
Development at Barnburgh Lane, Goldthorpe, Barnsley

Flood Risk Assessment

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GLOSSARY

A.E.P:	Annual exceedence probability
AOD(N):	Above Ordnance Datum (Newlyn)
Catchment:	The area of land over which rain falls which produces stream-flow
CCA:	Climate change allowance
CEH:	Centre for Ecology and Hydrology
DDF:	Depth-duration-frequency
FEH:	Flood Estimation Handbook
FRA:	Flood risk assessment
Freeboard:	The amount by which a ground or floor level is above the flood level.
HOST	Hydrology of soil types
MDC	Metropolitan District Council
NGR:	National Grid Reference
OBM:	Ordnance Survey Benchmark
PR:	Percentage run-off
SFRA:	Strategic Flood Risk Assessment
SPRHOST:	Standard percentage run-off derived from HOST soils data

1.0 INTRODUCTION AND BACKGROUND

JOC Consultants Ltd was instructed in November 2011 by Gleeson Regeneration and Homes Ltd to prepare a flood risk assessment (FRA), for a development site at Goldthorpe which is the subject of a planning application for a housing development.

References in this report to “the site” are references to the site to which the planning application applies. Specific references to sources of information used in the report are shown in square brackets and are listed in section 9. Figures 1 to 5 are presented immediately following page 13 and the appendices follow thereafter.

This report is prepared specifically for Gleeson Regeneration and Homes Ltd for the purpose of the aforementioned planning application and the report may not be used for any purpose other than for the purpose for which it was commissioned, and it may not be assigned to any third party without our written permission.

This flood risk assessment is based on data available at the time of its preparation and JOC Consultants Ltd accepts no liability for the consequences of any changes to or re-assessment of this data in the future.

2.0 OBJECTIVES

The objectives of this flood risk assessment are:

1. to establish whether the proposed development is likely to be affected by current or future flooding from any source;
2. to establish whether the proposed development will increase flood risk elsewhere;
3. to recommend, as appropriate, measures for managing flood risk; and
4. to establish whether the proposed development would satisfy the third requirement of the Exception Test¹, should it be necessary to apply the Exception Test.

3.0 PLANNING POLICY ON FLOOD RISK

3.1 Development and Flood Risk: Planning Policy Statement 25

Planning Policy Guidance Statement (PPS) 25, published in December 2006 [1], provides guidance to planning authorities on matters of flood risk and its interpretation is discussed in the Practice Guide to PPS 25, published in June 2008 [2].

PPS 25 emphasises that susceptibility to flooding is a material planning consideration and planning authorities are required to adopt a risk-based approach at all levels of the planning process. The requirements of a flood risk assessment are set out in Appendix E of PPS 25 which deals with all levels of assessment from regional to site-specific.

All land to which PPS 25 applies is grouped into flood zones which identify areas of varying flood risk. The following zones are defined in PPS 25:

¹ PPS 25: Paragraph D9(c)

- Zone 1: Low Probability: annual probability of flooding from rivers or sea is less than 0.1%;
- Zone 2: Medium Probability: annual probability of flooding from rivers is between 0.1% and 1% and from the sea is between 0.5% and 0.1%;
- Zone 3a: High Probability: annual probability of flooding from rivers is greater than 1% and from the sea is greater than 0.5%.
- Zone 3b: The Functional Floodplain: Land where water has to flow or be stored in times of flood and where the annual probability of flooding is greater than 5% or where the land is designed to flood in an extreme flood event.

A flood risk assessment is required to be submitted with planning applications for all new developments in flood zone 2 and flood zones 3a and 3b, (medium and high probability and the functional floodplain). A flood risk assessment must also be submitted for all new development proposals of 1ha or greater in flood zone 1 (low probability).

The assessment must consider all forms of potential flooding that could affect the development itself and that could occur as a result of the development. Flood risk assessments should be *inter alia*, "proportionate to the risk and appropriate to the scale, nature and location of the development" and should take into account the effects of climate change.

Local planning authorities are required to direct development to areas of lowest risk by adopting a sequential approach. Available land in flood zone 1 should therefore be developed first, followed by land in flood zones 2 and 3a respectively. This policy is implemented by the application of the Sequential Test which compares a proposed development site with other sites available for similar development in the area.

Following the application of the Sequential Test, the Exception Test must be applied when "more vulnerable" development and "essential infrastructure" cannot be located in flood zones 1 or 2, and when "highly vulnerable" development cannot be located in flood zone 1. The three requirements of the Exception Test² are:

- a) The wider sustainability benefits of the development must outweigh the flood risk;
- b) The development must be on developable previously developed land or, if it is not previously developed land, there must be no reasonable alternative sites on developable previously developed land; and
- c) A site specific flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere and, where possible, will reduce flood risk overall.

The suitability of a development in any particular flood zone depends on its vulnerability classification. The vulnerability classifications defined in PPS 25 are outlined in Table 3.1 below.

² The Exception Test is not required for Less Vulnerable and Water Compatible developments, (see Table 3.1)

Table 3.1: Flood Risk Vulnerability Classifications	
Classification	Examples
Essential infrastructure	Essential transport infrastructure & strategic utility infrastructure
Highly vulnerable	Emergency services; basement dwellings; caravan and mobile home parks used for permanent residence; hazardous substance installations.
More vulnerable	Hospitals, care homes, prisons, hostels and halls of residence; dwelling houses; health service establishments; educational establishments; waste management sites, holiday caravan and camping sites.
Less vulnerable	Commercial premises; agriculture and forestry sites; water and sewage treatment sites; minerals working and processing sites excluding sand and gravel; waste treatment sites excluding landfills and hazardous waste sites.
Water compatible	Flood control infrastructure; water and sewage pumping stations; sand and gravel workings; docks and navigation facilities; defence installations; shipbuilding; coastguard stations; etc.

All vulnerability classifications are compatible with Flood Zone 1.

In Flood Zone 2, all classifications are compatible except highly vulnerable developments unless they satisfy the Exception Test criteria.

In Flood Zone 3a, highly vulnerable development is not compatible and should not be permitted. Essential infrastructure and more vulnerable developments are compatible only if they pass the Exception Test, but water compatible and less vulnerable developments are acceptable.

In Flood Zone 3b, only water compatible development is acceptable. Essential infrastructure may also be acceptable provided it passes the Exception Test, but the remaining vulnerability classifications are not compatible and should not be permitted.

3.2 Barnsley Strategic Flood Risk Assessment

The Barnsley level 1 strategic flood risk assessment (SFRA) [6], published in September 2010, identifies areas of flood risk and flood hazard within the Barnsley borough, based on the Environment Agency flood maps. The SFRA provides information to allow the Sequential Test to be applied at a strategic level and also makes recommendations for managing flood risk through the development control process.

4.0 LOCATION AND DESCRIPTION OF THE SITE

The site is situated immediately to the east of the existing developed area in Barnburgh Lane, Goldthorpe, as shown in Figure 1, and extends to approximately 3.72ha.

The NGR coordinates at the approximate centre of the site are 446700E, 403840N.

The site is bounded by Barnburgh Lane to the north, Engine Lane (a track) to the east, agricultural land to the south and most of the west. The northern part of the western boundary, amounting to approximately 26% of its total length, abuts existing residential development in Barnburgh Lane and Lindale Gardens.

The site falls in elevation from approximately 35m AOD(N) in the north-west corner, to approximately 21m AOD(N) in the south-east corner. The average gradient of the site is approximately 1 in 23.

The site is currently undeveloped, being agricultural land. The subsoil is understood from preliminary investigations to be predominantly clay.

5.0 THE PROPOSED DEVELOPMENT

The development comprises 152 residential dwellings. The site layout plan is provided in Appendix A.

Full details of the proposed development are provided in the plans and documents included with the planning application.

6.0 FLOOD RISK

6.1 Methodology

PPS 25 Appendix E provides guidance on the matters that should be addressed by a flood risk assessment. The level of detail however must be appropriate to the scale of development and the extent of available information.

The methodology adopted for this assessment has therefore been as follows:

- Site inspection;
- review of large scale maps and the topographical survey plans for the site;
- review of Barnsley Strategic Flood Risk Assessment and flood zone data;
- interpretation of data acquired and assessment of fluvial flood risk in accordance with PPS 25;
- assessment of surface water run-off volumes in the pre-development and post development conditions of the site; and
- assessment of potential groundwater flooding at the site.

6.2 Data collection and consultations

The Environment Agency was not consulted for this flood risk assessment as the site is in flood zone 1 and there are no open watercourses in the vicinity which could affect the site.

We have been provided with copies of e-mail correspondence between a previous consultant acting for the client and Barnsley MBC Highways and Engineering

Department, in which an agreed rate of discharge to the local watercourse has been agreed to be 18.3 l/s. This correspondence is reproduced in Appendix B.

6.3 Existing flood defences

The site does not benefit from any flood defences.

6.4 History of Flooding

The Historical Flood Extents Map in the SFRA shows the site to have been unaffected by the flood events of 1947, 1982, 2000 and 2007. We have no evidence of any flooding at the site from other events.

6.5 Risk of fluvial flooding

The SFRA Maps 3 and 4 show that the site does not lie within flood zones 2 or 3. The site is therefore in flood zone 1: "Low probability", where the annual risk of fluvial flooding is less than 0.1% (1 in 1000 years). As there are no open watercourses that could affect the site there is no potential for fluvial flooding at the site.

6.6 Risk of surface water flooding

Risk to the site

In its present state, the risk of surface water flooding is low. Rain falling on the site will either infiltrate into the soil or will flow overland at shallow depth towards the southern boundary, eventually reaching the lower lying land to the south.

Effect of the proposed development on rapid-response run-off

Development of the site for housing will increase surface water run-off volume due to the conversion of a significant proportion of the site to impervious area. The extent of impervious area resulting from the proposed development is not known in detail but a reasonable estimate, based on similar developments elsewhere, would be approximately 75% of the gross site area.

The effect of the development on surface water flood risk is assessed in terms of the greenfield run-off rate and the post development volume of run-off generated by a storm of critical duration.

As the site has an area less than 50ha, the greenfield run-off rate has been estimated using the procedures stated in Table 4.2 of the SUDS Manual [7], which are based on IH Report 124 [6]. The greenfield run-off rate is estimated to be 16.32 l/s and the calculation of this figure is provided in Appendix C.

The volumes of run-off generated in the existing and post development conditions are estimated broadly in accordance with the procedures stated in sections 4.2.2 and 4.3.3 of the SUDS Manual [7] but for the post-development case, instead of basing the run-off volume on the 100 year 6-hour storm, which is arbitrary, we have estimated the volume generated by the critical storm duration. The estimated greenfield run-off volume calculation is provided in Appendix D and the post-development volume calculations are provided in Appendix E.

The effect of the development on rapid response run-off is shown in Figures 2 and 3 for the 3.3% and 1% A.E.P. rainfall events respectively. Tables E1 to E4 (see Appendix E) show the effect of the development to be an increase in rapid response run-off volume of approximately 167%. This is a conservative estimate based on 75% impervious area and this figure should be reviewed and verified at the detailed design stage.

6.7 Risk of groundwater flooding

There is no appreciable risk of groundwater flooding at the site.

6.8 Risk of sewer flooding

The Barnsley SFRA identifies Goldthorpe as being an area prone to sewer flooding but no specific details are given as to location.³ This matter should be checked with Yorkshire Water at the detailed design stage in order to identify any necessary mitigation measures.

6.9 Appropriate Land Use

In accordance with PPS 25: Table D.2, the proposed residential development falls within the vulnerability classification of "More Vulnerable".

As the site lies within flood zone 1, the proposed development at the site is appropriate, in accordance with PPS 25: Table D.3, with no requirement for the Exception Test.

6.10 Effects of Climate Change

The impact of climate change must be assessed over the lifetime of the development. For residential development, the Practice Guide to PPS 25 recommends a minimum lifetime of 100 years. Climate change effects should therefore be considered up to the year 2111.

Current estimates of climate change effects suggest an increase in peak river flows of 20% in the period after 2025 and an increase in peak rainfall intensity of 30% in the period 2085 to 2115[1].

Fluvial flooding

As the sites are not at risk from fluvial flooding, the effects of climate change will have no impact on fluvial flood risk.

Loss of floodplain storage

The development will result in no loss of floodplain storage.

Surface water run-off

The effect of climate change on surface water run-off over the lifetime of the development is shown in Figures 4 and 5 for the 3.3% and 1% A.E.P. rainfall events respectively.

³ Barnsley SFRA section 5.8

7.0 FLOOD RISK MANAGEMENT

7.1 Fluvial flood risk

No flood risk management measures are necessary in respect of fluvial flooding.

7.2 Surface water flood risk

The effect of the proposed development on surface water run-off volumes can be mitigated by the implementation of sustainable drainage principles. The Building Regulations require surface water to be discharged according to the following preference hierarchy:

1. to ground by infiltration;
2. to a watercourse;
3. to a sewer, if options (1) and (2) are not reasonably practicable.

As the sub-soil at the site is understood to have a high clay fraction, infiltration drainage is unlikely to be feasible. The preferred option is likely to be a controlled discharge to the watercourse to the south of the site, with on-site attenuation storage.

The drainage system for the development should ensure:

- no surface water flooding resulting from a rainfall event having an A.E.P. of 33% (1 in 30 years);
- only “tolerable” flooding resulting from a rainfall event having an A.E.P. of 1% (1 in 100 years).

“Tolerable” flooding would be flooding to a depth that does not result in flooding of buildings and which does not prevent safe access and egress to and from the site.

Preliminary estimates of the storage capacities required to mitigate the effect of the development on rapid response surface water run-off volumes from 3.3% and 1% A.E.P. rainfall events have been made for the purposes of this flood risk assessment. At the agreed permitted discharge of 18.3 l/s, the critical durations of the 3.3% and 1% A.E.P. rainfall events including CCA are estimated to be approximately 6 hours and 7 hours respectively. The storage capacities required to mitigate the effects of the development during these events are estimated to be approximately 478m³ and 1,028m³ respectively. These are preliminary estimates for the purposes of this flood risk assessment and they should be reviewed as part of the detailed drainage design.

7.3 Ground water flood risk

No flood risk management measures are required in respect of groundwater flooding.

7.4 Sewer flood risk

As stated in section 6.8 above, the location of sewer flooding in Goldthorpe should be ascertained with Yorkshire Water.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

1. The sites are in flood zone 1 where the annual probability of fluvial flooding is less than 0.1%.
2. There is no historical evidence of the sites having been affected by flooding.
3. The risk of surface water flooding at the site is assessed to be low.
4. It is estimated that the development will increase rapid response surface water run-off volumes by approximately 167% compared with existing conditions, assuming 75% impervious area.
5. Infiltration drainage is unlikely to be feasible, due to clay soils, and the preferred point of disposal for surface water is likely to be the watercourse to the south of the site. A permitted discharge rate of 18.3 l/s has already been agreed with Barnsley MBC.
6. Attenuation storage capacity for the excess surface water run-off will be required. The total storage capacity will need to be confirmed as part of the detailed drainage design, taking into account the characteristics of the drainage elements.
7. The risk of groundwater flooding at the site is assessed to be insignificant.
8. The development will not result in the loss of any floodplain storage.
9. Climate change effects are currently predicted to increase peak rainfall intensity by 30% over the lifetime of the development which, for the purposes of this assessment is assumed to be at least 100 years. The drainage scheme for the site will need to make provision for this increase.
10. The development will not increase flood risk elsewhere provided the flood risk management recommendations outlined in section 7 above are implemented.
11. The development falls within the "More Vulnerable" classification in PPS 25: Table D.2 and is an appropriate land use with no requirement for the Exception Test.

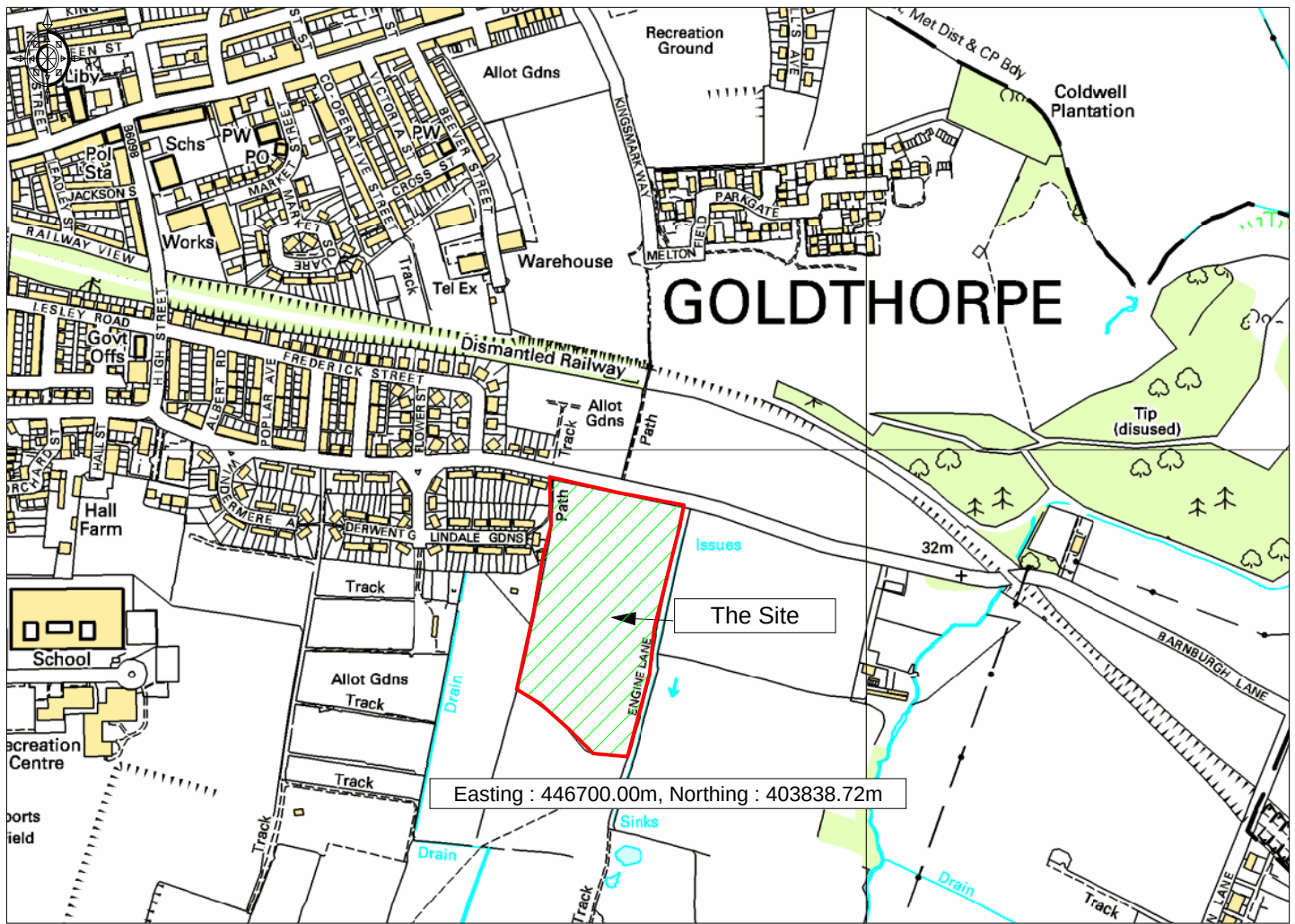
8.2 Recommendations

1. It is recommended that Yorkshire Water is consulted in order to ascertain the location of sewer flooding in Goldthorpe.,
2. It is recommended that a detailed drainage design is prepared in accordance with the principles stated in section 7.2 above and submitted to Barnsley MBC for approval prior to construction. This recommendation can be secured by an appropriately worded condition in any Grant of Planning Permission.

9.0 REFERENCES

1. Planning Policy Statement 25: Development and Flood Risk. Department for Communities and Local Government. December 2006.
2. Planning Policy Statement 25: Development and Flood Risk: Practice Guide. Department for Communities and Local Government, June 2008.
3. Barnsley Strategic Flood Risk Assessment. Barnsley Metropolitan Borough Council, September 2010.
4. Development and flood risk. Guidance for the construction industry. CIRIA Report No. C624. 2004.
5. Strategic Planning for Flood Risk in the Growth Areas – Insurance Considerations. Association of British Insurers, July 2004.
6. Flood Estimation for Small Catchments. Report No. 124. Institute of Hydrology June 1994.
7. The SUDS Manual, Woods-Ballart *et al.* CIRIA Report C697, 2007.

Site at Barnburgh Lane, Goldthorpe, Barnsley



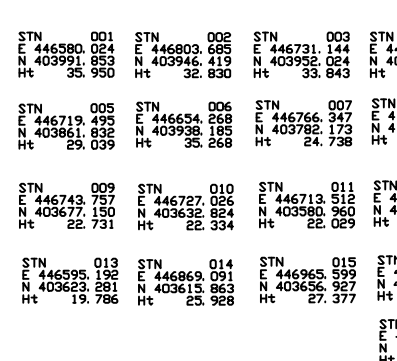
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Figure 1: Location Plan

APPENDIX A

Site layout plan and topographical survey details



APPENDIX B

Permitted surface water discharge rate agreed with Barnsley MBC

John O'Connor

From: Shaun Tonge [Shaun@stonge.fsnet.co.uk]
Sent: 21 September 2011 15:57
To: Peter Smith
Subject: Fw: Barnburgh Lane, Goldthorpe

Pete,

Confirmation of surface water discharge from Barnsley Drainage section below.

Give me a call if you require anything further.

Regards

Shaun

----- Original Message -----

From: [Atkins, Wayne](#)
To: Shaun@stonge.fsnet.co.uk
Sent: Wednesday, September 21, 2011 3:50 PM
Subject: RE: Barnburgh Lane, Goldthorpe

Hi Shaun

I can confirm that I have no objections in principal to the discharge of the surface water flows, controlled to a greenfield run off of 18.3l/s, from the proposed development site into the west moor dike watercourse.

Regards

Wayne Atkins

Senior Engineer - Drainage, Policy and Programming
Barnsley Metropolitan Borough Council
Highways and Engineering
Network Management
Westgate Plaza 1
PO Box 603
S70 9FA
Telephone: 01226 772182
Fax: 01226 772196
E-mail: wayneatkins@barnsley.gov.uk

From: Bell, Derek
Sent: 19 September 2011 12:20
To: Atkins, Wayne
Subject: FW: Barnburgh Lane, Goldthorpe

Wayne,

For info & action ...

From: Shaun Tonge [<mailto:Shaun@stonge.fsnet.co.uk>]
Sent: 19 September 2011 12:01
To: Bell, Derek
Subject: Fw: Barnburgh Lane, Goldthorpe

Hi Derek,

Have you had chance to look at this yet ?

Thanks
Shaun

Shaun Tonge Engineering

----- Original Message -----

From: [Shaun Tonge](#)

To: derekbell@barnsley.gov.uk

Cc: [Peter Smith](#)

Sent: Monday, September 12, 2011 12:58 PM

Subject: Barnburgh Lane, Goldthorpe

Hi Derek,

I refer to our telephone conversation regarding surface water disposal at the above proposed residential development.

The site is currently green field and is 3.7Ha in area. I have run calculations through Microdrainage IH 124 which gives a greenfield run off of 18.3l/s.

Ideally we would like to discharge surface water into west moor dike. Your approval in principal to this would be most welcomed.

Regards
Shaun

Shaun Tonge Engineering

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APPENDIX C

Calculation greenfield run-off rate for 100% A.E.P. event ($Q_{bar_{rural}}$)

Calculation of Q_{bar}_{rural}

AREA	3.715 ha
SAAR	700 mm
SOIL	0.45

$Q_{bar}_{rural} = 0.00108 \cdot AREA^{0.89} \cdot SAAR^{1.17} \cdot SOIL^{2.17}$ m^3/s

where:

AREA is in km^2

SAAR is in mm

For 50ha: 0.5 km^2

Q_{bar}_{rural} $0.22 \text{ m}^3/s$

For site:

Q_{bar}_{rural} 16.32 l/s

APPENDIX D

Calculation of greenfield surface water run-off volume

Calculation of PR_{rural}

$$PR_{\text{rural}} = SPR + DPR_{\text{CWI}} + DPR_{\text{rain}} \quad \text{FEH Vol. 4 eqn 2.13}$$

$$DPR_{\text{CWI}} = 0.25(\text{CWI} - 125) \quad \text{FEH Vol. 4 eqn 2.14}$$

$$DPR_{\text{rain}} = 0.45(P - 40)^{0.7} \quad \text{where } P > 40\text{mm} \quad \text{FEH Vol. 4 eqn 2.15}$$

Area: 3.715 ha

From catchment descriptors:

SAAR:	613 mm	
SPRHOST:	29.60 %	
CWI:	90 mm approx.	FEH Vol. 4 Fig. 3.7
Rainfall depth P:	62.1 mm	FEH DDF Model

Applying the above data:

$$PR_{\text{rural}} = \underline{\quad 24.78 \quad} \%$$

Calculation of greenfield run-off volume for 1% A.E.P. 6-hour event

$$\text{Volume} = PR_{\text{rural}} \times \text{Area} \times \text{Rainfall depth} \quad \text{SUDS Manual s.4.4.2}$$

Applying the above data:

$$\text{Volume} = \underline{\quad 571.66 \quad} \text{ m}^3$$

APPENDIX E

Calculation of post-development surface water run-off volumes

Table E1: Rapid response run-off from 3.3% A.E.P. rainfall event: existing condition							
Duration hours	Rainfall at Site mm	Area (m ²)			Volume (m ³)		
		Impervious Area (ha)	Pervious Area (ha)	Total Area (ha)	Impervious Area	Pervious Area	Run-off Volume
		PR 80.0%	PR 24.8%				
0.0	0.0	0.00	3.72	3.72	0.00	0.00	0.00
0.5	24.3	0.00	3.72	3.72	0.00	224.00	224.00
1.0	29.0	0.00	3.72	3.72	0.00	267.33	267.33
2.0	34.6	0.00	3.72	3.72	0.00	318.95	318.95
3.0	38.1	0.00	3.72	3.72	0.00	351.21	351.21
4.0	41.1	0.00	3.72	3.72	0.00	378.87	378.87
6.0	45.5	0.00	3.72	3.72	0.00	419.43	419.43
8.0	48.9	0.00	3.72	3.72	0.00	450.77	450.77
12.0	54.0	0.00	3.72	3.72	0.00	497.78	497.78
18.0	61.9	0.00	3.72	3.72	0.00	570.60	570.60
24.0	68.2	0.00	3.72	3.72	0.00	628.68	628.68
36.0	78.1	0.00	3.72	3.72	0.00	719.94	719.94
48.0	85.9	0.00	3.72	3.72	0.00	791.84	791.84
72.0	91.1	0.00	3.72	3.72	0.00	839.77	839.77
96.0	95.0	0.00	3.72	3.72	0.00	875.73	875.73
144.0	100.7	0.00	3.72	3.72	0.00	928.27	928.27
192.0	104.9	0.00	3.72	3.72	0.00	966.98	966.98

Table E2: Rapid response run-off from 1% A.E.P. rainfall event: existing condition							
Duration hours	Rainfall at Site mm	Area (m ²)			Volume (m ³)		
		Impervious Area (ha)	Pervious Area (ha)	Total Area (ha)	Impervious Area	Pervious Area	Run-off Volume
		PR 80.0%	PR 24.8%				
0.00	0.0	0.00	3.72	3.72	0.00	0.00	0.00
0.50	35.6	0.00	3.72	3.72	0.00	328.17	328.17
1.00	41.7	0.00	3.72	3.72	0.00	384.40	384.40
2.00	48.7	0.00	3.72	3.72	0.00	448.92	448.92
3.00	53.3	0.00	3.72	3.72	0.00	491.33	491.33
4.00	56.8	0.00	3.72	3.72	0.00	523.59	523.59
6.00	62.1	0.00	3.72	3.72	0.00	572.45	572.45
8.00	66.1	0.00	3.72	3.72	0.00	609.32	609.32
12.00	72.2	0.00	3.72	3.72	0.00	665.55	665.55
18.00	81.7	0.00	3.72	3.72	0.00	753.12	753.12
24.00	89.3	0.00	3.72	3.72	0.00	823.18	823.18
36.00	101.0	0.00	3.72	3.72	0.00	931.03	931.03
48.00	110.3	0.00	3.72	3.72	0.00	1016.76	1016.76
72.0	115.6	0.00	3.72	3.72	0.00	1065.62	1065.62
96.0	119.5	0.00	3.72	3.72	0.00	1101.57	1101.57
144.0	125.1	0.00	3.72	3.72	0.00	1153.19	1153.19
192.0	129.3	0.00	3.72	3.72	0.00	1191.91	1191.91

Table E3: Rapid response run-off from 3.3% A.E.P. rainfall event: post development condition

Duration hours	Rainfall at Site mm	Area (m ²)			Volume (m ³)		
		Impervious Area (ha)	Pervious Area (ha)	Total Area (ha)	Impervious Area	Pervious Area	Run-off Volume
		PR 80.0%	PR 24.8%				
0.0	0.0	2.79	0.93	3.72	0.00	0.00	0.00
0.5	24.3	2.79	0.93	3.72	542.38	56.00	598.38
1.0	29.0	2.79	0.93	3.72	647.28	66.83	714.11
2.0	34.6	2.79	0.93	3.72	772.27	79.74	852.01
3.0	38.1	2.79	0.93	3.72	850.39	87.80	938.19
4.0	41.1	2.79	0.93	3.72	917.35	94.72	1012.07
6.0	45.5	2.79	0.93	3.72	1015.56	104.86	1120.42
8.0	48.9	2.79	0.93	3.72	1091.45	112.69	1204.14
12.0	54.0	2.79	0.93	3.72	1205.28	124.45	1329.73
18.0	61.9	2.79	0.93	3.72	1381.61	142.65	1524.26
24.0	68.2	2.79	0.93	3.72	1522.22	157.17	1679.39
36.0	78.1	2.79	0.93	3.72	1743.19	179.98	1923.18
48.0	85.9	2.79	0.93	3.72	1917.29	197.96	2115.25
72.0	91.1	2.79	0.93	3.72	2033.35	209.94	2243.30
96.0	95.0	2.79	0.93	3.72	2120.40	218.93	2339.33
144.0	100.7	2.79	0.93	3.72	2247.62	232.07	2479.69
192.0	104.9	2.79	0.93	3.72	2341.37	241.75	2583.11

Table E4: Rapid response run-off from 1% A.E.P. rainfall event: post development condition

Duration hours	Rainfall at Site mm	Area (m ²)			Volume (m ³)		
		Impervious Area (ha)	Pervious Area (ha)	Total Area (ha)	Impervious Area	Pervious Area	Run-off Volume
		C _v 80.0%	C _v 24.8%				
0.00	0.0	2.79	0.93	3.72	0.00	0.00	0.00
0.50	35.6	2.79	0.93	3.72	794.59	82.04	876.63
1.00	41.7	2.79	0.93	3.72	930.74	96.10	1026.84
2.00	48.7	2.79	0.93	3.72	1086.98	112.23	1199.22
3.00	53.3	2.79	0.93	3.72	1189.66	122.83	1312.49
4.00	56.8	2.79	0.93	3.72	1267.78	130.90	1398.67
6.00	62.1	2.79	0.93	3.72	1386.07	143.11	1529.18
8.00	66.1	2.79	0.93	3.72	1475.35	152.33	1627.68
12.00	72.2	2.79	0.93	3.72	1611.50	166.39	1777.89
18.00	81.7	2.79	0.93	3.72	1823.54	188.28	2011.82
24.00	89.3	2.79	0.93	3.72	1993.18	205.80	2198.97
36.00	101.0	2.79	0.93	3.72	2254.32	232.76	2487.08
48.00	110.3	2.79	0.93	3.72	2461.90	254.19	2716.09
72.00	115.6	2.79	0.93	3.72	2580.19	266.40	2846.60
96.00	119.5	2.79	0.93	3.72	2667.24	275.39	2942.63
144.00	125.1	2.79	0.93	3.72	2792.23	288.30	3080.53
192.00	129.3	2.79	0.93	3.72	2885.98	297.98	3183.95

Table E5: Post-development rapid response run-off from impervious area (3.3% A.E.P. rainfall event including CCA)

[illegible]

Table E6: Post-development rapid response run-off from impervious area (1% A.E.P. rainfall event including CCA)

Duration hours	Rainfall at Site mm	Area (m ²)			Volume (m ³)			Controlled run off m ³	Tangent m ³
		Impervious Area (ha)	Pervious Area (ha)	Total Area (ha)	Impervious Area	Pervious Area	Run-off Volume		
		C _v 0.800	C _v 0.248					Controlled rate (l.s. ⁻¹ ha ⁻¹) 18.3	
0.00	0.0	2.79	0.93	3.72	0.00	0.00	0.00	0.00	1600.00
0.50	46.3	2.79	0.93	3.72	1032.97	106.65	1139.62	32.94	1632.94
1.00	54.2	2.79	0.93	3.72	1209.97	124.93	1334.90	65.88	1665.88
2.00	63.3	2.79	0.93	3.72	1413.08	145.90	1558.98	131.76	1731.76
3.00	69.3	2.79	0.93	3.72	1546.55	159.68	1706.23	197.64	1797.64
4.00	73.8	2.79	0.93	3.72	1648.11	170.17	1818.28	263.52	1863.52
6.00	80.7	2.79	0.93	3.72	1801.89	186.05	1987.94	395.28	1995.28
8.00	85.9	2.79	0.93	3.72	1917.96	198.03	2115.99	527.04	2127.04
12.00	93.9	2.79	0.93	3.72	2094.96	216.30	2311.26	790.56	2390.56
18.00	106.2	2.79	0.93	3.72	2370.61	244.77	2615.37	1185.84	2785.84
24.00	116.1	2.79	0.93	3.72	2591.13	267.53	2858.66	1581.12	3181.12
36.00	131.3	2.79	0.93	3.72	2930.62	302.59	3233.20	2371.68	3971.68
48.00	143.4	2.79	0.93	3.72	3200.46	330.45	3530.91	3162.24	4762.24
72.00	150.3	2.79	0.93	3.72	3354.25	346.33	3700.58	4743.36	6343.36
96.00	155.4	2.79	0.93	3.72	3467.41	358.01	3825.42	6324.48	7924.48
144.00	162.6	2.79	0.93	3.72	3629.90	374.79	4004.69	9486.72	11086.72
192.00	168.1	2.79	0.93	3.72	3751.77	387.37	4139.14	12648.96	14248.96
Total Storage Requirement (m ³)									1600.00

