KRS Environmental

Land to the east of 29 Harbour Road, Pagham

NPPF: Flood Risk Assessment

For Pagham Beach (Holdings) Ltd

KRS.0030.001.R.001.A

November 2013

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Land to the east of 29 Harbour Road, Pagham	
Project	NPPF: Flood Risk Assessment
Client	Pagham Beach (Holdings) Ltd
Status	Final
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Date	November 2013

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EXECUTIVE SUMMARY

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

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

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

The principal flood risk to the site is from tidal flooding from the English Channel. It is unlikely that the site would be inundated with floodwater for all events up to and including the present day 1 in 1000 event. There is a further freeboard of 0.21m above the 1 in 200 year water level and 0.02m above the 1 in 1000 year water level.

The site would only be inundated with floodwater during the 1 in 200 (plus climate change) event. The maximum water depth experienced on the site would be 0.93m during the 1 in 200 (plus climate change) event. .

However, the finished floor and threshold levels of the dwellings will be located at 5.50mAOD therefore the dwellings will not be inundated with floodwater for all events up to and including the 1 in 200 (climate change) event. The finished floor and threshold levels of the dwellings will have a further freeboard of 0.70m above the 1 in 200 year (climate change) water level of 4.80mAOD.

The risk of flooding from tidal flooding is considered to be of **medium significance.** A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

- Surface Water Flooding
- Sewer 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 proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0).

Approximately 50% of the site is located within Flood Zone 1 and therefore has a 'low probability' of tidal flooding, with a less than 1 in 1000 annual probability of sea flooding in any year (<0.1%).

However, approximately 50% of the site is located within Flood Zone 3 and therefore has a 'high probability' of tidal flooding, with a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

The proposed development is classified as 'more vulnerable', 'more vulnerable' uses are appropriate within Flood Zone 3a after the completion of a satisfactory FRA.

The site is unlikely to flood except in extreme conditions.

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The SWMS ensures that a sustainable drainage solution can be achieved which reduces the peak discharge rate to the greenfield runoff rate to manage and reduce the flood risk posed by the surface water runoff from the site.

For all development, both the Building Regulations and the NPPF promote a hierarchical approach to surface water management. This approach has been adopted within this SWMS with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the English Channel or an existing public sewer.

In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield runoff rate of 0.37l/s or 3.69l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, 19.60m^3 of storage will be incorporated into the site layout.

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located in underground systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

It is also proposed to locate a rainwater harvesting system within the site. This will collect the rainwater that falls on this area. .

Rainwater from roofs and other hardstanding areas such as car parks will be used within and around the development for a range of non-potable purposes such as flushing toilets and washing down of platforms. This will help reduce the rate and volume of surface water runoff discharging from the site. The water will be stored adjacent to each individual dwelling in underground tanks.

The annual rainwater yield at the site will meet the annual non-potable water demand of the site.

The flood risk at the site will be reduced by property level protection measures. Measured used:

Property Layout - Finished Floor/Threshold Level: Raising the finished floor and threshold levels of the buildings will be used to mitigate the effects of flooding at the site.

The finished floor and threshold levels of the dwellings will be located at a minimum of 5.50mAOD which is above the 1 in 200 year (climate change) tidal water level of 4.80mAOD plus a freeboard of 0.70m.

The site is located within an area subject to tidal flooding therefore, floodplain compensation is not required.

Property Layout - Sequential Approach: The most vulnerable use, the buildings, have been situated further away from the tidal flood risk source and on the higher part of the site at a lower risk of flooding with the more flood-compatible uses such as the car parking/landscaped areas being situated nearer the tidal flood risk source on the lower part of the site at a higher risk of flooding.

The dwellings have been located on the area of the site with higher ground levels. Ground levels rise towards the north of the site.

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Flood Resistance: Flood resistant measures will be used.

Flood Resilience: Robust materials and finishes will be used.

Access and Egress Routes: As the surrounding area is located within Flood Zone 1 a safe access and egress route, including emergency access, can be maintained for vehicles and/or by foot. Two safe access routes will be maintained via Harbour Road, the Parade and Harbour View Road.

These provide access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event. People will make their way to areas outside of the flood zone. The nearest locations outside of Flood Zone include:

- Nyetimber to the north;
- Areas of Pagham to the west; and
- Aldwick to the North.

Flood Warning: The property is located in a flood risk area therefore; the properties will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

Flood Plan: A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause will be developed (see http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx).

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1.0 INTRODUCTION

1.1 Background

This Flood Risk Assessment (FRA) has been prepared by KRS Environmental Limited at the request of Pagham Beach (Holdings) Ltd to support a planning application for the proposed development of land to the east of 29 Harbour Road, Pagham. 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 Technical 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 proposed development 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.

1.3 Report Structure

This FRA has the following report structure:

* Section 2 details the sources of information that have been consulted;

[1] Department for Communities and Local Government (2012) National Planning Policy Framework.
[2] Department for Communities and Local Government (2012) Technical Guidance to the National Planning Policy Framework.

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- Section 3 describes the location area and the existing and proposed development;
- Section 4 outlines the flood risk to the existing and proposed development;
- Section 5 details the sequential and exception tests;
- Section 6 details the proposed surface water drainage for the site and assesses the potential impacts of the proposed development on surface water drainage;
- Section 7 outlines mitigation measures to reduce the overall level of flood risk; and
- Section 8 presents a summary and conclusions.

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2.0 SOURCES OF INFORMATION

2.1 Discussion with Regulators

Consultation and discussions with the relevant regulators have been undertaken during this FRA including the Environment Agency, the Local Planning Authority (LPA), 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 – National Version 2.0, the NPPF and Technical 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.

Correspondence has been received from Jon Denman FCRM Officer at the Environment Agency (see Appendix 1).

2.1.2 Arun District Council

Arun District Council is the Local Planning Authority (LPA). Planning guidance written by Cornwall Council regarding flood risk was consulted to assess the mitigation policies in place.

The Arun District Council Strategic Flood Risk Assessment (SFRA) which covers the site has been reviewed.

2.1.3 West Sussex County Council

West Sussex County Council is the Lead Local Flood Authority (LLFA) and has responsibilities for 'local flood risk', which includes surface runoff, groundwater and ordinary watercourses.

The West Sussex Preliminary Flood Risk Assessment (PFRA) which covers the site has been reviewed.

2.1.4 Southern Water

Southern Water is responsible for the disposal of waste water and supply of clean for this area. Information with regards to sewer and water main flooding contained within the Arun District Council SFRA and the West Sussex PFRA have been consulted as part of this FRA. 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.

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3.0 LOCATION & DEVELOPMENT DESCRIPTION

3.1 Site Location

The site is located on land to the east of 29 Harbour Road, Pagham (see Drawing 1). The National Grid Reference (NGR) of the site is 489018, 97259.

The site comprises a piece of land covering an area of approximately 0.10 hectares (ha) or 1000m^2.

3.2 Existing Development

The site currently comprises a boat and yacht storage compound with adjacent car parking.

3.3 Proposed Development

It is understood that the proposals are for the erection of 3 detached bungalows, each with deck, garage and parking (see Appendix 2). The finished floor and threshold levels of the dwellings will be located at 5.50mA above Ordnance Datum (mAOD).

Further details with regard to the proposed development can be found in the accompanying information submitted with the planning application.

3.4 Ground Levels

The site is predominantly flat but with the adjacent Harbour Road at a slightly higher level. The site ground level is 3.87mAOD.

3.5 Catchment Hydrology

The English Channel is located approximately 150m to the south of the site (see Drawing 1). There are no other watercourses evident either on, or within the vicinity of the site.

3.6 Geology

The British Geological Survey (BGS) Map indicates that the bedrock underlying the site consists of the London Clay Formation – clay, silt and sand. The superficial deposits consist of Storm Beach Deposits – gravel.

3.7 Groundwater

The Environment Agency has designated the bedrock deposits as a Secondary A Aquifer- permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. No superficial aquifer is located at the site.

3.8 Source Protection Zone

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

3.9 Soil

Information from the National Soil Resource Institute[3] details the site area as being situated on freely draining sand dune soils.

[3] https://www.landis.org.uk/soilscapes/

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The Flood Studies Report WRAP soil map classification is type 3: i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England; ii) Permeable soils with shallow ground water in low-lying areas; and iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

3.10 Permeability/Infiltration Rate

In determining the future surface runoff from the site, the potential of using infiltration devices has been considered. As no site geotechnical information on the permeability and infiltration rate at the site has been acquired at this stage it is not possible to comment definitively upon the suitability of infiltration based systems. However, an overview of the general ground conditions (see Sections 3.6 to 3.9) may be used to gauge if there is potential for their application.

It has been concluded that there would be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales will work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations. Such work is beyond the scope of this FRA, but should be undertaken to inform the detailed drainage strategy for the site.

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4.0 FLOOD RISK

4.1 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.

4.1.1 Fluvial (river) Flooding

There are no watercourses evident either on, or within the vicinity of the site. The risk of flooding from fluvial flooding is considered to be **not significant.** Therefore, flooding from this source has not been considered further within this FRA.

4.1.2 Tidal (coastal) Flooding

The English Channel is located approximately 150m to the south of the site (see Drawing 1). Therefore, the principal flood risk to the site is from tidal flooding.

The site is protected against flooding by existing flood defence measures (see Section 4.3). The Pagham Harbour inland flood defences offer an estimated standard of protection of approximately 1 in 20 years (5%). The Pagham Beach coastal flood defences offer an estimated standard of protection of approximately 1 in 200 years (0.5%).

The associated flood risk is that of a residual nature, i.e. the flood risk as a result of a failure or breach in the flood defences. In extreme events the English Channel may inundate the site with floodwater via:

- Breach within the shingle bank.
- Over-topping of the shingle bank.
- Breach/over-topping of the harbour/lagoon.

The Environment Agency has provided tide levels for the site (see Appendix 1). The site is not subject to wave action and/or high waves due to the sites distance from the English Channel.

Table 1 confirms that it is unlikely that the site would be inundated with floodwater for all events up to and including the present day 1 in 1000 event. There is a further freeboard of 0.21m above the 1 in 200 year water level and a freeboard of 0.02m above the 1 in 1000 year water level.

The site would only be inundated with floodwater during the 1 in 200 year (plus climate change) event. The maximum water depth experienced on the site would be 0.93m during the 1 in 200 year (plus climate change) event.

However, the finished floor and threshold levels of the dwellings will be located at 5.50mAOD (see Section 7.2) therefore the dwellings will not be inundated with floodwater for all events up to and including the 1 in 200 (climate change) event. The finished floor and threshold levels of the dwellings will have a further freeboard of 0.70m above the 1 in 200 year (climate change) water level of 4.80mAOD.

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Table 1 - Tidal Water (mAOD) (source Environment Agency)

Return Period (years)			Site Ground Level	Finished Floor/Threshold Levels
200	1000	200+cc		
3.66	3.85	4.80	3.87	5.50

It can be concluded that the English Channel poses a flood risk to the site. The risk from the English Channel is mitigated by existing flood defences measure however, a residual flood risk exists due to a failure or breach in the flood defences exists. The flood risk will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from tidal flooding is considered to be of **medium significance**.

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 Arun District Council contains no recorded historic incidents of groundwater flooding within the vicinity of the site.

No below surface infrastructure and buildings are proposed for the site. The risk from this source will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). The risk of flooding from groundwater flooding is considered to be **not significant**. Therefore, flooding from this source has not been considered further within this FRA.

4.1.4 Surface Water (pluvial) Flooding

The site is not situated near to large areas of poor permeability or areas with the geology and/or topography which may result in surface water flooding. The site surroundings are relatively flat and there are no large catchments that would tend to generate surface water runoff towards the site. Surface water flow flooding tends to occur sporadically in both location and time such surface water flows would tend to be confined to the streets around the development.

The West Sussex County Council Surface Water Management Plan shows the majority of the site is not at risk of surface water flooding during the 1 in 200 year event (see Drawing 2). However, a small proportion of the site is shown as being at risk.

Therefore, the flood risk from surface water flooding is unlikely to be significant. The risk from this source will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). 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

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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.

It has been assumed that there are existing sewers located within the vicinity of the site and these will inevitably have a limited capacity so in extreme conditions there would be surcharges, which may in turn cause flooding. Flood flows could also be generated by burst water mains but these would tend to be of a restricted and much lower volume than weather generated events and so can be discounted for the purposes of this assessment.

Given the design parameters normally used for drainage design in recent times and allowing for some deterioration in the performance of the installed systems, which are likely to have been in place for many years, an appropriate flood risk probability from this source could be assumed to have a return period in the order of 1 in 10 to 1 in 20 years. The provision of adequate level difference between the ground floors and adjacent ground level would reduce the annual probability of damage to property from this source to 1 in 100 years or less.

Sewer flooding poses a flood risk to the site however, the risk from this source will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from sewer flooding is considered to be of **low significance**.

4.1.6 Flooding from Artifical 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 site. Drawing 3 shows that the site is not at risk of flooding from reservoir failure.

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

4.2 Environment Agency Flood Zones

A review of the Environment Agency's Flood Zones indicates that approximately 50% of the site is located within Flood Zone 1 and therefore has a 'low probability' of tidal flooding as shown in Drawing 4, with a less than 1 in 1000 annual probability of sea flooding in any year (<0.1%).

However, approximately 50% of the site is located within Flood Zone 3 and therefore has a 'high probability' of tidal flooding as shown in Drawing 4, with a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

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 Environment Agency Flood Zones and acceptable development types are explained in Table 2. Table 2 (highlighted in green), shows some development types are generally acceptable in Flood Zone 3.

In the Technical Guidance to the NPPF (Table 1) appropriate uses have been identified for the Flood Zones. Applying the Flood Risk Vulnerability Classification in Table 2 and 3 of the Technical Guidance to the NPPF, the proposed development is classified as 'more vulnerable'.

Table 3 of this report and Table 3 of the Technical Guidance to the NPPF state that 'more vulnerable' uses are appropriate within Flood Zone 3 after the completion of a satisfactory FRA.

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Table 2 - 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 3 - Flood Risk Vulnerability and Flood Zone 'Compatibility' as identified in Table 3 of the Technical Guidance to the NPPF

Flood Risk Vulnerability classification(see Table 1 of the Technical Guidance to the NPPF)	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	Yes	✓	✓
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.

4.3 Historic Flooding

The Environment Agency has confirmed that the site has not historically flooded (see Appendix 1).

Data from the BGS indicates that the types of deposits in the locality of the site are of the type normally associated with coastal floodplains. This normally relates to flooding which happened many thousands of years ago. This data should only be considered as complementary to the Environment Agency's Flood Map. This BGS data does not indicate the likelihood of flooding, since such deposits may be due to flood events which occurred thousands of years ago. It was produced

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by characterising Superficial (Drift) Deposits in terms of their likely vulnerability to flooding, either from coastal or inland water flow and reflects areas which may have flooded in the recent geological past.

There are no records of anecdotal information of flooding at the site. The British Hydrological Society "Chronology of British Hydrological Event[4]" has no information on flooding within the vicinity of the site. No other historical records of flooding for the site have been recorded.

Therefore, it has been assumed that the site has not flooded within the recent past (i.e. the last thousand years).

4.4 Existing and Planned Flood Defence Measures

The Environment Agency has confirmed that there are formal flood defences within this area (see Appendix 1 and Drawing 4).

The Pagham Harbour inland flood defences offer an estimated standard of protection of approximately 1 in 20 years (5%). The Pagham Beach coastal flood defences offer an estimated standard of protection of approximately 1 in 200 years (0.5%).

Further property level protection measures will be used to protect the site from flooding these are discussed in Section 7.0.

4.5 Site Specific Flood Risk Assessment

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

Table 4 - Risk Posed by Flooding Sources

Sources of Flooding	Potential Flood Risk	Potential Source	Probability/Significance
Fluvial Flooding	No	None Reported	None
Tidal Flooding	Yes	English Channel	Medium
Groundwater Flooding	No	None Reported	None
Surface Water Flooding	Yes	Poor Permeability	Low
Sewer Flooding	Yes	Local Sewers	Low
Flooding from Artificial Drainage Systems/Infrastructure Failure	No	None Reported	None

The principal flood risk to the site is from tidal flooding from the English Channel. The site is unlikely that the site would be inundated with floodwater for all events up to and including the present day 1 in 1000 event. There is a further freeboard of 0.21m above the 1 in 200 year water level and 0.02m above the 1 in 1000 year water level.

The site would only be inundated with floodwater during the 1 in 200 year (plus climate change) event. The maximum water depth experienced on the site would be 0.93m during the 1 in 200 year (plus climate change) event.

However, the finished floor and threshold levels of the dwellings will be located at 5.50mAOD therefore the dwellings will not be inundated with floodwater for all events up to and including the 1

[4] http://www.dundee.ac.uk/geography/cbhe/

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in 200 (climate change) event. The finished floor and threshold levels of the dwellings will have a further freeboard of 0.70m above the 1 in 200 year (climate change) water level of 4.80mAOD.

The risk of flooding from tidal flooding is considered to be of **medium significance.** A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

* Surface Water Flooding
* Sewer 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 proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0).

As noted in Section 4.2, approximately 50% of the site is located within Flood Zone 1 and therefore has a 'low probability' of tidal flooding, with a less than 1 in 1000 annual probability of sea flooding in any year (<0.1%).

However, approximately 50% of the site is located within Flood Zone 3 and therefore has a 'high probability' of tidal flooding, with a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

The proposed development is classified as 'more vulnerable', 'more vulnerable' uses are appropriate within Flood Zone 3a after the completion of a satisfactory FRA.

The site is unlikely to flood except in extreme conditions.

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5.0 SURFACE WATER DRAINAGE

5.1 Surface Water

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

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 proposed development, unless specific off-site arrangements are made and result in the same net effect.

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 proposed development, 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 soon to be released National Sustainable Drainage Systems (SUDS) Standards.

5.2 Discharge of Surface Water

There are three possible options to discharge the surface water runoff in accordance with requirement H3 of the Building Regulations 2002, 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.

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5.2.1 Soakaway/Infiltration System

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations. Such work is beyond the scope of this FRA, but should be undertaken to inform the detailed drainage strategy for the site.

5.2.2 Watercourse

The English Channel is located approximately 150m to the south of the site (see Drawing 1). Therefore, it may be possible to discharge surface water runoff from the site into the English Channel.

5.2.3 Sewer

It has been assumed that there are existing public sewers near to the site. It should be confirmed with Southern Water if they have the capacity to accept any discharge of surface water from the site. If so, it may be possible to discharge to the public sewers after attenuating the surface water on site.

5.3 Surface Water Runoff Rates

The site currently comprises a boat and yacht storage compound with adjacent car park.

It is understood that the existing drainage infrastructure at the site efficiently and effectively manages surface water runoff generated at the site. As there is no history of surface water flooding at the site it is likely that the current drainage system is sufficient for the current site use.

It is understood that the proposals are for the erection of 3 detached bungalows, each with deck, garage and parking (see Appendix 2). The incorporation of a garden and landscaped areas will allow a proportion of the rainfall to infiltrate into the soil substrate.

The site comprises a piece of land covering an area of approximately 0.10ha or 1000m^2. Table 5 shows that the existing site is constructed from 0.10ha (100%) of impermeable surfaces with no permeable surfaces located on the site. The proposed development will decrease the impermeable area to 0.05ha (50%) generating lower higher surface water runoff post-development.

Table 5 - Site Areas

Element	Pre-development	Post-development	Difference
Permeable Surfaces (ha)	0.00 (00m^2)	0.05 (500m^2)	+ 0.05 (500m^2)
Impermeable Surfaces (ha)	0.10 (1000m^2)	0.05 (500m^2)	- 0.05 (500m^2)
Total (ha)	**0.10 (1000m^2)**	**0.10 (1000m^2)**	----

In order to quantify any potential changes in surface water runoff, the pre- and post-development runoff rates from the site must be determined. The rates of runoff have been determined using the current 'industry best practice' guidelines as outlined in the Interim Code of Practice for SUDS[5]. The recommended methodology for sites up to 50 hectares in area is the Institute of Hydrology Report 124 method (IoH124)[6].

[5] Office of the Deputy Prime Minister, National SUDS Working Group, July 2004, Interim Code of Practice for sustainable drainage systems.
[6] Institute of Hydrology (1994) Flood estimation for small catchments. Report no 124.

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The following parameters have been incorporated into the runoff calculations within the Masterdrain Drainage Software:

- Catchment Area: 0.1ha;
- M5-60 (mm): 17.5;
- R = 0.35;
- Soil Runoff: 0.40;
- SAAR: 750;
- Hydrological Area: 7;
- Hydrological Zone: 8;
- Soil Classification for WRAP Type: 3
- Urbanisation:
  - Pre-application = 100%
  - Post-application = 50%

Table 6 below shows a comparison of surface water runoff rates pre- (see Appendix 3) and post-development (see Appendix 4) and indicates that the proposed development would result in an decrease in the 1 in 100 year (plus climate change) peak runoff by 2.71l/s or 27.01l/s/ha if the surface water runoff from the developed site is not attenuated.

The greenfield runoff rate has been calculated using the method described in IoH 124. QBAR (rural) has been calculated to be 0.37l/s or 3.69l/s/ha.

Table 6 - Pre-development and Post-development Peak Flows

Return Period (years)	Pre-development		Post-development		Difference	
	l/s	l/s/ha	l/s	l/s/ha	l/s	l/s/ha
1	1.26	12.57	0.70	6.96	-0.56	-5.61
2	1.48	14.79	0.82	8.19	-0.66	-6.6
30	3.30	32.98	1.83	18.26	-1.47	-14.72
100	4.66	46.58	2.58	25.80	-2.08	-20.78
100 + cc	6.06	60.55	3.35	33.54	-2.71	-27.01

Note:

30% added to the data to account for long-term climate change as stated in the NPPF. The 1 year, 30 year and 100 year annual probability events are of importance to the NPPF, Water Companies and the Environment Agency when looking at surface water discharge and flood risk.

5.4 Site Storage Volumes

The provision of suitable storage on site to mitigate the flood risk resulting from the development of the site will be a key factor in the evolution of the site development layout. The provision of large volumes of attenuation, as is likely in this case, 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 NPPF that these are considered as the primary means of collection, control and disposal for storm water as close to source as possible.

Table 7 shows the volume of storage required for the proposed development estimated using the Masterdrain Drainage Software for the 1, 30 and 100 year events, with a 30% allowance for climate change assuming the proposed 50% impermeable area with the greenfield runoff rate of 0.37l/s or 3.69l/s/ha used as the limiting discharge rate (see Appendix 5). Due to the low runoff rates this would result in the calculation of conservative storage volumes.

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Table 7 - Storage Volume

Return Period (years)	Limiting Discharge Rate (l/s)	Rainfall Intensity (mm/hr)	Total Runoff (m^3)	Storage Volume (m^3)
1 + 30%	0.37l/s or 3.69l/s/ha	2.44	14.30	3.70
30 + 30%		4.93	28.90	13.45
100 + 30%		6.33	37.00	19.60

This volume may be reduced by implementing a complex control at the outfall which would increase the rate of discharge from the site for events above the 1 in 30 year event. This should be explored at detailed design stage and agreed with the LPA and Environment Agency.

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

5.5 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 proposed development site therefore, managing the flood risk to the site and surrounding areas from surface water runoff.

A hierarchy of techniques is identified[7]:

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

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

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- 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[8] 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 8.

Table 8 - 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 9). This is designed to ensure that the receiving environments are not put at risk of pollution by new development therefore; accordingly one treatment train will be used on this site.

[8] CIRIA C697 SUDS Manual, 2007.

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Table 9 - Number of Treatment Train Components (assuming effective pre-treatment is in place)

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

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.

5.5.1 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.

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

(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. It is also possible to provide plot-by-plot systems connecting in to a site wide system. There may be scope to apply these features on a plot-by-plot basis as the layout develops further.

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.

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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 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.

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

(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.

It is also proposed to locate a rainwater harvesting system within the site. This will collect the rainwater that falls on this area.

Rainwater from roofs and other hardstanding areas such as car parks will be used within and around the development for a range of non-potable purposes such as flushing toilets and washing down of platforms. This will help reduce the rate and volume of surface water runoff discharging from the site. The water will be stored adjacent to each individual dwelling in underground tanks.

Table 7 shows that 14.30m^3, 28.90m^3 and 37.00m^3 of rainwater is available for rainwater harvesting during the 1 in 1 year (plus climate change), 1 in 30 year (plus climate change) 1 in 100 year (plus climate change) events respectively. The annual rainwater yield at the site will meet the annual non-potable water demand of the site.

(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 25-125 mm 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.

As the buildings will not have flat roofs and the application of green roofs in a domestic scenario is limited due to on-going maintenance and access requirements of any system therefore, this is not a practical option and is therefore not considered further.

5.5.2 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

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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

Infiltration trenches are essentially linear soakaways which allows water to infiltrate into the soils as it is transported to a disposal point. There is space available on this site to provide a length of infiltration trench.

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

(ii) Swales

Swales are open wide trapezoidal channels across a site which allows water to infiltrate into the soils as it is transported to a disposal point. There is space available on this site to provide a length of swale.

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

(iii) Filter Strips

Filter strips will be smaller in plan area than a swale although the swale can be landscaped to be incorporated in to the verge of the carriageway, combining two functions. There is space available on this site to provide a length of swale and it is likely that these will provide a suitable means of surface water disposal.

It has been concluded that there may be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales may work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

5.5.3 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.

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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 this site and options are therefore considered in outline below.

(i) Ponds and Basins

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.

Basins 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.

In this case, the small size of the site would not permit the use of these systems.

(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 site.

(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.

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(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 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 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.

As the site is small, the safe management of flows on the surface and the mobilisation of sufficient attenuation volumes will be very difficult. It is therefore recommended that these systems are only used in emergency circumstances.

5.6 Proposed Surface Water Management Strategy (SWMS)

The objective of this SWMS is to ensure that a sustainable drainage solution can be achieved which reduces the peak discharge rate to the greenfield runoff rate to manage and reduce the flood risk posed by the surface water runoff from the site.

For all development, both the Building Regulations and the NPPF promote a hierarchical approach to surface water management (see Section 6.2). This approach has been adopted within this SWMS with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the English Channel or an existing public sewer.

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In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield runoff rate of 0.37l/s or 3.69l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, 19.60m^3 of storage will be incorporated into the site layout (see Table 6).

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located in underground systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

It is also proposed to locate a rainwater harvesting system within the site. This will collect the rainwater that falls on this area.

Rainwater from roofs and other hardstanding areas such as car parks will be used within and around the development for a range of non-potable purposes such as flushing toilets and washing down of platforms. This will help reduce the rate and volume of surface water runoff discharging from the site. The water will be stored adjacent to each individual dwelling in underground tanks.

The annual rainwater yield at the site will meet the annual non-potable water demand of the site.

One treatment train will be used on this site, to ensure that the receiving environments are not put at risk of pollution by new developments.

Consequently, all areas drained have been designed to accommodate a 100 year (+30% climate change) storm event.

The remainder of the site that is not formally drained, i.e. gardens and areas of open space, 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.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for this site.

These preliminary considerations are based on the outline development scheme provided and hence the design purposes.

The adoption of a surface water management strategy for the site represents an enhancement from the current conditions as the current surface water runoff from the 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.

At this stage of the planning process it is proposed that a planning condition can be adopted to cover the detailed design of the surface water runoff from the site. It is proposed that the detailed drainage design of the final scheme would be secured by a planning condition attached to any

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planning permission granted and agreed with the Environment Agency, Southern Water and the LPA prior to works commencing.

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

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[9].

The attenuation requirements have been designed to accommodate the 100 year storm event plus climate change (+ 30%). To prevent flooding of the proposed properties if the design event is exceeded the surface flows generated will be managed.

The design of the site layout provides an opportunity to manage this exceedance flow and ensure that indiscriminate flooding of property does not occur.

There will not be an extensive sewerage network on the proposed development 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 dwellings because finished floor levels will be a minimum of 1600mm above surrounding ground levels, ensuring any exceedance flooding would not affect the building. Exceedance flows would be contained within Harbour Road to the north of the site.

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.

Therefore, managing and mitigating the flood risk from surface water runoff to the proposed properties from surface water runoff generated by the site development and to offsite locations as well the risk from surface water runoff generated offsite.

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

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6.0 RISK MANAGEMENT

6.1 Introduction

The flood risk at this location is considered suitable for 'more 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 and form of the development and the use of flood mitigation measures.

A number of techniques and mitigation strategies to manage and reduce the overall flood risk in the area will be used. 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 proposed development on flood risk generally; and;
- Minimal disruption to natural heritage.

The flood risk at the site will be reduced by property level protection measures (see Table 10); these are discussed in more detail below.

Table 10 - Property Level Protection Measures

Measure	Details	Description
Property Layout	1. Finished Floor Levels/Raised Thresholds 2. Sequential Approach	Prevents water ingress
Flood Resistance	1. External doors will be fitted with removable flood barriers 2. Air brick will be fitted with flood barriers 3. Sealant used around external doors and windows 4. All windows will be located 1000mm above the ground levels etc.	Prevents water ingress
Flood Resilience	1. Hard surfaces 2. All electrical and gas meters to be not less than 1200mm above ground floor level etc.	Reduce cost and time required to reinstate the property
Safe Access and Egress Routes	1. Safe access and escape route to areas outside of floodplain	Reduce vulnerability of occupants to flooding
Flood Warning	1. Warning so the property can be safely evacuated and mitigation measures to be put in place	Reduce vulnerability of occupants to flooding
Flood Plan	1. Outlines precautions and actions taken when a flood event is anticipated	Reduce vulnerability of occupants to flooding and makes them aware of the mechanisms of flooding at the site

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6.2 Property Layout

6.2.1 Finished Floor/Threshold Level

Raising the finished floor and threshold levels of the buildings will be used to mitigate the effects of flooding at the site.

The finished floor and threshold levels of the dwellings will be located at a minimum of 5.50mAOD which is above the 1 in 200 year (climate change) tidal water level of 4.80mAOD plus a freeboard of 0.70m.

The site is located within an area subject to tidal flooding therefore, floodplain compensation is not required.

6.2.2 Sequential Approach

The sequential approach has been applied within the development site by locating the most vulnerable elements of the development in the lowest risk areas. The most vulnerable use, the buildings, have been situated further away from the tidal flood risk source and on the higher part of the site at a lower risk of flooding with the more flood-compatible uses such as the car parking/landscaped areas being situated nearer the tidal flood risk source on the lower part of the site at a higher risk of flooding.

The dwellings have been located on the area of the site with higher ground levels. Ground levels rise towards the north of the site.

6.3 Flood Resistance

Flood risk can be mitigated through the design of the building. Flood resistance measures are measures that help resist floodwaters entering a property (airbrick covers are an example of a flood resistance measure). Flood resistant measures will be used, including:

- external doors will be fitted with removable flood barriers; and
- air bricks will be fitted with flood barriers.

Sealant will used around external doors and windows. All windows will be located 1000mm above the ground levels. All external doors and windows will be constructed from synthetic materials.

These methods prevent water entering the property and make the property more resistant to seepage.

6.4 Flood Resilience

Flood resilience measures are designed in such a way as to reduce the cost and time required to reinstate the property should it be flooded (tiled floors are an example of a flood resilience measure).

The properties will be constructed in such a way that although floodwater may enter the building, elements that are damaged by flood water can be easily repaired or replaced. This is a form of flood resilience. They are suitable as no other measure is practicable.

Robust materials and finishes will be used, including:

- laying 1 or 2 layers of plasterboards at base of internal studwork construction to ground floors;
- fixings to be galvanised/stainless steel or copper - no mild steel to be used - cause rust/staining or walls;
- water resistant render & lime based plaster to be used;

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- low permeability lime based paints to be used rather than emulsion - allows walls to dry out quickly;
- cavities insulated with closed cell type insulation - use celotex;
- install a second dpc layer min 900mm above ground level;
- install waterproof membrane within foundation trenches;
- separate hobs and built in ovens to be used in preference to combined free standing cookers;
- separate free standing fridge and freezer best considered - it is easier to lift in the event of flooding.
- all electrics wiring, switches, sockets, socket outlets etc. to be located a minimum of 1200mm above ground level;
- all electrical and gas meters to be not less than 1200mm above ground floor level; and
- fit non return valves/anti flow valves at last point of inspection chamber before connection to existing drains.

6.5 Access and Egress Routes

The NPPF requires that, where required, safe access and escape is available to/from new developments in flood risk areas. Access routes should be such that occupants can safely access and exit their dwellings in design flood conditions. These routes must also provide the emergency services with access to the development during a flood event and enable flood defence authorities to carry out any necessary duties during the period of flood.

As the surrounding area is located within Flood Zone 1 a safe access and egress route, including emergency access, can be maintained for vehicles and/or by foot. Two safe access routes will be maintained via Harbour Road, the Parade and Harbour View Road (see Drawing 5).

Ground levels of Harbour Road adjacent to the site are between 3.80mAOD and 3.89mAOD rising to the west and east. Harbour Road would remain dry during the 1 in 200 year event to the west and east of the site. During the 1 in 1000 year event Harbour Road would remain dry to the east of the site with minor flooding of a low hazard rating to the west of the site, as per Table 13.1 of the R & D document - Flood Risk Assessment Guidance for New developments FD2320/TR2.

These routes provide access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event. People will make their way to areas outside of the flood zone. The nearest locations outside of Flood Zone include:

- Nyetimber to the north;
- Areas of Pagham to the west; and
- Aldwick to the North.

In the event of a Flood Warning, vital belongings, including waterproof clothing, necessary medication and essentials for infants and children will be collected. It will be ensured that all members of your party are accounted for, and then exit the site using the routes shown in Drawing 5.

6.6 Flood Warning

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The property is located in a flood risk area therefore; the properties will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

The site will register contact details with the Environment Agency' Flood Warnings Direct Service (Floodline 0845 988 1188) in order to receive Flood Warnings for this area. All occupants and visitors to the site will be made aware of the Environment Agency Floodline telephone number (0845 988 1188) and the three Flood Warning Codes and their meaning.

The Environment Agency uses three Flood Warnings Codes. They can be issued in any order, usually ending with an 'all clear'. They are issued by the Environment Agency through their website[10] and Floodline Warning Direct.

6.7 Flood Plan

A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause will be developed (see http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx). Sensible precautions would include raising electrical items, irreplaceable items and sentimental items off the ground or where possible moving them to a higher floor, rolling up carpets and rugs and turning off utilities. In addition, consider what actions you would take should the property need to be evacuated including access and egress routes and preparing a flood kit in advance containing warm clothing, medication, a torch, food and wellingtons.

The Flood Plan is a 'living' document and therefore should be periodically reviewed and updated to provide advice and guidance to occupants in the event of an extreme flood.

The Flood Plan will therefore reduce the vulnerability of the occupants to flooding and makes them aware of the mechanisms of flooding at the property.

If flooding starts to affect the site without any pre-warning i.e. in real time (e.g. through a failure of the flood warning delivery) the following actions will be taken:

- Occupants and visitors should consider evacuating the site.
- If flood levels continue to rise, occupants and visitors are advised to evacuate before safe access is lost. Occupants and visitors should monitor the flood progression and evacuate.

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.

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

[10] Available at http://www.environment-agency.gov.uk/homeandleisure/floods/31618.aspx. Where specific information can be found by entering the house postcode or address.

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7.0 SUMMARY AND CONCLUSIONS

7.1 Introduction

This report presents a FRA in accordance with the NPPF for the proposed development of land to the east of 29 Harbour Road, Pagham.

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.

7.2 Flood Risk

The principal flood risk to the site is from tidal flooding from the English Channel. It is unlikely that the site would be inundated with floodwater for all events up to and including the present day 1 in 1000 event. There is a further freeboard of 0.21m above the 1 in 200 year water level and 0.02m above the 1 in 1000 year water level.

The site would only be inundated with floodwater during the 1 in 200 (plus climate change) event. The maximum water depth experienced on the site would be 0.93m during the 1 in 200 (plus climate change) event. .

However, the finished floor and threshold levels of the dwellings will be located at 5.50mAOD therefore the dwellings will not be inundated with floodwater for all events up to and including the 1 in 200 (climate change) event. The finished floor and threshold levels of the dwellings will have a further freeboard of 0.70m above the 1 in 200 year (climate change) water level of 4.80mAOD.

The risk of flooding from tidal flooding is considered to be of **medium significance.** A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

- Surface Water Flooding
- Sewer 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 proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0).

Approximately 50% of the site is located within Flood Zone 1 and therefore has a 'low probability' of tidal flooding, with a less than 1 in 1000 annual probability of sea flooding in any year (<0.1%).

However, approximately 50% of the site is located within Flood Zone 3 and therefore has a 'high probability' of tidal flooding, with a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

The proposed development is classified as 'more vulnerable', 'more vulnerable' uses are appropriate within Flood Zone 3a after the completion of a satisfactory FRA.

The site is unlikely to flood except in extreme conditions.

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7.3 Surface Water Drainage

The SWMS ensures that a sustainable drainage solution can be achieved which reduces the peak discharge rate to the greenfield runoff rate to manage and reduce the flood risk posed by the surface water runoff from the site.

For all development, both the Building Regulations and the NPPF promote a hierarchical approach to surface water management. This approach has been adopted within this SWMS with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the English Channel or an existing public sewer.

In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield runoff rate of 0.37l/s or 3.69l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, 19.60m^3 of storage will be incorporated into the site layout.

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located in underground systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

It is also proposed to locate a rainwater harvesting system within the site. This will collect the rainwater that falls on this area.

Rainwater from roofs and other hardstanding areas such as car parks will be used within and around the development for a range of non-potable purposes such as flushing toilets and washing down of platforms. This will help reduce the rate and volume of surface water runoff discharging from the site. The water will be stored adjacent to each individual dwelling in underground tanks.

The annual rainwater yield at the site will meet the annual non-potable water demand of the site.

One treatment train will be used on this site, to ensure that the receiving environments are not put at risk of pollution by new developments.

Consequently, all areas drained have been designed to accommodate a 100 year (+30% climate change) storm event.

The remainder of the site that is not formally drained, i.e. gardens and areas of open space, 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.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for this site.

These preliminary considerations are based on the outline development scheme provided and hence the design purposes.

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The adoption of a surface water management strategy for the site represents an enhancement from the current conditions as the current surface water runoff from the 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.

At this stage of the planning process it is proposed that a planning condition can be adopted to cover the detailed design of the surface water runoff from the site. It is proposed that the detailed drainage design of the final scheme would be secured by a planning condition attached to any planning permission granted and agreed with the Environment Agency, Southern Water and the LPA prior to works commencing.

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.

7.4 Risk Management

The flood risk at the site will be reduced by property level protection measures. Measured used:

Property Layout - Finished Floor/Threshold Level: Raising the finished floor and threshold levels of the buildings will be used to mitigate the effects of flooding at the site.

The finished floor and threshold levels of the dwellings will be located at a minimum of 5.50mAOD which is above the 1 in 200 year (climate change) tidal water level of 4.80mAOD plus a freeboard of 0.70m.

The site is located within an area subject to tidal flooding therefore, floodplain compensation is not required.

Property Layout - Sequential Approach: The most vulnerable use, the buildings, have been situated further away from the tidal flood risk source and on the higher part of the site at a lower risk of flooding with the more flood-compatible uses such as the car parking/landscaped areas being situated nearer the tidal flood risk source on the lower part of the site at a higher risk of flooding.

The dwellings have been located on the area of the site with higher ground levels. Ground levels rise towards the north of the site.

Flood Resistance: Flood resistant measures will be used.

Flood Resilience: Robust materials and finishes will be used.

Access and Egress Routes: As the surrounding area is located within Flood Zone 1 a safe access and egress route, including emergency access, can be maintained for vehicles and/or by foot. Two safe access routes will be maintained via Harbour Road, the Parade and Harbour View Road.

These provide access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event. People will make their way to areas outside of the flood zone. The nearest locations outside of Flood Zone include:

* Nyetimber to the north;
* Areas of Pagham to the west; and
* Aldwick to the North.

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Flood Warning: The property is located in a flood risk area therefore; the properties will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

Flood Plan: A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause will be developed (see http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx).

7.5 Conclusion

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

Table 11 summarises the probability and consequence of flooding for the site with and without mitigation measures.

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

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

Table 11 - Probability and Consequences of all Sources of Flooding

Sources of Flooding	Potential Source	Probability	Consequence & Impact Without Mitigation	Consequence & Impact With Mitigation	Comment
Fluvial Flooding	None Reported	None	Negligible	Negligible	None
Tidal Flooding	English Channel	High	Medium	Medium	Mitigation measures used
Groundwater Flooding	None Reported	None	Negligible	Negligible	None
Surface Water Flooding	Poor Permeability	Low	Low	Low	Mitigation measures used
Sewer Flooding	Local Sewers	Low	Low	Low	Mitigation measures used
Flooding from Artificial Drainage Systems/Infrastructure Failure	None Reported	None	Negligible	Negligible	None

ARUN DISTRICT COUNCIL P/94/15/PL

ARUN DISTRICT COUNCIL P/94/15/PL

DRAWING 1 – Site Location

ARUN DISTRICT COUNCIL P/94/15/PL



KEY

The Site

KRS Environmental

PROJECT	Land to the east of 29 Harbour Road, Pagham
CLIENT	Pagham Beach (Holdings) Ltd
TITLE	Site Location
PROJECT REF	KRS.0030.001
DRAWING NO	1
SCALE	1:10,000@A3
DATE	October 2013

ARUN DISTRICT COUNCIL P/94/15/RL

DRAWING 2 – Surface Water Flood Outline

ARUN DISTRICT COUNCIL P/94/15/PL



KEY

- The Site
- 1 in 200 Year Event Surface Water Flood Outline
- 1 in 100 Year River and 1 in 200 Year Sea Flood Outline

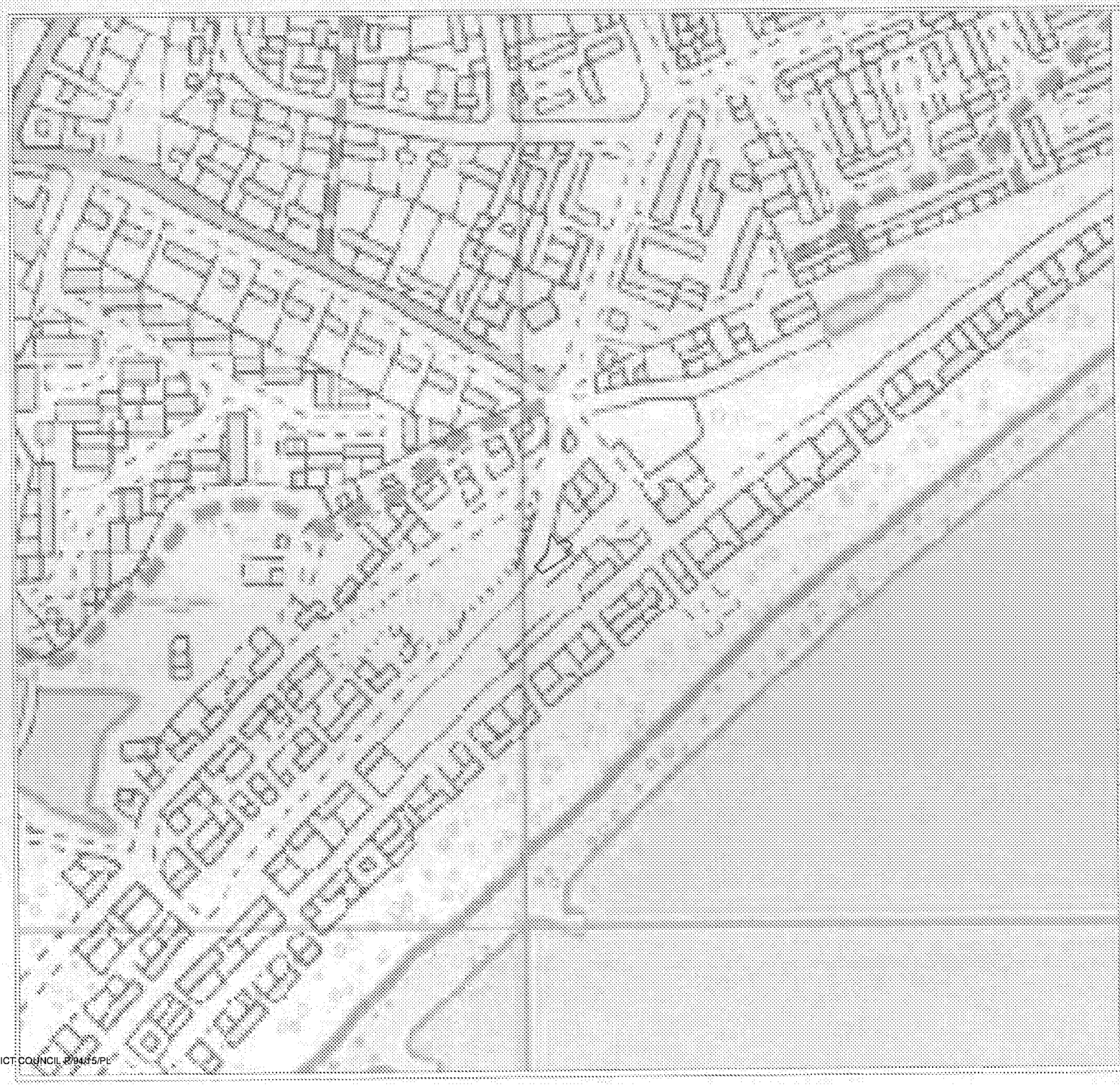
KRS Environmental

PROJECT	Land to the east of 29 Harbour Road, Pagham
CLIENT	Pagham Beach (Holdings) Ltd
TITLE	Surface Water Flood Outlines
PROJECT REF	KRS.0030.001
DRAWING NO	2
SCALE	NTS@A3
DATE	October 2013

ARUN DISTRICT COUNCIL PLANNING

DRAWING 3 – Environment Agency Reservoir Flood Map

ARUN DISTRICT COUNCIL P/94/15/PL



KEY

The Site

Reservoir Flood Outline

KRS Environmental

PROJECT

Land to the east of 29 Harbour Road, Pagham

CLIENT

Pagham Beach (Holdings) Ltd

TITLE

Environment Agency Reservoir Flood Map

PROJECT REF

KRS.0030.001

DRAWING NO

3

SCALE

NTS@A3

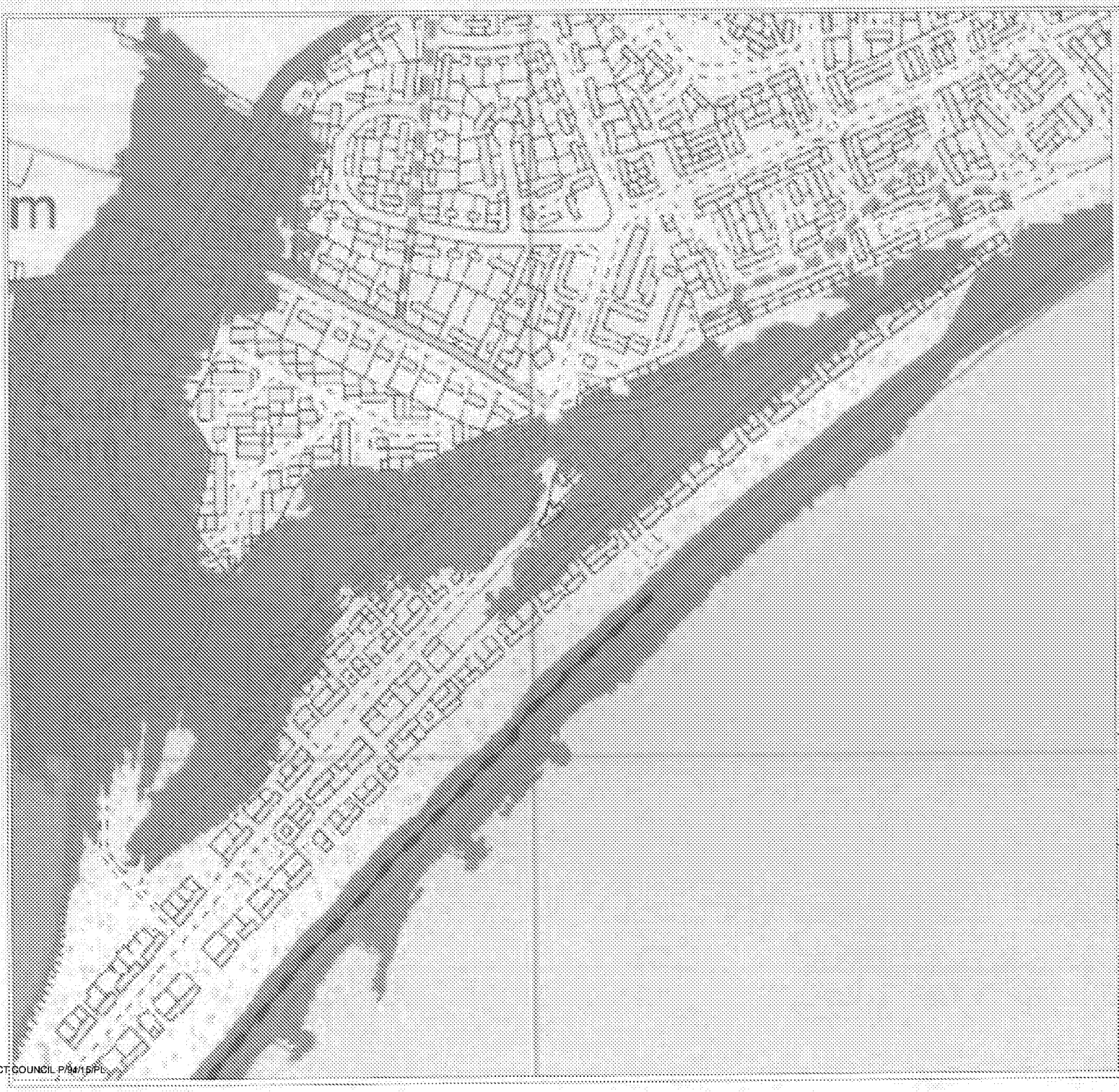
DATE

October 2013

ARUN DISTRICT COUNCIL P/94/15/PL

DRAWING 4 – Environment Agency Flood Zones

ARUN DISTRICT COUNCIL P/94/15/PL



KRS Environmental

PROJECT
Land to the east of 29 Harbour Road, Pagham

CLIENT
Pagham Beach (Holdings) Ltd

TITLE
Environment Agency Flood Zones

PROJECT REF
KRS.0030.001

DRAWING NO
4

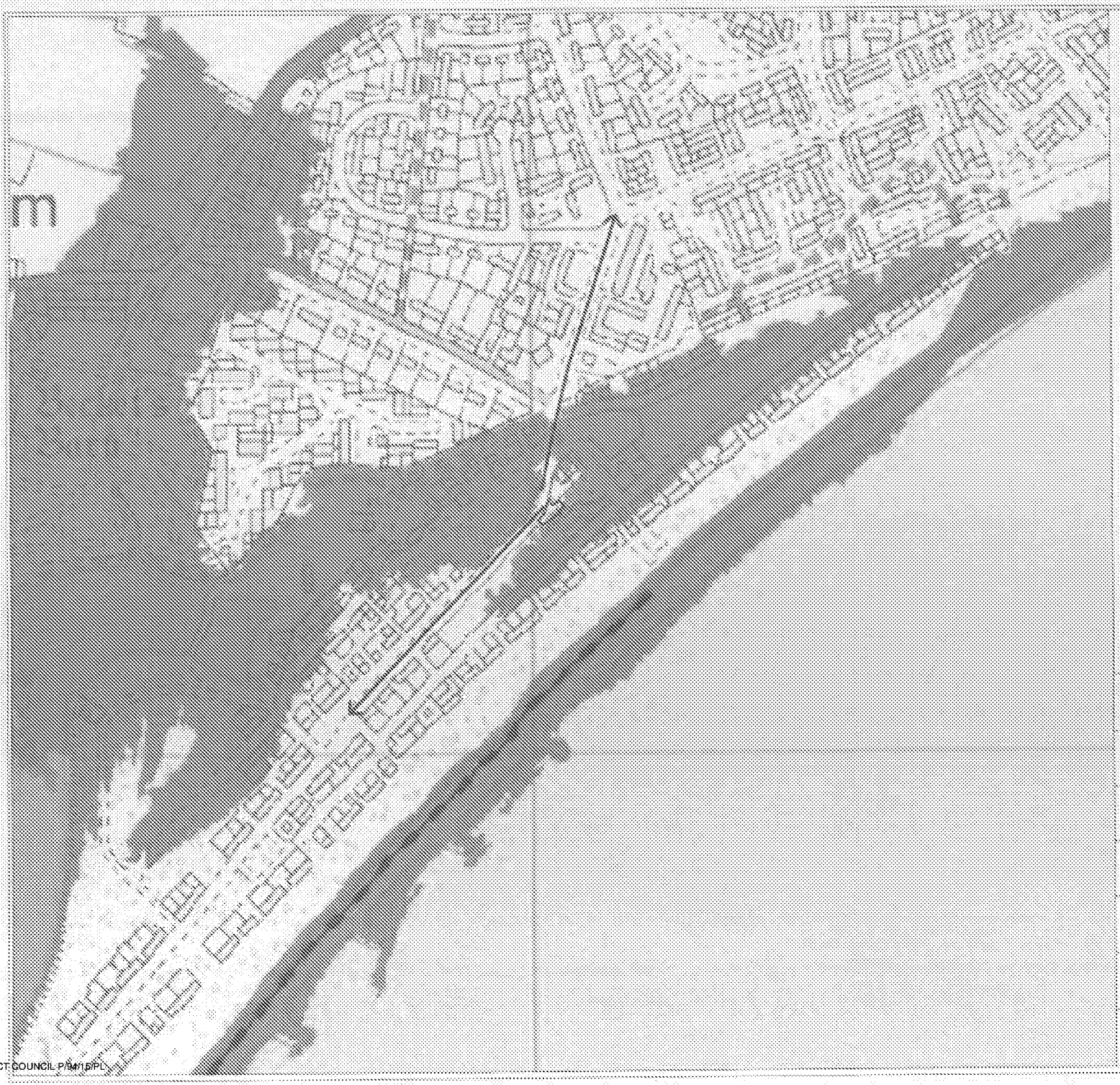
SCALE
NTS@A3

DATE
October 2013

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DRAWING 5 – Safe Access and Egress Routes

ARUN DISTRICT COUNCIL P/94/15/PL



KEY

- The Site
- Flood Zone 3
- Flood Zone 2
- Flood Zone 1
- Flood Defences
- Safe Access and Egress Routes

KRS Environmental

PROJECT	Land to the east of 29 Harbour Road, Pagham
CLIENT	Pagham Beach (Holdings) Ltd
TITLE	Safe Access and Egress Routes
PROJECT REF	KRS.0030.001
DRAWING NO	5
SCALE	NTS@A3
DATE	October 2013

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ARUN DISTRICT COUNCIL P/94/15/PL

APPENDIX 1 – Environment Agency Correspondence

ARUN DISTRICT COUNCIL P/94/15/PL

Keelan Sarjeant
29a Green Abbey
Hade Edge
Holmfirth
Huddersfield
West Yorkshire
HD9 2SH

Our ref: SSD/1883/VH
Your ref:

Date: 17/09/2013

Dear Sir/Madam

Provision of Product 4 for Land East of 29 Harbour Road, Pagham

Thank you for your request to use Environment Agency data. The information is attached.

If you have requested this information to help inform a development proposal, then you should note the detail in the attached advisory text on the use of Environment Agency Information for Flood Risk Assessments / Flood Consequence Assessments.

Supporting Information

This information is provided subject to the enclosed notice, which you should read.

Modelled Flood Levels

In the absence of detailed modelling for this location we have supplied projected tide levels from the 2011 Coastal Extremes Project. Updated modelling is currently underway for this area and we expect to have the final outputs by April 2014. I suggest contacting us again closer to the time for an update on the progress of this updated modelling.

Tide levels taken from 2011 Coastal Extremes Project	
Return Period	Water Level [mAOD]
0.5% 1in200yr	3.66
0.1% 1in1000yr	3.85
0.5% 1in200yr +CC	4.80

Guildbourne House, Chatsworth Road, Worthing, West Sussex BN11 1LD
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

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Flood History

We do not have any records of previous flood events affecting this location. However, I would suggest contacting Arun District Council for a more comprehensive flood history check.

Flood Defences

The Pagham Harbour inland flood defences offer an estimated standard of protection of approximately 1in20yr (5%). Pagham Beach coastal flood defences offer an estimated standard of protection of approximately 1in200yr (0.5%).

If you have any queries or would like to discuss the content of this letter further please don't hesitate to contact me.

Yours faithfully

[redacted]

Jon Denman
FCRM Officer
Partnership and Strategic Overview Team – West Sussex

[redacted]

Enc. Detailed FRA/FCA Map

[Standard Notice]

ARUN DISTRICT COUNCIL P/94/15/PL

Use of Environment Agency Information for Flood Risk / Flood Consequence Assessments

Important
If you have requested this information to help inform a development proposal, then we recommend that you undertake a formal pre-application enquiry using the form available from our website:-

http://www.environment-agency.gov.uk/research/planning/33580.aspx

Depending on the enquiry, we may also provide advice on other issues related to our responsibilities including flooding, waste, land contamination, water quality, biodiversity, navigation, pollution, water resources, foul drainage or Environmental Impact Assessment.

In **England**, you should refer to the Environment Agency's Flood Risk Standing Advice and PPS25 and its associated Practice Guide for information about what flood risk assessment is needed for new development in the different flood zones. These documents can be accessed via:

http://www.environment-agency.gov.uk/research/planning/82587.aspx
http://www.communities.gov.uk/publications/planningandbuilding/pps25floodrisk
http://www.communities.gov.uk/publications/planningandbuilding/pps25practiceguide

You should also consult the Strategic Flood Risk Assessment produced by your local planning authority.

In **Wales,** you should refer to TAN15 for information about what flood consequence assessment is needed for new development in the different flood zones
http://new.wales.gov.uk/splash;jsessionid=8yiGTfGZthmB0t2vno6hS1Gc81LXvZzB3Yiczf20Xn7LK3zK0nMk!981825250?orig=/topics/planning/policy/tans/tan15/

You should also consult the Strategic Flood Consequence Assessment if one has been produced by your local planning authority.

In both **England and Wales** you should note that:

1. Information supplied by the Environment Agency may be used to assist in producing a Flood Risk / Consequence Assessment (FRA / FCA) where one is required, but does not constitute such an assessment on its own.

2. This information covers flood risk from main rivers and the sea, and you will need to consider other potential sources of flooding, such as

ARUN DISTRICT COUNCIL P/94/15/PL

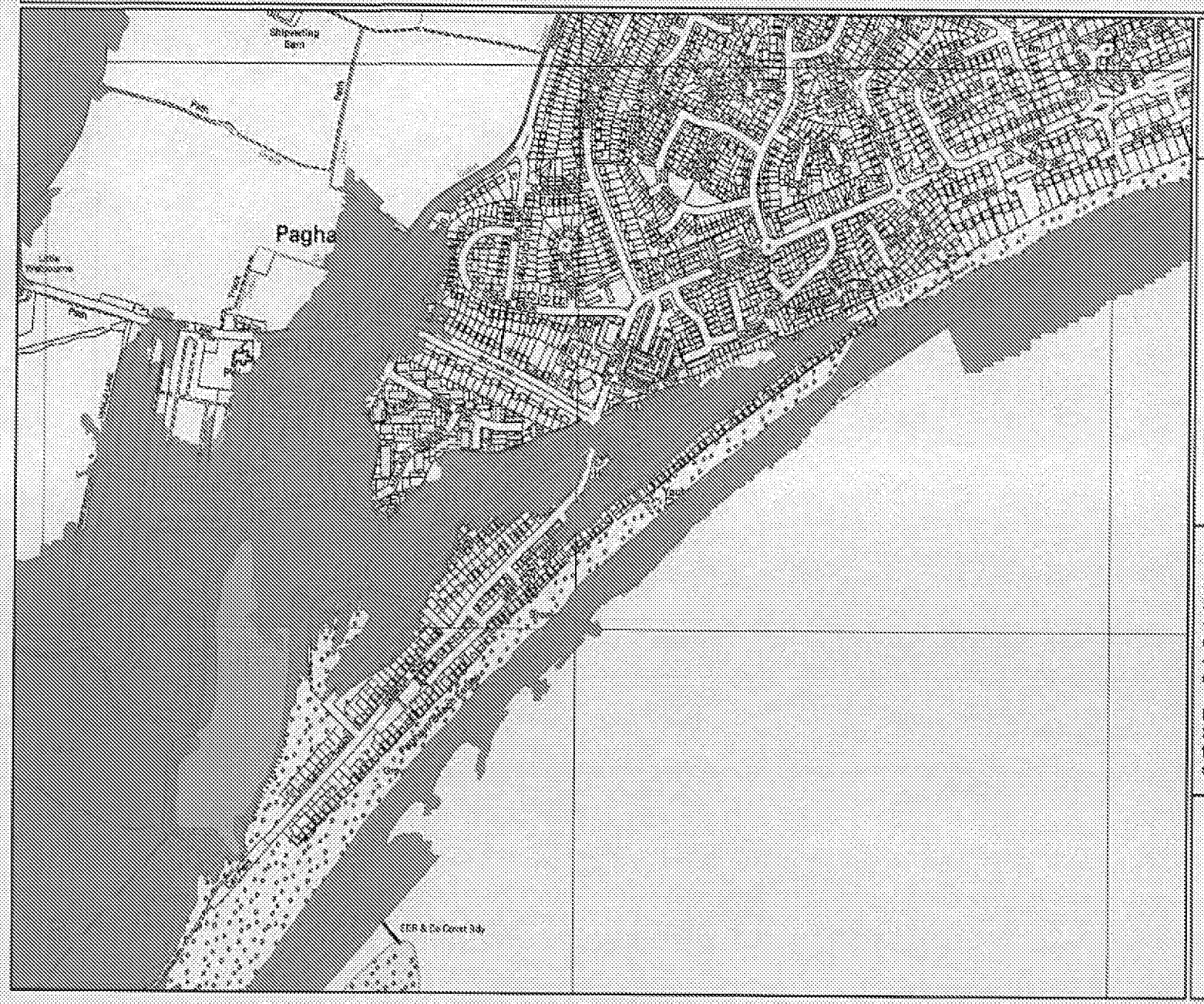
groundwater or overland runoff. The information produced by the local planning authority referred to above may assist here.

3. Where a planning application requires a FRA / FCA and this is not submitted or deficient, the Environment Agency may well raise an objection.

4. For more significant proposals in higher flood risk areas, we would be pleased to discuss details with you ahead of making any planning application, and you should also discuss the matter with your local planning authority.

ARUN DISTRICT COUNCIL P/94/15/PL

Flood Map Centered on Land East of 29 Harbour Road, Pagham - Created 24/09/2013 [Ref: SSD/2008/VH]



Environment Agency

Legend

- Flood Zone 3
- Flood Zone 2

Flood Map Areas (assuming no defences)

Flood Zone 3
Shows the area that could be affected by flooding
- from the sea with an 1 in 200 or greater chance of happening each year.
- or from a river with a 1 in 100 or greater chance of happenening each year.

Flood Zone 2
Shows the extent of an extreme flood from rivers of the sea with up to a 1 in 1000 chance of occuring each year.

1:10,000 *

*when printed at A4.

N

0 260 520

Meters

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Contact Us: National Customer Contact Centre, PO BOX 544, Rotherham, S60 1BY. Tel: 08708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

APPENDIX 2 – Proposed Site Layout

ARUN DISTRICT COUNCIL P/94/15/PL

APPENDIX 3 – Pre-development Surface Water Runoff Rates

ARUN DISTRICT COUNCIL P/94/15/PL

	Company: KRS Environmental Ltd			Project: Land to the east of 29 Harbour Road, Pagh	
	Item: Pre-development Runoff Rates			Job Ref: KSR.0030.001	Sheet no.: 1
MasterDrain Hydrology 8.6	Calc. by: KS	Date: 01/07/13	Checked by:	Date:	Approved by: Date:

Hydrological Data:-

FSR Hydrology:-

Location = PAGHAM
M5-60 (mm) = 17.5
Soil runoff = 0.40
WRAP = 3
Hydrological area = 7

Grid reference = SZ8897
r = 0.35
SAAR (mm/yr) = 750
Area = England & Wales
Hydrological zone = 8

Soil classification for WRAP type 3
i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Design data:-

Area = 0.001 Km² - 0.1 Ha - 1000 m² % Urbanisation = 100.00%

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 =28.485 CWI =80.446 NC =0.740

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 0.002

$Q_{BAR(rural)}$ = 0.369 (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 $Q_{BAR(urban)}$ = 1.48 l/s

Values for $Q_{BAR(urban)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.001	0.001	0.002	0.003	0.005	0.005	cumecs
1.26	1.48	1.89	3.30	4.66	5.47	l/s
12.57	14.79	18.93	32.98	46.58	54.71	l/s/Ha
0.850	1.000	1.280	2.230	3.150	3.700	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).

ARUN DISTRICT COUNCIL P/94/15/PL

APPENDIX 4 – Post-development Surface Water Runoff Rates

ARUN DISTRICT COUNCIL P/94/15/PL

Company: KRS Environmental Ltd				Project: Land to the east of 29 Harbour Road, Pagh	
Item: Post-development Runoff Rates				Job Ref: KSR.0030.001	Sheet no.: 1
MasterDrain Hydrology 8.6	Calc. by: KS	Date: 01/07/13	Checked by:	Date:	Approved by: Date:

Hydrological Data:-

FSR Hydrology:-

Location = PAGHAM
M5-60 (mm) = 17.5
Soil runoff = 0.40
WRAP = 3
Hydrological area = 7

Grid reference = SS8897
r = 0.35
SAAR (mm/yr) = 750
Area = England & Wales
Hydrological zone = 8

Soil classification for WRAP type 3
i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Design data:-

Area = 0.001 Km² - 0.1 Ha - 1000 m² % Urbanisation = 50.00%

Calculation method:-

Runoff is calculated from:-

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

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 - 0.000092SAAR

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

CIND =28.485 CWI =80.446 NC =0.748

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 0.002

$Q_{BAR(rural)}$ = 0.369 (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 $Q_{BAR(urban)}$ = 0.82 l/s

Values for $Q_{BAR(urban)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.001	0.001	0.001	0.002	0.003	0.003	cumecs
0.70	0.82	1.05	1.83	2.58	3.03	l/s
6.96	8.19	10.48	18.26	25.80	30.30	l/s/Ha
0.850	1.000	1.280	2.230	3.150	3.700	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 5 – Storage Volumes

ARUN DISTRICT COUNCIL P/94/15/PL

KRS Environmental Limited.	29a Green Abbey, Hade Edge, Holmfirth, Huddersfield HD9 2RH	Job No. KRS.0030.001
www.krsenvironmental.com	[redacted]	Sheet no. 1
		Date 06/11/13

MasterDrain SW	Project: Land to the east of 29 Harbour Road, Pagham	By	Checked	Reviewed
	Title: 1 in 1 year (+cc) Storage Volumes	KS		

Data:-

Hydrology:-

Grid reference = SZ8897 | Location = PAGHAM
M5-60 (mm) = 17.5 | r = 0.35
WRAP/Soil = 3 / 0.40 | SAAR (mm/yr) = 750
Return period = 1 | Mean intensity = 2.4mm/hr for a 15 hour storm
Climate change factor = 30%
Pipeline storage = 0.0 m³ | Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 78.0% calculated from:-

Percentage runoff = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7

where

PIMP = ImpervArea*100/(ImpervArea+PervArea) = 100.0
UCWI = Calculated value for Wetness Index = 80.4

Imperv. area = 500 m² | Pervious area = 0 m²
Total area = 500 m² | Equiv area = 390 m² (Tot. area x % runoff).
Total runoff = 14.3 m³ | Discharge rate = 0.370 l/s
Storage (m³) = 3.7 m³ (Sum of all balance quantities)
Total rainfall depth = 36.6 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.150	32.0	0.8	0.046	0.200	0.000	0.000
0.300	33.0	0.8	0.047	0.200	0.000	0.000
0.450	33.0	0.8	0.047	0.200	0.000	0.000
0.600	34.0	0.8	0.049	0.200	0.000	0.000
0.750	34.0	0.8	0.049	0.200	0.000	0.000
0.900	35.0	0.9	0.050	0.200	0.000	0.000
1.050	35.0	0.9	0.050	0.200	0.000	0.000
1.200	36.0	0.9	0.051	0.200	0.000	0.000
1.350	36.0	0.9	0.051	0.200	0.000	0.000
1.500	37.0	0.9	0.053	0.200	0.000	0.000
1.650	37.0	0.9	0.053	0.200	0.000	0.000
1.800	38.0	0.9	0.054	0.200	0.000	0.000
1.950	38.0	0.9	0.054	0.200	0.000	0.000
2.100	39.0	1.0	0.056	0.200	0.000	0.000
2.250	40.0	1.0	0.057	0.200	0.000	0.000
2.400	42.0	1.0	0.060	0.200	0.000	0.000
2.550	42.0	1.0	0.060	0.200	0.000	0.000
2.700	43.0	1.1	0.061	0.200	0.000	0.000
2.850	44.0	1.1	0.063	0.200	0.000	0.000
3.000	45.0	1.1	0.064	0.200	0.000	0.000
3.150	46.0	1.1	0.066	0.200	0.000	0.000
3.300	48.0	1.2	0.069	0.200	0.000	0.000
3.450	49.0	1.2	0.070	0.200	0.000	0.000
3.600	51.0	1.2	0.073	0.200	0.000	0.000
3.750	52.0	1.3	0.074	0.200	0.000	0.000
3.900	54.0	1.3	0.077	0.200	0.000	0.000
4.050	56.0	1.4	0.080	0.200	0.000	0.000
4.200	58.0	1.4	0.083	0.200	0.000	0.000
4.350	61.0	1.5	0.087	0.200	0.000	0.000
4.500	64.0	1.6	0.091	0.200	0.000	0.000
4.650	68.0	1.7	0.097	0.200	0.000	0.000
4.800	72.0	1.8	0.103	0.200	0.000	0.000
4.950	78.0	1.9	0.111	0.200	0.000	0.000
5.100	84.0	2.1	0.120	0.200	0.000	0.000
5.250	91.0	2.2	0.130	0.200	0.000	0.000
5.400	99.0	2.4	0.141	0.200	0.000	0.000
5.550	110.0	2.7	0.157	0.200	0.000	0.000
5.700	123.0	3.0	0.176	0.200	0.000	0.000
5.850	136.0	3.3	0.194	0.200	0.000	0.000
6.000	152.0	3.7	0.217	0.200	0.017	0.017

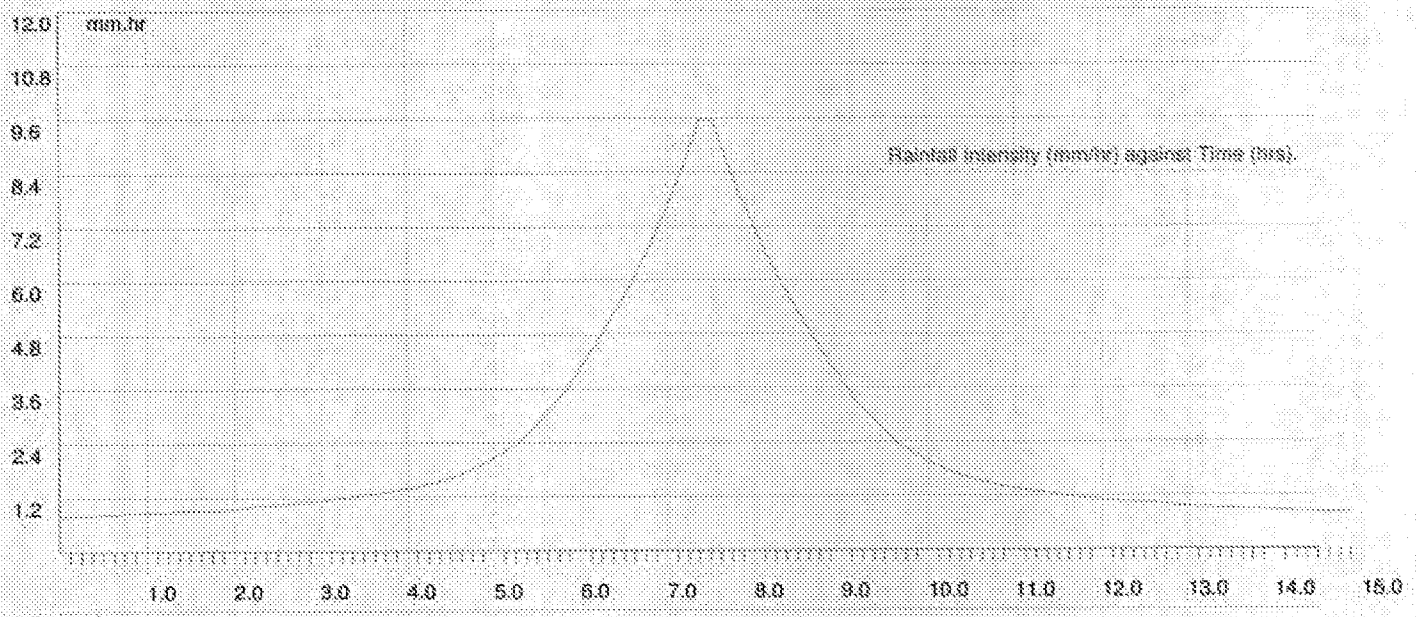
KRS Environmental Limited.	89a Green Abbey, Hade Edge, Holmfirth, Huddersfield HD9 2RH	Job No. KRS.0030.001
www.krsenvironmental.com	[redacted]	Sheet no. 2
		Date 06/11/13
MasterDrain SW	Project: Land to the east of 29 Harbour Road, Pagham	By: KS / Checked / Reviewed
	Title: 1 in 1 year (+cc) Storage Volumes	

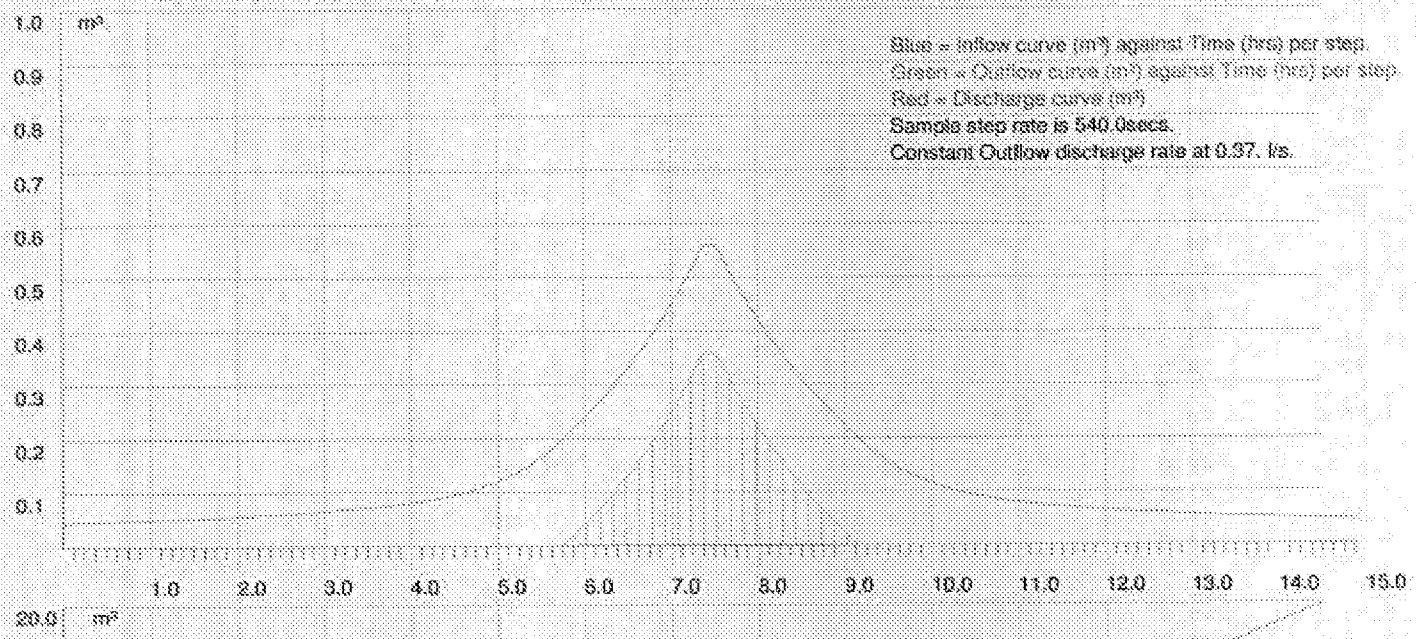
Calculations (cont.) :-

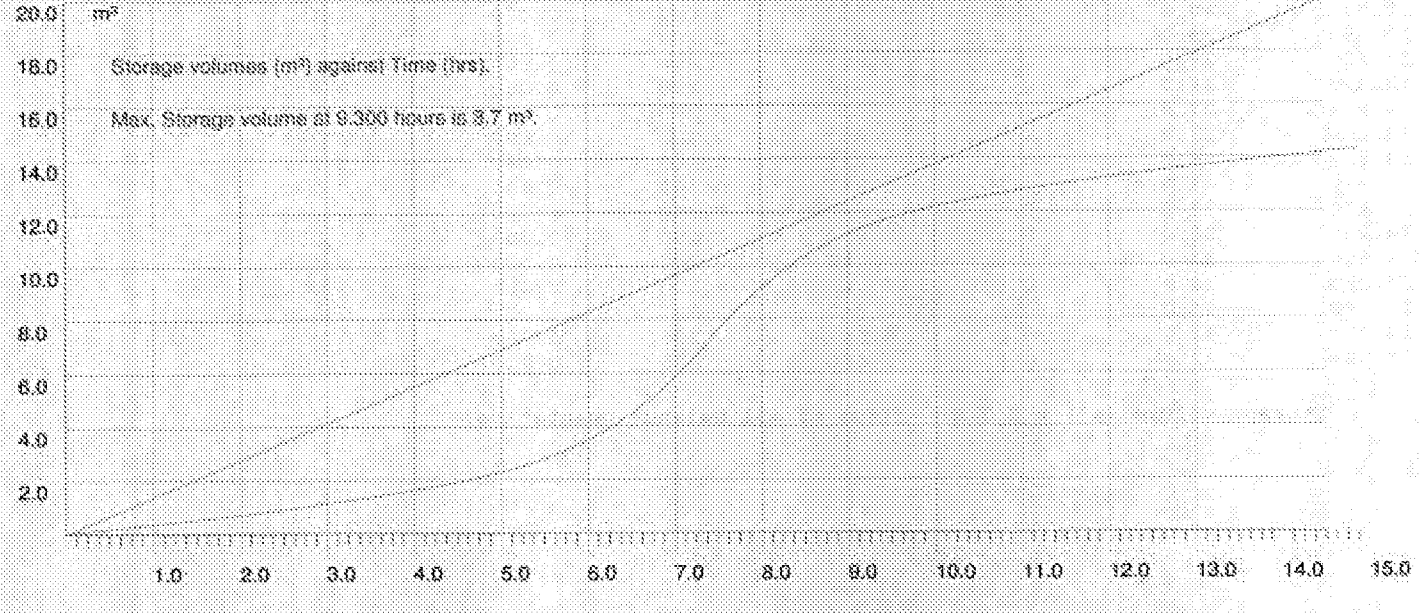
Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
6.150	170.0	4.2	0.243	0.200	0.043	0.061
6.300	188.0	4.6	0.269	0.200	0.069	0.129
6.450	208.0	5.1	0.297	0.200	0.097	0.227
6.600	228.0	5.6	0.326	0.200	0.126	0.353
6.750	250.0	6.1	0.357	0.200	0.157	0.510
6.900	274.0	6.7	0.392	0.200	0.192	0.702
7.050	300.0	7.3	0.429	0.200	0.229	0.931
7.200	328.0	8.0	0.469	0.200	0.269	1.200
7.350	358.0	8.7	0.512	0.200	0.312	1.512
7.500	392.0	9.6	0.560	0.200	0.360	1.872
7.650	392.0	9.6	0.560	0.200	0.360	2.232
7.800	358.0	8.7	0.512	0.200	0.312	2.544
7.950	328.0	8.0	0.469	0.200	0.269	2.813
8.100	300.0	7.3	0.429	0.200	0.229	3.042
8.250	274.0	6.7	0.392	0.200	0.192	3.234
8.400	250.0	6.1	0.357	0.200	0.157	3.391
8.550	228.0	5.6	0.326	0.200	0.126	3.517
8.700	208.0	5.1	0.297	0.200	0.097	3.614
8.850	188.0	4.6	0.269	0.200	0.069	3.683
9.000	170.0	4.2	0.243	0.200	0.043	3.726
9.150	152.0	3.7	0.217	0.200	0.017	3.744
9.300	136.0	3.3	0.194	0.200	0.000	3.738
9.450	123.0	3.0	0.176	0.200	0.000	3.714
9.600	110.0	2.7	0.157	0.200	0.000	3.672
9.750	99.0	2.4	0.141	0.200	0.000	3.613
9.900	91.0	2.2	0.130	0.200	0.000	3.544
10.050	84.0	2.1	0.120	0.200	0.000	3.464
10.200	78.0	1.9	0.111	0.200	0.000	3.375
10.350	72.0	1.8	0.103	0.200	0.000	3.279
10.500	68.0	1.7	0.097	0.200	0.000	3.176
10.650	64.0	1.6	0.091	0.200	0.000	3.068
10.800	61.0	1.5	0.087	0.200	0.000	2.955
10.950	58.0	1.4	0.083	0.200	0.000	2.838
11.100	56.0	1.4	0.080	0.200	0.000	2.718
11.250	54.0	1.3	0.077	0.200	0.000	2.596
11.400	52.0	1.3	0.074	0.200	0.000	2.470
11.550	51.0	1.2	0.073	0.200	0.000	2.343
11.700	49.0	1.2	0.070	0.200	0.000	2.213
11.850	48.0	1.2	0.069	0.200	0.000	2.082
12.000	46.0	1.1	0.066	0.200	0.000	1.948
12.150	45.0	1.1	0.064	0.200	0.000	1.813
12.300	44.0	1.1	0.063	0.200	0.000	1.676
12.450	43.0	1.1	0.061	0.200	0.000	1.537
12.600	42.0	1.0	0.060	0.200	0.000	1.398
12.750	42.0	1.0	0.060	0.200	0.000	1.258
12.900	40.0	1.0	0.057	0.200	0.000	1.115
13.050	39.0	1.0	0.056	0.200	0.000	0.971
13.200	38.0	0.9	0.054	0.200	0.000	0.826
13.350	38.0	0.9	0.054	0.200	0.000	0.680
13.500	37.0	0.9	0.053	0.200	0.000	0.533
13.650	37.0	0.9	0.053	0.200	0.000	0.386
13.800	36.0	0.9	0.051	0.200	0.000	0.238
13.950	36.0	0.9	0.051	0.200	0.000	0.090
14.100	35.0	0.9	0.050	0.200	0.000	0.000
14.250	35.0	0.9	0.050	0.200	0.000	0.000
14.400	34.0	0.8	0.049	0.200	0.000	0.000
14.550	34.0	0.8	0.049	0.200	0.000	0.000
14.700	33.0	0.8	0.047	0.200	0.000	0.000
14.850	33.0	0.8	0.047	0.200	0.000	0.000
15.000	32.0	0.8	0.046	0.200	0.000	0.000

Storage volume (m^3) = 3.7 m^3 (Sum of all balance quantities)

MasterDrain SW	KRS Environmental Limited. www.krsenvironmental.com	23a Green Abbey, Hade Edge Holmfirth Huddersfield HD9 2SH [redacted]	Job No. KRS.0030.001 Sheet no. 3 Date 06/11/13
Project: Land to the east of 29 Harbour Road, Pagham			By: KS; Checked; Reviewed
Title: 1 in 1 year (+cc) Storage Volumes			







MasterDrain SW	KRS Environmental Limited. www.krsenvironmental.com	29a Green Abbey, Hade Edge Holmfirth Huddersfield HD9 2RH [redacted]	Job No. KRS.0030.001 Sheet no. 4 Date 06/11/13
	Project: Land to the east of 29 Harbour Road, Pagham		By: KS; Checked: ; Reviewed:
	Title: 1 in 1 year (+cc) Storage Volumes		

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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.

	KRS Environmental Limited. www.krsenvironmental.com	29a Green Abbey, Slade Edge Holmfirth Huddersfield HD9 2SH [redacted]	Job No. KRS.0030.001 Sheet no. 1 Date 06/11/13
MasterDrain SW	Project: Land to the east of 29 Harbour Road, Pagham		By: KS; Checked: ; Reviewed:
	Title: 1 in 30 year (+cc) Storage Volums		

Data:-

Hydrology:-

Grid reference = SZ8897 Location = PAGHAM
M5-60 (mm) = 17.5 r = 0.35
WRAF/Soil = 3 / 0.40 SAAR (mm/yr) = 750
Return period = 30 Mean intensity = 4.9mm/hr for a 15 hour storm
Climate change factor = 30%
Pipeline storage = 0.0 m³ Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 78.0% calculated from:-
Percentage runoff = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7
where
PIMP = ImpervArea*100/(ImpervArea+PervArea) = 100.0
UCWI = Calculated value for Wetness Index = 80.4

Imperv. area = 500 m² Pervious area = 0 m²
Total area = 500 m² Equiv area = 390 m² (Tot. area x % runoff).
Total runoff = 28.9 m³ Discharge rate = 0.370 l/s
Storage (m³) = 13.4 m³ (Sum of all balance quantities)
Total rainfall depth = 74.0 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.150	32.0	1.6	0.092	0.200	0.000	0.000
0.300	33.0	1.6	0.095	0.200	0.000	0.000
0.450	33.0	1.6	0.095	0.200	0.000	0.000
0.600	34.0	1.7	0.098	0.200	0.000	0.000
0.750	34.0	1.7	0.098	0.200	0.000	0.000
0.900	35.0	1.7	0.101	0.200	0.000	0.000
1.050	35.0	1.7	0.101	0.200	0.000	0.000
1.200	36.0	1.8	0.104	0.200	0.000	0.000
1.350	36.0	1.8	0.104	0.200	0.000	0.000
1.500	37.0	1.8	0.107	0.200	0.000	0.000
1.650	37.0	1.8	0.107	0.200	0.000	0.000
1.800	38.0	1.9	0.110	0.200	0.000	0.000
1.950	38.0	1.9	0.110	0.200	0.000	0.000
2.100	39.0	1.9	0.113	0.200	0.000	0.000
2.250	40.0	2.0	0.115	0.200	0.000	0.000
2.400	42.0	2.1	0.121	0.200	0.000	0.000
2.550	42.0	2.1	0.121	0.200	0.000	0.000
2.700	43.0	2.1	0.124	0.200	0.000	0.000
2.850	44.0	2.2	0.127	0.200	0.000	0.000
3.000	45.0	2.2	0.130	0.200	0.000	0.000
3.150	46.0	2.3	0.133	0.200	0.000	0.000
3.300	48.0	2.4	0.139	0.200	0.000	0.000
3.450	49.0	2.4	0.141	0.200	0.000	0.000
3.600	51.0	2.5	0.147	0.200	0.000	0.000
3.750	52.0	2.6	0.150	0.200	0.000	0.000
3.900	54.0	2.7	0.156	0.200	0.000	0.000
4.050	56.0	2.8	0.162	0.200	0.000	0.000
4.200	58.0	2.9	0.167	0.200	0.000	0.000
4.350	61.0	3.0	0.176	0.200	0.000	0.000
4.500	64.0	3.2	0.185	0.200	0.000	0.000
4.650	68.0	3.4	0.196	0.200	0.000	0.000
4.800	72.0	3.6	0.208	0.200	0.008	0.008
4.950	78.0	3.8	0.225	0.200	0.025	0.033
5.100	84.0	4.1	0.242	0.200	0.043	0.076
5.250	91.0	4.5	0.263	0.200	0.063	0.139
5.400	99.0	4.9	0.286	0.200	0.086	0.225
5.550	110.0	5.4	0.318	0.200	0.118	0.343
5.700	123.0	6.1	0.355	0.200	0.155	0.498
5.850	136.0	6.7	0.393	0.200	0.193	0.691
6.000	152.0	7.5	0.439	0.200	0.239	0.930

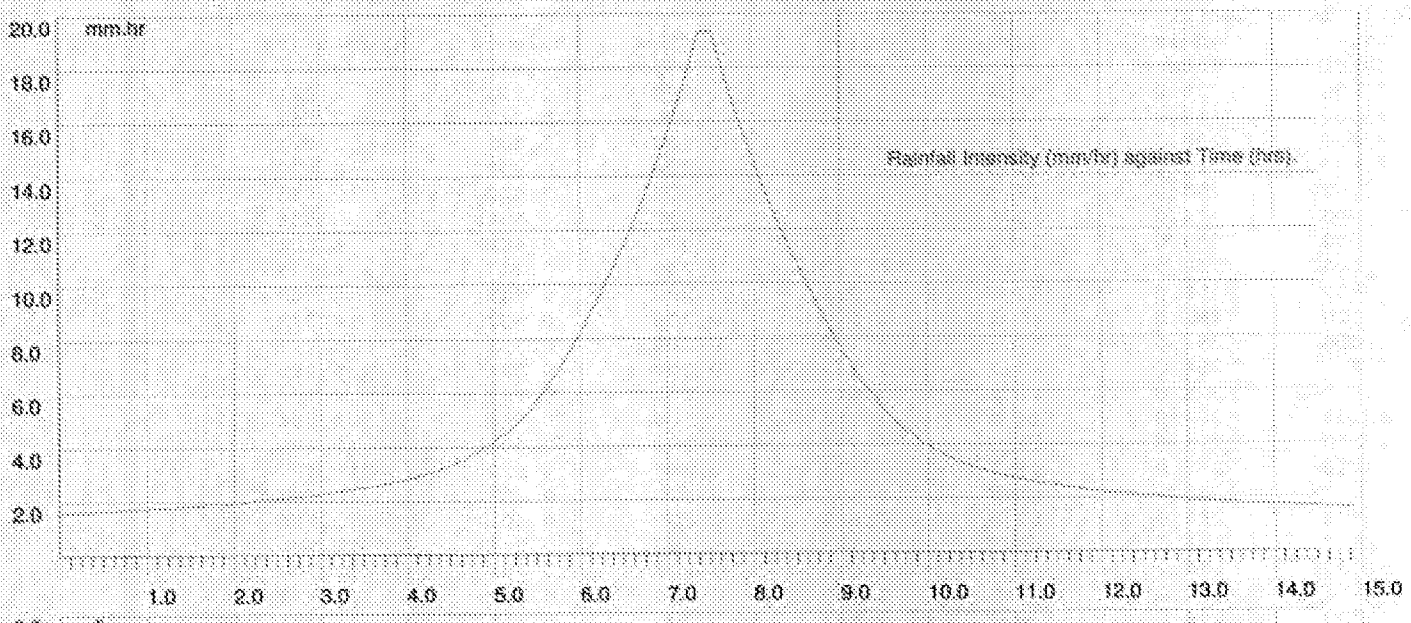
KRS Environmental Limited.	29a Green Abbey, Nade Edge, Holmfirth, Huddersfield HD9 2SH	Job No. KRS.0030.001
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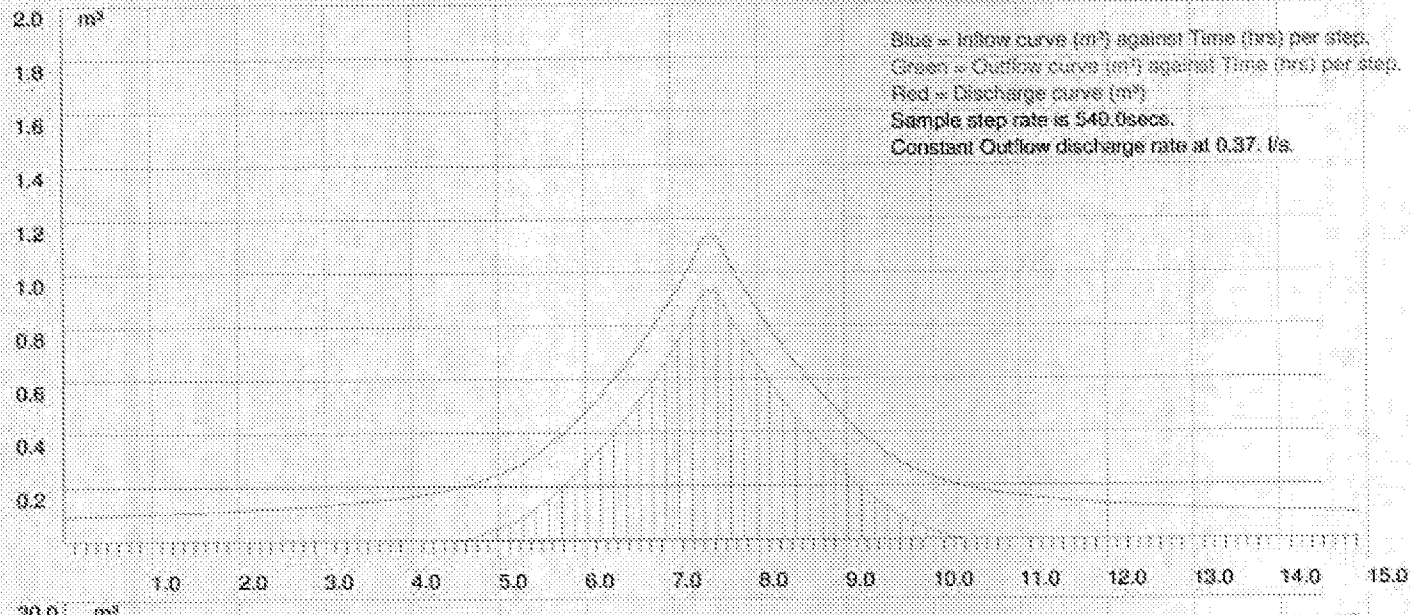
Calculations (cont.) :-

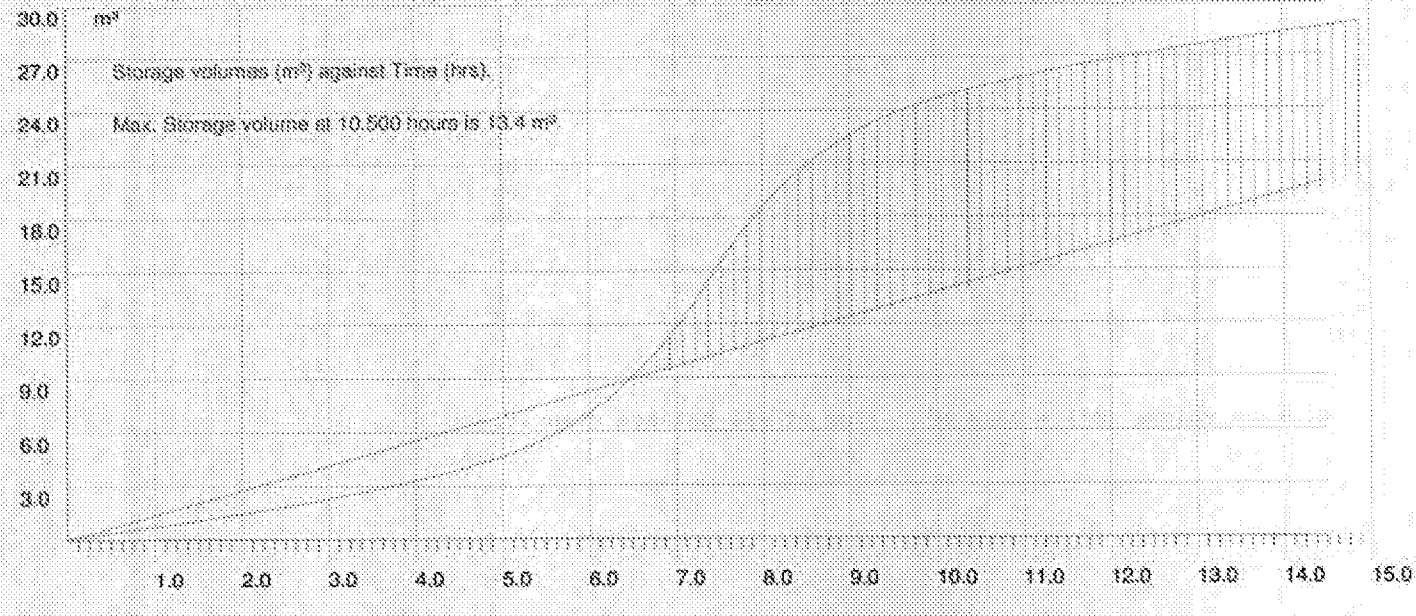
Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
6.150	170.0	8.4	0.491	0.200	0.291	1.221
6.300	188.0	9.3	0.543	0.200	0.343	1.564
6.450	208.0	10.3	0.600	0.200	0.401	1.964
6.600	228.0	11.3	0.658	0.200	0.458	2.423
6.750	250.0	12.3	0.722	0.200	0.522	2.945
6.900	274.0	13.5	0.791	0.200	0.591	3.536
7.050	300.0	14.8	0.866	0.200	0.666	4.202
7.200	328.0	16.2	0.947	0.200	0.747	4.949
7.350	358.0	17.7	1.033	0.200	0.834	5.783
7.500	392.0	19.3	1.132	0.200	0.932	6.715
7.650	392.0	19.3	1.132	0.200	0.932	7.647
7.800	358.0	17.7	1.033	0.200	0.834	8.480
7.950	328.0	16.2	0.947	0.200	0.747	9.227
8.100	300.0	14.8	0.866	0.200	0.666	9.894
8.250	274.0	13.5	0.791	0.200	0.591	10.485
8.400	250.0	12.3	0.722	0.200	0.522	11.007
8.550	228.0	11.3	0.658	0.200	0.458	11.465
8.700	208.0	10.3	0.600	0.200	0.401	11.866
8.850	188.0	9.3	0.543	0.200	0.343	12.209
9.000	170.0	8.4	0.491	0.200	0.291	12.500
9.150	152.0	7.5	0.439	0.200	0.239	12.739
9.300	136.0	6.7	0.393	0.200	0.193	12.931
9.450	123.0	6.1	0.355	0.200	0.155	13.087
9.600	110.0	5.4	0.318	0.200	0.118	13.204
9.750	99.0	4.9	0.286	0.200	0.086	13.290
9.900	91.0	4.5	0.263	0.200	0.063	13.353
10.050	84.0	4.1	0.242	0.200	0.043	13.396
10.200	78.0	3.8	0.225	0.200	0.025	13.421
10.350	72.0	3.6	0.208	0.200	0.008	13.429
10.500	68.0	3.4	0.196	0.200	0.000	13.426
10.650	64.0	3.2	0.185	0.200	0.000	13.411
10.800	61.0	3.0	0.176	0.200	0.000	13.387
10.950	58.0	2.9	0.167	0.200	0.000	13.355
11.100	56.0	2.8	0.162	0.200	0.000	13.317
11.250	54.0	2.7	0.156	0.200	0.000	13.273
11.400	52.0	2.6	0.150	0.200	0.000	13.223
11.550	51.0	2.5	0.147	0.200	0.000	13.171
11.700	49.0	2.4	0.141	0.200	0.000	13.112
11.850	48.0	2.4	0.139	0.200	0.000	13.051
12.000	46.0	2.3	0.133	0.200	0.000	12.984
12.150	45.0	2.2	0.130	0.200	0.000	12.914
12.300	44.0	2.2	0.127	0.200	0.000	12.841
12.450	43.0	2.1	0.124	0.200	0.000	12.766
12.600	42.0	2.1	0.121	0.200	0.000	12.687
12.750	42.0	2.1	0.121	0.200	0.000	12.609
12.900	40.0	2.0	0.115	0.200	0.000	12.524
13.050	39.0	1.9	0.113	0.200	0.000	12.437
13.200	38.0	1.9	0.110	0.200	0.000	12.347
13.350	38.0	1.9	0.110	0.200	0.000	12.257
13.500	37.0	1.8	0.107	0.200	0.000	12.164
13.650	37.0	1.8	0.107	0.200	0.000	12.071
13.800	36.0	1.8	0.104	0.200	0.000	11.975
13.950	36.0	1.8	0.104	0.200	0.000	11.879
14.100	35.0	1.7	0.101	0.200	0.000	11.780
14.250	35.0	1.7	0.101	0.200	0.000	11.682
14.400	34.0	1.7	0.098	0.200	0.000	11.580
14.550	34.0	1.7	0.098	0.200	0.000	11.478
14.700	33.0	1.6	0.095	0.200	0.000	11.374
14.850	33.0	1.6	0.095	0.200	0.000	11.269
15.000	32.0	1.6	0.092	0.200	0.000	11.162

Storage volume (m^3) = 13.4 m^3 (Sum of all balance quantities)

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MasterDrain SW	Project: Land to the east of 29 Harbour Road, Pagham	By: KS	Checked:	Reviewed:
	Title: 1 in 30 year (+cc) Storage Volums		







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MasterDrain SW	Project: Land to the east of 29 Harbour Road, Pagham Title: 1 in 30 year (+cc) Storage Volume	By: KS	Checked / Reviewed

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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.

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	Project: Land to the east of 29 Harbour Road, Pagham		By KS	Checked	Reviewed
	Title: 1 in 100 year (+cc) Storage Volumes			

Data:-

Hydrology:-

Grid reference = SZ8897
M5-60 (mm) = 17.5
WRAP/Soil = 3 / 0.40
Return period = 100
Climate change factor = 30%
Pipeline storage = 0.0 m³
Offline storage = 0.0 m³

Location = PAGHAM
r = 0.35
SAAR (mm/yr) = 750
Mean intensity = 6.3mm/hr for a 15 hour storm

Available MH storage = 0.0 m³

Percentage runoff = 78.0% calculated from:-

Percentage runoff = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7

where

PIMP = ImpervArea*100/(ImpervArea+PervArea) = 100.0
UCWI = Calculated value for Wetness Index = 80.4

Imperv. area = 500 m²
Total area = 500 m²
Total runoff = 37.0 m³

Pervious area = 0 m²
Equiv area = 390 m² (Tot. area x % runoff).
Discharge rate = 0.370 l/s

Storage (m³) = 19.6 m³ (Sum of all balance quantities)

Total rainfall depth = 94.9 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.150	32.0	2.0	0.118	0.200	0.000	0.000
0.300	33.0	2.1	0.122	0.200	0.000	0.000
0.450	33.0	2.1	0.122	0.200	0.000	0.000
0.600	34.0	2.2	0.126	0.200	0.000	0.000
0.750	34.0	2.2	0.126	0.200	0.000	0.000
0.900	35.0	2.2	0.130	0.200	0.000	0.000
1.050	35.0	2.2	0.130	0.200	0.000	0.000
1.200	36.0	2.3	0.133	0.200	0.000	0.000
1.350	36.0	2.3	0.133	0.200	0.000	0.000
1.500	37.0	2.3	0.137	0.200	0.000	0.000
1.650	37.0	2.3	0.137	0.200	0.000	0.000
1.800	38.0	2.4	0.141	0.200	0.000	0.000
1.950	38.0	2.4	0.141	0.200	0.000	0.000
2.100	39.0	2.5	0.144	0.200	0.000	0.000
2.250	40.0	2.5	0.148	0.200	0.000	0.000
2.400	42.0	2.7	0.156	0.200	0.000	0.000
2.550	42.0	2.7	0.156	0.200	0.000	0.000
2.700	43.0	2.7	0.159	0.200	0.000	0.000
2.850	44.0	2.8	0.163	0.200	0.000	0.000
3.000	45.0	2.8	0.167	0.200	0.000	0.000
3.150	46.0	2.9	0.170	0.200	0.000	0.000
3.300	48.0	3.0	0.178	0.200	0.000	0.000
3.450	49.0	3.1	0.181	0.200	0.000	0.000
3.600	51.0	3.2	0.189	0.200	0.000	0.000
3.750	52.0	3.3	0.193	0.200	0.000	0.000
3.900	54.0	3.4	0.200	0.200	0.000	0.000
4.050	56.0	3.5	0.207	0.200	0.008	0.008
4.200	58.0	3.7	0.215	0.200	0.015	0.023
4.350	61.0	3.9	0.226	0.200	0.026	0.049
4.500	64.0	4.1	0.237	0.200	0.037	0.086
4.650	68.0	4.3	0.252	0.200	0.052	0.138
4.800	72.0	4.6	0.267	0.200	0.067	0.205
4.950	78.0	4.9	0.289	0.200	0.089	0.294
5.100	84.0	5.3	0.311	0.200	0.111	0.405
5.250	91.0	5.8	0.337	0.200	0.137	0.542
5.400	99.0	6.3	0.367	0.200	0.167	0.709
5.550	110.0	7.0	0.407	0.200	0.208	0.916
5.700	123.0	7.8	0.455	0.200	0.256	1.172
5.850	136.0	8.6	0.504	0.200	0.304	1.476
6.000	152.0	9.6	0.563	0.200	0.363	1.839

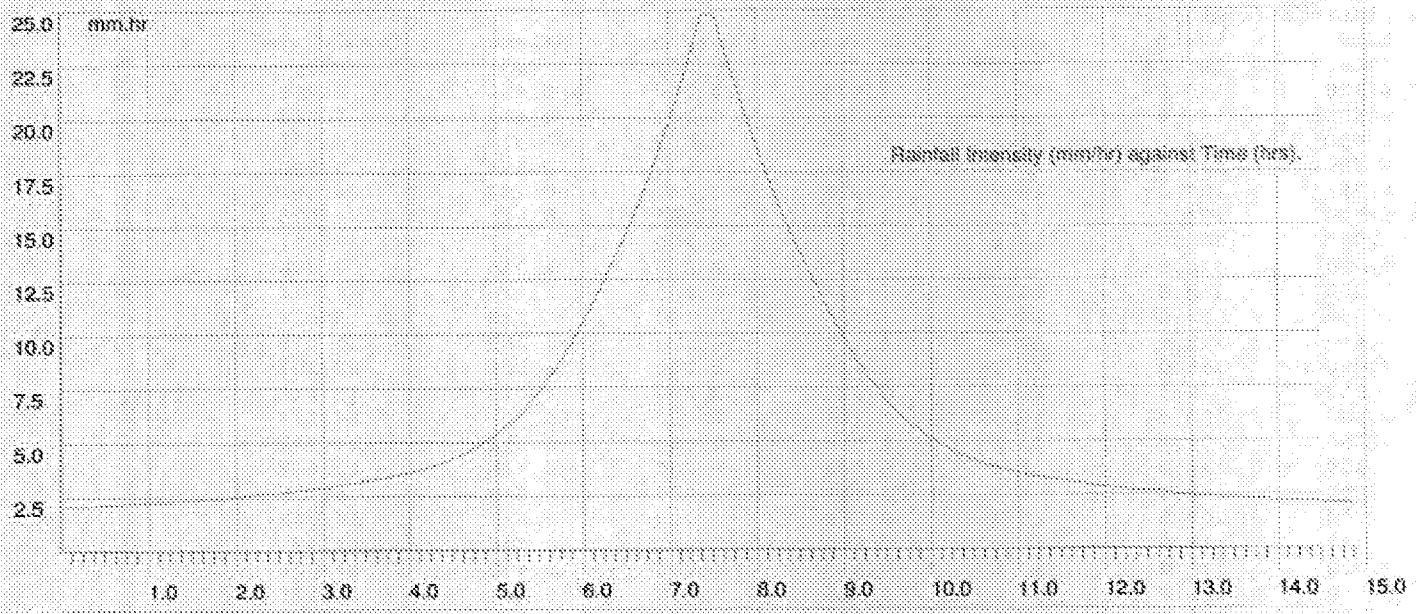
KRS Environmental Limited.	29a Green Abbey, Nade Edge, Holmfirth, Huddersfield HD9 2SH	Job No. KRS.0030.001
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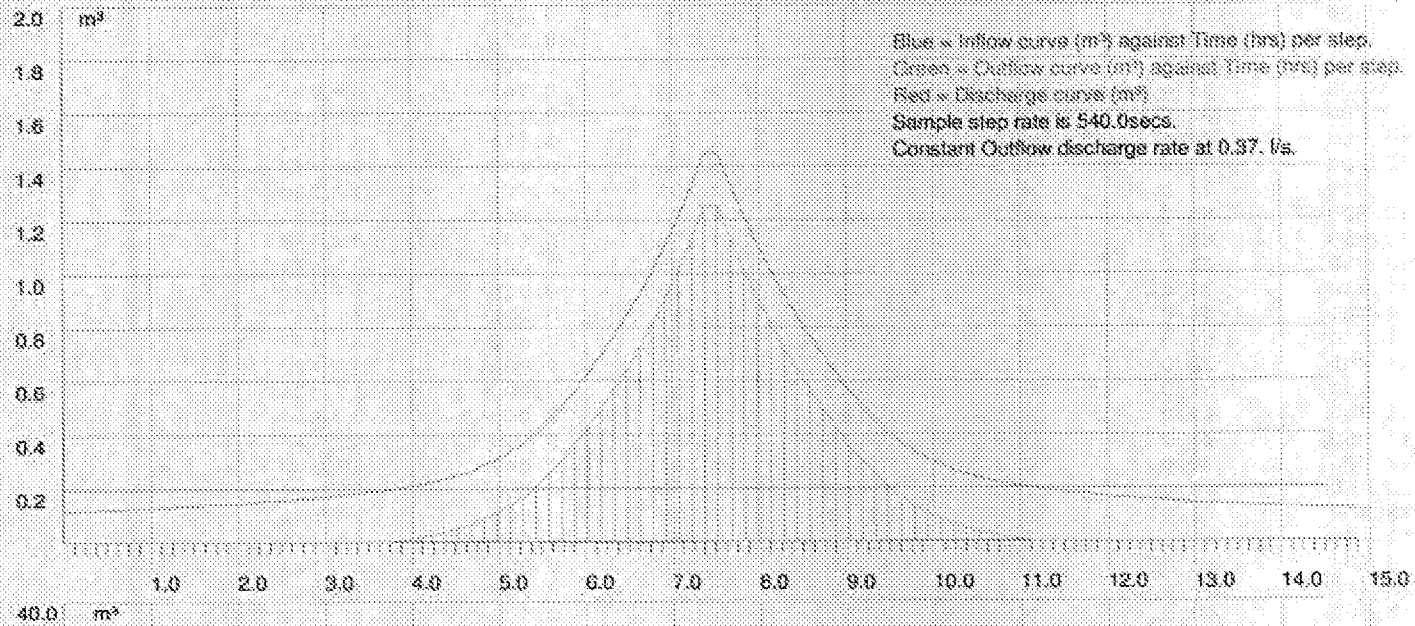
Calculations (cont.) :-

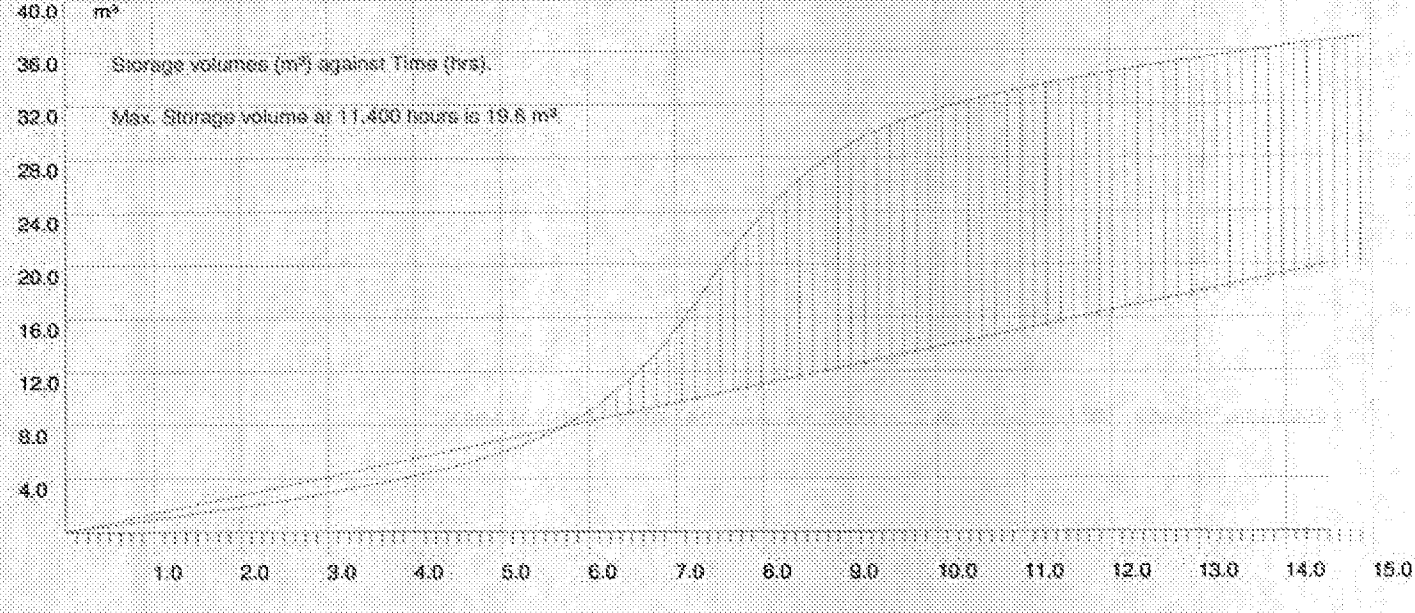
Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
6.150	170.0	10.8	0.629	0.200	0.430	2.269
6.300	188.0	11.9	0.696	0.200	0.496	2.765
6.450	208.0	13.2	0.770	0.200	0.570	3.335
6.600	228.0	14.4	0.844	0.200	0.644	3.980
6.750	250.0	15.8	0.926	0.200	0.726	4.706
6.900	274.0	17.3	1.015	0.200	0.815	5.520
7.050	300.0	19.0	1.111	0.200	0.911	6.431
7.200	328.0	20.8	1.215	0.200	1.015	7.446
7.350	358.0	22.7	1.326	0.200	1.126	8.572
7.500	392.0	24.8	1.451	0.200	1.252	9.824
7.650	392.0	24.8	1.451	0.200	1.252	11.075
7.800	358.0	22.7	1.326	0.200	1.126	12.201
7.950	328.0	20.8	1.215	0.200	1.015	13.216
8.100	300.0	19.0	1.111	0.200	0.911	14.127
8.250	274.0	17.3	1.015	0.200	0.815	14.942
8.400	250.0	15.8	0.926	0.200	0.726	15.667
8.550	228.0	14.4	0.844	0.200	0.644	16.312
8.700	208.0	13.2	0.770	0.200	0.570	16.882
8.850	188.0	11.9	0.696	0.200	0.496	17.379
9.000	170.0	10.8	0.629	0.200	0.430	17.808
9.150	152.0	9.6	0.563	0.200	0.363	18.171
9.300	136.0	8.6	0.504	0.200	0.304	18.475
9.450	123.0	7.8	0.455	0.200	0.256	18.731
9.600	110.0	7.0	0.407	0.200	0.208	18.938
9.750	99.0	6.3	0.367	0.200	0.167	19.105
9.900	91.0	5.8	0.337	0.200	0.137	19.242
10.050	84.0	5.3	0.311	0.200	0.111	19.353
10.200	78.0	4.9	0.289	0.200	0.089	19.442
10.350	72.0	4.6	0.267	0.200	0.067	19.509
10.500	68.0	4.3	0.252	0.200	0.052	19.561
10.650	64.0	4.1	0.237	0.200	0.037	19.598
10.800	61.0	3.9	0.226	0.200	0.026	19.624
10.950	58.0	3.7	0.215	0.200	0.015	19.639
11.100	56.0	3.5	0.207	0.200	0.008	19.647
11.250	54.0	3.4	0.200	0.200	0.000	19.647
11.400	52.0	3.3	0.193	0.200	0.000	19.640
11.550	51.0	3.2	0.189	0.200	0.000	19.629
11.700	49.0	3.1	0.181	0.200	0.000	19.610
11.850	48.0	3.0	0.178	0.200	0.000	19.588
12.000	46.0	2.9	0.170	0.200	0.000	19.559
12.150	45.0	2.8	0.167	0.200	0.000	19.526
12.300	44.0	2.8	0.163	0.200	0.000	19.489
12.450	43.0	2.7	0.159	0.200	0.000	19.448
12.600	42.0	2.7	0.156	0.200	0.000	19.404
12.750	42.0	2.7	0.156	0.200	0.000	19.360
12.900	40.0	2.5	0.148	0.200	0.000	19.308
13.050	39.0	2.5	0.144	0.200	0.000	19.253
13.200	38.0	2.4	0.141	0.200	0.000	19.194
13.350	38.0	2.4	0.141	0.200	0.000	19.134
13.500	37.0	2.3	0.137	0.200	0.000	19.072
13.650	37.0	2.3	0.137	0.200	0.000	19.009
13.800	36.0	2.3	0.133	0.200	0.000	18.942
13.950	36.0	2.3	0.133	0.200	0.000	18.876
14.100	35.0	2.2	0.130	0.200	0.000	18.806
14.250	35.0	2.2	0.130	0.200	0.000	18.735
14.400	34.0	2.2	0.126	0.200	0.000	18.662
14.550	34.0	2.2	0.126	0.200	0.000	18.588
14.700	33.0	2.1	0.122	0.200	0.000	18.510
14.850	33.0	2.1	0.122	0.200	0.000	18.432
15.000	32.0	2.0	0.118	0.200	0.000	18.351

Storage volume (m^3) = 19.6 m^3 (Sum of all balance quantities)

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MasterDrain SW	Project Land to the east of 29 Harbour Road, Pagham	By KS	Checked / Reviewed
	Title 1 in 100 year (+cc) Storage Volumes		







MasterDrain SW

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Title: 1 in 100 year (+cc) Storage Volumes	KS		

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	9.98	0.25	105.74	0.0	
0.5	13.21	0.50	71.15	0.0	
1	16.53	1.00	45.80	0.6	
2	19.61	2.00	28.55	1.2	
3	21.02	3.00	21.38	1.8	
4	21.67	4.00	17.30	2.4	
5	21.88	5.00	14.63	3.0	Peak found
6	21.78	~~~	12.72	3.6	
7	21.59	~~~	11.32	4.2	
8	21.28	~~~	10.23	4.8	
9	20.99	~~~	9.35	5.4	
10	20.74	~~~	8.63	6.0	
12	20.27	~~~	7.51	7.2	
15	19.65	~~~	6.33	9.0	
18	19.07	~~~	5.50	10.8	
20	18.69	~~~	5.07	12.0	
24	17.92	~~~	4.41	14.4	
30	16.76	~~~	3.71	18.0	
36	15.62	~~~	3.22	21.6	
42	14.47	~~~	2.85	25.2	
48	13.35	~~~	2.57	28.8	
54	12.27	~~~	2.34	32.4	
60	11.22	~~~	2.16	36.0	
66	10.18	~~~	2.00	39.6	
72	9.23	~~~	1.87	43.2	
84	7.43	~~~	1.65	50.4	
96	5.85	~~~	1.49	57.6	
120	3.29	~~~	1.25	72.0	
150	1.18	~~~	1.04	90.0	
175	0.28	~~~	0.92	105.0	
200	0.00	~~~	0.83	120.0	
250	0.00	~~~	0.70	150.0	
300	0.00	~~~	0.60	180.0	
375	0.00	~~~	0.51	225.0	
500	0.00	~~~	0.40	300.0	
750	0.00	~~~	0.29	450.0	
1000	0.00	~~~	0.23	600.0	
1250	0.00	~~~	0.20	750.0	
1500	0.00	~~~	0.17	900.0	
1570	0.00	~~~	0.17	942.0	
2000	0.00	~~~	0.14	1200.0	
2500	0.00	~~~	0.12	1500.0	
3000	0.00	~~~	0.10	1800.0	
3500	0.00	~~~	0.09	2100.0	
4000	0.00	~~~	0.08	2400.0	

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		Sheet no. 5	
		Date 06/11/13	
MasterDrain SW	Project Land to the east of 29 Harbour Road, Pagham	By KS	Checked / Reviewed
	Title 1 in 100 year (+cc) Storage Volumes		

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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.



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