordance with the NPPF aims to steer new development to areas at the lowest probability of flooding (i.e. Flood Zone 1).

The Application Site is located within Flood Zone 1 with a 'low probability' of flooding, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%). Therefore, the Sequential Test will not need to be undertaken as part of this planning application.

7.2 Exception Test

Applications located within Flood Zone 1 are not subject to the Exception Test as confirmed within Table 4-8 of this report and Table 3 of the Planning Practice Guidance to the NPPF.

8 Summary and Conclusions

8.1 Introduction

This report presents an FRA in accordance with the NPPF for the proposed Energy Recovery Facility development on Kingmoor Park, Carlisle, CA6 4SJ. The FRA includes an assessment of the existing and proposed surface water drainage of the Application Site.

8.2 Flood Risk

The Application Site is unlikely to flood except in extreme conditions. The primary, but unlikely, flood risk to the Application Site is from surface water (pluvial) flooding due to the direct rainfall onto the Application Site exceeding the infiltration capacity of the soils rather than overland flow from adjacent areas. It is understood that ponding occurs at the location of topographical lows on the Application Site. The Application Site has no other history of flooding.

Using a conservative estimate of water velocity of 0.00m/s and a maximum water depth of 0.50m any flooding would result in a ‘moderate’ flood hazard with a dangerous for some (i.e. children) - “danger: Flood zone with deep or fast flowing water”. Therefore, the risk of flooding from surface water flooding is considered to be of **low significance**.

A number of secondary flooding sources have been identified which may pose a **low significant** risk to the Application Site. These are:

- Fluvial Flooding
- Groundwater Flooding

The flooding sources will only inundate the Application Site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the Application Site.

The risk from fluvial sources will be further mitigated by using a number of risk management measures to manage and reduce the overall flood risk at the Application Site.

The Proposal is classified as ‘less vulnerable’, ‘less vulnerable’ uses are appropriate within Flood Zone 1 after the completion of a satisfactory FRA.

In conclusion, the development will be situated in Flood Zone 1, with a low annual probability of flooding and from all sources. The chance of flooding from all sources each year is low or not significant.

8.3 SUDS Strategy

The SUDS Strategy ensures that a sustainable drainage solution can be achieved which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the Application Site. The SUDS Strategy takes into account the following principles:

- No increase in the volume or runoff rate of surface water runoff from the site.

- No increase in flooding to people or property off-site as a result of the development.
- No surface water flooding of the site.
- The proposals take into account a 40% increase in rainfall intensity due to climate change.

In line with adopting a 'management train' it is recommended that water is managed as close to source as possible. This will reduce the size and cost of infrastructure further downstream and also shares the maintenance burden more equitably. It is therefore recommended that the Application Site provides its own attenuation. This will be in the form of:

- Settlement of solids will be promoted by the SUDS measures, by using a pond/lagoon.
- For larger events storage in other areas such as landscaping, provided that it will not cause damage or prevent access.
- Where required correctly sized oil interceptors/separators will be installed before discharge to the pond/lagoon.

For all development, a hierarchical approach to surface water management is promoted. This approach has been adopted within this SUDS Strategy. Infiltration will not be possible therefore, surface water runoff from the Application Site will be discharged to Cargo Beck at the QBAR runoff rate after attenuation within a pond/lagoon.

The size of the pond/lagoon has been calculated such that the Application Site has the capacity to accommodate the 1 in 100 year rainfall event including a 40% increase in rainfall intensity that is predicted to occur as a result of climate change. Consequently, all areas drained have been designed to accommodate a 100 year (+40% climate change) storm event.

The remainder of the Application Site that is not formally drained, i.e. landscaped areas, will be permeable (grass). The majority of rainwater falling on these areas will soak into the ground. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

Surface water runoff from all hard surfaces will receive an appropriate level of treatment in accordance with the SUDS Manual which will minimise the risk of pollution to the River Eden SSSI, River Eden SAC and off site locations. The surface water runoff will be directed to the north east of the Application Site and impact on the stability of the West Coast Main Railway Line or RAF MU14 landfill site (Site 8E – Glory Hole).

This restriction in surface water runoff will also provide significant flood mitigation benefits to existing third party property and land downstream of the Application Site that may be potentially at risk from flooding.

8.4 Risk Management

The flooding sources will be managed on the Application Site by using a number of mitigation strategies to manage and reduce the overall flood risk at the Application Site and will ensure the development will be safe. Measures used:

Minimum Floor Level: There is no minimum finished floor level proposed as a result of fluvial flooding; however, it is recommended that all buildings are located above the back of the footway of the adjacent carriageway by 150mm to enable the full capacity of any secondary flood conveyance to be utilised.

Buffer Strip: A buffer strip adjacent to the top of Cargo Beck will be maintained for maintenance purposes. This will be free of buildings and permanent structures as per the terms of The Environmental Permitting (England and Wales) (Amendment) (No.2) Regulations 2016 and the Flood risk activities set out in Paragraph 3 Part 1 of Schedule 23ZA, the prior written consent of the Environment Agency may be required for any works in, over, under or within 8m of the 'main river', or 16m if tidal or within 8 metres of a flood defence structure/ culvert, 16m if tidal.

The buffer strip will also mitigate the impact of flooding from this source should the Cargo Beck overtop its banks.

Flood Resilience and Resistance: The development of the layout should always consider that the Application Site is potentially at risk from an extreme event and as such the implementation of flood resilience and resistance methods should be assessed.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from buildings can be easily and economically incorporated into the development of the Application Site.

Access and Egress: The Application Site and surrounding area is located within Flood Zone 1 therefore a permanently safe and dry access can be maintained.

SUDS Strategy: The surface water runoff produced by the Application Site during a rainfall event is restricted which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the Application Site.

Designing for Local Drainage System Failure: The landscaped areas will include preferential flow paths that convey water away from buildings. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

There will not be an extensive sewerage network on the Application Site and therefore any potential exceedance flooding would be from the public sewers located within the vicinity of the Application Site. An exceedance or blockage event of the sewers would not affect the proposed property because finished floor levels will be above surrounding ground levels, ensuring any exceedance flooding would not affect the building. Exceedance flows would be contained within the highways surrounding the buildings.

8.5 Sequential Approach

The Sequential Test will not need to be undertaken as part of this planning application as the Application Site is located within Flood Zone 1. Applications located within Flood Zone 1 are not subject to the Exception Test.

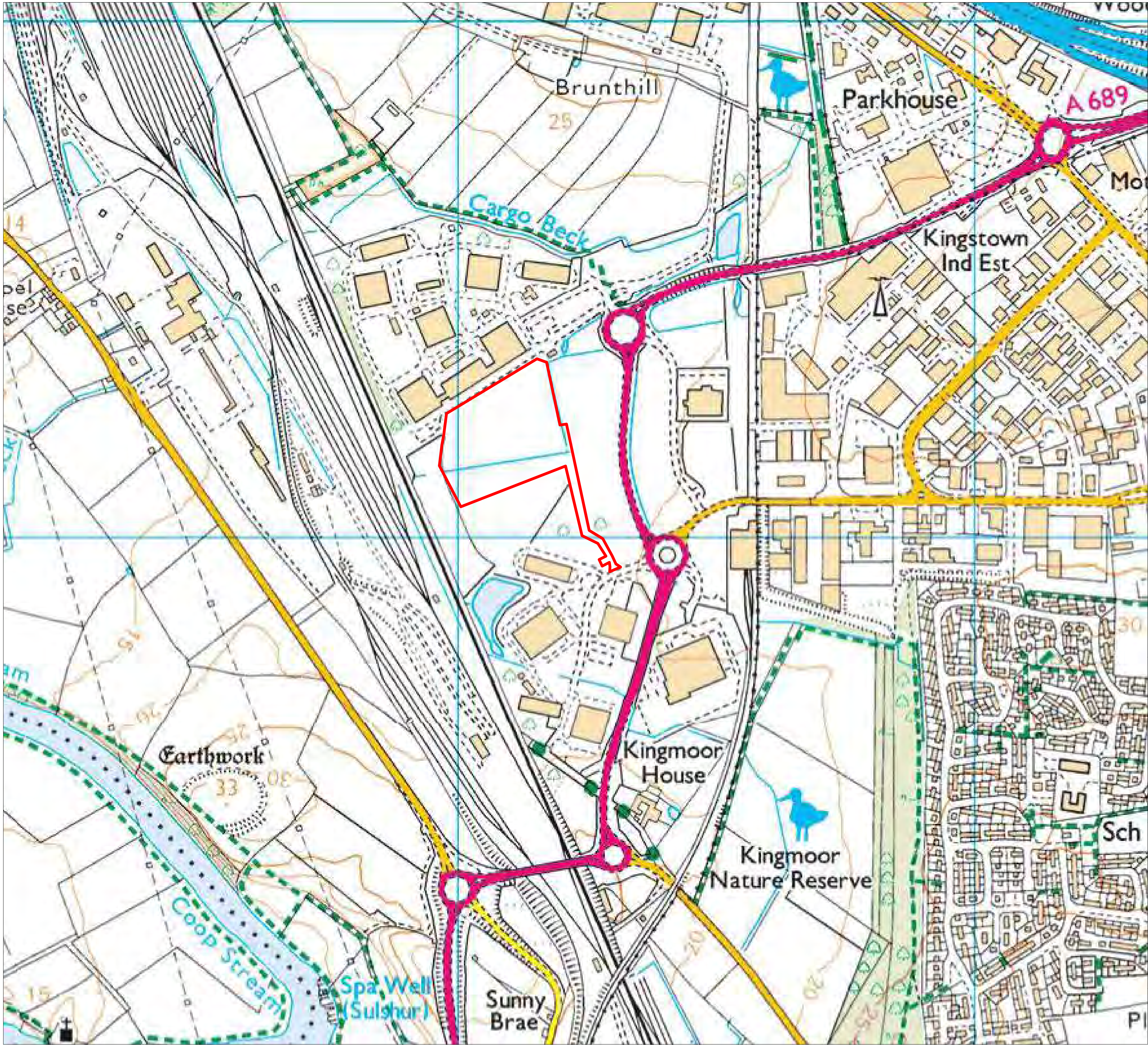
8.6 Conclusion

In conclusion, the Application Site will be situated in Flood Zone 1, with a low annual probability of flooding and from all sources. The chance of flooding from all sources each year is low.

This FRA demonstrates that the proposal would be operated with minimal risk from flooding, would not increase flood risk elsewhere and is compliant with the requirements of the NPPF.

The proposal should not therefore be precluded on the grounds of flood risk.

Drawings

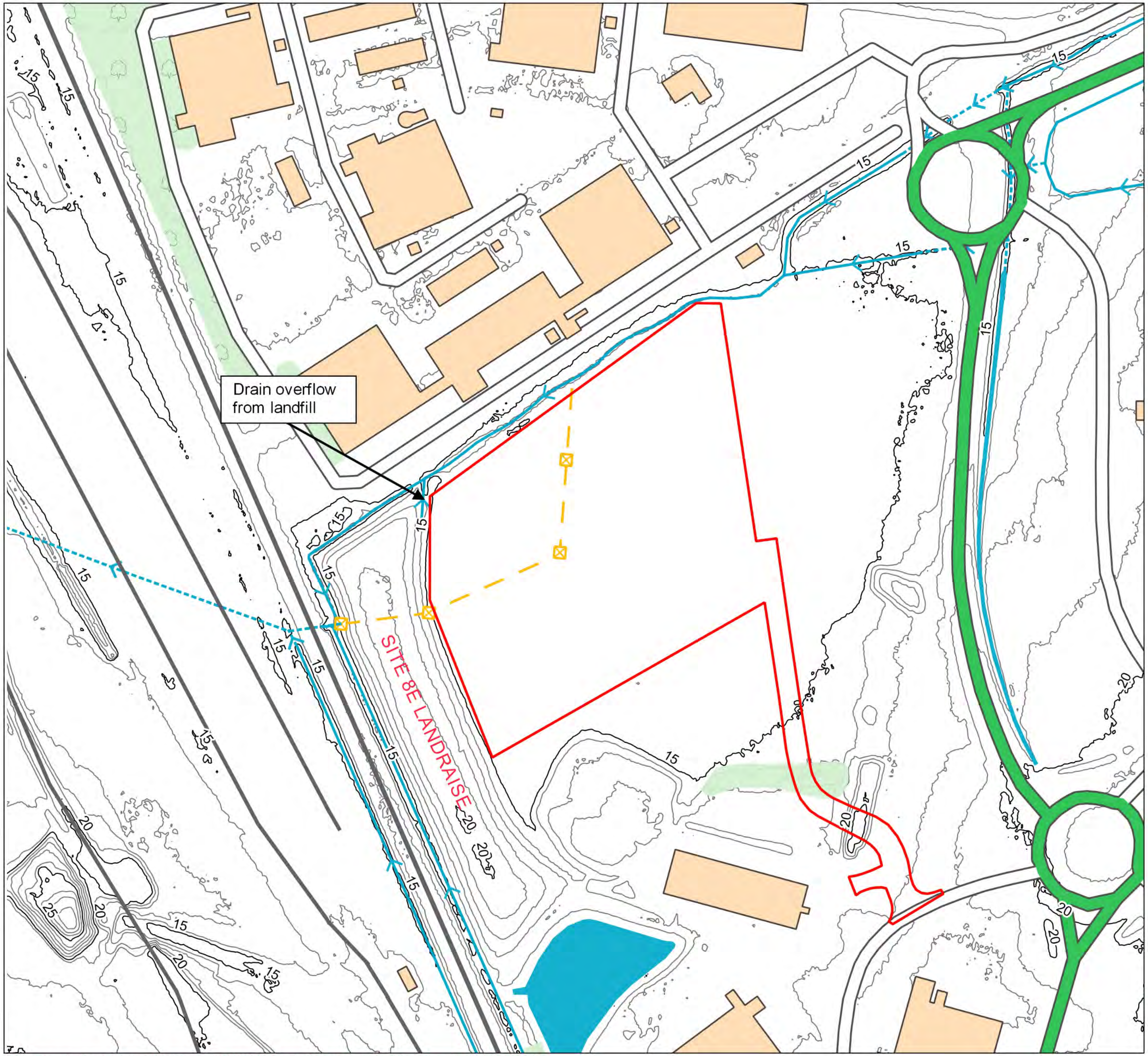


KEY

Site Boundary

HYDROGEO
Groundwater and Environment

PROJECT	Kingmoor Energy Recovery Facility
CLIENT	Verus Energy Boltzmann Limited
TITLE	Site Location
PROJECT REF	HYG259
DRAWING NO	1
SCALE	1:10,000@A3
DATE	May 2016



Verus Energy Boltzmann Limited

HYDROGEO Groundwater and Environment

STEPHENSON HALLIDAY

Kingmoor Energy Recovery Facility

DRAWING 2
Site Plan and Surface Water Features

KEY
Site Boundary (OLD)

WATER FEATURES

Watercourse

Culvert

DRAINAGE FEATURES

Inspection Chamber

Disused Pumping Station Outfall

TOPOGRAPHY

5m Contour Line

1m Contour Line

50 0 50 m

NORTH

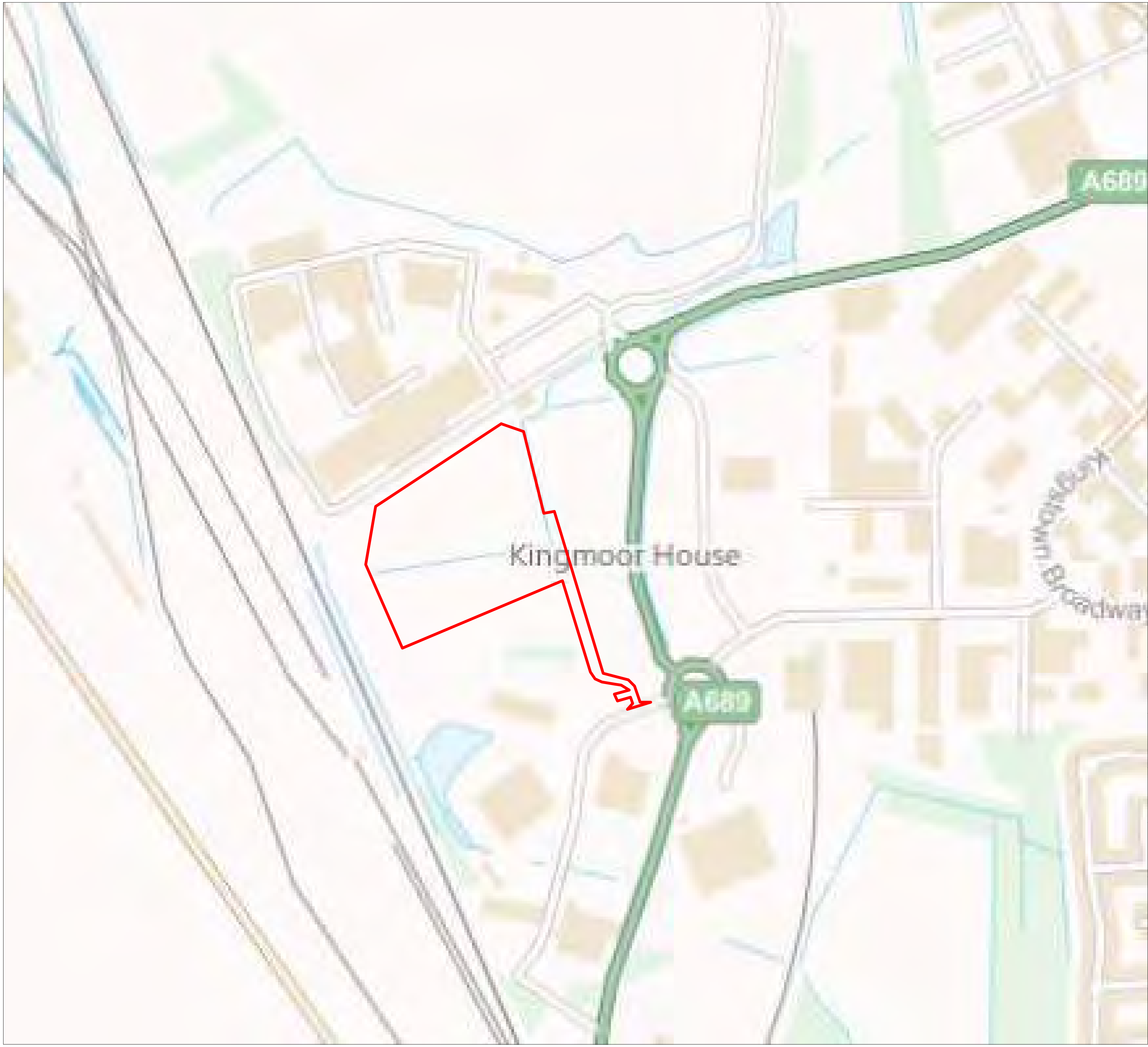
DATE	BY	PAPER	SCALE	QA	REV
03 2016	PM	A3	1:2,500	YY	1

KEY

- Site Boundary
- Very Low
- Low
- Medium
- High

HYDROGEO
Groundwater and Environment

PROJECT	Kingmoor Energy Recovery Facility
CLIENT	Verus Energy Boltzmann Limited
TITLE	Environment Agency Surface Water Flood Map
PROJECT REF	HYG259
DRAWING NO	3
SCALE	NTS@A3
DATE	May 2016



KEY

Site Boundary

Reservoir Flood Outline

HYDROGEO
Groundwater and Environment

PROJECT
Kingmoor Energy Recovery Facility

CLIENT
Verus Energy Boltzmann Limited

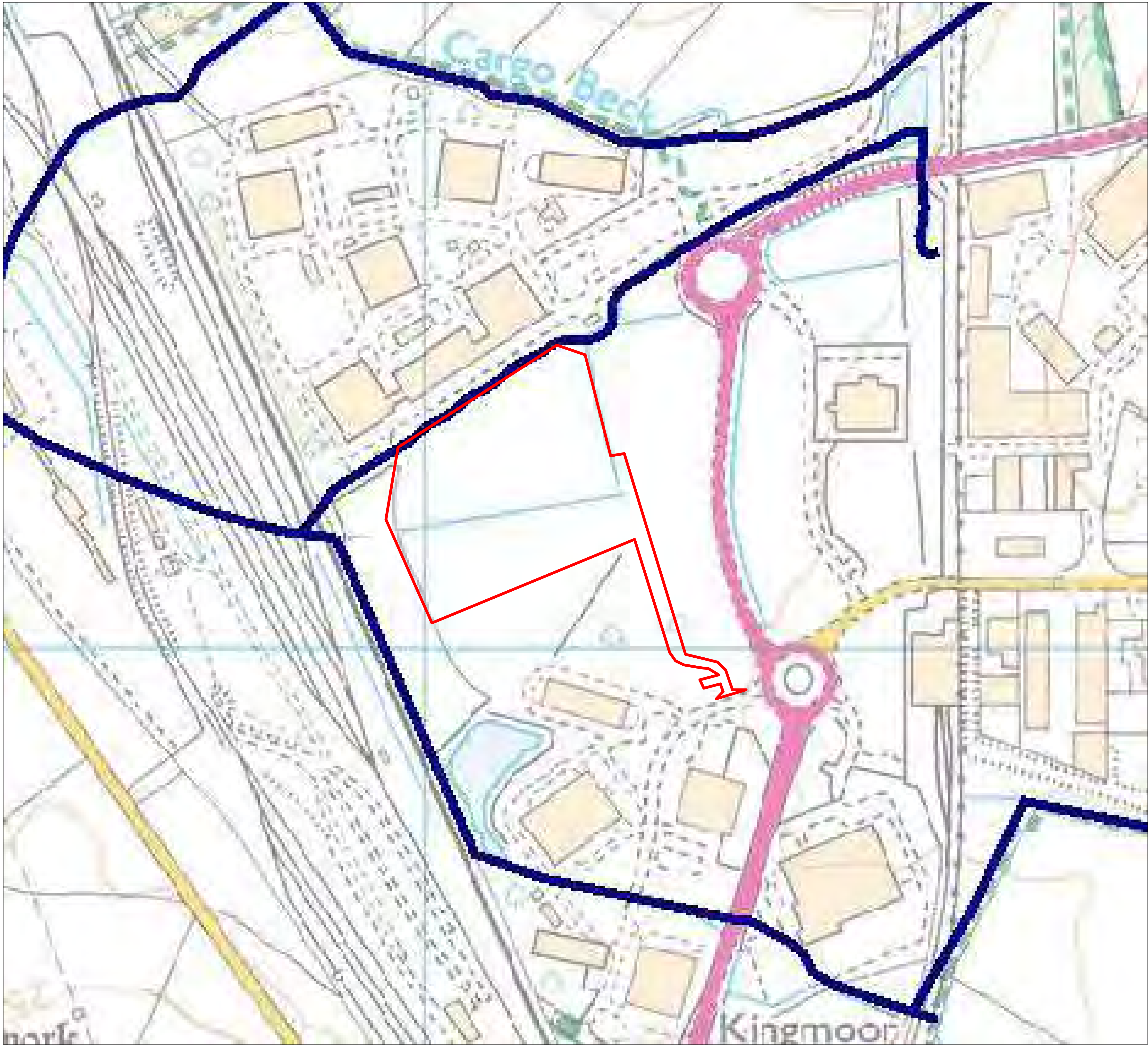
TITLE
Environment Agency Reservoir Flood Map

PROJECT REF
HYG259

DRAWING NO
4

SCALE
NTS@A3

DATE
May 2016



KEY

- Site Boundary
- Flood Zone 3
- Flood Zone 2
- Flood Zone 1

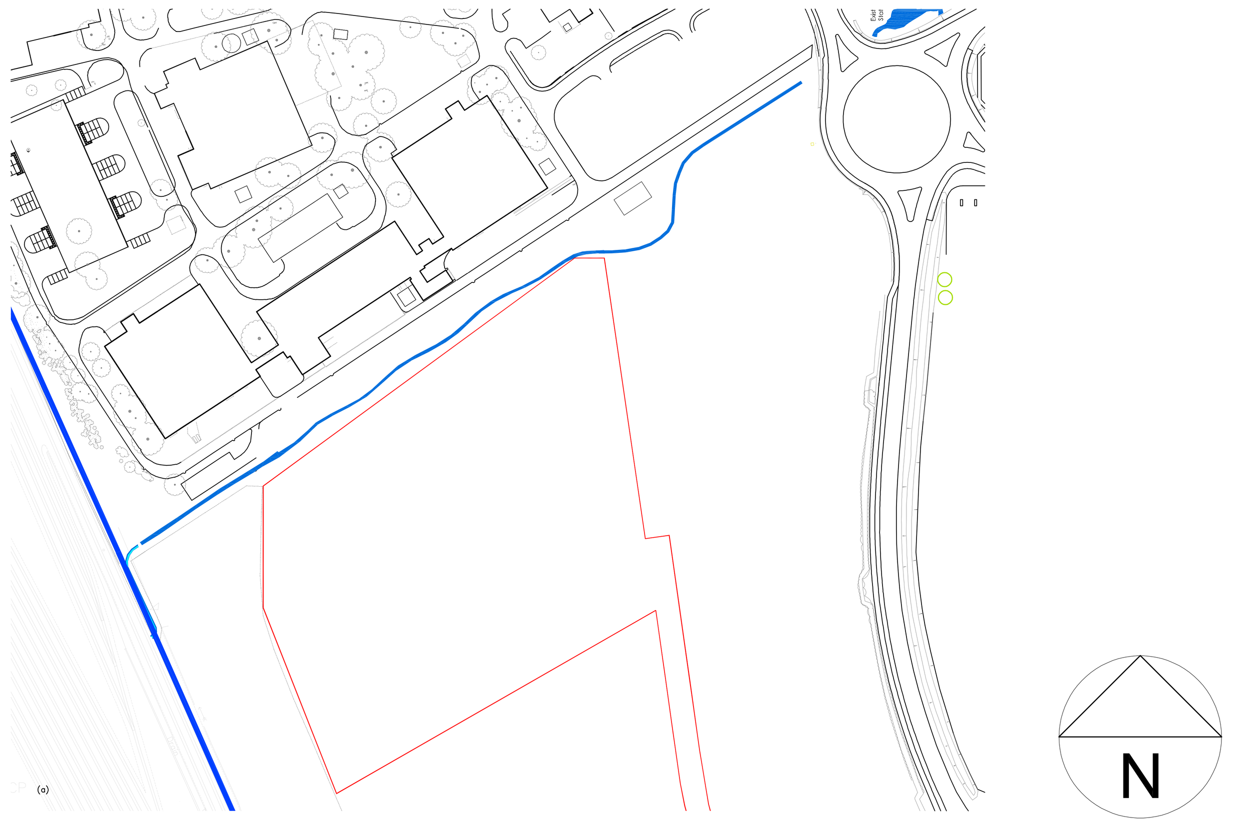
HYDROGEO
Groundwater and Environment

PROJECT	Kingmoor Energy Recovery Facility
CLIENT	Verus Energy Boltzmann Limited
TITLE	Environment Agency Flood Zones
PROJECT REF	HYG259
DRAWING NO	5
SCALE	NTS@A3
DATE	May 2016

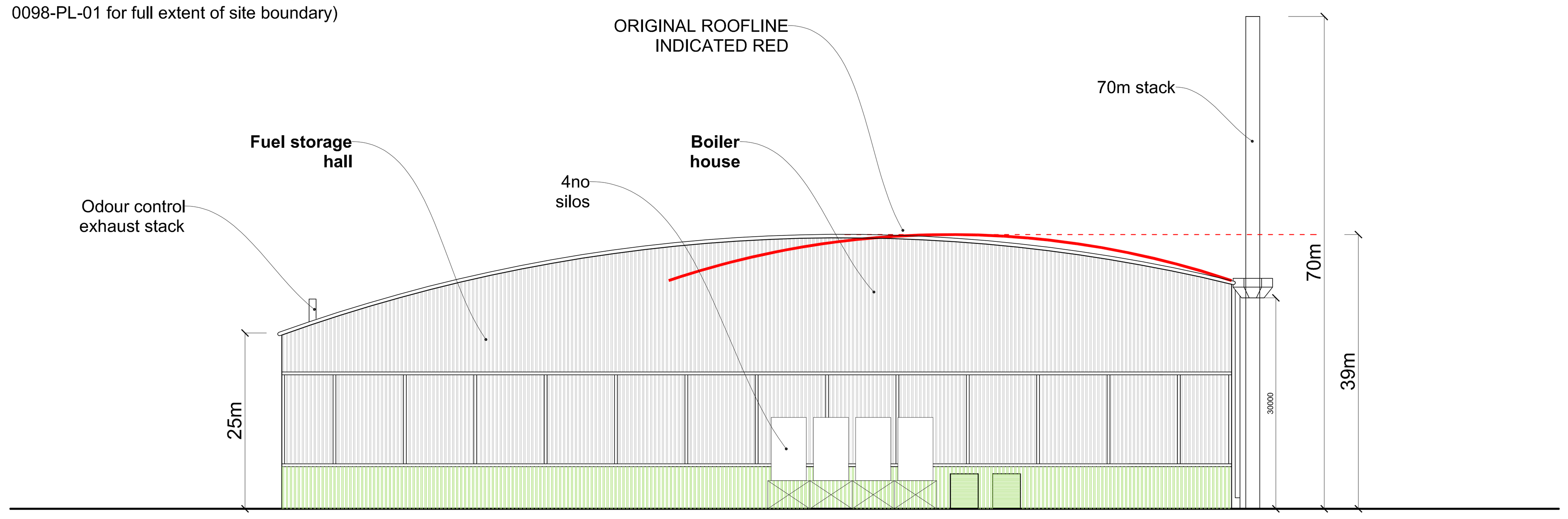
Appendices

Appendix 1

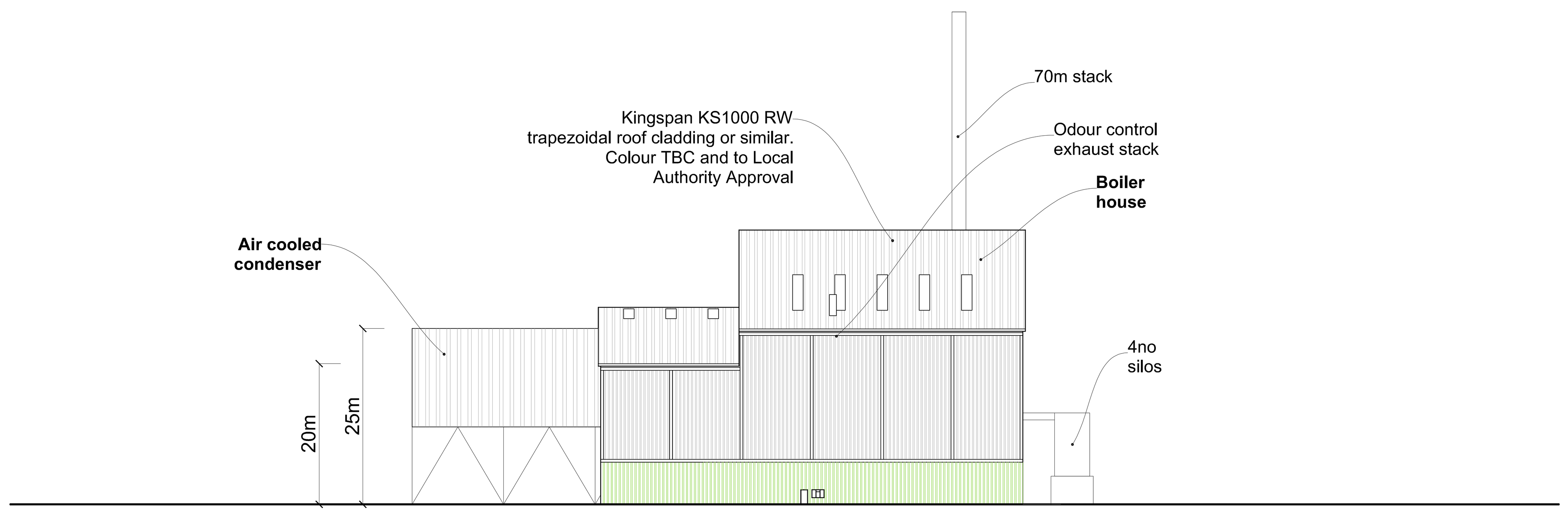
Proposed Site Layout



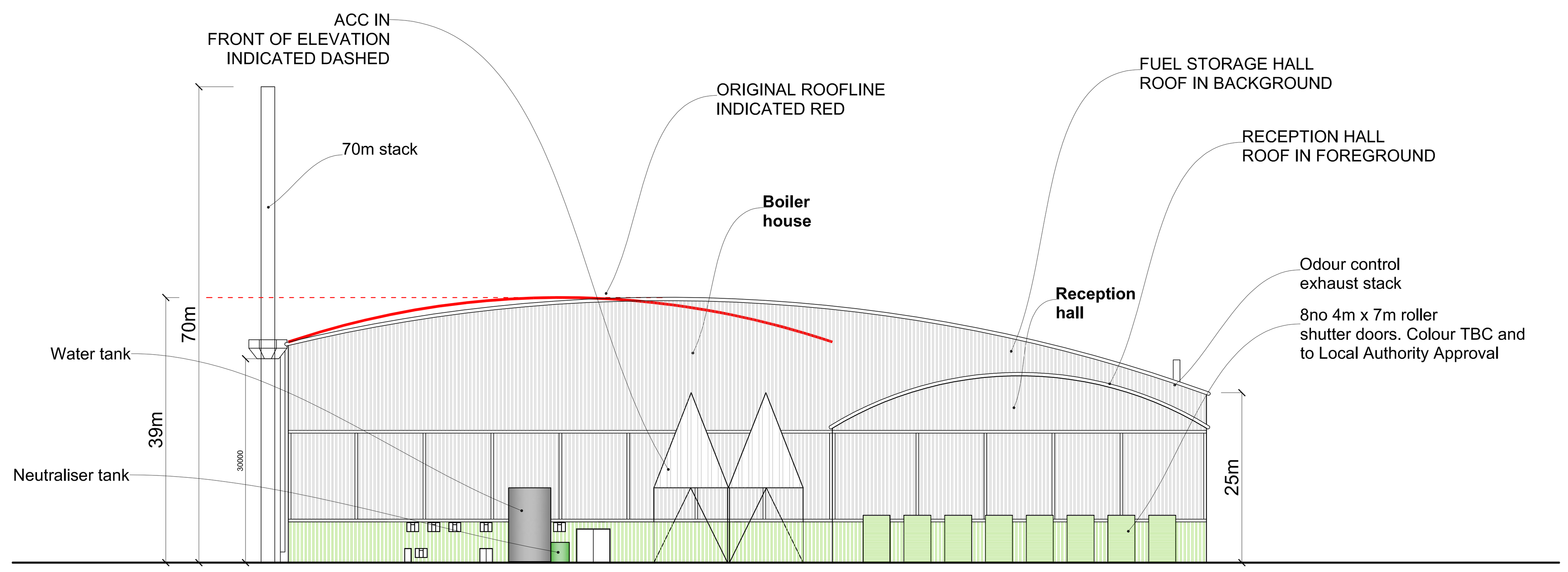
EXISTING Location Plan 1:2500
(See proposed Location Plan drawing ref: 0098-PL-01 for full extent of site boundary)



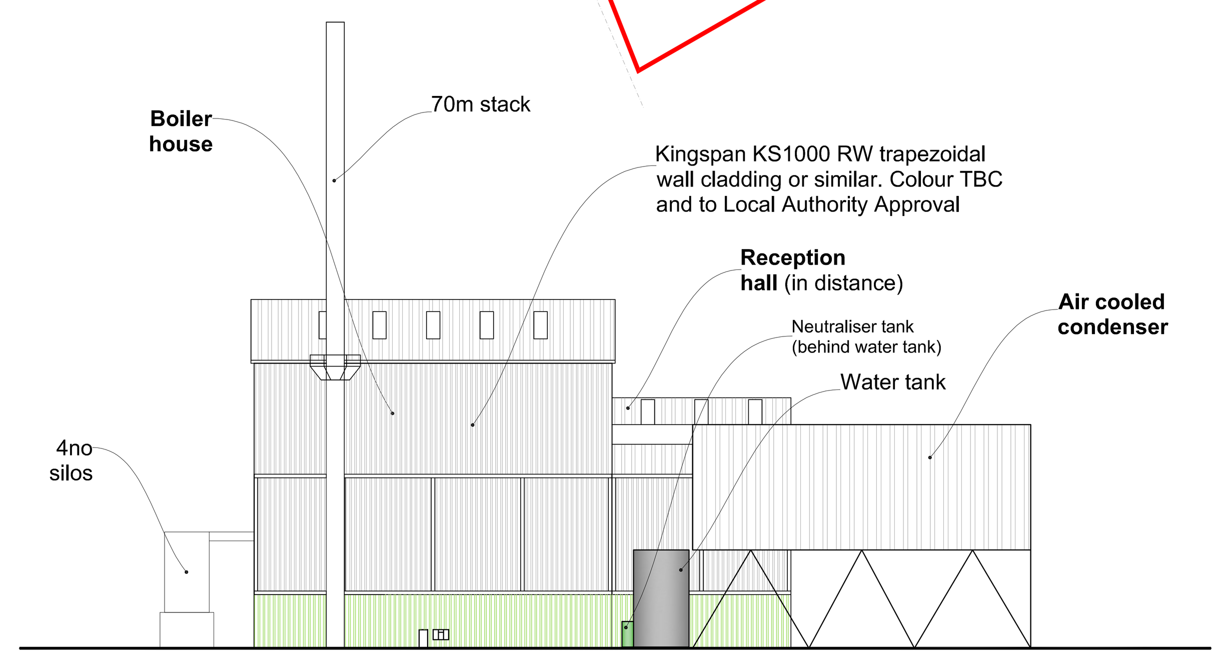
ELEVATION 'A' 1:500



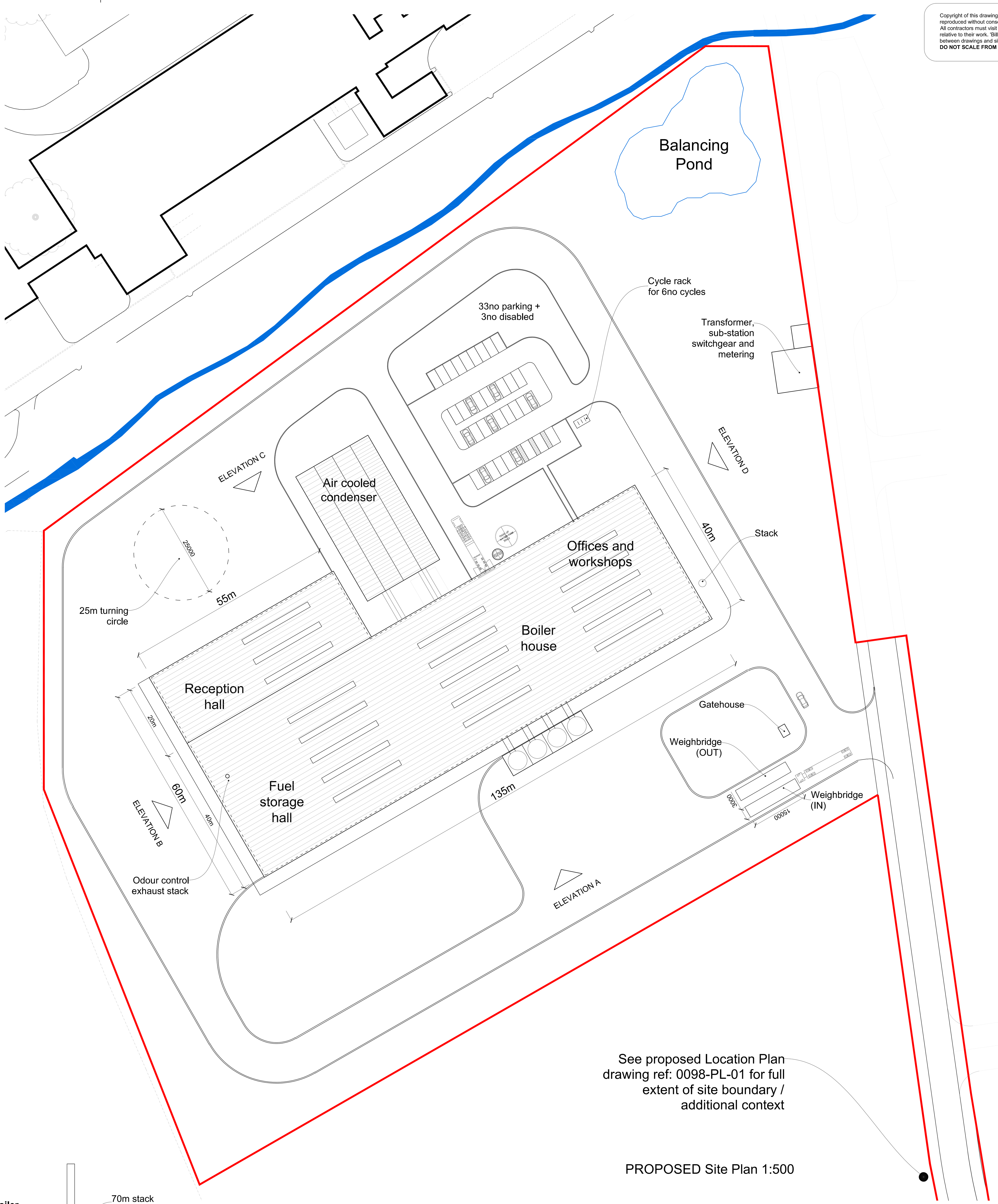
ELEVATION 'B' 1:500



ELEVATION 'C' 1:500



ELEVATION 'D' 1:500



PROPOSED Site Plan 1:500

IN PROGRESS 14.6.18

Scale Bar (1:500)
0m 5m 10m 20m 50m 100m

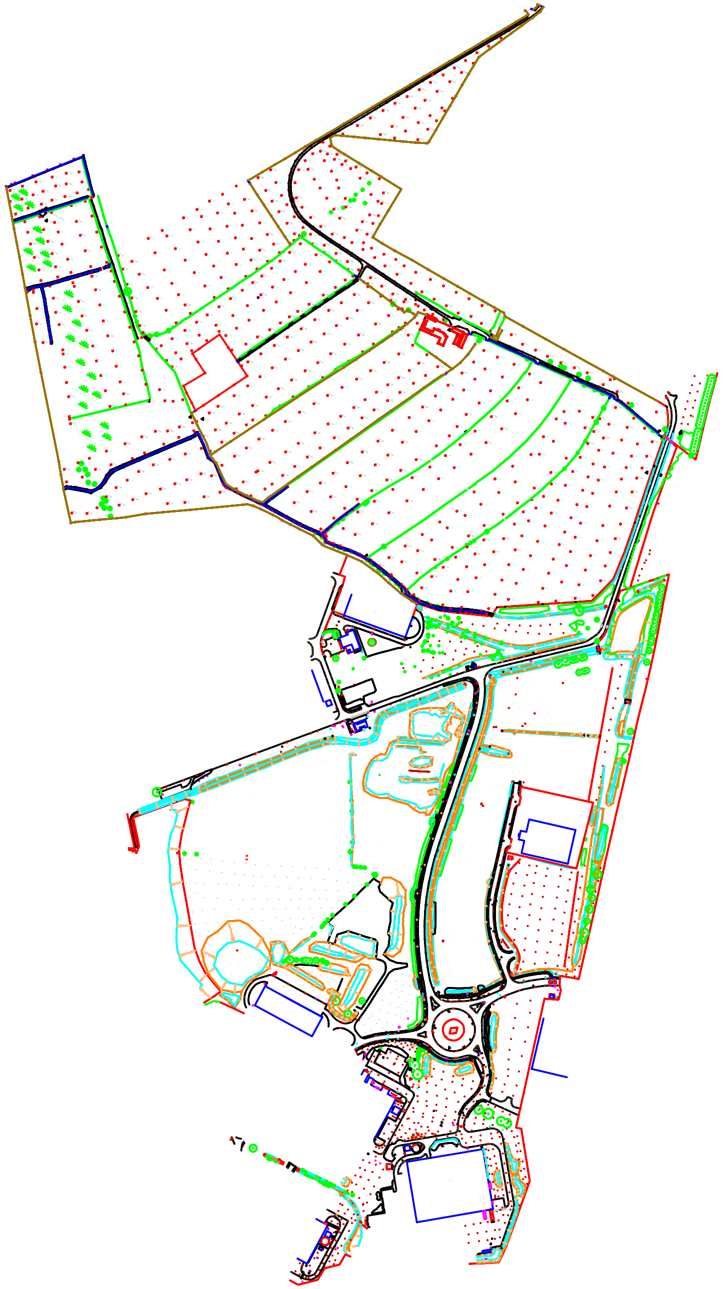
Verus Energy Boltzmann Limited
verusenergy.co.uk

Client: Verus Energy
Job: Proposed Industrial Development
Title: Existing Location Plan / Proposed Site Plan / Elevations
Status: FOR COMMENT
Scale: As noted @ A0
Drawing No: 0098-PL-02
Date: MARCH.18

Drawing prepared by 'Billy Architects'
Mob: 07532076846
Email: gavin@billystudio.co.uk

Appendix 2

Topographical Survey



Appendix 3

Cargo Beck Catchment Descriptors

VERSION	FEH CD-RO	Version	3	exported a	11:18:48 GMT	Fri	29-Apr-16
CATCHMEI	GB	338050	559100	NY 38050 59100			
AREA	0.55						
ALTBAR	28						
ASPBAR	217						
ASPVAR	0.39						
BFIHOST	0.378						
DPLBAR	1.55						
DPSBAR	10.8						
FARL	1						
LDP	2.51						
PROPWET	0.62						
RMED-1H	10.3						
RMED-1D	29.1						
RMED-2D	36.5						
SAAR	820						
SAAR4170	806						
SPRHOST	39.69						
URBCONC1	0.818						
URBEXT19!	0.4129						
URBLOC19	0.938						
C	-0.02657						
D1	0.31145						
D2	0.43956						
D3	0.38557						
E	0.282						
F	2.33981						
C(1 km)	-0.027						
D1(1 km)	0.312						
D2(1 km)	0.447						
D3(1 km)	0.391						
E(1 km)	0.282						
F(1 km)	2.345						

Appendix 4

Cargo Beck Peak Flows

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name		**Catchment name**		**Date/time modelled**	03-May-2016 12:39
Company name		**Catchment easting**	338050	**Version**	1.3
Project name		**Catchment northing**	559100		
		Catchment area	0.55		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	100	**C_{max} (mm)**	266	**T_p (hr)**	0.55	**BL (hr)**	8
Duration (hr)	3	**C_{ini} (mm)**	43	**U_p**	0.65	**BR**	1.1
Timestep (hr)	1	**α factor**	0.63	**U_k**	0.8	**BF_0 (m^3/s)**	0
Season	Summer						

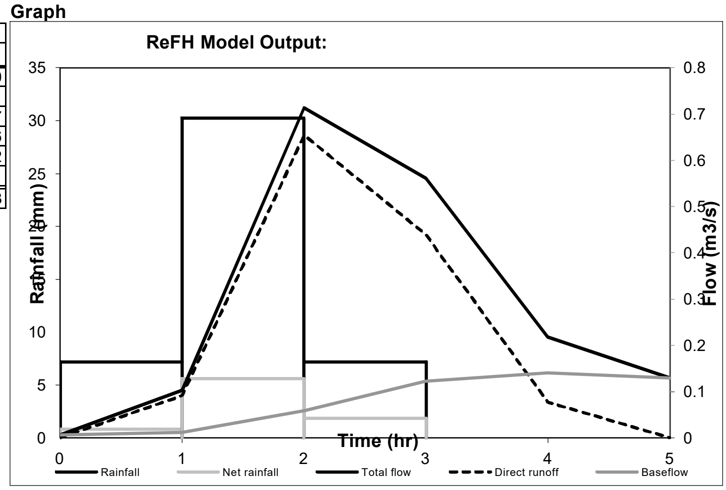
Summary of results

FEH DDF rainfall (mm)	46.8	**Peak rainfall (mm)**	30.2
Design rainfall (mm)	44.6	**Peak flow (m^3/s)**	0.7

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0	7.2	0.8	0.0	0.0	0.0
1	30.2	5.6	0.1	0.0	0.1
2	7.2	1.8	0.7	0.1	0.7
3	0.0	0.0	0.4	0.1	0.6
4	0.0	0.0	0.1	0.1	0.2
5	0.0	0.0	0.0	0.1	0.1
Total (mm)	**44.6**	**8.3**	**8.3**	**3.1**	**11.3**

Graph



Audit comments

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DPSBAR value of 10.8 used
URBEXT value of 0.4129 used
C value of -0.02657 used
D1 value of 0.31145 used
D2 value of 0.43956 used
D3 value of 0.38557 used
E value of 0.282 used
F value of 2.33981 used

Rainfall
Recommended season is Summer, as URBEXT => 0.125
ReFH design standard Seasonal Correction Factor of 0.98 applied
ReFH design standard Areal Reduction Factor of 0.98 applied

Loss Model
C_{Max} derived from catchment descriptors
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model
T_p derived from catchment descriptors
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors
BR derived from catchment descriptors
ReFH design standard BF_0 used

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name		**Catchment name**		**Date/time modelled**	03-May-2016 12:44
Company name		**Catchment easting**	338050	**Version**	1.3
Project name		**Catchment northing**	559100		
		Catchment area	0.55		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	1000	**C_{max} (mm)**	266	**T_p (hr)**	0.55	**BL (hr)**	8
Duration (hr)	3	**C_{ini} (mm)**	43	**U_p**	0.65	**BR**	1.1
Timestep (hr)	1	**α factor**	0.41	**U_k**	0.8	**BF_0 (m^3/s)**	0
Season	Summer						

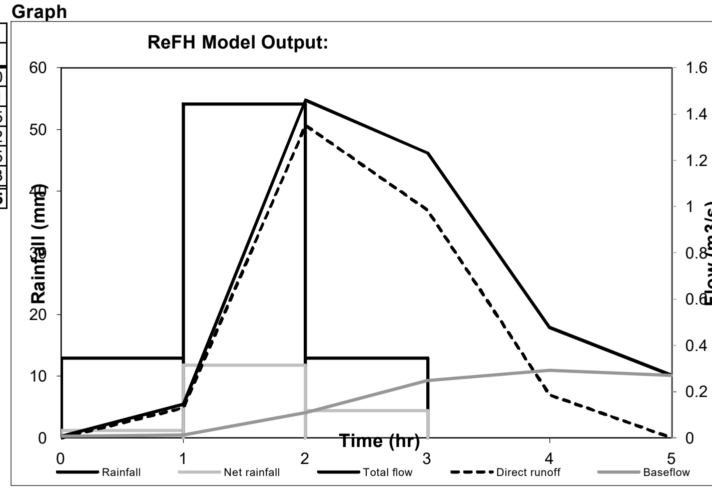
Summary of results

FEH DDF rainfall (mm)	83.8	**Peak rainfall (mm)**	54.2
Design rainfall (mm)	80	**Peak flow (m^3/s)**	1.5

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0	12.9	1.2	0.0	0.0	0.0
1	54.2	11.8	0.1	0.0	0.1
2	12.9	4.4	1.4	0.1	1.5
3	0.0	0.0	1.0	0.2	1.2
4	0.0	0.0	0.2	0.3	0.5
5	0.0	0.0	0.0	0.3	0.3
Total (mm)	**80.0**	**17.4**	**17.4**	**6.1**	**23.5**

Graph



Audit comments

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DPSBAR value of 10.8 used
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D1 value of 0.31145 used
D2 value of 0.43956 used
D3 value of 0.38557 used
E value of 0.282 used
F value of 2.33981 used

Rainfall
Recommended season is Summer, as URBEXT => 0.125
ReFH design standard Seasonal Correction Factor of 0.98 applied
ReFH design standard Areal Reduction Factor of 0.98 applied

Loss Model
C_{Max} derived from catchment descriptors
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model
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ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors
BR derived from catchment descriptors
ReFH design standard BF_0 used

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name		**Catchment name**		**Date/time modelled**	03-May-2016 12:44
Company name		**Catchment easting**	338050	**Version**	1.3
Project name		**Catchment northing**	559100		
		Catchment area	0.55		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	20	**C_{max} (mm)**	266	**T_p (hr)**	0.55	**BL (hr)**	8
Duration (hr)	3	**C_{ini} (mm)**	43	**U_p**	0.65	**BR**	1.1
Timestep (hr)	1	**α factor**	0.84	**U_k**	0.8	**BF_0 (m^3/s)**	0
Season	Summer						

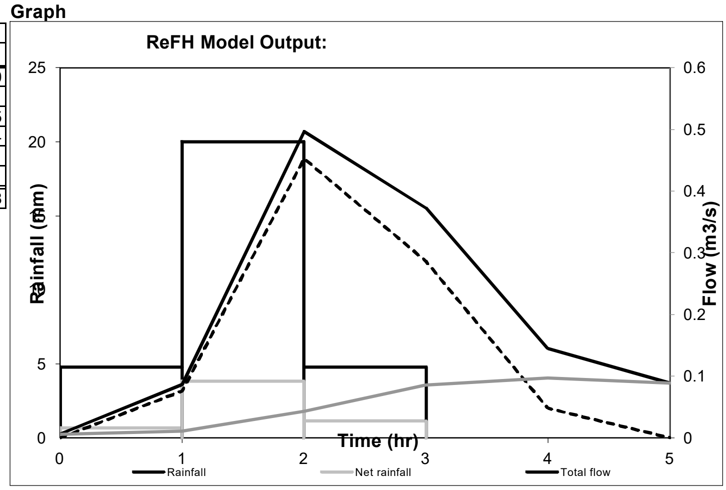
Summary of results

FEH DDF rainfall (mm)	31	**Peak rainfall (mm)**	20
Design rainfall (mm)	29.6	**Peak flow (m^3/s)**	0.5

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0	4.8	0.7	0.0	0.0	0.0
1	20.0	3.8	0.1	0.0	0.1
2	4.8	1.1	0.5	0.0	0.5
3	0.0	0.0	0.3	0.1	0.4
4	0.0	0.0	0.0	0.1	0.1
5	0.0	0.0	0.0	0.1	0.1
Total (mm)	**29.6**	**5.6**	**5.6**	**2.2**	**7.8**

Graph



Audit comments

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C value of -0.02657 used
D1 value of 0.31145 used
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D3 value of 0.38557 used
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F value of 2.33981 used

Rainfall
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ReFH design standard Areal Reduction Factor of 0.98 applied

Loss Model
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ReFH design standard α factor used

Routing Model
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ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors
BR derived from catchment descriptors
ReFH design standard BF_0 used

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name		**Catchment name**		**Date/time modelled**	03-May-2016 12:45
Company name		**Catchment easting**	338050	**Version**	1.3
Project name		**Catchment northing**	559100		
		Catchment area	0.55		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	2	**C_{max} (mm)**	266	**T_p (hr)**	0.55	**BL (hr)**	8
Duration (hr)	3	**C_{ini} (mm)**	43	**U_p**	0.65	**BR**	1.1
Timestep (hr)	1	**α factor**	1	**U_k**	0.8	**BF_0 (m^3/s)**	0
Season	Summer						

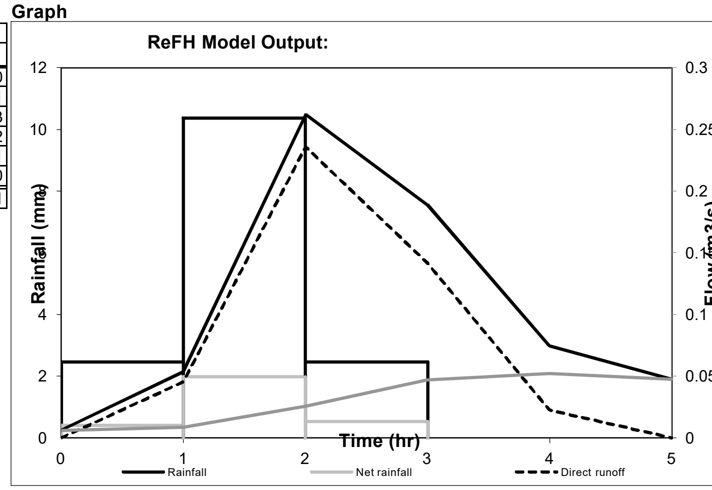
Summary of results

FEH DDF rainfall (mm)	16	**Peak rainfall (mm)**	10.4
Design rainfall (mm)	15.3	**Peak flow (m^3/s)**	0.3

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0	2.5	0.4	0.0	0.0	0.0
1	10.4	2.0	0.0	0.0	0.1
2	2.5	0.5	0.2	0.0	0.3
3	0.0	0.0	0.1	0.0	0.2
4	0.0	0.0	0.0	0.1	0.1
5	0.0	0.0	0.0	0.0	0.0
Total (mm)	**15.3**	**2.9**	**2.9**	**1.2**	**4.1**

Graph



Audit comments

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ReFH design standard α factor used

Routing Model
T_p derived from catchment descriptors
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors
BR derived from catchment descriptors
ReFH design standard BF_0 used

Appendix 5

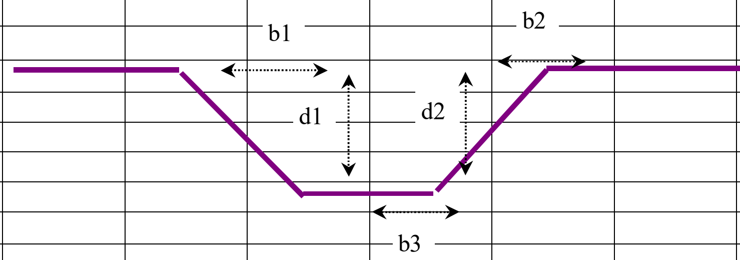
Cargo Beck Bankfull Capacity

Determination of Channel Flow - Using Manning's Equation

Mannings Equation is:

$$V = \frac{R^{0.67} x S^{0.5}}{n}$$

Given a typical channel section:



Mannings n	
0.013	Smooth concrete channel
0.02	Spoil, earth of masonry channel
0.03	Short grass
0.03	Clean, straight natural stream
0.04	Clean winding natural stream
0.1	Overgrown stream or channel

When channel dimensions are:

b1 = **0.500** (m)
d1 = **1.000** (m)

b2 = **0.500** (m)
d2 = **1.000** (m)

b3 = **1.000** (m)

Height Change (m)	Length (m)
1	500

S = **0.002** (dim)

n = **0.03** (dim)

where:

V	Velocity (m/s)
R	(Cross Sectional Area of ditch) / (Wetted Perimeter)
S	Slope
n	Mannings Coefficient of Roughness

Gives:

R = 0.464

V = 0.891 (m/s)

Q = 1.336 (m^3/s bankfull)

Appendix 6

Surface Water Runoff Rates and Volumes

Return period (yrs)	Urbanised peak flow (m^3/s)	Urbanised direct runoff (ML)	As-rural peak flow (m^3/s)
1	0.037079118	0.477314542	0.022604064
2	0.041425916	0.536449353	0.025314304
5	0.054918334	0.720753036	0.033934953
10	0.064436646	0.851442346	0.040182621
30	0.080919106	1.079034082	0.051319017
50	0.089482582	1.197908495	0.057260672
75	0.096890746	1.301085819	0.062485031
100	0.102557013	1.380213388	0.066533105
200	0.118107274	1.598290114	0.077870872
1000	0.163362345	2.240361946	0.112702618

As-rural direct runnof (ML)
0.313216694
0.353627727
0.481719488
0.574460112
0.73959866
0.827624581
0.904980879
0.96489406
1.132585011
1.646875348

Appendix 7

IoH 124 Method Calculations

MasterDrain HY 9.3	HYDROGEO Groundwater and Environment	Job No.		
		Sheet no. 1		
		Date 25/05/16		
	Project Kingmoor	By	Checked	Reviewed
	Title Pre-development Surface Water Runoff			

Hydrological Data:-

FSR Hydrology:-

Location = CARLISLE	Grid reference = NY3955
M5-60 (mm) = 17.1	r = 0.35
Soil runoff = 0.45	SAAR (mm/yr) = 800
WRAP = 4	Area = England & Wales
Hydrological area = 10	Hydrological zone = 8

Soil classification for WRAP type 4
Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.

Design data:-

Area = 0.0453 Km² - 4.53 Ha - 45300 m² % Urbanisation = 0.00%

Calculation method:-

Runoff is calculated from:-

$$Q_{BAR(urban);} = Q_{BAR(rural)} (1 + URBAN)^{2NC} [1 + URBAN\{(21/CIND) - 0.3\}]$$

where:-

NC varies with the value of SAAR:-
for 500<SAAR<1100 mm then NC = 0.92 - 0.00024SAAR
for 1100<SAAR<3000 mm then NC = 0.74 - 0.000082SAAR

CIND = 102.4SOIL + 0.28(CWI - 125) CWI = Catchment Wetness Index

CIND =35.160 CWI =86.000 NC =0.728

For areas less than 50Ha, a modified calculation which multiplies the 50Ha runoff value by the ratio of the site area to 50Ha is used
Reducing factor used for these calculations is 0.091

$Q_{BAR(rural)}$ = 23.266 (l/s)

$Q_{BAR(urban)}$ is then multiplied by a growth factor - GC(T) - for different storm return periods derived from EA publication W5-074/A.

Calculated data:-

Mean Annual Peak Flow $Q_{BAR(urban)}$ = 23.27 l/s

Values for $Q_{BAR(urban)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.020	0.023	0.028	0.039	0.049	0.056	cumecs
19.78	23.27	28.15	39.09	48.86	55.84	l/s
4.37	5.14	6.21	8.63	10.79	12.33	l/s/Ha
0.850	1.000	1.210	1.680	2.100	2.400	GC(T)

The above is based on the Institute of Hydrology Report 124 to which you are referred for further details (see Sect 7). Note that the 200 year growth curve was taken from W5-074/A.

For WRAP type 1 soils, CIND can become negative for lower values of SAAR. In this case the CIND value is multiplied by -1 to return a positive value (CIND is very small at this point).

Appendix 8

Storage Volumes

MasterDrain SW

Project	Kingmoor	Job No.		
		Sheet no.	1	
		Date	18/06/18	
Title	1 in 100 Year (+40%) Storage Volume	By	Checked	Reviewed

Data:-

FEH Hydrology:-

Location = CARLISLE
Grid reference = NY3955
c = -0.0270
d1 = 0.3100
d2 = 0.4420
d3 = 0.3800
e = 0.2820
f = 2.3410
Return period = 100
Climate change = +40%

Pipeline storage = 0.0 m³
Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 100.0% (manual setting)

Imperv. area = 21616 m²
Pervious area = 0 m²
Total area = 21616 m²
Equiv area = 21616 m² (Tot. area x % runoff).
Total runoff = 1411.3 m³
Discharge rate = 23.270 l/s
Storage (m³) = 1195.3 m³ (Sum of all balance quantities)
Total rainfall depth = 65.3 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.030	20.0	4.4	2.823	2.513	0.309	0.309
0.060	20.0	4.4	2.823	2.513	0.309	0.619
0.090	21.0	4.6	2.964	2.513	0.451	1.069
0.120	21.0	4.6	2.964	2.513	0.451	1.520
0.150	22.0	4.8	3.105	2.513	0.592	2.112
0.180	23.0	5.0	3.246	2.513	0.733	2.845
0.210	24.0	5.2	3.387	2.513	0.874	3.718
0.240	26.0	5.7	3.669	2.513	1.156	4.875
0.270	27.0	5.9	3.811	2.513	1.297	6.172
0.300	29.0	6.3	4.093	2.513	1.580	7.752
0.330	31.0	6.7	4.375	2.513	1.862	9.614
0.360	32.0	7.0	4.516	2.513	2.003	11.617
0.390	33.0	7.2	4.657	2.513	2.144	13.761
0.420	34.0	7.4	4.798	2.513	2.285	16.046
0.450	36.0	7.8	5.081	2.513	2.568	18.613
0.480	38.0	8.3	5.363	2.513	2.850	21.463
0.510	39.0	8.5	5.504	2.513	2.991	24.454
0.540	40.0	8.7	5.645	2.513	3.132	27.586
0.570	42.0	9.1	5.927	2.513	3.414	31.000
0.600	45.0	9.8	6.351	2.513	3.838	34.838
0.630	49.0	10.7	6.915	2.513	4.402	39.240
0.660	53.0	11.5	7.480	2.513	4.967	44.207
0.690	57.0	12.4	8.044	2.513	5.531	49.738
0.720	62.0	13.5	8.750	2.513	6.237	55.975
0.750	66.0	14.4	9.315	2.513	6.801	62.777
0.780	71.0	15.5	10.020	2.513	7.507	70.284
0.810	77.0	16.8	10.867	2.513	8.354	78.638
0.840	84.0	18.3	11.855	2.513	9.342	87.979
0.870	91.0	19.8	12.843	2.513	10.330	98.309
0.900	98.0	21.3	13.831	2.513	11.318	109.627
0.930	105.0	22.9	14.819	2.513	12.305	121.932
0.960	114.0	24.8	16.089	2.513	13.576	135.508
0.990	125.0	27.2	17.641	2.513	15.128	150.636
1.020	135.0	29.4	19.053	2.513	16.539	167.175
1.050	143.0	31.1	20.182	2.513	17.668	184.844
1.080	154.0	33.5	21.734	2.513	19.221	204.064
1.110	164.0	35.7	23.145	2.513	20.632	224.697
1.140	173.0	37.7	24.415	2.513	21.902	246.599
1.170	183.0	39.8	25.827	2.513	23.314	269.912
1.200	194.0	42.2	27.379	2.513	24.866	294.778

MasterDrain SW

HYDROGEO Groundwater and Environment

Job No.	
Sheet no.	2
Date	18/06/18

Project: Kingmoor

Title: 1 in 100 Year (+40%) Storage Volume

By	Checked	Reviewed

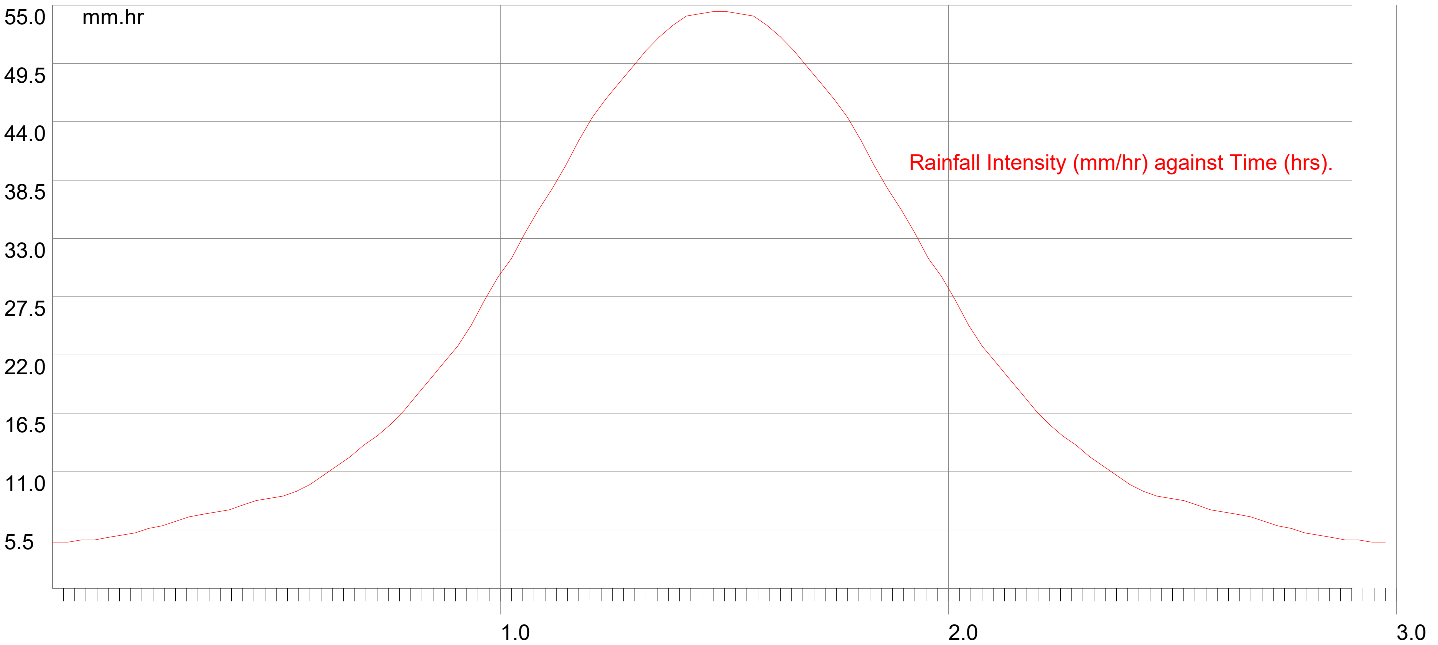
Calculations (cont.) :-

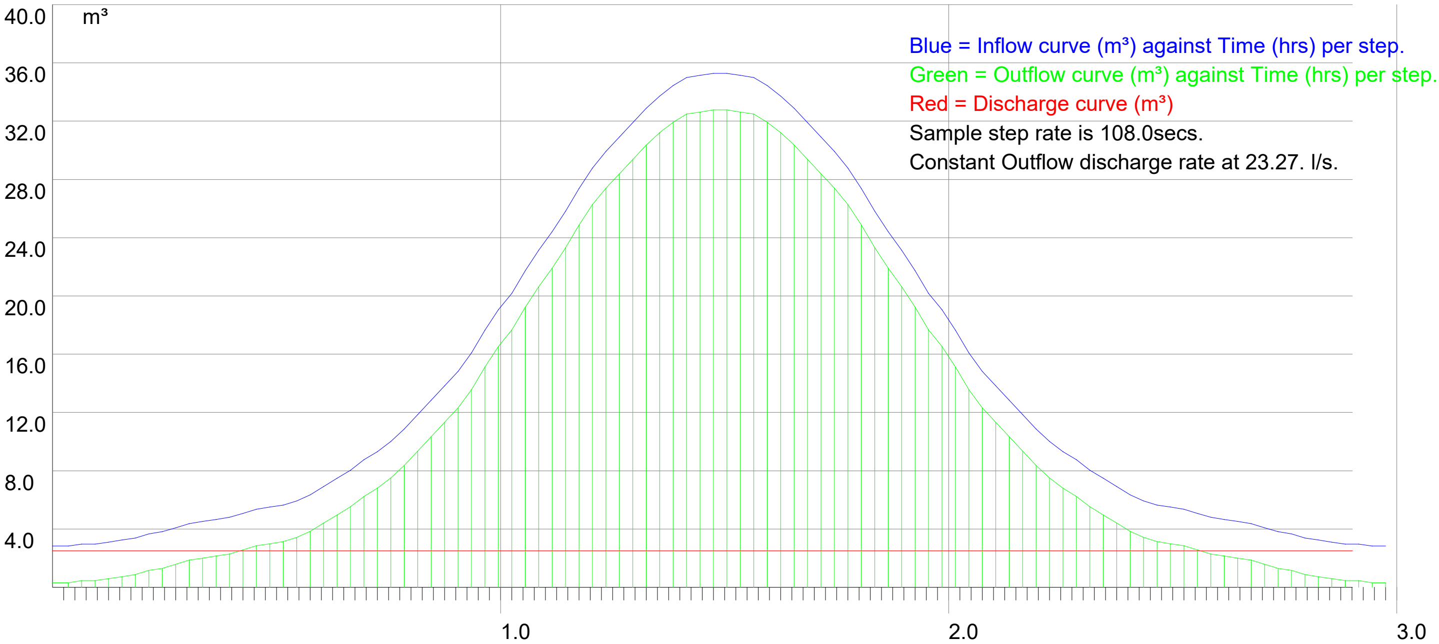
Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
1.230	204.0	44.4	28.791	2.513	26.277	321.056
1.260	212.0	46.1	29.920	2.513	27.406	348.462
1.290	219.0	47.7	30.907	2.513	28.394	376.856
1.320	226.0	49.2	31.895	2.513	29.382	406.239
1.350	233.0	50.7	32.883	2.513	30.370	436.609
1.380	239.0	52.0	33.730	2.513	31.217	467.826
1.410	244.0	53.1	34.436	2.513	31.923	499.748
1.440	248.0	54.0	35.000	2.513	32.487	532.235
1.470	249.0	54.2	35.141	2.513	32.628	564.863
1.500	250.0	54.4	35.282	2.513	32.769	597.633
1.530	250.0	54.4	35.282	2.513	32.769	630.402
1.560	249.0	54.2	35.141	2.513	32.628	663.030
1.590	248.0	54.0	35.000	2.513	32.487	695.517
1.620	244.0	53.1	34.436	2.513	31.923	727.440
1.650	239.0	52.0	33.730	2.513	31.217	758.657
1.680	233.0	50.7	32.883	2.513	30.370	789.027
1.710	226.0	49.2	31.895	2.513	29.382	818.409
1.740	219.0	47.7	30.907	2.513	28.394	846.803
1.770	212.0	46.1	29.920	2.513	27.406	874.210
1.800	204.0	44.4	28.791	2.513	26.277	900.487
1.830	194.0	42.2	27.379	2.513	24.866	925.353
1.860	183.0	39.8	25.827	2.513	23.314	948.667
1.890	173.0	37.7	24.415	2.513	21.902	970.569
1.920	164.0	35.7	23.145	2.513	20.632	991.201
1.950	154.0	33.5	21.734	2.513	19.221	1010.422
1.980	143.0	31.1	20.182	2.513	17.668	1028.090
2.010	135.0	29.4	19.053	2.513	16.539	1044.630
2.040	125.0	27.2	17.641	2.513	15.128	1059.758
2.070	114.0	24.8	16.089	2.513	13.576	1073.333
2.100	105.0	22.9	14.819	2.513	12.305	1085.639
2.130	98.0	21.3	13.831	2.513	11.318	1096.957
2.160	91.0	19.8	12.843	2.513	10.330	1107.286
2.190	84.0	18.3	11.855	2.513	9.342	1116.628
2.220	77.0	16.8	10.867	2.513	8.354	1124.982
2.250	71.0	15.5	10.020	2.513	7.507	1132.489
2.280	66.0	14.4	9.315	2.513	6.801	1139.291
2.310	62.0	13.5	8.750	2.513	6.237	1145.527
2.340	57.0	12.4	8.044	2.513	5.531	1151.059
2.370	53.0	11.5	7.480	2.513	4.967	1156.025
2.400	49.0	10.7	6.915	2.513	4.402	1160.428
2.430	45.0	9.8	6.351	2.513	3.838	1164.265
2.460	42.0	9.1	5.927	2.513	3.414	1167.680
2.490	40.0	8.7	5.645	2.513	3.132	1170.812
2.520	39.0	8.5	5.504	2.513	2.991	1173.803
2.550	38.0	8.3	5.363	2.513	2.850	1176.652
2.580	36.0	7.8	5.081	2.513	2.568	1179.220
2.610	34.0	7.4	4.798	2.513	2.285	1181.505
2.640	33.0	7.2	4.657	2.513	2.144	1183.649
2.670	32.0	7.0	4.516	2.513	2.003	1185.652
2.700	31.0	6.7	4.375	2.513	1.862	1187.514
2.730	29.0	6.3	4.093	2.513	1.580	1189.094
2.760	27.0	5.9	3.811	2.513	1.297	1190.391
2.790	26.0	5.7	3.669	2.513	1.156	1191.547
2.820	24.0	5.2	3.387	2.513	0.874	1192.421
2.850	23.0	5.0	3.246	2.513	0.733	1193.154
2.880	22.0	4.8	3.105	2.513	0.592	1193.746
2.910	21.0	4.6	2.964	2.513	0.451	1194.196
2.940	21.0	4.6	2.964	2.513	0.451	1194.647
2.970	20.0	4.4	2.823	2.513	0.309	1194.956
3.000	20.0	4.4	2.823	2.513	0.309	1195.266

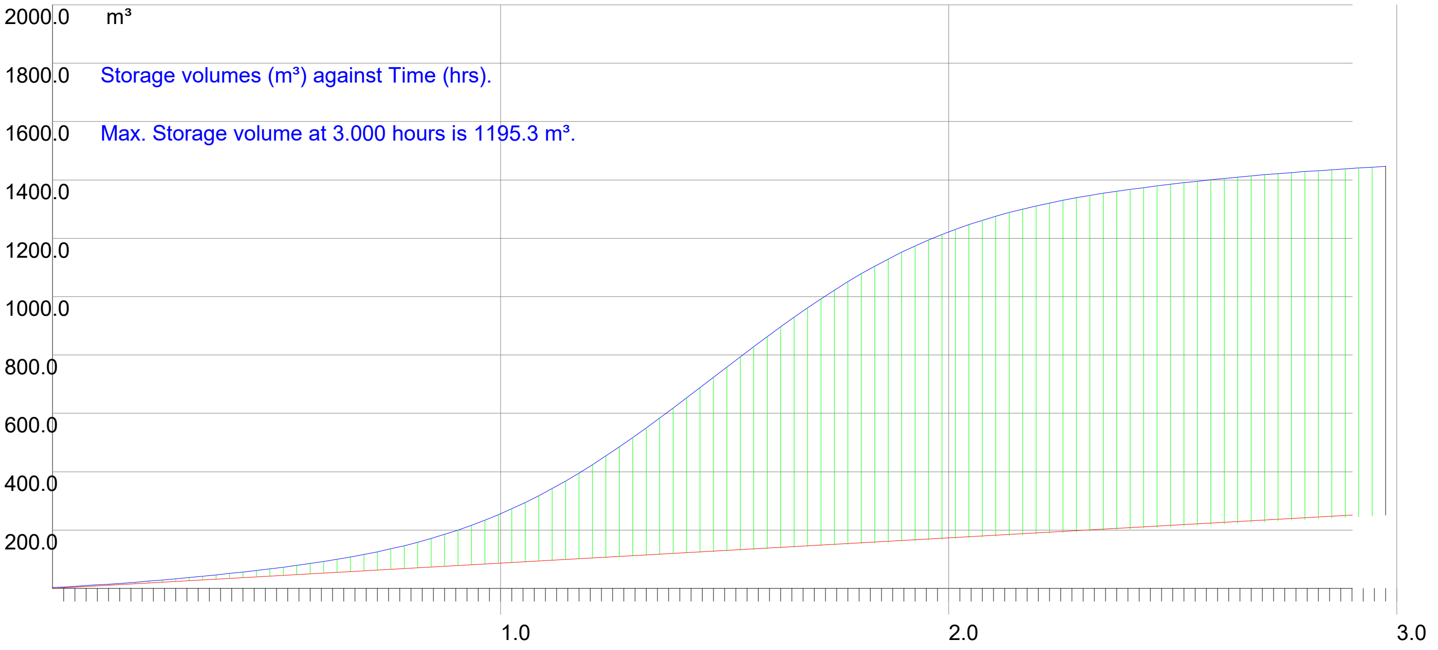
Storage volume (m^3) = 1195.3 m^3 (Sum of all balance quantities)

MasterDrain SW

Job No.			
Sheet no.	3		
Date	18/06/18		
Project	Kingmoor	By	Checked	Reviewed
Title	1 in 100 Year (+40%) Storage Volume		







MasterDrain SW

HYDROGEO Groundwater and Environment

Job No.	
Sheet no.	4
Date	18/06/18

Project Kingmoor

Title 1 in 100 Year (+40%) Storage Volume

By	Checked	Reviewed

Maximum storage volumes for varying duration storms.

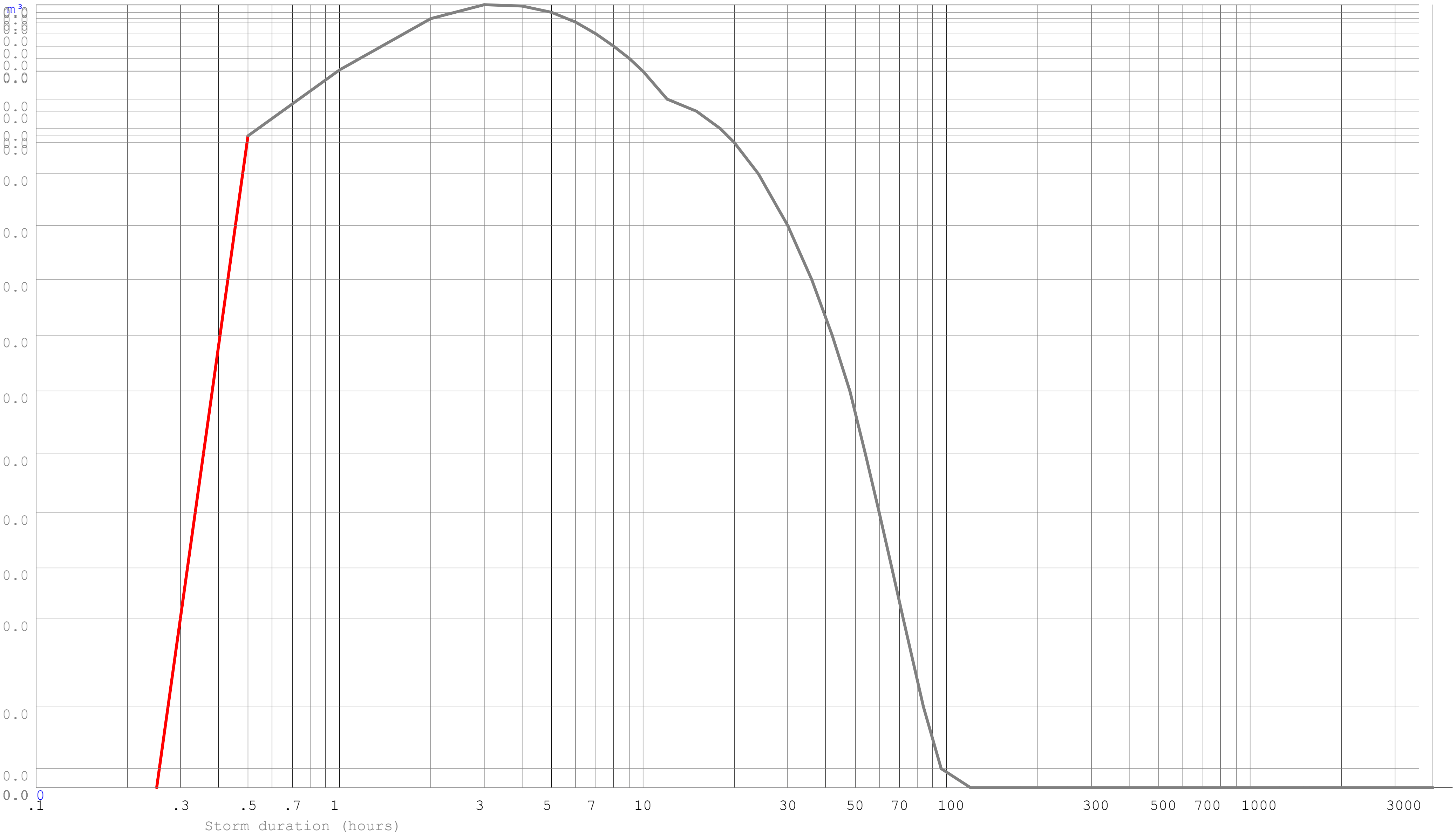
Storm length (hrs)	Max. Vol (m^3)	Max. Vol time	Mean intens (mm/hr)	Step time. (mins)	Peak found
0.25	0.00	0.00	21.76	0.2	
0.5	995.08	0.50	93.60	0.3	
1	1095.72	1.00	53.23	0.6	
2	1174.06	2.00	30.28	1.2	
3	1195.27	3.00	21.76	1.8	Peak found
4	1193.46	---	17.22	2.4	
5	1183.83	---	14.36	3.0	
6	1168.59	---	12.38	3.6	
7	1151.07	---	10.92	4.2	
8	1132.22	---	9.79	4.8	
9	1113.54	---	8.90	5.4	
10	1093.72	---	8.17	6.0	
12	1051.16	---	7.04	7.2	
15	1032.65	---	6.05	9.0	
18	1005.95	---	5.34	10.8	
20	984.86	---	4.97	12.0	
24	937.42	---	4.39	14.4	
30	858.34	---	3.77	18.0	
36	775.70	---	3.33	21.6	
42	690.60	---	2.99	25.2	
48	605.33	---	2.73	28.8	
54	509.66	---	2.50	32.4	
60	419.46	---	2.32	36.0	
66	335.48	---	2.16	39.6	
72	257.73	---	2.02	43.2	
84	123.18	---	1.80	50.4	
96	28.99	---	1.63	57.6	
120	0.00	---	1.38	72.0	
150	0.00	---	1.17	90.0	
175	0.00	---	1.04	105.0	
200	0.00	---	0.95	120.0	
250	0.00	---	0.80	150.0	
300	0.00	---	0.70	180.0	
375	0.00	---	0.59	225.0	
500	0.00	---	0.48	300.0	
750	0.00	---	0.35	450.0	
1000	0.00	---	0.29	600.0	
1250	0.00	---	0.24	750.0	
1500	0.00	---	0.21	900.0	
1570	0.00	---	0.20	942.0	
2000	0.00	---	0.17	1200.0	
2500	0.00	---	0.14	1500.0	
3000	0.00	---	0.13	1800.0	
3500	0.00	---	0.11	2100.0	
4000	0.00	---	0.10	2400.0	

MasterDrain SW

HYDROGEO
Groundwater and Environment

Project Kingmoor		Job No.		
Title 1 in 100 Year (+40%) Storage Volume		Sheet no. 5		
		Date 18/06/18		
		By	Checked	Reviewed

Sequential storage volume at specific storm durations.



Explanatory notes for Peak Flow Storage

1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
2) The balance is calculated from the inflow minus the outflow.
3) The storage volume is the maximum value of the balance curve.
4) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
5) References to 'storm duration' relate only to the hydrograph method (qv).
6) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

1) The user has the choice of Summer or Winter curves
2) The mean intensity varies with the duration of the storm curve
3) There are always 120 steps in the calculation process, irrespective of storm duration.
4) The balance is calculated from the inflow minus the outflow.
5) The storage volume is the sum of the balance values for each step.
6) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function. Please be aware that this function needs the full design data file to function.

Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

It can be seen that these two methods are very different, and the user may have the choice of which result to use. This is not an exact science, though is often treated as such by those that do not understand the principles of the calculations.