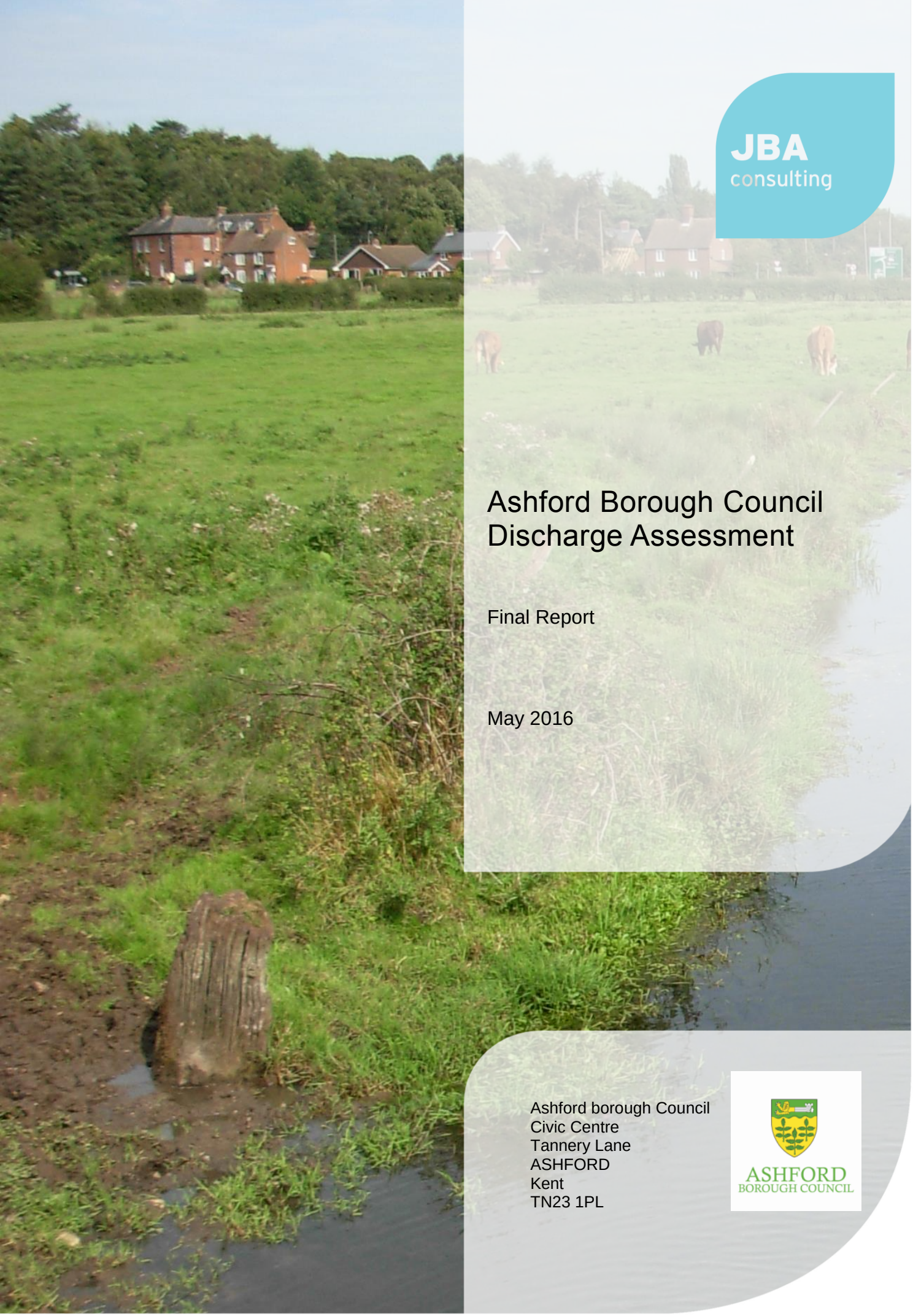


Ashford Borough Council Discharge Assessment

Final Report

May 2016

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Contract

This report describes work commissioned by Katy Wiseman, on behalf of Ashford Borough Council. Ashford Borough Council's representative for the contract was Katy Wiseman. Zoe Carroll and Jack Southon of JBA Consulting carried out this work.

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Purpose

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Executive Summary

JBA Consulting were appointed by Ashford Borough Council (ABC) to undertake a borough wide discharge runoff assessment for 53 sites. The assessment was carried out to identify the optimum discharge rates to be applied throughout the Ashford Borough, while investigating the effects of changing discharge rates on the study sites, and how the proposed developments would affect the flood risk in Ashford Borough. The key objective of this assessment is to provide evidence to whether or not Ashford Borough Council will need to over-attenuate to avoid increased flood risk in the future, and if there is an overall percentage that can be applied to improve discharge rates across the Borough. This assessment will form the evidence base for the emerging local plan.

Methodology

Three scenarios of discharge runoff calculations were undertaken for each study site using Revitalised Flood Hydrograph 2 (ReFH2) method. These scenarios were based on the existing, greenfield and post-development impervious profile of the individual sites. The impervious area for the existing site was estimated from satellite imagery of the site, and calculated as a percentage of the total site area. Post-development imperviousness was calculated on the development percentages provided by ABC and the runoff calculations for this scenario were based on no attenuation taking place post-development. The greenfield calculations, which represent the baseline conditions in the modelling, were based on the site have no impervious coverage. The storm profile for each runoff calculation was for the 1% Annual Exceedance Probability (AEP) rainfall event. Climate change 1% AEP storm event, represented by a 40% increase, was applied to the post development scenario.

2D modelling (ISIS-TUFLOW), using the existing EA model, was undertaken as part of this assessment in order to understand the impact on flood risk of the aforementioned scenarios. Three additional runoff scenarios were calculated and modelled to represent the effect of over-attenuating runoff at each development site. The over-attenuation values were based on the greenfield runoff values, and were calculated by reducing the greenfield runoff rate by 10%, 30% and 50%.

Results

The assessment found that the Ashford Borough Council's recommended standard discharge rates of 4 l/s/ha, and the industry recommended discharge rate of 5 l/s/ha were not viable to the majority of sites (33 out of 53). The study did find that 51 out of 53 sites could discharge to half the stored volume with greenfield conditions in 24 hours or less, with 46 of the sites being identified to be viable for over-attenuation.

The reduction in flood risk found through modelling the hydrograph and volume outputs of the ReFH2 method demonstrated a slight reduction in flood outline in the town of Ashford from the Greenfield with 50% over attenuation scenario.

Conclusion and recommendations

The conclusion of the study showed that a standard discharge rate is not achievable for all development sites within the borough, especially small scale developments. In order to achieve the recommended ABC's discharge rate of 4 l/s/ha, long term storage SuDS would need to be incorporated into the drainage designs of the site. This, on a small scale, is not, however viable.

It is therefore recommended that the discharge requirements should not necessarily be based on arbitrary values but on site-specific conditions and monitoring (if available). By undertaking site-specific studies, a detailed analysis of what SuDS could be implemented into the site could also be achieved.

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Abbreviations

ABC	Ashford Borough Council
AEP	Annual Exceedance Probability
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CIRIA	Construction Industry Research and Information Association
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
JBA	Jeremy Benn Associates
LFRMS	Local Flood Risk Management Strategy
LLFA	Lead Local Flood Authority
mAOD	Metres Above Ordinance Datum
NPPF	National Planning Policy Framework
PFRA	Preliminary Flood Risk Assessment
PPG	Planning Practice Guidance
QMED	Median Annual Flood (with return period 2 years)
PD	Post development
PPS25	Planning and Policy Statement 25
ReFH	Revitalised Flood Hydrograph Method
SAAR	Standard Average Annual Rainfall (mm)
SFRA	Strategic Flood Risk Assessment
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
Tp(0)	Time to peak of the instantaneous unit hydrograph
uFMfSW	Updated Flood Map for Surface Water
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990

1 Introduction

JBA Consulting were appointed by Ashford Borough Council (ABC) to undertake a borough wide discharge runoff assessment for 53 sites (Figure 2-2). The assessment was carried out to identify the optimum discharge rates to be applied throughout the Ashford Borough, while investigating the effects of changing discharge rates on the study sites, and how the proposed developments would affect the flood risk in Ashford Borough. The key objective of this assessment is to provide evidence to whether or not Ashford Borough Council will need to over-attenuate to avoid increased flood risk in the future, and if there is an overall percentage that can be applied to improve discharge rates across the Borough.

The assessment will form part of the evidence base for the emerging Local Plan (which will replace the Core Strategy[1]), in support of a revised sustainable drainage system (SuDS) policy. The aim of the Local Plan is to provide SuDS designers / engineers with an updated understanding of local and national policy requirements. This assessment will therefore make reference to the key changes in legislation, technical guidance and improved knowledge of flood risk and runoff rates since the Core Strategy was completed in 2008.

1.1 Summary of the runoff assessment

Three scenarios of discharge runoff calculations were undertaken for each study site using Revitalised Flood Hydrograph 2 (ReFH2) method. These scenarios were based on the existing, greenfield and post-development impervious profile of the individual sites. The impervious area for the existing site was estimated from satellite imagery of the site, and calculated as a percentage of the total site area. Post-development imperviousness was calculated on the development percentages provided by ABC and the runoff calculations for this scenario were based on no attenuation taking place post-development. The greenfield calculations, which represent the baseline conditions in the modelling, were based on the site have no impervious coverage. The storm profile for each runoff calculation was for the 1% Annual Exceedance Probability (AEP) rainfall event. Climate change 1% AEP storm event, represented by a 40% increase, was applied to the post development scenario.

2D modelling, using the existing EA model, was undertaken as part of this assessment in order to understand the impact on flood risk of the aforementioned scenarios. Three additional runoff scenarios were calculated and modelled to represent the effect of over-attenuating runoff at each development site. The over-attenuation values were based on the greenfield runoff values, and were calculated by reducing the greenfield runoff rate by 10%, 30% and 50%.

1 Ashford Borough Council Local Development Framework, Core Strategy (July 2008)

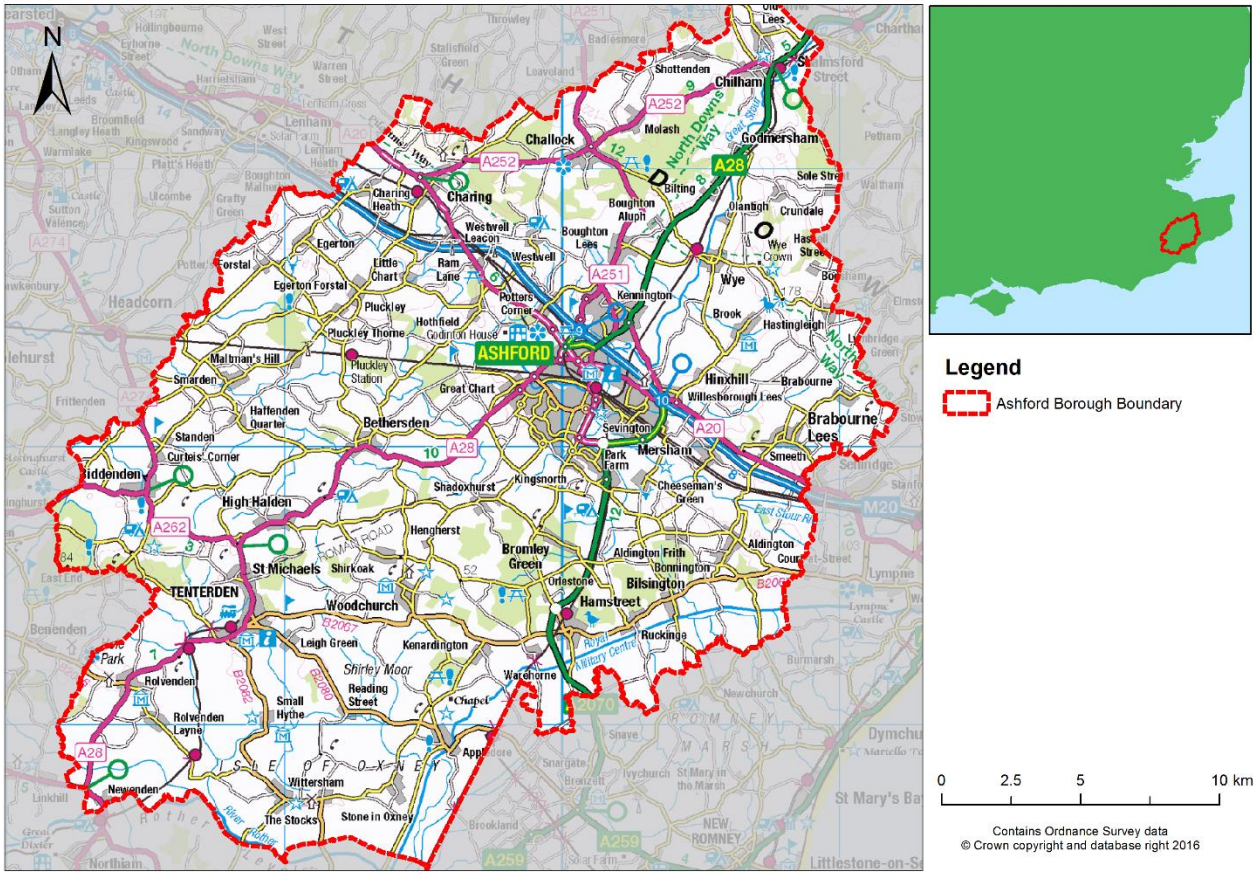
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2 Study area

Ashford Borough is predominantly rural, with few large urban areas. The main urban areas in the Borough are Ashford, Tenterden, Biddenden, Bethersden, Hamstreet, Woodchurch, Charing, Smarden, Wittersham, Wye, Hothfield and Branbourne Lees (Table 2-1). As part of Ashford's Local Plan 2030, the Council are proposing to extend the urban area of the borough by creating an additional 31,000 homes and 28,000 jobs over the period of 2001 to 2031[2]. Chilmington Green, south west of the town of Ashford is one of the new proposed large urban developments.

53 development sites were shortlisted by ABC to be investigated for the runoff assessment. The sites are identified in Table 2-1 below and the locations of the sites are shown in Figure 2-2.

Figure 2-1: Ashford Borough Study Area



2 Ashford Borough Council Urban Sites and Infrastructure DPD Local Plan, Inspector's Report (September 2012)

Figure 2-2: Ashford Borough Council's study sites for runoff assessment

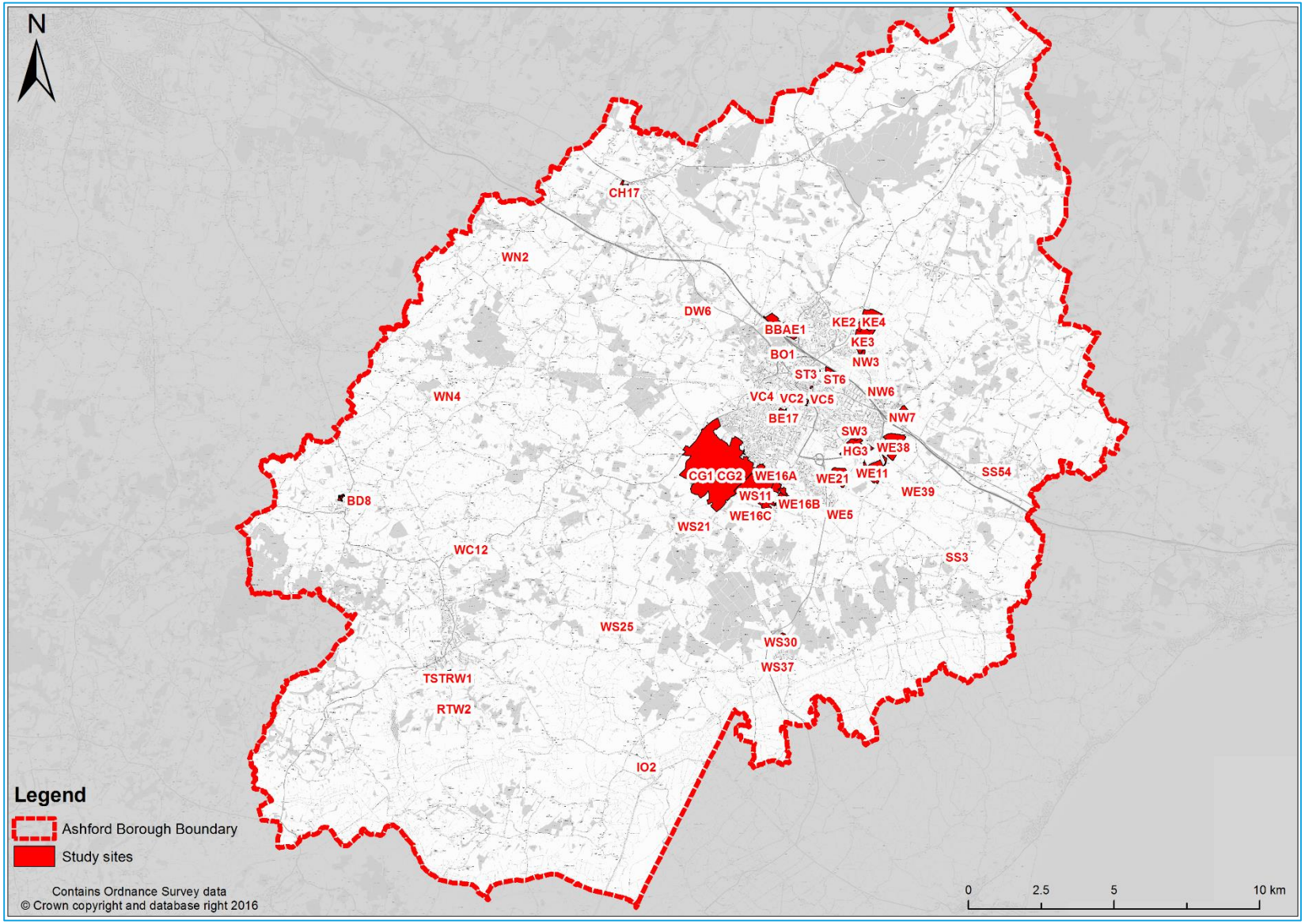


Table 2-1: Ashford Borough Council Shortlisted Development Sites

Site ID	Name	Village / Area	Area (ha)	Easting	Northing
BBAE1	Eureka Leisure Park	Eureka	41.3	600455	144653
BD8	North Street	Biddenden	3.3	584987	138908
BE16	Ashford South Primary School	South Ashford	2.7	600159	141826
BE17	K College Jemmett Road	South Ashford	3.8	600248	141750
BO1	Former Park and Ride	Warren	4.2	600273	143857
CG1 CG2	Chilmington Green	Chilmington Green	438.5	597905	139872
CH4	South of Maidstone Road (A20)	Charing	1.4	594610	149692
CH17	South of Maidstone Road (A20)	Charing	7.2	594775	149444
DW6	Hope Farm	Hothfield	3.0	597267	145390
HG3 HG4	Vacant employment plots	Orbital Park	40.5	602687	140512
IO2	Rear of Doctors surgery and village hall	Appledore	16.6	595448	129741
KE2	Various sites around Orchard Farm	Kennington Area	5.6	602832	144753
KE3	Various sites around Orchard Farm	Kennington Area	33.3	602896	144266
KE4	Various sites around Orchard Farm	Kennington Area	36.5	603277	144795
KE5	Various sites around Orchard Farm	Kennington Area	0.6	602677	144816
NW3	Julie Rose	Conningbrook	3.0	602885	143737
NW6	Blackwall Road	Willesborough	1.4	603550	142652
NW7	Land at Willesborough Lees	Willesborough	17.7	604302	141769
RTW2	Various Town Centre Sites	Town Centre	1.0	588901	131705
SS3	Land south and west of Quarry Wood	Aldington	1.9	606162	136986
SS7	Church Road	Smeeth/Brab	0.6	607549	139968
SSS4	Church Road	Smeeth/Brab	0.9	607549	139877
ST3	Mabledon Avenue	Edge of TC	1.1	601385	143252
ST5	Maidstone Road	Edge of TC	0.5	601715	142264
ST6	Lower Queens Road	Edge of TC	20.4	601931	142986
ST8	Henwood Employment area – vacant areas	Edge of TC	1.4	600200	142870
SW3	Vacant employment plots	Orbital Park	3.8	602541	140958
SW6	Vacant employment plots	Orbital Park	1.1	602387	140721
TSTR W1	Phase 2 of Tenterden extension	Tenterden	11.0	588542	132757
VC1	Leacon Road	Edge of TC	1.3	600655	142410
VC2	Leacon Road	Edge of TC	2.5	600556	142372
VC3	Leacon Road	Edge of TC	2.4	600972	142283
VC4	Kennard Way, (Henwood)	Edge of TC	2.0	599505	142449
VC5	Leacon Road	Edge of TC	0.6	601169	142703
WC12	Hope House	High Halden	2.2	589459	137214
WE5	Park Farm East Extension	Park Farm	5.4	601920	138445
WE11	Waterbrook Park	Cheesemans' Green/Waterbroo	37.9	603260	139851
WE16A	Court Lodge Farm area	Kingsnorth Area	9.9	599887	139239
WE16B	Court Lodge Farm area	Kingsnorth Area	15.2	600201	138776
WE16C	Court Lodge Farm area	Kingsnorth Area	10.9	599688	138610
WE16D	Court Lodge Farm area	Kingsnorth Area	4.5	600201	139090
WE21	East of Finberry	Cheesemans' Green/Waterbrook	23.5	602202	139503

Site ID	Name	Village / Area	Area (ha)	Easting	Northing
WE34	Vacant employment plots	Orbital Park	0.1	602945	140629
WE38	Sevington Employment site	Sevington	46.0	603921	140711
WE39	Village Hall	Mersham	0.6	604831	139206
WN2	New Road	Egerton	1.7	591005	147248
WN4	Smarden Village Hall	Smarden	3.5	588716	142485
WS11	Court Lodge Farm area	Kingsnorth Area	98.0	599056	139110
WS21	Rear of Kings Head	Shadoxhurst	1.6	597129	138021
WS25	Lower Road	Woodchurch	1.4	594446	134560
WS28	Front Road	Woodchurch	0.7	594362	134433
WS30	North of St. Mary's Close	Hamstreet	8.5	600119	134034
WS37	Parker Farm	Hamstreet	0.7	599982	133176

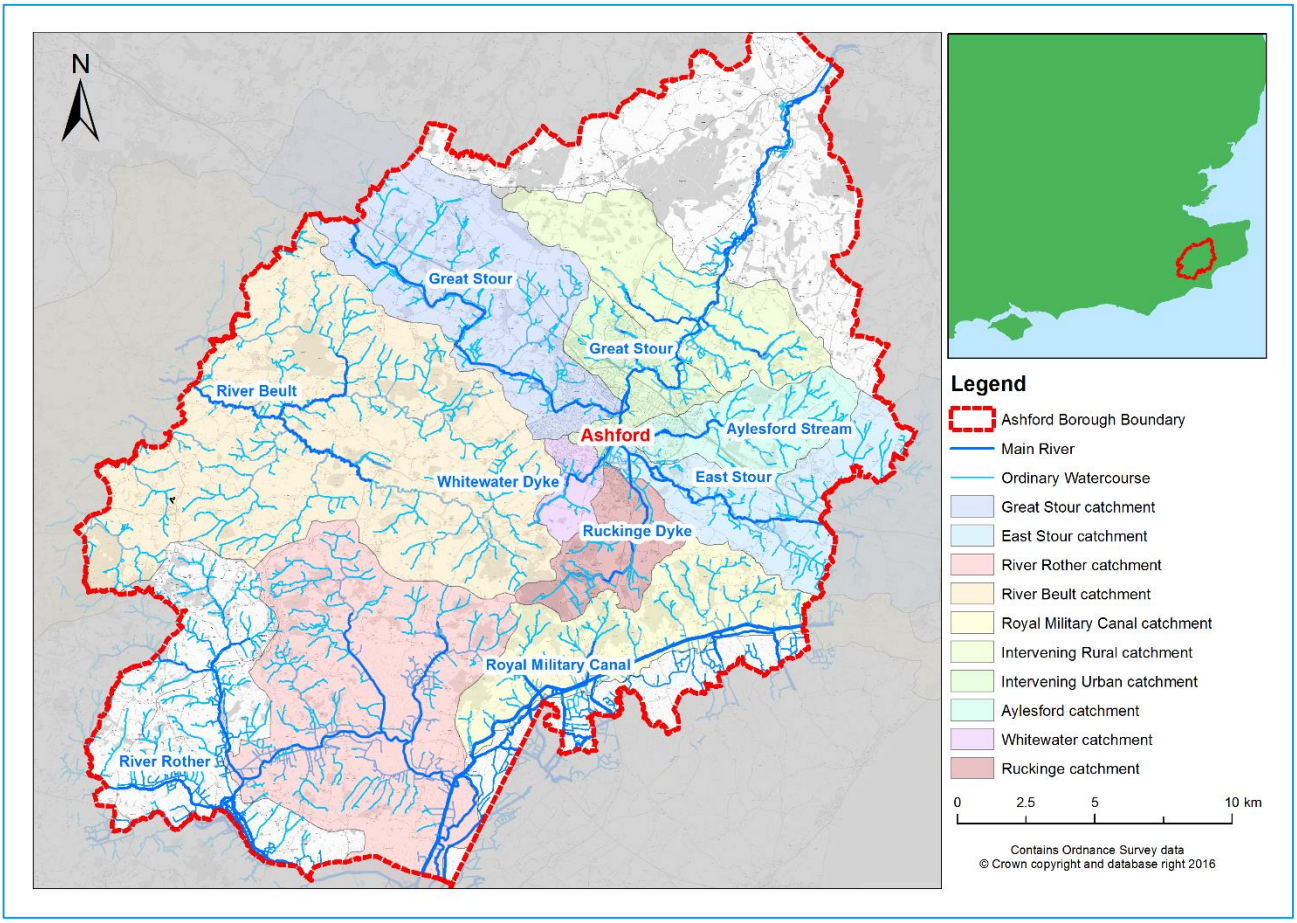
2.1 Watercourses

There are several watercourses that flow through Ashford Borough (Figure 2-3). Ashford town is built upon the confluence of five main rivers:

- Great Stour
- East Stour
- Aylesford Stream
- Whitewater Dyke
- Ruckinge Dyke

The catchments of the Kentish Stour (Great and East), the River Rother / Romney Marshes and the River Medway are the main drainage paths in the borough. Runoff from the northern portion of the borough drains to the River Beult, with the southern area of the borough draining to the watercourses that discharge to the River Rother and the Romney Marshes. The main river catchments are fed by many ordinary watercourse, as identified in Figure 2-3 below.

Figure 2-3: Ashford Borough watercourses and catchments



2.2 Geology and topography

The British Geological Society[3] has identified the borough to be predominantly permeable, with chalk of the North Downs to the north eastern part of the borough, with outcrops of Gault Clay, Lower Greensand and Weald Clay along the south-west margins of the borough Figure 2-4. A map of the superficial deposits in the borough has also been provided in Figure 2-4. The geology and soil types of each individual study site is summarised in Table 2-2.

The topography of the study area ranges from 210mAOD in the northern area of the boundary (North Downs) to sea level at the southern area, where the Romney Marshes are located.

[3] http://mapapps.bgs.ac.uk/geologyofbritain/home.html

Figure 2-4: Ashford Borough bedrock geology

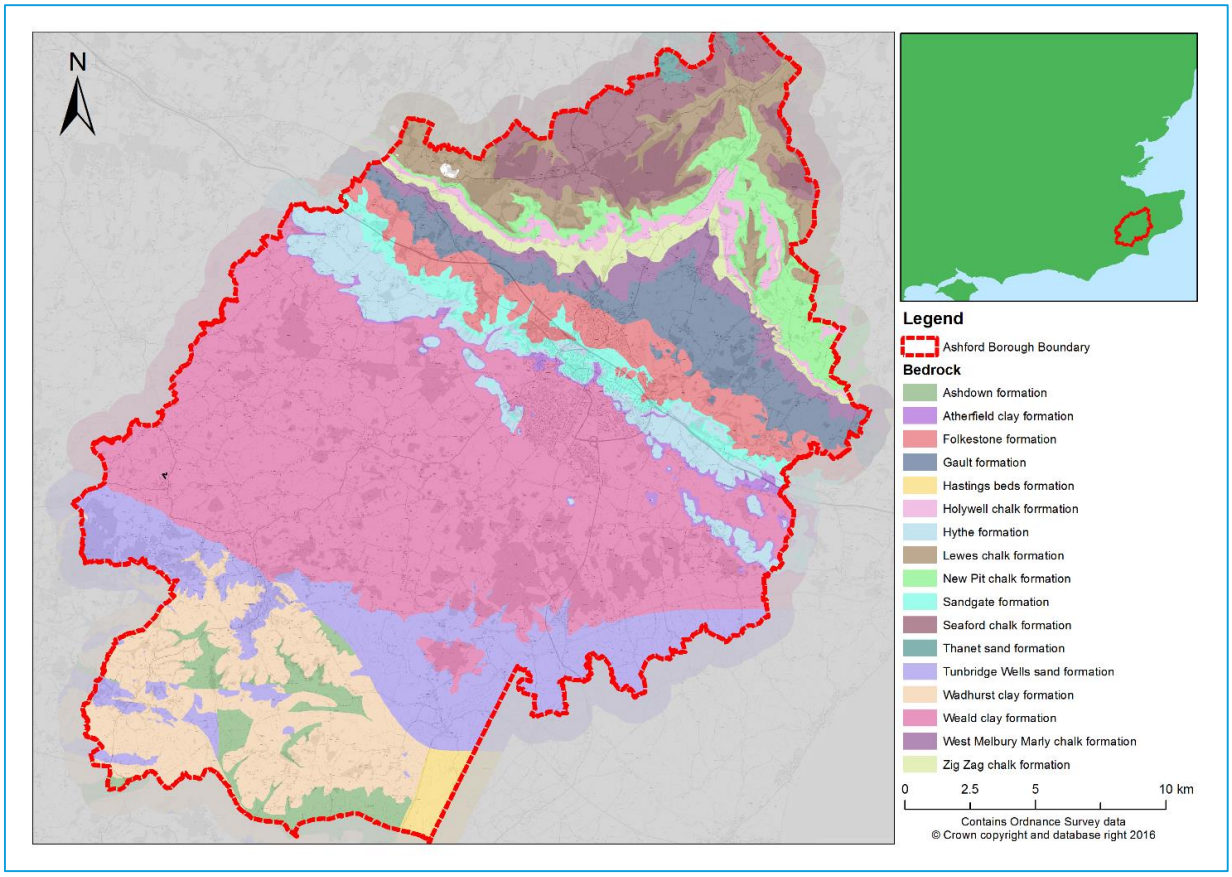


Figure 2-5: Ashford Borough superficial geology

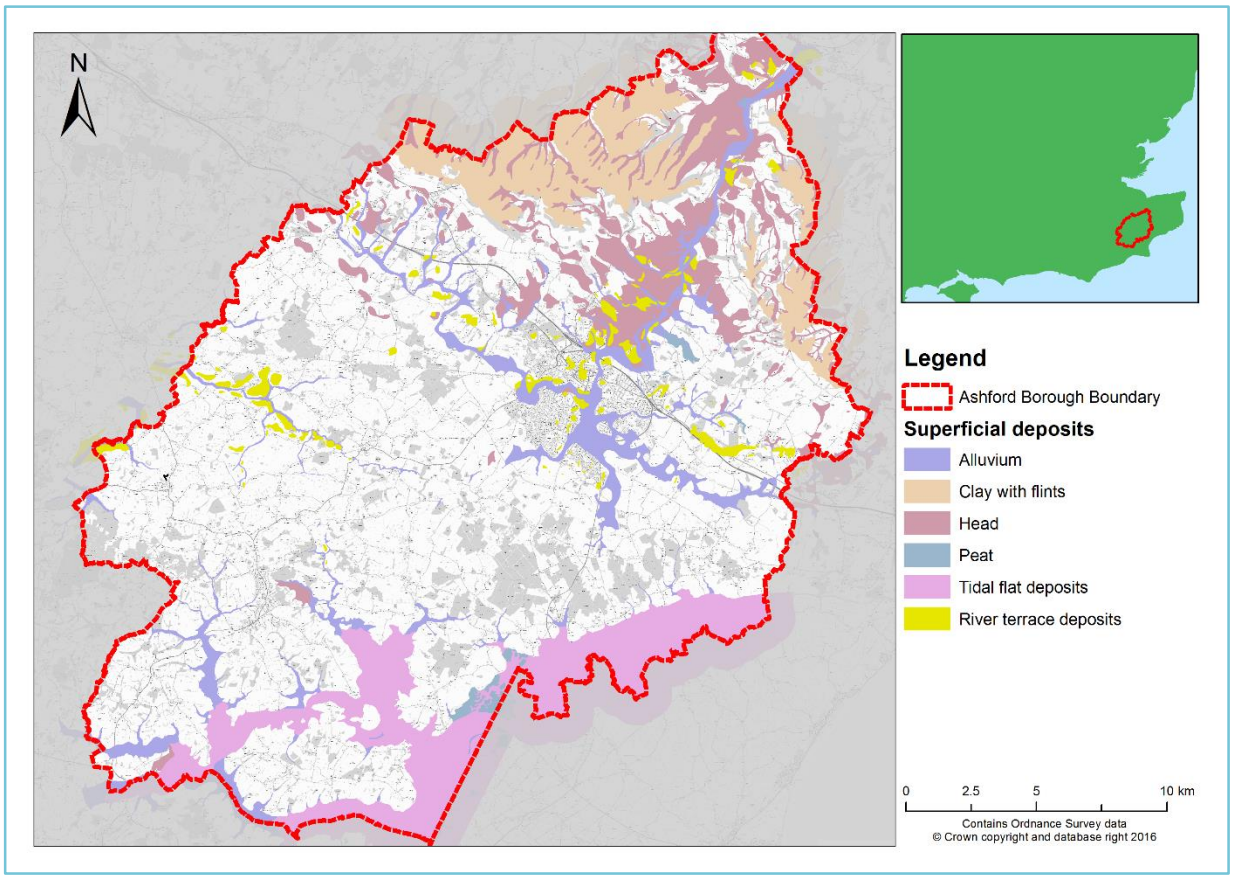


Table 2-2: Study site's soil type and geology

Site ID	Soil Type	Geology	
		Bedrock	Superficial
BBAE1	Loamy – freely draining	Lower Greensand Group (Sandstone + Mudstone)	None
BD8	Loamy + Clayey soils - impeded drainage	Wealden Group (Sandstone + Siltstone)	None
BE16	Loamy + Clayey soils - impeded drainage	Wealden Group (Sandstone, Siltstone + Mudstone)	None
BE17	Loamy + Clayey soils - impeded drainage	Wealden Group (Sandstone, Siltstone + Mudstone)	None
BO1	Loamy – freely draining	Hythe Formation (Sandstone + limestone)	None
CG1 CG2	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
CH4	Loamy – freely draining	White Chalk Subgroup (Chalk)	Clay with flints (Diamicton)
CH17	Loamy – freely draining	White Chalk Subgroup (Chalk)	Clay with flints (Diamicton)
DW6	Loamy – freely draining	Folkestone Formation (Sandstone)	None
HG3 HG4	Loamy – freely draining	Weald Clay Formation (Mudstone)	None
IO2	Loamy + Clayey soils - impeded drainage	Wealden Group (Sandstone + Siltstone)	None
KE2	Loamy – freely draining	Folkestone Formation (Sandstone)	Head (Clay + Silt)
KE3	Loamy – freely draining	Folkestone Formation (Sandstone)	Head (Clay + Silt)
KE4	Loamy – freely draining	Folkestone Formation (Sandstone)	Head (Clay + Silt)
KE5	Loamy – freely draining	Gault Formation (Mudstone)	Head (Clay + Silt)
NW3	Loamy – freely draining	Gault Formation + Upper Greensand Formation (Mudstone, Sandstone + Limestone)	Brickearth (Silt)
NW6	Loamy – freely draining	Sandgate Formation (Sandstone, Siltstone + Mudstone)	None
NW7	Loamy – freely draining	Sandgate Formation (Sandstone, Siltstone + Mudstone)	None
RTW2	Loamy + Clayey soils - impeded drainage	Wadhurst Clay Formation (Mudstone)	None
SS3	Loamy – freely draining	Lower Greensand Group (Sandstone + Mudstone)	None
SS7	Loamy – freely draining	Folkestone Formation (Sandstone)	None
SSS4	Loamy – freely draining	Folkestone Formation (Sandstone)	None
ST3	Loamy – freely draining	Hythe Formation (Sandstone + limestone)	None
ST5	Loamy – freely draining	Weald Clay Formation (Mudstone)	Alluvium (Clay, Silt, Sand + Gravel)
ST6	Loamy – freely draining	Sandgate Formation (Sandstone, Siltstone + Mudstone)	None
ST8	Loamy – freely draining	Atherfield Clay Formation (Mudstone, Sandy)	None
SW3	Loamy – freely draining	Weald Clay Formation (Mudstone)	None
SW6	Loamy – freely draining	Weald Clay Formation (Mudstone)	None
TSTRW1	Loamy + Clayey soils - impeded drainage	Wadhurst Clay Formation (Mudstone)	None
VC1	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	Alluvium (Clay, Silt, Sand + Gravel)
VC2	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	Alluvium (Clay, Silt, Sand + Gravel)

Site ID	Soil Type	Geology	
		Bedrock	Superficial
VC3	Loamy – freely draining	Weald Clay Formation (Mudstone)	Alluvium (Clay, Silt, Sand + Gravel)
VC4	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
VC5	Loamy – freely draining	Weald Clay Formation (Mudstone)	None
WC12	Loamy + Clayey soils - impeded drainage	Wealden Group (Sandstone, Siltstone + Mudstone)	None
WE5	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WE11	Loamy + Clayey soils - high groundwater	Grey Chalk Subgroup (Chalk)	Clay with flints (Diamicton)
WE16A	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WE16B	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WE16C	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WE16D	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WE21	Loamy + Clayey soils - high groundwater	Grey Chalk Subgroup (Chalk)	Clay with flints (Diamicton)
WE34	Loamy – freely draining	Weald Clay Formation (Mudstone)	None
WE38	Loamy – freely draining	Hythe Formation (Sandstone + Limestone)	None
WE39	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WN2	Loamy – freely draining	Lower Greensand Group (Sandstone + Mudstone)	None
WN4	Loamy – high water table	Weald Clay Formation (Mudstone)	River Terrace Deposits 2 (Sand + Gravel)
WS11	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WS21	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Mudstone)	None
WS25	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Sandstone)	None
WS28	Loamy + Clayey soils - impeded drainage	Weald Clay Formation (Sandstone)	None
WS30	Loamy + Clayey soils – impeded drainage	Wealden Group (Mudstone, Sandstone + Siltstone)	None
WS37	Loamy + Clayey soils – high groundwater	Wealden Group (Mudstone, Sandstone + Siltstone)	None

2.3 Surface water flood risk

The national Environment Agency (EA) updated surface water flood risk map has identified the borough to be predominantly at risk of surface water flooding. The Surface Water Management Plan for Ashford Borough (October 2013)[4] has identified Bethersden to be prone to excess surface water flooding during extreme rainfall events.

The National Planning Policy Framework (NPPF; March 2012) has identified that with climate change, peak rainfall intensity is set to increase by 30% by 2115. As of the 19th February 2016, the guidance for climate change has changed[5], and the upper end estimate of peak rainfall intensity by 2115 is an increase of 40% from current peak rainfall intensity.

Development of the shortlisted sites will create further impervious areas which will subsequently exacerbate the flood risk on and off-site, unless the surface water is attenuated.

4 Kent County Council: Ashford Stage 1 Surface Water Management Plan (October 2013)

5 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1

3 Background Policy

The Core Strategy was adopted by Ashford Borough Council on the 10th July 2008 and was the central part of the Local Development Framework, setting out the Council's overall vision and objectives for the delivery of growth in the borough between 2006 and 2021. The Core Strategy is currently under formal review by the Council and is planned to be replaced by the Local Plan. The Local Plan will determine the most sustainable and deliverable pattern of growth that can be achieved within the borough until 2030.

The Core Strategy established local policy guidance for Sustainable Drainage Systems (SuDS) in Ashford Borough. The Core Strategy requires developments to include appropriate SuDS for the management of surface water in order to avoid any increase in flood risk or adverse impact on water quality. Since the Core Strategy was completed in 2008, there have been several key changes in legislation, technical guidance and knowledge of flood risk. As such, it is a requirement for the Local Plan to incorporate these changes and build upon the work of the Core Strategy. As part of this assessment, a review of revised SuDS policies will be undertaken to provide evidence for the emerging Local Plan. The aim of the policy review is to help the Council understand the dynamics of applying improved discharge rates on new major development across the borough.

3.1 National guidance

3.1.1 Flood and Water Management Act (2010)

The Flood and Water Management Act (FWMA)[6] was passed on the 8th April 2010. The Act was created to provide a set of legislations for the regulation and management of flooding and coastal erosion risks. The Act created the role of Lead Local Flood Authority (Kent County Council for the borough of Ashford) to develop, maintain, monitor and apply a strategy for local flood risk management in its authorising area. The role of the Lead Local Flood Authority (LLFA) is to aim to achieve sustainable development by investigating the local flood risks in their area, and provide guidance on how to achieve this.

The FWMA also requires the LLFA to establish a SuDS Approving Body (SAB) which will be responsible for approving, adopting and maintaining drainage plans and SuDS schemes that meet new national standards for design, construction, operation and maintenance. It is understood that Kent County Council is the SAB at the time of this assessment. This assessment will therefore attain to the FWMA by providing guidance on how much ABC should attenuate surface water for new developments.

3.1.2 Localism Act (2011)

The Localism Act was given Royal Assent on the 15th November 2011[7] and was passed to shift power from central government to local governing bodies of councils, as well as to communities and individuals. The Act allows councils to establish their own development plans which should take in account local employment, housing and other land uses in the plan making process. Provision 110 of the Act[8] was introduced to encourage councils to achieve sustainable development practices from the encouragement of cooperation during the planning process. Provision 110 requires Local Authorities to "engage constructively, actively and on an ongoing basis in any process by means of which development plan documents are prepared so far as relating to a strategic matter".

3.1.3 National Planning Policy Framework (2012)

The National Planning Policy Framework (NPPF)[9] was published on the 27th of March 2012 by the Department for Communities and Local Government (DCLG) and acts as a key part of the government's reforms to make the planning system less complex and more accessible. It is the predecessor of the PPS25 and acts as a guidance tool for local planning authorities and decision-takers, when submitting planning applications.

One of the core principle guidance in the NPPF is for Local Planning Authorities (LPAs) to adopt proactive strategies to mitigate and adapt to climate change, by taking in full account of flood risk.

6 UK HM Government, Flood and Water Management Act (2010):

7 UK HM Government, Localism Act (2011).

8 UK HM Government, Localism Act (2011): Provision 110 of the Act.

9 Department of Communities and Local Government, National Planning Policy Framework (2010).

Development should be allocated to low flood risk areas, but if this is not attainable, development should provide mitigation to make them safe, while not increasing flood risk elsewhere. The NPPF does not, however provide further guidance to the application of SuDS, other than SuDS measures should be incorporated in all new developments.

3.2 Local guidance

3.2.1 Ashford Borough Council Core Strategy (2008)

The Core Strategy (2008) is the central part of Ashford Borough's Local Development Framework up until 2021. The Local Plan 2030 is to replace the Core Strategy at the end of 2015. The Core Strategy outlined several key development strategies for the borough, including policy CS20 Sustainable Drainage. Policy CS20 outlines the Council's planned approach to the delivery of SuDS in developments across the borough, and states that all development should include appropriate SuDS for the disposal of surface water in order to avoid any increase in flood risk or adverse impact on water quality.

Current guidance for greenfield developments in the Ashford Growth Area (AGA) that drain to the River Stour, is that SuDS are required to achieve an overall reduction in the pre-development runoff rate. On all other sites in the borough, developments should aim to achieve a reduction from the existing runoff rate, but must at least result in no net additional increase in runoff rates.

Policy CS20 also states that SuDS should be provided onsite. If this cannot be achieved in the AGA, then more strategic forms of SuDS should be explored, and developers will need to contribute towards the cost of provisions. SuDS should also be "sensitively designed and located to promote improved biodiversity, an enhanced landscape and good quality spaces that improve public amenities in the area".

In all cases, developers will need to demonstrate that acceptable management arrangements are funded and in place so that SuDS schemes are well maintained in the future.

3.2.2 Sustainable Drainage Supplementary Planning Document (2010)

The Supplementary Planning Document (SPD) for ABC's Local Development Framework was completed in October 2010[10] and sets out how developers can meet the requirements of Policy CS20 of the ABC's Core Strategy (2008). The guidance provided outlines the current post-development runoff rate standards that need to be achieved by all future developments. The post-development runoff rate standards differ across the borough and are summarised in Table 3-1. The SPD also provides guidance on what SuDS are appropriate and how SuDS schemes can be developed to comply with CS20.

The aim of this assessment is to provide ABC with evidence to understand if the required runoff rates outlined in the SPD are achievable across the borough, as well as to provide the potential optimum discharge rates that could be achieved across the borough.

10 Ashford Borough Council, Sustainable Drainage Supplementary Planning Document (2010).

Table 3-1: Current runoff rate standards for development in different areas of Ashford Borough

Area	Type	Required Runoff Rates
Growth Area (north of M20)	Greenfield	2l/s/ha
	Previously developed	Best endeavours to achieve 2l/s/ha Failing this, aim to achieve a reduction from existing runoff rates for the site (where this can be established). As an absolute minimum, this must not lead to a net increase in runoff above the existing rate (where this can be established) or 10.26l/s/ha (where rates cannot be established).
Growth Area (south of M20 including urban extension areas at Cheeseman's Green and Chilmington Green (east))	Greenfield (Stour catchment)	4l/s/ha
Growth Area (south of M20 including Chilmington Green (west))	Greenfield (Beult catchment)	Encouraged to achieve 4l/s/ha where possible. Must avoid any runoff rate in excess of the existing greenfield rate for the site (where this can be established) or 6l/s/ha (where the greenfield rate cannot be established).
Growth Area (south of M20 including town centre regeneration sites)	Previously developed	Best endeavours to achieve 4l/s/ha Failing this, aim to achieve a reduction from existing runoff rates for the site (where this can be established). As an absolute minimum, this must not lead to a net increase in runoff above the existing rate (where this can be established) or 10.26l/s/ha (where rates cannot be established).
Rest of the borough	Greenfield	Encouraged to achieve 4l/s/ha where possible. Must avoid any runoff rate in excess of the existing greenfield rate for the site (where this can be established) or 6l/s/ha (where the greenfield rate cannot be established).
	Previously developed	Best endeavours to achieve 6l/s/ha Failing this, aim to achieve a reduction from existing runoff rates for the site (where this can be established). As an absolute minimum, this must not lead to a net increase in runoff above the existing rate (where this can be established) or 10.26l/s/ha (where rates cannot be established).

3.2.3 Kent County Council Surface Water Management Plan (2013)

The Kent County Council's Stage 1 Surface Water Management Plan (SWMP)[11] for Ashford was completed in October 2013 by JBA Consulting. The Ashford SWMP was undertaken as part of the Kent County Council's duty as LLFA to investigate the local flood risks in Ashford Borough as part of their remit for strategic oversight of local flood risk management in Kent. The SWMP follows on from the Kent County Council's Preliminary Flood Risk Assessment[12] which identified Ashford to be an area potentially at risk of local surface water flooding.

The SWMP has subdivided the Borough into five drainage areas of Ashford Rural Mid, Ashford Rural North, Ashford Rural South, Ashford Town and Hamstreet. An action plan for each of the drainage areas has been included in the SWMP report which identifies the roles of partners and priority actions required in the borough.

3.2.4 Ashford Borough Council Strategic Flood Risk Assessment (2014)

ABC's Strategic Flood Risk Assessment (SFRA)[13] was completed by JBA Consulting in July 2014. The 2014 SFRA replaced the original SFRA that was published in 2006. The updated SFRA advises that connection of surface water drainage to an existing surface water sewer should only be consider as a last resort in Ashford.

11 Kent County Council, Ashford Stage 1 Surface Water Management Plan (2013)
12 Kent County Council, Preliminary Flood Risk Assessment (2011)
13 Ashford Borough Council, Strategic Flood Risk Assessment (2014)

3.3 Technical Guidance

3.3.1 Ashford Sustainable Drainage Strategy Technical Guidance Document (2008)

The Ashford SuDS Technical Guidance was completed by Atkins in March 2008[14]. The technical guidance states that the objective of the SPD is to reduce downstream flooding by attenuating runoff to below natural "greenfield" runoff rates using SuDS. The guidance also states that successful SuDS design requires drainage to be "carefully integrated into the site whilst taking into account the original greenfield drainage patterns".

The technical guidance states that post-development runoff rates for greenfield developments in Ashford should be attenuated to 2l/s/ha if north of the M20 and 4/l/s/ha if south of the M20. These values are based on the permeability of underlying geology and soils within the borough. The guidance also states that ABC requires developers to maximise runoff control opportunities and to incorporate the use of swales and other landscaped features to collect and convey water as far as is practicable. The use of piped systems is discouraged within Ashford Borough, as well as infiltration devices due to the area being underlain by impermeable clays, such as those within the AGA.

3.3.2 National Planning Practice Guidance (2014)

The National Planning Practice Guidance (NPPG)[15] was published in 2014 online by the DCLG to be periodically updated by the Government. The web-based guidance advises on the causes and impacts of flooding which should be reduced by the incorporation of SuDS in development plans. SuDS schemes may not be practicable for all forms of development (e.g. mineral extraction sites) but should be incorporated unless demonstrated to be inappropriate. The online guidance states that all major developments are required to provide a SuDS scheme as part of the planning application.

3.3.3 Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems (2015)

The SuDS: Non-statutory technical standards for sustainable drainage systems[16] was published by the Department of Environment, Food and Rural Affairs (DEFRA) in March 2015. The document outlines guidance on peak flow and volume control guidance.

It states that for greenfield developments, the 1% AEP rainfall event should never exceed the peak greenfield runoff rate / volume for the same event, and that for previously developed sites, peak runoff rate / volume must be as reasonably close to the greenfield runoff rate for the same event. Where it is not reasonably practicable to constrain the volume or runoff to any drain, sewer or surface water body in accordance with the above, then the runoff volume must be discharged at a rate that does not adversely affect flood risk.

The guidance also states that all drainage systems must be designed so that they do not flood the site in the 1% AEP rainfall event, unless an area is designated to hold and/or convey water as part of the drainage design.

3.3.4 The SuDS Manual C753 (2015)

The SuDS Manual C753[17] was updated by CIRIA in 2015. The updated manual acts as guidance for the planning, design, construction and maintenance of SuDS to assist with their effective implementation within both new and existing developments in the UK. The manual states that integration of SuDS is the most effective way to achieve the desired objectives of SuDS use and that the SuDS approach should use the natural hydrology as the baseline in which system performance is evaluated.

14 Ashford Borough Council, Sustainable Drainage Strategy Technical Guidance Document (2008)

15 Department for Communities and Local Government, Planning Practice Guidance (2014)

16 Department for Environment, Food and Rural Affairs, SuDS non-statutory technical standards for drainage systems (2015)

17 CIRIA, The SuDS Manual (C753) (2015)

4 Small Scale Development Sites

The CIRIA SuDS manual guidance on SuDS capacity design states that all drainage systems should be designed to the 3.33% AEP minimum service and control the peak runoff rates up to the 1% AEP year event. The SuDS manual does not specify an industry standard to comply to but advises Councils and local planning authorities to adopt a discharge rate standard, depending on the position of the site and management.

It has, however suggested that discharge rates to the watercourse or sewer system should try to achieve a minimum of 5l/s/ha. Ashford Borough Council SuDS SPD has stated that achieving this volume is proving to be difficult for small-scale development sites (<0.25ha). Current runoff guidance in the borough is to restrict rates to 4l/s/ha, which has been identified by the Council to be difficult to design for on sites less than 0.25ha. As such, they have advised for small-scale sites to aim to achieve a maximum discharge limit of 2l/s by incorporating flow control devices.

A flow control device limits the flow causing the water to back up in the SuDS component, allowing the attenuation storage volume to be filled. Guidance for flow control devices is found in the CIRIA SuDS Manual. As part of this assessment, flow control devices will be reviewed, along with what discharge rates are considered acceptable to maintain lower flows.

Other discharge rate guidance from the EA's Rainfall Runoff Management for Developments Report (2013)[18] advises that if infiltration is not possible at the site, then the volume of storage needs to be specifically designed to discharge at a maximum of 2l/s/ha if long term storage (LTS) is used in the development. The report also states that greenfield flow rate is not actually applied to define the limiting discharge on small sites, as they would require impractically small controls to achieve the required flow rates. Therefore the EA advises that the minimum flow of 5l/s should be used on small-scale sites. The Code for Sustainable Homes Technical Guide (2010)[19] also specifies that the flow rate at discharge point from the site should be up to 5l/s. Both of the above guidance does not discriminate the maximum discharge rate based on the size of a site, and therefore only provide a standard discharge rate for all potential development sites.

4.1 Flow control

There are three types of flow structures used in a SuDS component: an inlet structure, an outlet structure and a control structure. The SuDS Manual highlights that flow control structures are critical to the delivery of effective SuDs management. Key influences when considering the flow control design are: the hydraulic performance, risk of blockages and energy dissipation/erosion risk.

Flow control structures allows for attenuation storage to be discharge over a certain amount of time. A standard design of discharge time for storage SuDS is 24 hours. As part of this runoff assessment it will be assessed whether the individual sites can be attenuated to 4l/s/ha or 5l/s/ha in 24 hours and less.

4.2 Pre-development monitoring

Pre-development monitoring on greenfield sites can help developers understand where the site drains to naturally. By incorporating monitoring prior to development, observations of overland flow routes, amount of infiltration and groundwater flows can be understood at the site.

On brownfield sites where drainage infrastructure may already be in place, pre-development monitoring can help understand the capacity of drainage on a site by site basis.

Site monitoring is always encouraged, particularly for large sites, where flow monitoring of at least 12 months can support runoff estimations including site response and time to peak, and potentially calibrating models of existing drainage models.

Where infiltration is proposed via soakaways then a min. 12 months' worth of groundwater level monitoring info is recommended to established seasonal range.

18 Environment Agency, Rainfall Runoff Management for Developments Report - SC030219 (October 2013)

19 Department of Communities and Local Government, Code for Sustainable Homes: Technical Guide (November 2010)

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5 Method statement

The following chapter outlines the methods chosen to assess the optimal runoff rates and discharge time for the shortlisted sites in Ashford Borough.

5.1 ReFH2 method

The SuDS Manual (2015)[20] identifies that Flood Estimation Handbook (FEH) methods should be the preferred approach for developing runoff estimates for use in surface water management design. The document describes the FEH Statistical method and the Revitalised Flood Hydrograph (ReFH method.

A requirement of this study is to assess post-development runoff rates and volumes. In the FEH Statistical method the process of urban adjustment gives the typical net increase in river flow between a rural and an urban catchment but includes all effects of flood alleviation measures. The gross effect (i.e. without any management of urban runoff) will be higher than this typical net increase. The urban adjustment should therefore not be used to assess the impact of development within a catchment. Due to this the FEH Statistical method was ruled out for use in this study.

The ReFH method has more potential for estimation of pre- and post-development runoff. ReFH2 also includes parameter equations for plot-scale applications. ReFH1 is not recommended for use on permeable catchments; ReFH2, through revised initial conditions, has addressed this limitation. A brief assessment of the Ashford Borough area has revealed that it is reasonably permeable therefore ReFH2 was selected as the method for undertaking the runoff assessment.

Some caution needs to be applied in the use of ReFH2. It has not been peer reviewed or fully published, and there is currently no guidance or approval of its use from the Environment Agency. The plot-scale equations are useful for pre- and post-development runoff estimation and are referenced in the latest SuDS Manual guidance but plot-scale research is ongoing and the method is likely to require more testing before it is widely used.

After taking all of this into consideration, it is recommended that for this study the ReFH2 method plot-scale approach is the most suitable to estimate the runoff rates and volumes required. This approach avoids the need to determine URBEXT2000 values for the proposed development sites; instead the urban area is set to be equal to the area of impervious surfaces.

For assessment of runoff rates, the design storm duration used was the site-specific critical duration; ReFH2 calculates this automatically. For assessment of runoff volumes the six hour storm duration will be used, as defined in the SuDS Manual.

The FEH99 rainfall statistics were used for the assessment. Comparison of FEH99 with FEH13 rainfall for a large site catchment (CG1 CG2) and a small site catchment (DW6) showed a reduction in rainfall volume by about 3mm for the FEH13 rainfall value. Although the ReFH2 Technical Guidance recommends the use of FEH13 rainfall statistics with the ReFH2 software, it is not essential to do this. Therefore FEH99, which is available automatically with the ReFH2 software was used for this study. Further study of discharge rates and volumes in the future should attempt to incorporate the FEH13 rainfall statistics.

FEH guidelines and the SuDS Manual suggest that for catchments <0.5km^2 and small plots of land runoff, estimates are derived from the nearest suitable catchment (>0.5km^2) for which descriptors are defined, and scaled down by the ratio of catchment areas. ReFH2 plot-scale equation automatically adjust the ratios to represent the smaller catchment.

As noted in the SuDS Manual, FEH methods are the preferred approach for developing runoff estimates for the use of surface water management. The estimates provided, especially for very small catchments, as represented in this study, are regarded as approximates and are therefore not representative of the whole catchment in which they are derived from.

The catchments derived from FEH CD-Rom were also chosen based on their locality to the study sites (sites were within the chosen catchments) and checked to see if they represented the sites. The list of catchment descriptors for each site is found in Appendix A.1.

20 CIRIA, The SuDS Manual (C753) (2015)

5.2 Runoff assessment

5.2.1 FEH-CD Rom catchments

Catchments descriptors were exported from FEH CD-ROM for each of the shortlisted development sites and imported into the ReFH2 software. For all sites the following adjustments to the model were made:

- ReFH2 technical guidance recommends that the winter storm defaults should be used in all but the most heavily urbanised catchments. The catchments used had URBEXT values of between 0.00 - 0.125, and are therefore considered to be essentially rural to moderately urbanised catchment. The storm profile was therefore set to winter for not only the greenfield scenarios, but also for the previously developed and post-developed scenarios for consistency within the study.
- The AREA was adjusted to represent the total area of the shortlisted sites, and not the whole catchment. DPLBAR was also adjusted by multiplying AREA to the power of 0.548 to calculate the new DPLBAR value.
- The TP (time to peak) and BL (baseflow lag) was recorded for all small sites (<0.5km^2) before the AREA and DPLBAR values were adjusted. The recorded TP and BL values were then used to override the new values, as recommended by the ReFH2 Technical Guidance.
- URBEXT 2000 values were not used for this study as the values are not appropriately representative of the extent of the urban area across each development site.
- The urban area was adjusted for the previously developed and post-developed scenario for each of the shortlisted sites.
    - The previously developed (existing) scenario urban adjustment was based on the amount of impermeable cover estimated from satellite imagery of the site. This was taken as a percentage of the total site area and used for the urban area value.
    - The percentage of development that ABC has estimated to take place at each development site was provided by ABC prior to the commencement of the study. Urban area was adjusted to represent the proposed development on site. Values for development ranged between 50% to 100% development. The impervious factor (IF) was also adjust to 0.5 for residential developments, 0.55 for mixed developments, and 0.6 for commercial developments.
    - For the greenfield scenario, urban area was adjusted to 0 to represent no development onsite.
- For all small site (<0.5km^2) the impervious factor (IF) was adjusted to represent the density of urban development for each site. This adjustment is recommended in the ReFH2 Technical Guidance and represents the proportion of the identified urban area which is impervious, e.g. covered by roofs, paving or roads. For the larger sites (>0.5km^2) that were calculated using the catchment equations, the default IF value (0.3) was kept for the proportion of urban development, taking into account the open spaces (in the form of parks or gardens) that would be present on the existing site or post-development.
- The Urban Runoff Factor (URF) which represents the proportion of rainfall that results in direct runoff for the defined area was 0.7, the default value for ReFH2. This value was used for all site calculations for consistency.
- Two storm durations were used in ReFH2: the 6.25hr (with a time step of 0.25hr) to calculate the total volume and flow rates for modelling, and the critical duration, which was based on the recommended storm duration after the AREA was adjusted, along with the urban area and IF. The site specific critical duration is the amount of time that runoff rate would naturally occur for the given scenario.
- The Areal Reduction Factor (ARF) was adjusted to 1 for all small sites (<0.5km^2). For large sites (>0.5km^2), the ARF was set to default value.

5.2.2 Climate change

The SuDS manual states that rainfall intensity factors will need to be applied to design rainfall depths for developed site runoff assessment. To represent climate change, total flow values were increased by 1.4 to represent a maximum upper end 40% increase in peak rainfall intensity, as recommended by the Environment Agency's updated guidance on Flood Risk Assessment: Climate

Change Guidance (19th February 2016)[21]. The ReFH2 method does not have a way of increasing rainfall intensity, and therefore the approach of increasing rainfall was tested in ReFH1 ISIS Bus. By applying a factor of 1.4 to the flow, the rainfall hyetograph doesn't change but the flow hydrograph ordinates are increased by 30% and hence the volume increases by 30% in ReFH1 ISIS Bus. By adding an observed rainfall into ReFH1 ISIS Bus with a 30% increase, the generated peak flow and volume was 2% higher than alone applying a 1.3. It is assumed that the results from ReFH1 ISIS Bus would be similar for ReFH2.

The SuDS manual also states that storage volumes will approximately increase by the square of any rainfall uplift factor e.g. a 10% increase in rainfall will result in a 20% increase in storage. This method was applied to BBAE1 volume. Storage required for post development with no climate change was calculated as 10.78ML while storage for post development with climate change was 15.7ML. Therefore the climate change storage volume is 1.46 times high than without climate change and is therefore considered to be fairly representative of climate change.

5.2.3 Over-attenuation of greenfield volumes

The greenfield 100 year return event six hour storm duration volumes with a reduction of 10%, 30% and 50% applied were also calculated as part of this assessment. This is to assess if any reduction in flood risk can be achieved by stipulating runoff rates less than the greenfield rate for the new development (i.e. over-attenuating surface water runoff). To achieve this the following calculation were undertaken for the Post-development (PD) attenuation:

$$PD\ attenuation\ volume = PD_{vol} - Greenfield_{vol}$$

With vol = volume (m^3) and the values used the six hour storm duration 1:100 year + climate change calculations.

To calculate the discharge times for attenuation storage, the site-specific critical duration greenfield runoff rate (or peak flow (m^3s^{-1})) was used to calculate the greenfield discharge time.

$$Greenfield\ attenuation\ time\ (hr) = \left(\frac{PD\ attenuation\ _{vol}}{Greenfield\ runoff\ rate}\right) \div 3600$$

To calculate the over-attenuation values of 10%, 30% and 50% of PD attenuation volume the following equation was applied:

$$Greenfield - 10\%\ attenuation\ time\ (hr) = \left(\frac{PD\ attenuation\ _{vol}}{Greenfield\ runoff\ rate\ \times 0.9}\right) \div 3600$$

$$Greenfield - 30\%\ attenuation\ time\ (hr) = \left(\frac{PD\ attenuation\ _{vol}}{Greenfield\ runoff\ rate\ \times 0.7}\right) \div 3600$$

$$Greenfield - 50\%\ attenuation\ time\ (hr) = \left(\frac{PD\ attenuation\ _{vol}}{Greenfield\ runoff\ rate\ \times 0.5}\right) \div 3600$$

5.3 Other descriptors

Information regarding the geology and soil type for each development site was required to be provided as part of Stage 1 of the study. This information is detailed in Table 2-2 in section 2.2.

5.4 Assumptions

The following assumptions were made in the runoff assessment:

- The ReFH2 technical guidance states that the water balance is closed within the model and therefore direct runoff should not exceed net rainfall volume. It was noted in the study that baseflow continued for several hours once the direct from the site had finished. This caused the original calculation, especially for the greenfield values, to have a higher total flow than was perceived to be accurate.

  The final volumes were calculated by removing the extended baseflow 'tail' for the Total Flow hydrographs once Runoff had reached 0.00m^3s^{-1}.

  An example of the pre and post-altered total flow hydrographs is shown is Figure 5-1 and 5-2. The new total volumes (ML) were then calculated from the sum of the adjusted Total Flow, and the results were collated for further analysis. This was applied to all the 6.25

21 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1

hour storm duration results for all scenarios tested and resulted in a lower total flow for the greenfield scenarios in comparison to the post-development scenario, except for the two larger sites.

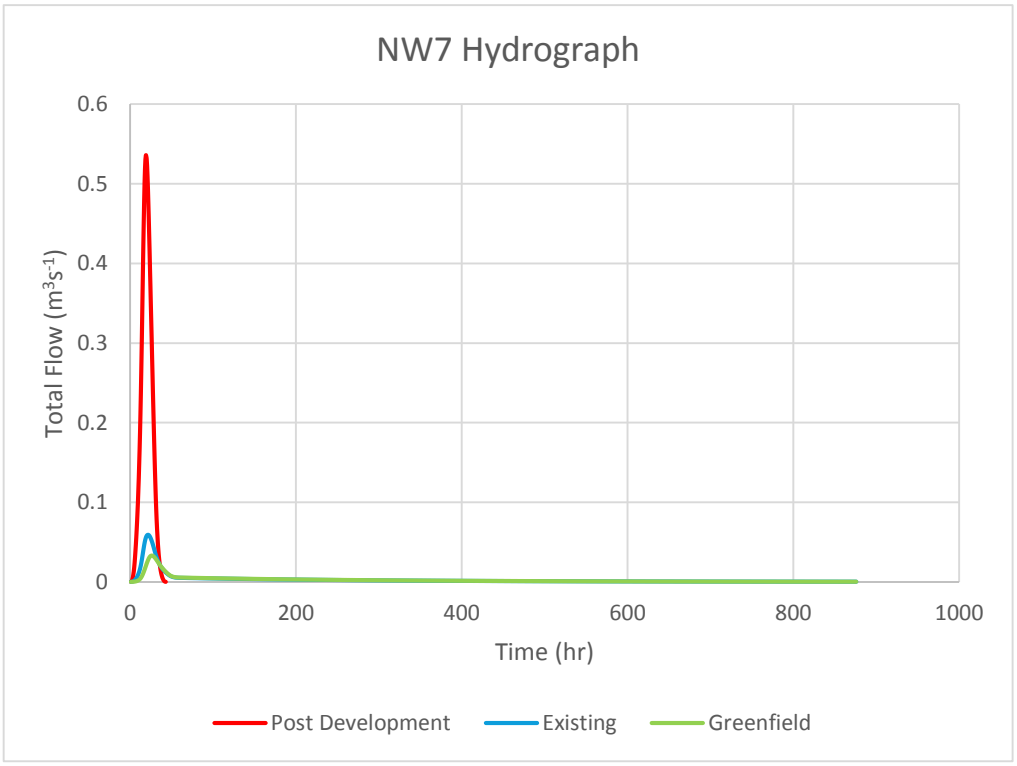


Figure 5-1: Original ReFH2 Total Flow hydrograph output for site

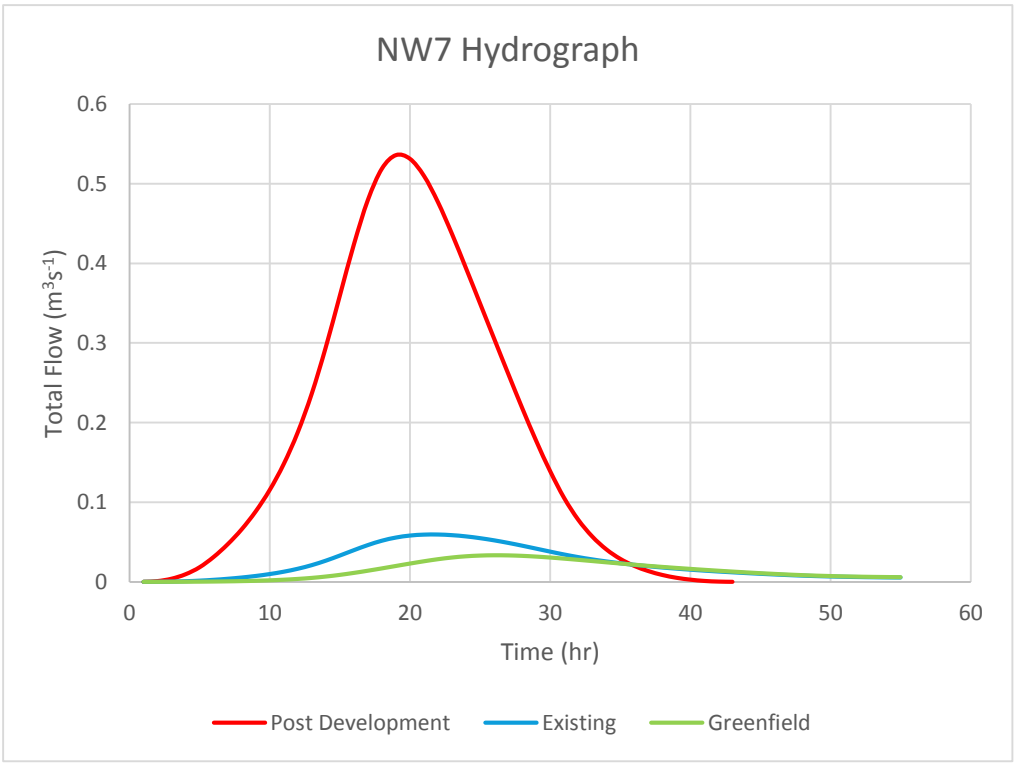


Figure 5-2: Adjusted Total Flow hydrograph

- The catchment equation was applied to the two sites >0.5km^2 (CG1 CG2 and WS11). Both of these sites had a higher total flow for the greenfield scenario in comparison to post-development total flow, even after the adjustment of hydrographs, as mentioned above.

  To overcome this, the Volume$_{xs}$ equation[22] (see below) from the SuDS Manual was applied to the two larger site catchments (>0.50km^2) to estimate the extra runoff volume for the proposed development both sites would have compared to the existing developed site. The values from the Volume$_{xs}$ equation were compared to the ReFH2 outputs and were chosen as a better representation of the estimates for both of the larger sites. The values from the Volumexs equation were therefore used for all additional calculations.

$$Vol_{xs} = RD \times A \times 10\left[(0.8 - SPR)\frac{PIMP_2}{100} + (SPR - 0.8)\frac{PIMP_1}{100}\right]$$

Where:

Vol_{xs}	=	Extra runoff volume of the proposed development runoff over the runoff volume from the previously developed site (m3)
RD	=	Rainfall depth for the 1:100 year, 6 hour event (mm)
A	=	Area of the site (ha)
SPR	=	SPR index for the SOIL or HOST class (specified as a decimal proportion); this specifies the proportion of runoff from previous surfaces (if SPRHOST values are used, the minimum value should be set to 0.1)
$PIMP_2$	=	Percentage impermeability of the proposed site
$PIMP_1$	=	Percentage impermeability of the previously developed site

5.5 Sensibility checks

Sensibility checks were applied at random to a site. Volume$_{xs}$ equation was chosen to compare the ReFH2 volume outputs.

Due to the assumed total flow values, based on reducing the total values to when direct runoff ends in the simulation, the confidence level of the values is low.

5.6 Hydraulic Modelling

Detailed hydraulic modelling of the shortlisted sites was undertaken using ISIS-TUFLOW. The existing Environment Agency Great Stour hydraulic model was licensed for the study and re-run to check outputs of the ReFH2 methods.

Modelling was carried out using ISIS TUFLOW to provide estimates of the flood extents at the study sites with an annual probability of 1% AEP including an allowance for climate change (40% increase). The baseline model was updated with the hydrographs and volumes obtained from the ReFH2 method (see section 5.2 for details).

The existing model was updated with the volumes and hydrographs obtained from the ReFH2 six scenarios for the 1% AEP with allowance for climate change (40% increase) event.

22 CIRIA, The SuDS Manual (C753) (2015): Equation 24.11 Estimating the extra runoff volume from a proposed development site compared to the previously developed site, page 536

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6 Results

6.1 Discharge volumes

Using ReFH2 the discharge volumes under each scenario were calculated. Many of the sites existing development was classified as greenfield or had the same level of development proposed by ABC. The post-development volumes chosen to represent the post-development scenario was from the 1% AEP + Climate Change calculations. The volume needed to attenuate to greenfield in the post-development scenario was also calculated to provide the discharge volume, rate and time required for SuDS design. The results are shown in Table 2-1.

Table 6-1: Discharge volumes for greenfield, existing and post-development scenarios

	Discharge volumes calculated			
Site ID	Greenfield volume (m^3)	Existing volume (m^3)	Post development volume + CC (m^3)	Volume to attenuate for greenfield PD (m^3)
BBAE1	1879		12727	10848
BD8	1250		1679	429
BE16	61	1043	1331	1270
BE17	108	1520	1873	1765
BO1	173		1485	1313
CG1 CG2				26215*
CH4	85	257	451	366
CH17	605		2449	1844
DW6	260	314	981	722
HG3 HG4	3568	15820	15145	11577
IO2	3805	3669	7083	3278
KE2	437		2128	1691
KE3	4615		12600	7985
KE4	4973	7022	13811	8838
KE5	83	149	231	148
NW3	103	193	892	788
NW6	48		416	368
NW7	622	1140	5263	4641
RTW2	300	378	494	194
SS3	489		864	375
SS7	159		220	61
SSS4	252		318	66
ST3	36	266	375	339
ST5	45	201	375	330
ST6	2069	8333	8078	6009
ST8	310	351	483	173
SW3	351	1262	414	63
SW6	94		1431	1336
TSTRW1	4607		5863	1256
VC1	407		640	233
VC2	781	957	1180	400
VC3	751	921	1180	429
VC4	626	810	984	358
VC5	174	233	280	106
WC12	971		1228	257
WE5	1769		2703	935
WE11	5140	6178	13409	8269
WE16A	3348		4943	1595
WE16B	5129		7591	2462
WE16C	3678		5443	1765
WE16D	1518		2247	729
WE21	7338		10955	3617

Site ID	Discharge volumes calculated			
	Greenfield volume (m^3)	Existing volume (m^3)	Post development volume + CC (m^3)	Volume to attenuate for greenfield PD (m^3)
WE34	6	27	32	27
WE38	2373	2575	16156	13783
WE39	33		211	178
WN2	252		421	169
WN4	1484		1842	359
WS11				8286*
WS21	508		776	268
WS25	699		861	162
WS28	229		361	133
WS30	2898		4778	1880
WS37	325	285	440	114

* Volumes have been calculated using the $Volume_{xs}$ equation for the CIRIA SuDS guidance

6.2 Greenfield runoff assessment

The greenfield runoff rates were calculated from the ReFH2 critical duration (site-specific) method. ABC's SuDS SPD guidance for greenfield runoff rates (Policy CS20) suggests that the maximum greenfield discharge rate for a development site should be 4l/s/ha, while the recommended standard suggested by the SuDS manual and Environment Agency is 5l/s/ha, as discussed previously in section 4. The results are shown in Appendix A.2.

6.3 Is over-attenuation viable in Ashford?

It is required within the study scope to understand whether the proposed development sites can be attenuated to greenfield post-development. ABC have also requested that over-attenuation of greenfield should be investigated as part of this discharge assessment. The viability of attenuation was based upon discharge depleting to half of the stored volume within 24 hours. Any discharge times above 24 hours was not considered to be viable, and would therefore need long-term storage.

Table 6-2 summarises which sites can be attenuated to greenfield, which sites can be over-attenuate, and if so to what extent. Table 6-2 also summarises whether ABC's SPD SuDS greenfield runoff rate of 4 l/s/ha is achievable at the shortlisted sites, or if 5 l/s/ha runoff rate, as recommended by the Environment Agency and CIRIA SuDS guidance, is a more achievable value in 48 hours.

Table 6-2: Attenuation and over-attenuation of post-development scenario to greenfield or less for each study site.

- Red cells = not viable
- Green cells = viable
- Blue cells = over-attenuation viable to percentage reduction shown in cell.

	Can sites be attenuated to greenfield post development?			
Site ID	**Half of attenuation volume viable in 24 hours**	**Over-Attenuation Viable**	**EA and CIRIA greenfield runoff rate to 5l/s/ha**	**ABC's greenfield runoff rate to 4l/s/ha**
BBAE1	x	x	x	x
BD8	✓	50%	x	x
BE16	✓	50%	x	x
BE17	✓	50%	x	x
BO1	✓	x	x	x
CG1 CG2	✓	30%	x	x
CH4	✓	30%	✓	✓
CH17	✓	50%	x	x
DW6	✓	30%	x	x
HG3 HG4	✓	50%	x	x
IO2	✓	50%	x	x
KE2	✓	50%	x	x
KE3	✓	50%	x	x
KE4	✓	50%	x	x
KE5	✓	50%	✓	✓
NW3	✓	x	x	x
NW6	✓	x	✓	✓
NW7	✓	x	x	x
RTW2	✓	50%	✓	✓
SS3	✓	50%	✓	✓
SS7	✓	50%	✓	✓
SSS4	✓	50%	✓	✓
ST3	✓	50%	✓	✓
ST5	✓	x	✓	✓
ST6	✓	30%	x	x
ST8	✓	50%	✓	✓
SW3	✓	50%	✓	✓
SW6	x	x	x	x
TSTRW1	✓	50%	x	x
VC1	✓	50%	✓	✓

Site ID	Can sites be attenuated to greenfield post development?			
	Half of attenuation volume viable in 24 hours	Over-Attenuation Viable	EA and CIRIA greenfield runoff rate to 5l/s/ha	ABC's greenfield runoff rate to 4l/s/ha
VC2	✓	50%	x	x
VC3	✓	50%	x	x
VC4	✓	50%	x	x
VC5	✓	50%	✓	✓
WC12	✓	50%	x	x
WE5	✓	50%	x	x
WE11	✓	50%	x	x
WE16A	✓	50%	x	x
WE16B	✓	50%	x	x
WE16C	✓	50%	x	x
WE16D	✓	50%	x	x
WE21	✓	50%	x	x
WE34	✓	30%	✓	✓
WE38	✓	10%	x	x
WE39	✓	10%	✓	✓
WN2	✓	50%	✓	✓
WN4	✓	50%	x	x
WS11	✓	50%	x	x
WS21	✓	50%	✓	x
WS25	✓	50%	✓	x
WS28	✓	50%	✓	✓
WS30	✓	50%	x	x
WS37	✓	50%	✓	✓

The results of the attenuation to greenfield assessment resulted in two sites not being able to attenuate to greenfield discharge rates as it would take greater than 24 hours to discharge to half the stored volume based on the current forecasted impermeable area provided by ABC. Out of 51 sites that could be attenuated to half of the greenfield discharge volume in 24 hours or less, only 16 could achieve the ABC's recommended rate of 4l/s/ha.

By increasing the greenfield runoff rate to the 5l/s/ha (in line with CIRA), an additional three sites (SS3, WS21 and WS25) could be attenuated in 48 hours. It was observed that the majority of the study site's greenfield runoff rate was around 8.8l/s/ha, double the recommended maximum greenfield runoff rate.

There are no clear trends when comparing the site's geology to whether they can achieve the recommended runoff rates. The aforementioned sites have a range of geology and levels of permeability, however, one trend is that the soil type identified in Table 2-2 is loamy and freely draining for all sites that can achieve at least the 5 l/s/ha discharge rate. It therefore suggests that infiltration at these sites has an influence over the amount of runoff.

This study has looked only at one method of single site attenuation and discharge. The benefits of soakaways or other loses to infiltration have not been considered. One way to reduce discharge rate for sites that are not currently forecast to be able to attenuate to 50% greenfield rate, or either standard rate would be to reduce the site impermeable area or increase other losses (such as via soakaway). Another option would be to allow for relaxation of the requirement to discharge half the stored volume within 24 hours, to a period of more than 48 hours provided that robust exceedance measures are in place.

6.4 Flood outlines

As part of the requirements for the discharge assessment, hydraulic modelling was undertaken to understand how the different discharge scenarios would impact the floodplain of the Great Stour

river. The change in flood outlines is shown in Figure A-1. Further zoomed in mapping of the flood outlines is shown in Appendix A.4.

The results of the modelling show that there was not a great reduction in the flood outline for the greenfield discharge scenarios. The greatest reduction was shown to be in the vicinity of WS11 (Figure A-1) development and in the area of Aylesford Green in Ashford (Figure A-3).

River flow hydrographs were observed from the ISIS 1D results for a select number of nodes:

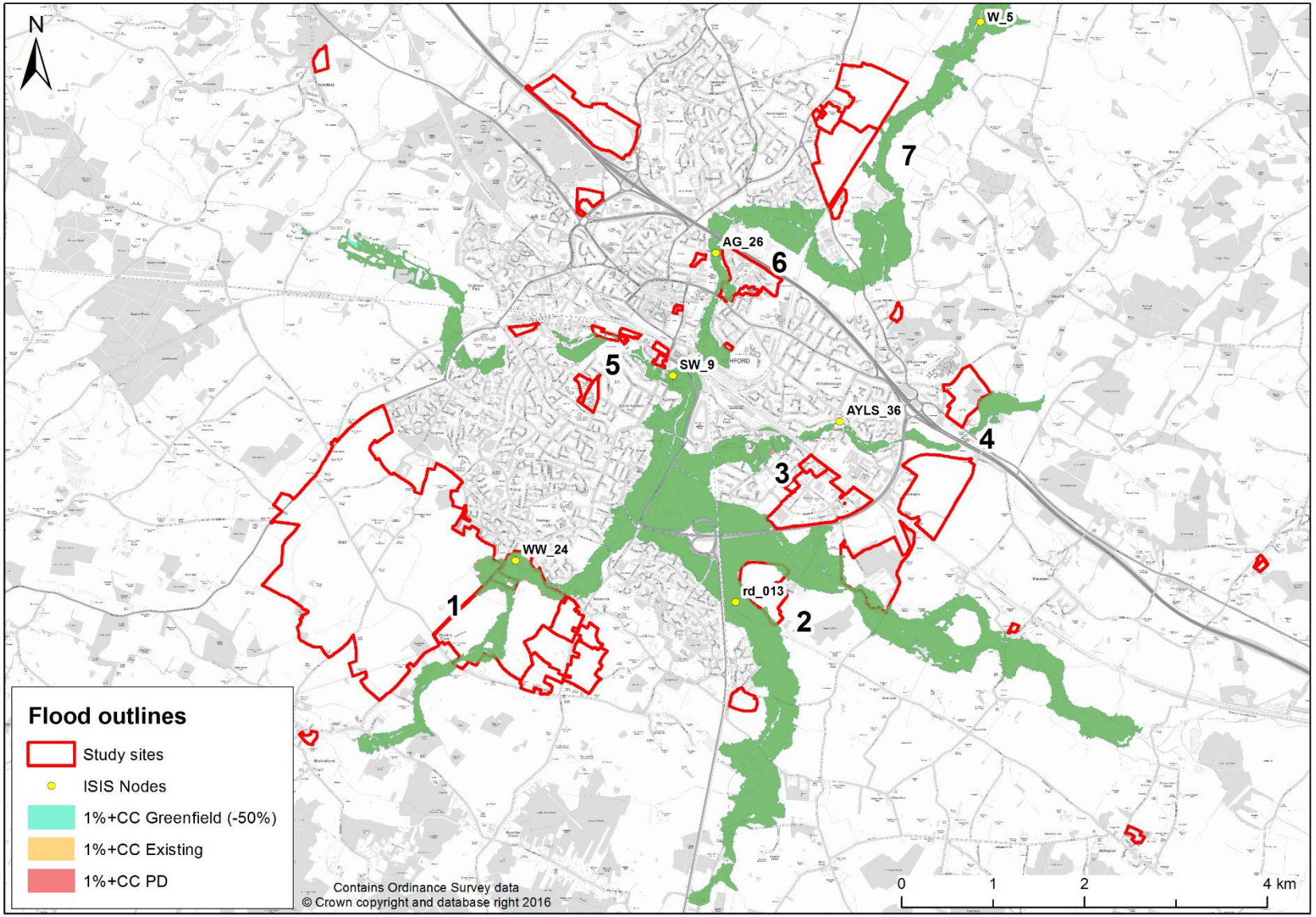
- AG_26 – adjacent to sites ST6 and ST3, on the Great Stour river
- AYLS_36 - downstream of Aylesford Stream,
- rd_013 – downstream of Ruckinge Dyke, adjacent to WE21 site
- SW_9 – adjacent to VC1 site, on the Great Stour river
- W_5 – upstream of Ashford on the Great Stour river
- WW_24 – downstream of Whitewater Dyke, north of sites WS11 and CG1CG2

The node locations are shown on Figure 6-1.

Flow hydrographs were derived (see Appendix A.5) to understand if the greenfield discharge rates impacted river flows. Node WW_24, downstream of study sites WS11, CG1CG2, WE16A, B, C and D, was shown to have a reduced peak flow for the greenfield and greenfield with 50% attenuation scenario, in comparison to the post development scenario. This trend was also observed at node SW_9 within the ISIS 1D model.

However, a reduction in peak flow from discharging to greenfield scenario became diluted further downstream of the catchment.

Figure 6-1: 1% AEP + Climate change flood extent for Ashford



*Number on the map correspond to the area of the figures found in Appendix A.5

7 Conclusion and Recommendations

JBA Consulting were appointed by Ashford Borough Council to undertake a borough-wide runoff assessment in order to provide evidence for the emerging Local Plan (which will replace the Core Strategy[23]), in support of a revised sustainable drainage system (SuDS) policy. The assessment was also undertaken in order to understand whether the CS20 policy of reducing discharge rates post development to greenfield or 4 l/s/ha is achievable on smaller sites, and whether there is a possibility to over-attenuate.

The results of the discharge assessment demonstrated that the current Ashford Borough Council SuDS SPD policy (CS20) standard of 4 l/s/ha is difficult to achieve when applying it to small site developments. Infrastructure required to store that amount needed to achieve this discharge rate would not be feasible to apply on smaller sites, as long term storage requires large amount of land.

The majority of sites (51 out of 53) are, however, able to discharge at least half the stored volume to greenfield rates in 24 hours of less, with 46 of the sites being identified to have potential for over-attenuation. The study found that the median greenfield discharge rate from the site was 8.8 l/s/ha. This is double the current recommended ABC discharge rate, and just under double the industry recommended discharge rate of 5 l/s/ha.

The modelled channel hydrographs show that there is greater potential to impact river flows and volumes by attenuating to greenfield discharge rates. The impact, however, is diluted further downstream.

7.1 Local Hydrological Requirements

In order to improve runoff rates and discharge volumes in the borough, the following recommendations are made:

- Provide a local study of the sites in order to understand surface water interaction on a local scale;
- Provide monitoring for all potential development sites, as recommended in section 4.2.
- Undertake infiltration studies to understand the potential for soakaways and infiltration SuDS.

7.2 Recommendations

It is recommended that the discharge requirements should not necessarily be based on arbitrary values but on site-specific conditions and monitoring (if available). By undertaking site-specific studies, a detailed analysis of what SuDS could be implemented into the site could also be achieved.

It is also recommended that ABC should consider a higher discharge rate than 4 l/s/ha to apply borough wide if the site is previously not greenfield. This study has outlined that the majority of the shortlisted sites can be attenuated to greenfield in less than 48 hours based on a discharge rate of 8 l/s/ha.

For all sites with discharge time under 24 hours, flow control devices could be incorporated into the SuDS designs for these sites. The sites that couldn't be attenuated to half within 24 hours had varying greenfield discharge times up to 176 hours. It is advised that long term solutions should be investigated for all sites above 48-hour discharge times.

23 Ashford Borough Council Local Development Framework, Core Strategy (July 2008)

Appendices

A Technical

A.1 Catchment descriptors

Site ID	Catchment Descriptors																	
	Easting	Northing	Catchment AREA (km^2)	Revised AREA (km^2)	Storm duration (hr)	Time to Peak TP (hr)	Baseflow Lag BL (hrs)	Baseflow Recharge BR	Season of design event	Storm area for ARF	Imperiousness Factor (IF)	Urban area (km^2) Existing	Urban area (km^2) Post Development	FARL	PROPWET	BFIHOST	Revised DPLBAR	SAAR
BBAE1	600450	144650	2.68	0.413	5.50	3.02	61.62	2.22	Winter	1	0.50	0.000	0.413	1	0.34	0.83	0.62	722
BD8	584800	138900	1.29	0.033	4.50	2.36	23.71	0.62	Winter	1	0.55	0.000	0.033	1	0.34	0.28	0.15	707
BE16	601000	141400	0.95	0.027	3.50	2.25	35.34	0.93	Winter	1	0.50	0.010	0.027	0.97	0.34	0.39	0.14	723
BE17	601000	141400	0.95	0.038	3.50	2.25	35.34	0.93	Winter	1	0.50	0.030	0.038	0.97	0.34	0.39	0.17	723
BO1	600450	144050	0.50	0.041	3.25	1.88	55.15	0.04	Winter	1	0.60	0.000	0.041	1	0.34	0.85	0.74	725
CG1 CG2	596850	139000	5.06	4.385	8.50	4.68	29.26	4.39	Winter	0.97	0.55	0.000	1.860	1	0.34	0.30	2.25	717
CH4	594550	149600	0.58	0.014	3.25	1.93	52.91	2.08	Winter	1	0.50	0.010	0.014	1	0.34	0.79	0.09	746
CH17	594650	149400	1.06	0.072	3.50	2.29	53.58	1.95	Winter	1	0.50	0.000	0.072	1	0.34	0.75	0.24	745
DW6	597900	145100	3.36	0.030	5.50	3.22	57.98	1.92	Winter	1	0.50	0.000	0.030	1	0.34	0.74	0.15	721
HG3 HG4	602650	140500	0.73	0.405	3.50	2.08	51.46	1.91	Winter	1	0.60	0.405	0.405	1	0.34	0.73	0.61	729
IO2	595400	129700	0.65	0.166	3.50	2.04	42.23	1.36	Winter	1	0.55	0.010	0.150	1	0.34	0.54	0.37	710
KE2	603250	144550	0.55	0.056	3.25	1.93	47.74	1.73	Winter	1	0.50	0.000	0.056	1	0.34	0.67	0.20	727
KE3	603300	144650	0.63	0.333	3.50	2.00	48.37	1.74	Winter	1	0.50	0.000	0.333	1	0.34	0.68	0.55	727
KE4	603300	144650	0.63	0.365	3.50	2.00	48.37	1.74	Winter	1	0.50	0.010	0.365	1	0.34	0.68	0.58	727
KE5	603300	144650	0.63	0.006	3.50	2.00	48.37	1.74	Winter	1	0.50	0.001	0.006	1	0.34	0.68	0.06	727
NW3	603500	142900	1.19	0.030	4.50	2.38	60.04	2.37	Winter	1	0.50	0.001	0.030	1	0.34	0.88	0.15	735
NW6	603500	142900	1.19	0.014	4.50	2.38	60.04	2.37	Winter	1	0.50	0.000	0.014	1	0.34	0.88	0.10	735
NW7	603500	142900	1.19	0.177	4.50	2.38	60.04	2.37	Winter	1	0.50	0.010	0.177	1	0.34	0.88	0.39	735
RTW2	589350	132100	2.98	0.010	5.50	3.11	32.80	0.69	Winter	1	0.60	0.001	0.010	1	0.34	0.30	0.80	720
SS3	606100	137750	0.59	0.019	3.25	1.95	37.00	1.08	Winter	1	0.50	0.000	0.020	1	0.34	0.45	0.11	736
SS7	606100	139950	0.85	0.006	3.50	2.13	46.60	1.56	Winter	1	0.50	0.000	0.006	1	0.34	0.61	0.06	760
SSS4	608250	139850	0.89	0.009	3.50	2.16	47.34	1.60	Winter	1	0.50	0.000	0.009	1	0.34	0.63	0.07	760
ST3	601900	144000	1.74	0.011	4.50	2.67	54.34	1.87	Winter	1	0.50	0.006	0.011	1	0.34	0.72	0.08	723
ST5	601900	144000	1.74	0.005	4.50	2.67	54.34	1.87	Winter	1	0.50	0.005	0.005	1	0.34	0.72	0.05	723
ST6	601900	144000	1.74	0.204	4.50	2.67	54.34	1.87	Winter	1	0.60	0.204	0.204	1	0.34	0.72	0.42	723
ST8	601900	144000	1.74	0.014	4.50	2.67	54.34	1.87	Winter	1	0.50	0.014	0.014	1	0.34	0.72	0.10	723
SW3	602250	140600	1.02	0.038	3.50	2.29	52.51	1.89	Winter	1	0.60	0.030	0.038	1	0.34	0.73	0.17	728
SW6	602250	140600	1.02	0.011	3.50	2.29	52.51	1.89	Winter	1	0.60	0.000	0.011	1	0.34	0.73	0.09	728
TSTRW1	588950	132900	0.77	0.110	3.50	2.12	29.72	0.70	Winter	1	0.55	0.000	0.090	1	0.34	0.31	0.30	723
VC1	601000	141350	0.86	0.013	3.50	2.19	35.13	0.93	Winter	1	0.50	0.000	0.013	0.97	0.34	0.39	0.09	723
VC2	601000	141350	0.86	0.025	3.50	2.19	35.13	0.93	Winter	1	0.50	0.010	0.025	0.97	0.34	0.39	0.13	723
VC3	601000	141350	0.86	0.024	3.50	2.19	35.13	0.93	Winter	1	0.50	0.010	0.024	0.97	0.34	0.39	0.13	723
VC4	601000	141350	0.86	0.020	3.50	2.19	35.13	0.93	Winter	1	0.50	0.020	0.020	0.97	0.34	0.39	0.12	723
VC5	601000	141350	0.86	0.006	3.50	2.19	35.13	0.93	Winter	1	0.50	0.006	0.006	0.97	0.34	0.39	0.06	723
WC12	589500	136700	0.92	0.022	3.50	2.25	25.34	0.51	Winter	1	0.50	0.000	0.010	1	0.34	0.23	0.12	712
WE5	601900	138450	1.31	0.054	4.50	2.46	29.78	0.65	Winter	1	0.50	0.000	0.054	1	0.34	0.29	0.20	724
WE11	603100	139950	0.64	0.379	3.50	2.01	49.79	1.83	Winter	1	0.55	0.060	0.340	1	0.34	0.71	0.59	730
WE16A	599650	138600	0.50	0.099	3.25	1.88	24.19	0.51	Winter	1	0.50	0.000	0.099	1	0.34	0.23	0.28	720
WE16B	599650	138600	0.50	0.152	3.25	1.88	24.19	0.51	Winter	1	0.50	0.000	0.152	1	0.34	0.23	0.36	720
WE16C	599650	138600	0.50	0.109	3.25	1.88	24.19	0.51	Winter	1	0.50	0.000	0.109	1	0.34	0.23	0.30	720
WE16D	599650	138600	0.50	0.045	3.25	1.88	24.19	0.51	Winter	1	0.50	0.000	0.045	1	0.34	0.23	0.18	720
WE21	602400	139750	0.50	0.235	3.25	1.88	35.27	1.01	Winter	1	0.50	0.000	0.210	1	0.34	0.42	0.45	727
WE34	602850	140450	0.70	0.001	3.50	2.06	51.29	1.91	Winter	1	0.50	0.001	0.001	1	0.34	0.73	0.02	729

Site ID	Catchment Descriptors																	
	Easting	Northing	Catchment AREA (km^2)	Revised AREA (km^2)	Storm duration (hr)	Time to Peak TP (hr)	Baseflow Lag BL (hrs)	Baseflow Recharge BR	Season of design event	Storm area for ARF	Imperiousness Factor (IF)	Urban area (km^2) Existing	Urban area (km^2) Post Development	FARL	PROPWET	BFIHOST	Revised DPLBAR	SAAR
WE38	604550	141500	1.45	0.460	4.50	2.50	58.40	2.19	Winter	1	0.60	0.000	0.460	1	0.34	0.82	0.65	743
WE39	604550	141500	1.45	0.007	4.50	2.50	58.40	2.19	Winter	1	0.50	0.000	0.007	1	0.34	0.82	0.06	743
WN2	591350	147700	0.51	0.017	3.25	1.92	52.27	2.07	Winter	1	0.50	0.000	0.017	1	0.34	0.78	0.11	703
WN4	588500	142450	1.41	0.035	4.50	2.61	29.14	0.62	Winter	1	0.50	0.000	0.020	1	0.34	0.28	0.16	670
WS11	599250	139050	3.00	0.980	5.50	3.09	21.54	0.54	Winter	0.98	0.50	0.000	0.980	1	0.34	0.24	0.99	719
WS21	597150	138000	1.65	0.016	4.50	2.64	26.49	0.51	Winter	1	0.50	0.000	0.016	1	0.34	0.23	0.10	716
WS25	594600	134400	1.83	0.014	4.50	2.72	26.70	0.51	Winter	1	0.50	0.000	0.010	1	0.34	0.23	0.10	715
WS28	594600	134400	1.83	0.007	4.50	2.72	26.70	0.51	Winter	1	0.50	0.000	0.007	1	0.34	0.23	0.07	715
WS30	600350	133850	1.80	0.085	4.50	2.71	26.73	0.51	Winter	1	0.55	0.000	0.060	1	0.34	0.23	0.26	716
WS37	599950	133200	1.29	0.007	4.50	2.48	26.35	0.52	Winter	1	0.50	0.001	0.007	1	0.34	0.24	0.07	709

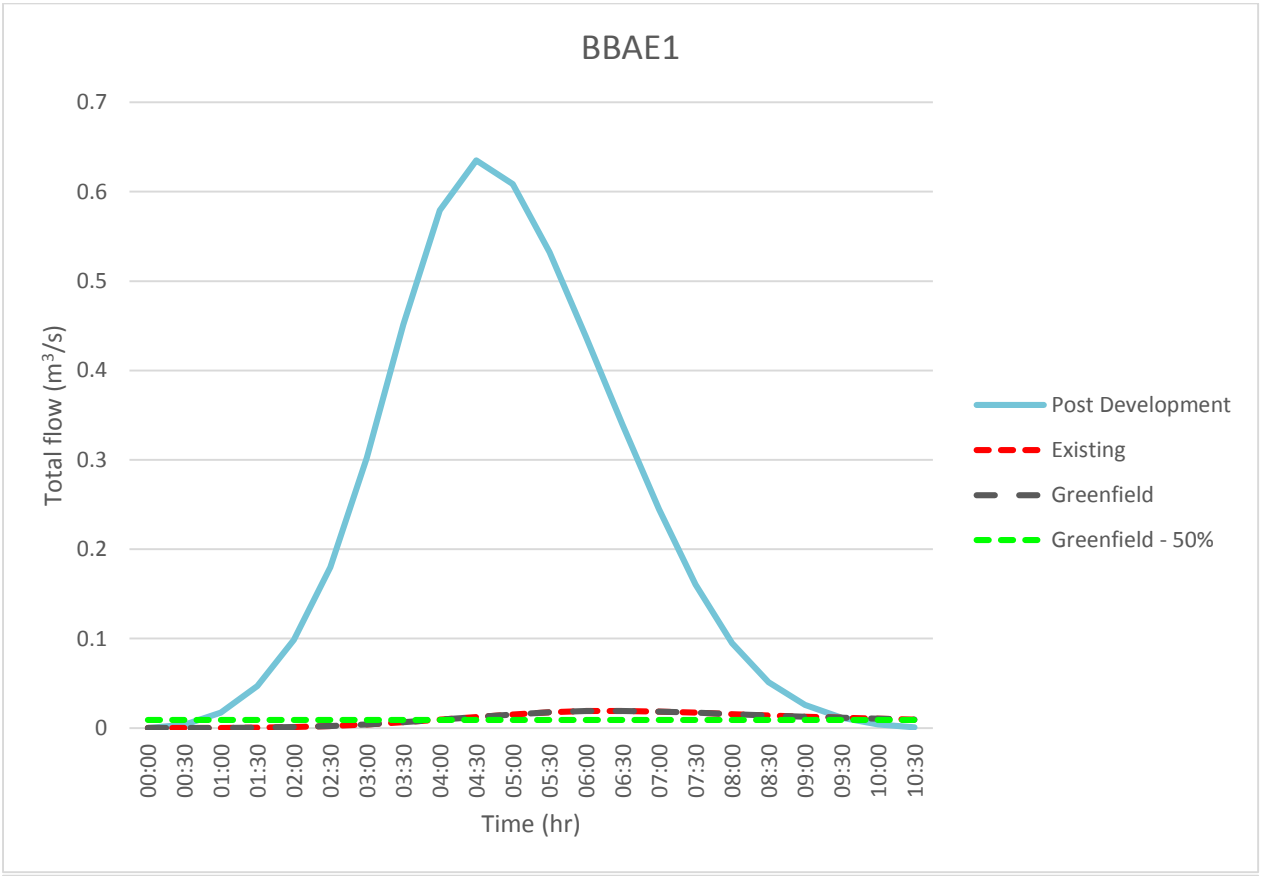
A.2 Greenfield runoff calculations

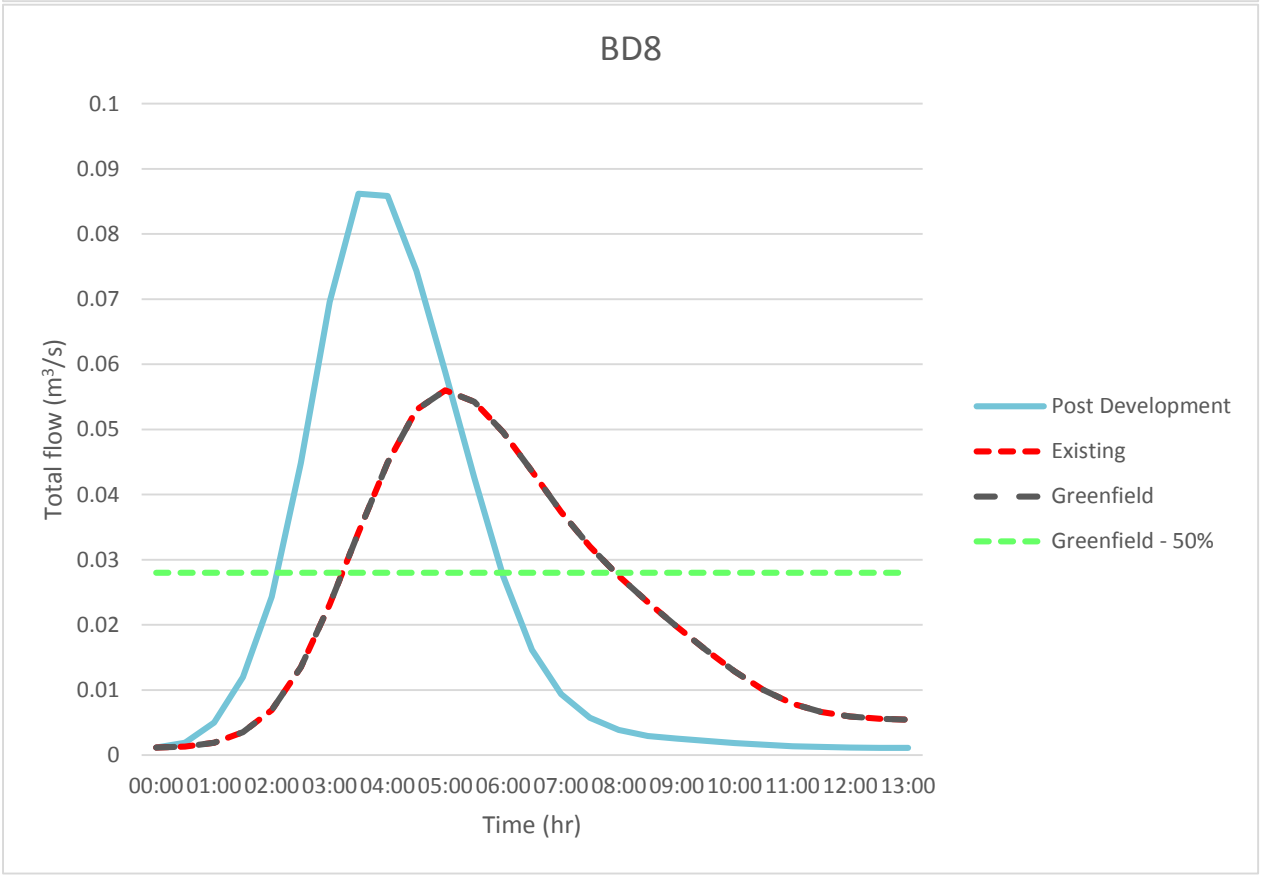
Site information					Post Development	Greenfield runoff rate				Time required for greenfield discharge from site			
ID	Area (ha)	ABC's development allocation (%)	ABC's development type	Impervious coverage of development (%)	Attenuation volume + CC to greenfield (m^3)	Runoff rate (no reduction) (l/s/ha)	Runoff rate 10% reduction (l/s/ha)	Runoff rate 30% reduction (l/s/ha)	Runoff rate 50% reduction (l/s/ha)	Discharge (hr)	Discharge 10% reduction (hr)	Discharge 30% reduction (hr)	Discharge 50% reduction (hr)
BBAE1	41.30	100	Housing	50	12727	0.46	0.41	0.32	0.23	186.09	206.77	265.85	372.19
BD8	3.30	90	Mixed	55	1679	16.97	15.27	11.88	8.48	8.33	9.25	11.90	16.66
BE16	2.70	100	Housing	50	1331	15.42	13.88	10.79	7.71	8.88	9.87	12.69	17.77
BE17	3.80	100	Housing	50	1873	15.42	13.88	10.79	7.71	8.88	9.87	12.69	17.76
BO1	4.10	100	Employment	60	1485	2.22	2.00	1.55	1.11	45.35	50.39	64.79	90.70
CG1 CG2	438.50	43	Mixed	55	221774	11.01	9.91	7.71	5.50	12.761	14.178	18.229	25.521
CH4	1.40	100	Housing	50	451	3.48	3.13	2.43	1.74	25.73	28.59	36.76	51.46
CH17	7.20	100	Housing	50	2449	3.94	3.55	2.76	1.97	23.95	26.61	34.21	47.89
DW6	3.00	100	Housing	50	981	3.48	3.14	2.44	1.74	26.08	28.97	37.25	52.15
HG3 HG4	40.50	100	Employment	60	15145	4.42	3.98	3.09	2.21	23.51	26.12	33.58	47.01
IO2	16.60	90	Mixed	55	7083	9.79	8.81	6.85	4.89	12.11	13.46	17.30	24.22
KE2	5.60	100	Housing	50	2128	7.29	6.56	5.10	3.64	14.49	16.10	20.70	28.98
KE3	33.30	100	Housing	50	12600	7.04	6.34	4.93	3.52	14.93	16.59	21.33	29.86
KE4	36.50	100	Housing	50	13811	7.03	6.33	4.92	3.52	14.95	16.61	21.35	29.89
KE5	0.60	100	Housing	50	231	7.05	6.35	4.94	3.53	15.17	16.85	21.67	30.33
NW3	3.00	100	Housing	50	892	1.71	1.54	1.20	0.86	48.24	53.60	68.91	96.47
NW6	1.40	100	Housing	50	416	1.71	1.54	1.20	0.86	48.19	53.55	68.85	96.39
NW7	17.70	100	Housing	50	5263	1.71	1.54	1.20	0.86	48.25	53.61	68.92	96.49
RTW2	1.00	100	Employment	60	494	14.08	12.67	9.86	7.04	9.75	10.83	13.93	19.50
SS3	1.90	100	Housing	50	864	13.66	12.29	9.56	6.83	9.25	10.28	13.21	18.50

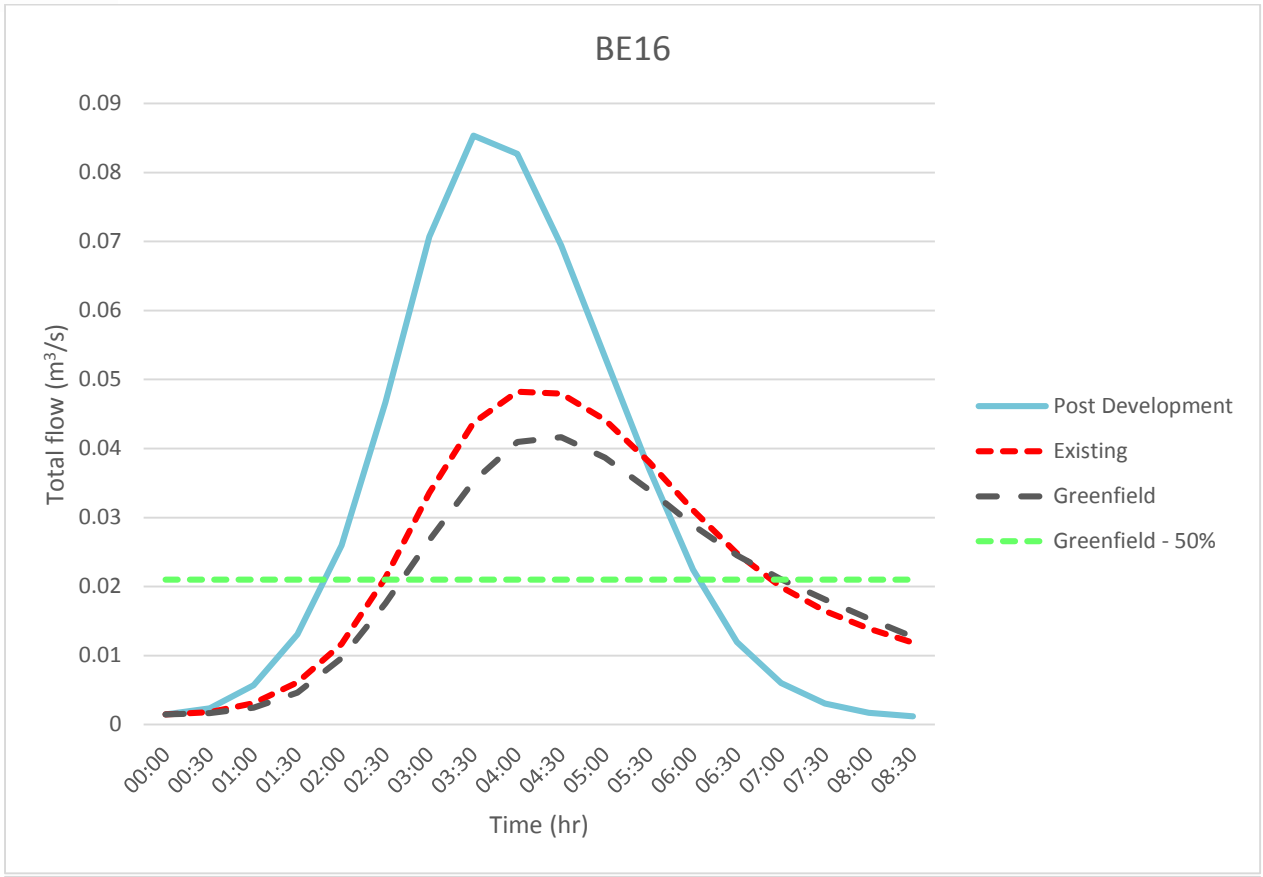
Site information					Post Development	Greenfield runoff rate				Time required for greenfield discharge from site			
ID	Area (ha)	ABC's development allocation (%)	ABC's development type	Impervious coverage of development (%)	Attenuation volume + CC to greenfield (m^3)	Runoff rate (no reduction) (l/s/ha)	Runoff rate 10% reduction (l/s/ha)	Runoff rate 30% reduction (l/s/ha)	Runoff rate 50% reduction (l/s/ha)	Discharge (hr)	Discharge 10% reduction (hr)	Discharge 30% reduction (hr)	Discharge 50% reduction (hr)
SS7	0.60	80	Housing	50	220	6.71	6.04	4.70	3.35	15.17	16.85	21.67	30.33
SSS4	0.90	80	Housing	50	318	6.21	5.59	4.35	3.11	15.79	17.54	22.56	31.58
ST3	1.10	100	Housing	50	375	4.50	4.05	3.15	2.25	21.07	23.41	30.10	42.14
ST5	0.50	100	Housing	50	375	4.75	4.27	3.32	2.37	43.93	48.81	62.75	87.85
ST6	20.40	100	Employment	60	8078	4.52	4.07	3.17	2.26	24.32	27.03	34.75	48.65
ST8	1.40	50	Housing	50	483	4.52	4.07	3.17	2.26	21.19	23.55	30.27	42.38
SW3	3.80	100	Employment	60	414	4.33	3.90	3.03	2.17	6.99	7.77	9.99	13.98
SW6	1.10	100	Employment	60	1431	4.16	3.74	2.91	2.08	86.85	96.50	124.08	173.71
TSTRW1	11.00	80	Mixed	55	5863	17.08	15.37	11.96	8.54	8.67	9.63	12.38	17.34
VC1	1.30	100	Housing	50	640	15.60	14.04	10.92	7.80	8.76	9.74	12.52	17.53
VC2	2.50	100	Housing	50	1180	15.37	13.83	10.76	7.68	8.53	9.48	12.19	17.06
VC3	2.40	100	Housing	50	1180	15.38	13.84	10.77	7.69	8.88	9.87	12.69	17.76
VC4	2.00	100	Housing	50	984	15.43	13.89	10.80	7.72	8.86	9.84	12.65	17.72
VC5	0.60	100	Housing	50	280	15.60	14.04	10.92	7.80	8.31	9.23	11.87	16.62
WC12	2.20	50	Housing	50	1228	16.25	14.63	11.38	8.13	9.54	10.60	13.63	19.08
WE5	5.40	100	Housing	50	2703	16.30	14.67	11.41	8.15	8.53	9.48	12.19	17.06
WE11	37.90	90	Mixed	55	13409	5.48	4.93	3.83	2.74	17.95	19.94	25.64	35.89
WE16A	9.90	100	Housing	50	4943	19.16	17.24	13.41	9.58	7.24	8.04	10.34	14.48
WE16B	15.20	100	Housing	50	7591	19.16	17.24	13.41	9.58	7.24	8.04	10.34	14.48
WE16C	10.90	100	Housing	50	5443	19.16	17.24	13.41	9.58	7.24	8.04	10.34	14.48
WE16D	4.50	100	Housing	50	2247	23.00	20.70	16.10	11.50	6.03	6.70	8.62	12.06
WE21	23.50	90	Housing	50	10955	15.62	14.06	10.93	7.81	8.29	9.21	11.84	16.58

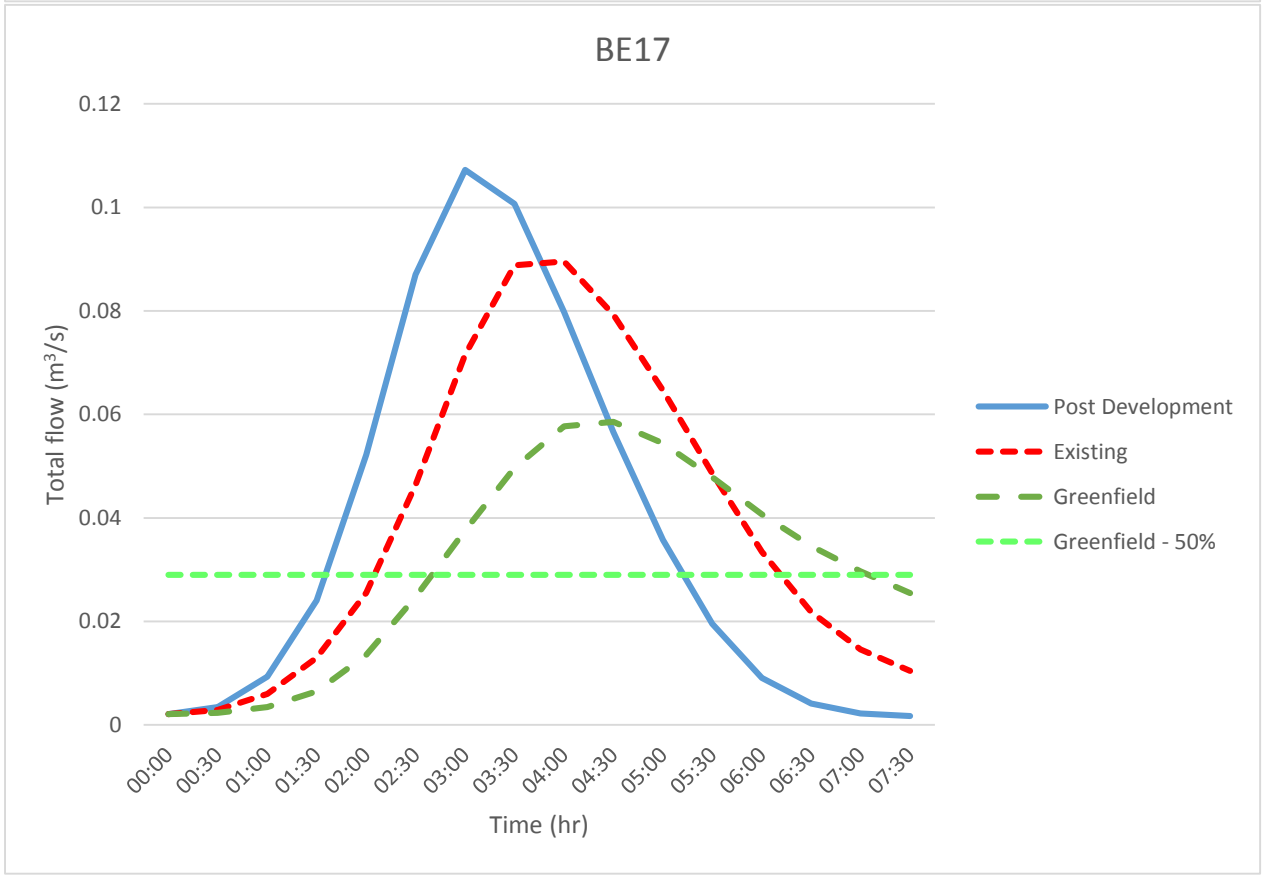
Site information					Post Development	Greenfield runoff rate				Time required for greenfield discharge from site			
ID	Area (ha)	ABC's development allocation (%)	ABC's development type	Impervious coverage of development (%)	Attenuation volume + CC to greenfield (m^3)	Runoff rate (no reduction) (l/s/ha)	Runoff rate 10% reduction (l/s/ha)	Runoff rate 30% reduction (l/s/ha)	Runoff rate 50% reduction (l/s/ha)	Discharge (hr)	Discharge 10% reduction (hr)	Discharge 30% reduction (hr)	Discharge 50% reduction (hr)
WE34	0.10	100	Housing	50	32	3.02	2.72	2.11	1.51	29.64	32.93	42.34	59.27
WE38	46.00	100	Employment	60	16156	2.26	2.03	1.58	1.13	43.17	47.96	61.67	86.34
WE39	0.70	100	Housing	50	211	2.37	2.13	1.66	1.19	35.40	39.33	50.57	70.79
WN2	1.70	100	Housing	50	421	3.05	2.75	2.14	1.53	22.58	25.08	32.25	45.15
WN4	3.50	60	Housing	50	1842	14.38	12.94	10.07	7.19	10.17	11.30	14.53	20.34
WS11	98.00	100	Housing	50	44758	14.57	13.11	10.20	7.29	8.71	9.67	12.44	17.41
WS21	1.60	100	Housing	50	268	15.04	13.54	10.53	7.52	8.95	9.95	12.79	17.91
WS25	1.40	50	Housing	50	162	16.06	14.45	11.24	8.03	10.64	11.82	15.20	21.27
WS28	0.70	100	Housing	50	133	14.70	13.23	10.29	7.35	9.75	10.83	13.93	19.50
WS30	8.50	75	Mixed	55	1880	16.06	14.45	11.24	8.03	9.72	10.80	13.89	19.45
WS37	0.70	50	Housing	50	114	17.40	15.66	12.18	8.70	10.02	11.14	14.32	20.05

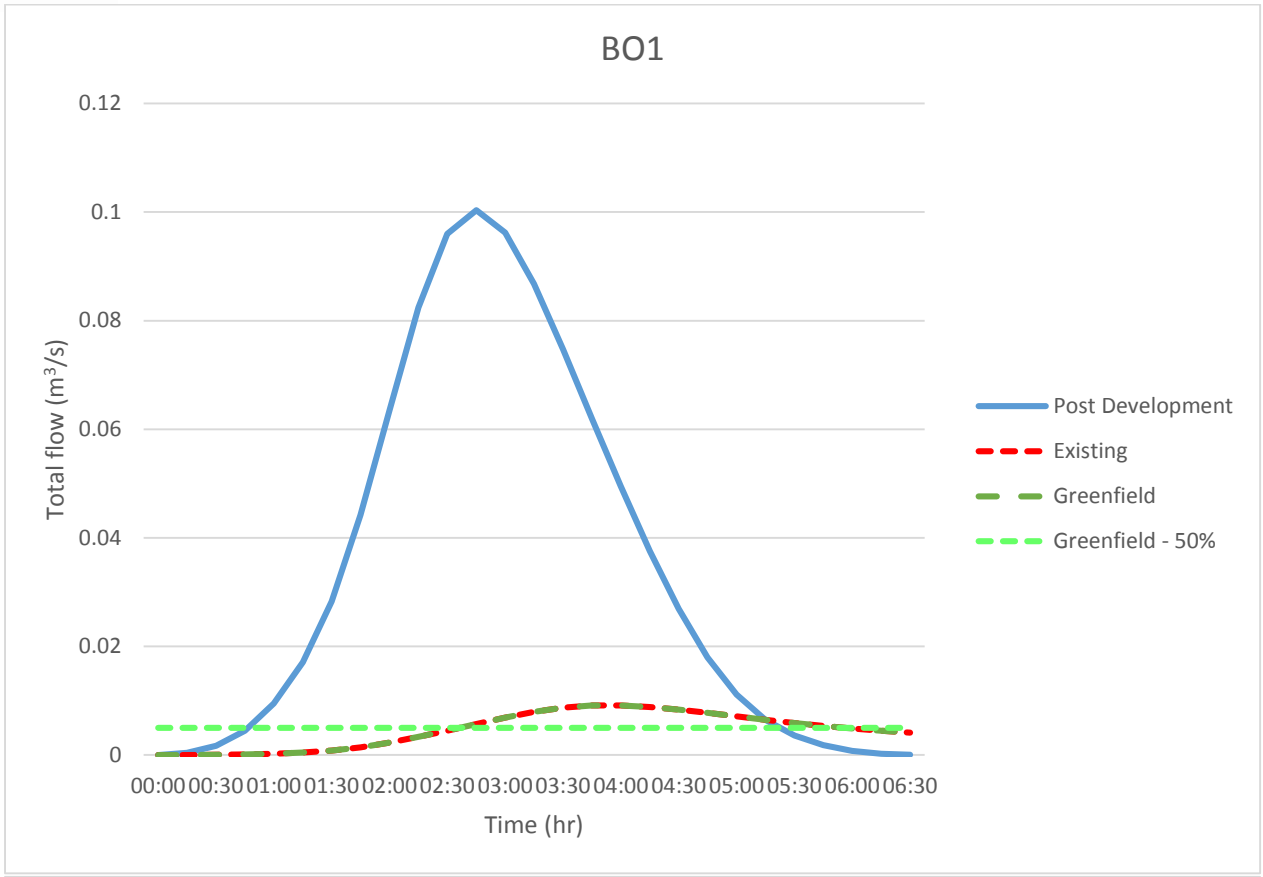
A.3 Site hydrographs

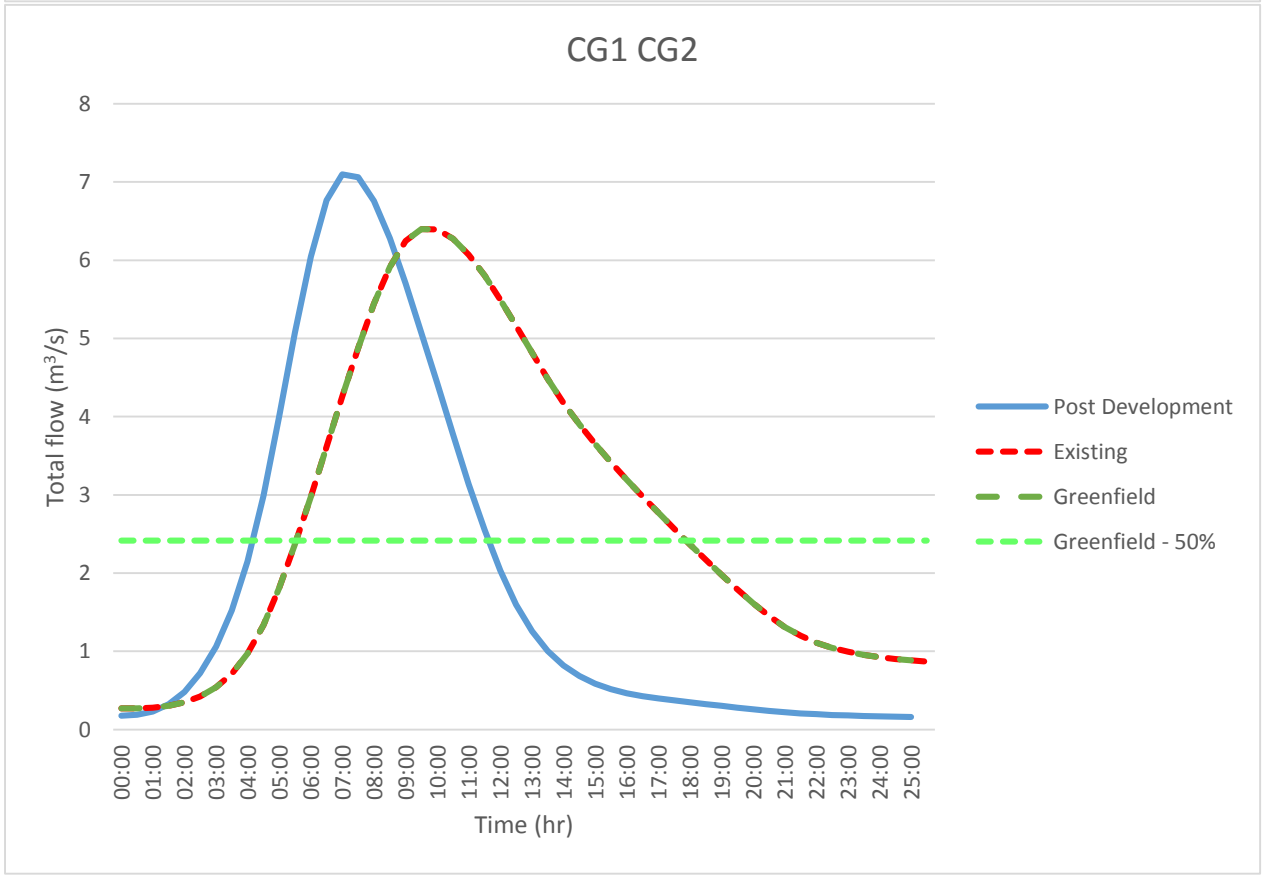


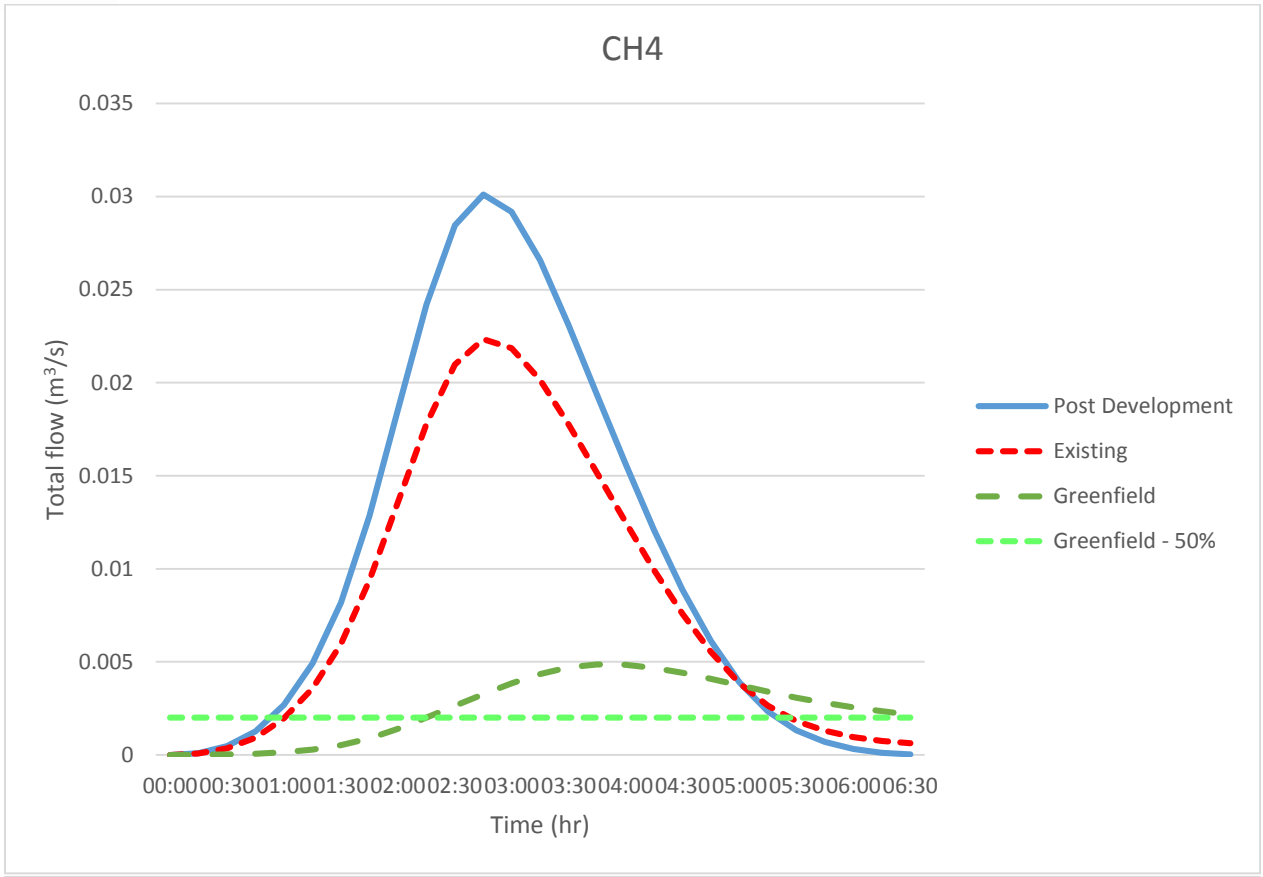


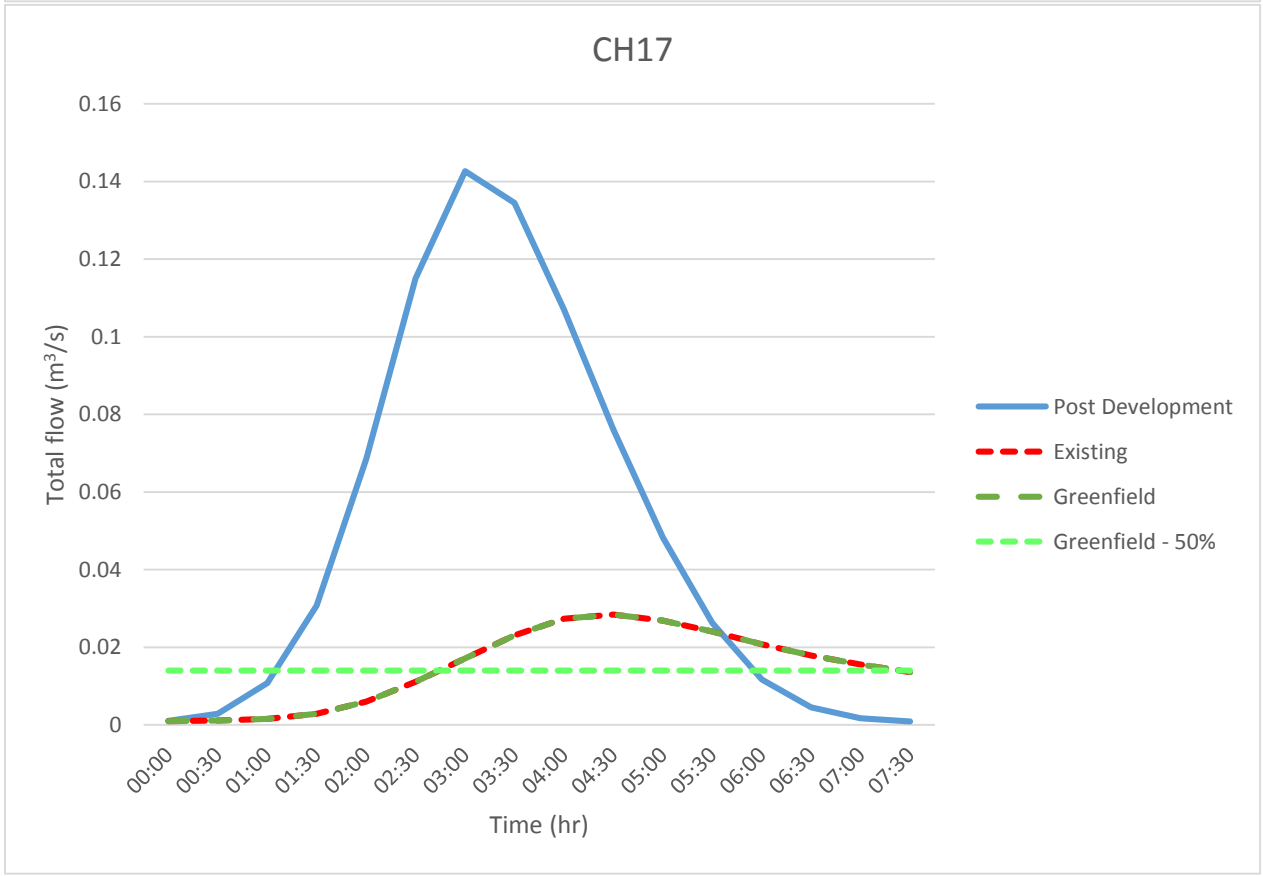

BE16
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

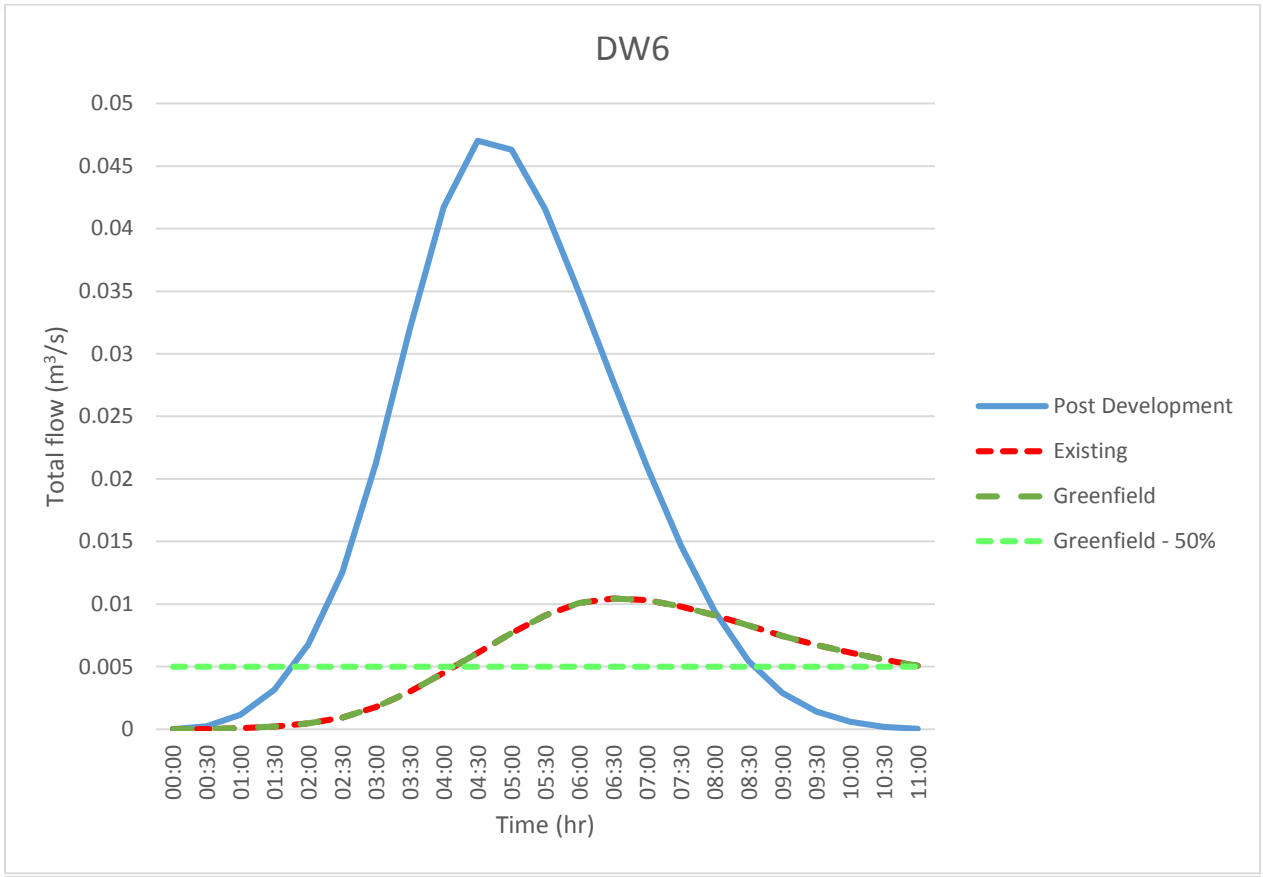

BE17
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

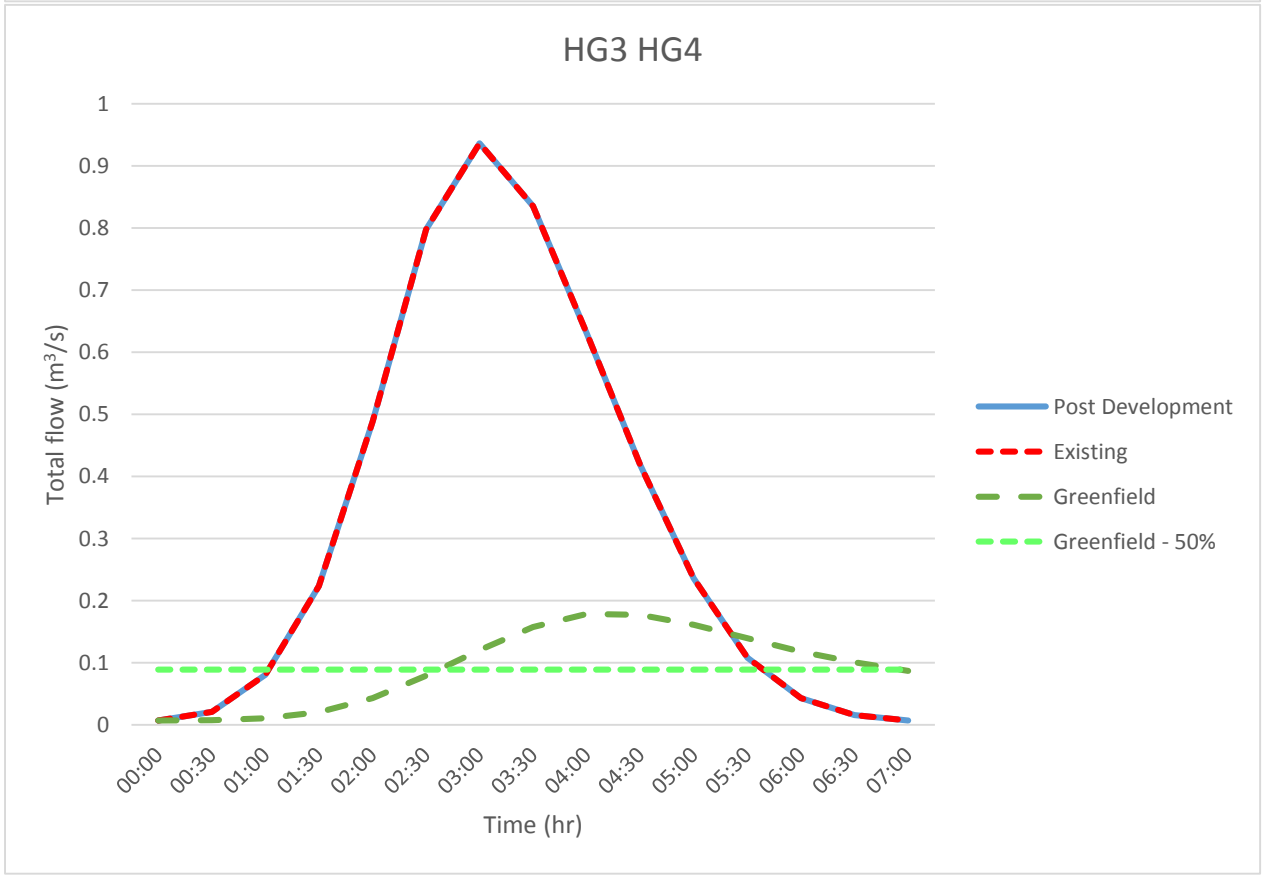

BO1
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00 00:30 01:00 01:30 02:00 02:30 03:00 03:30 04:00 04:30 05:00 05:30 06:00 06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

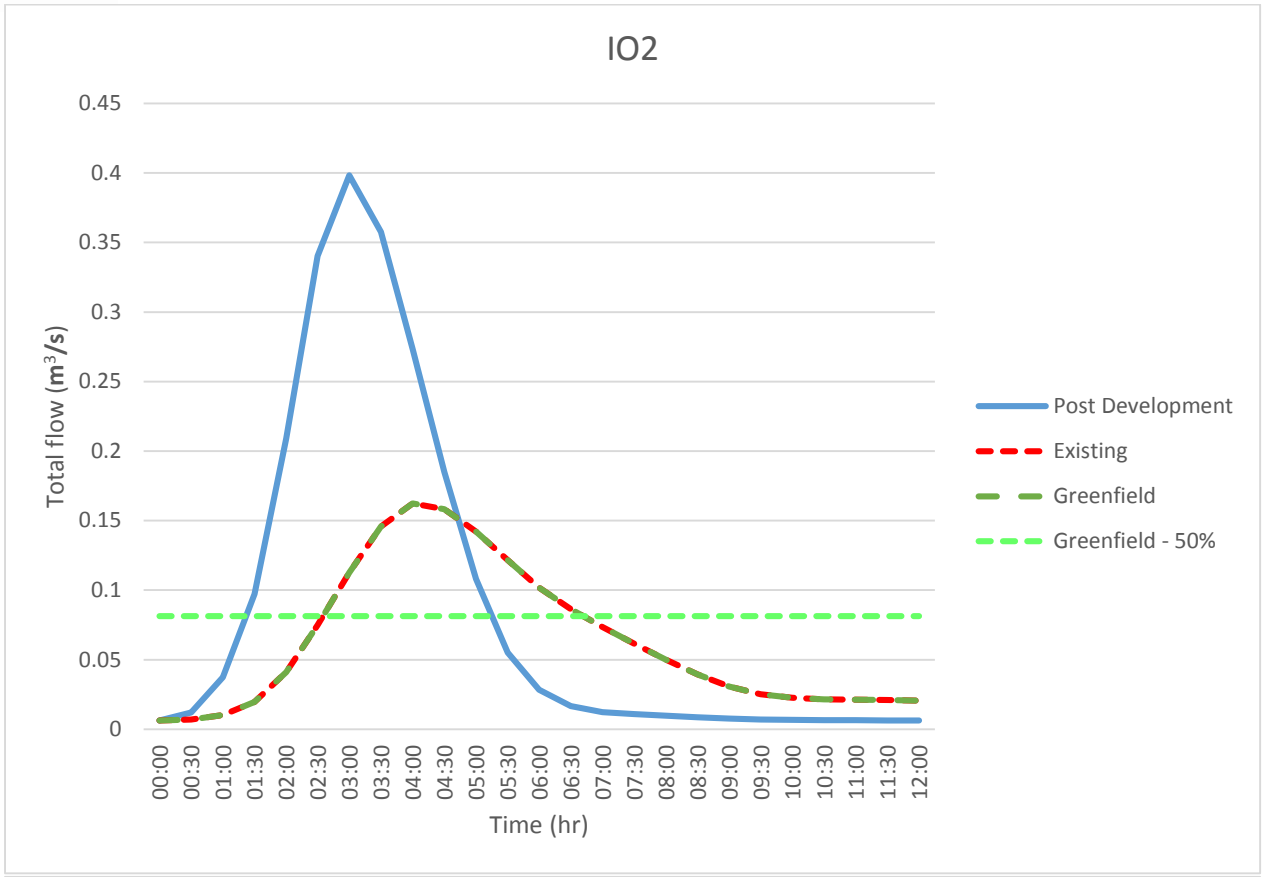

CG1 CG2
8
7
6
5
4
3
2
1
0
Total flow (m³/s)
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00 25:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

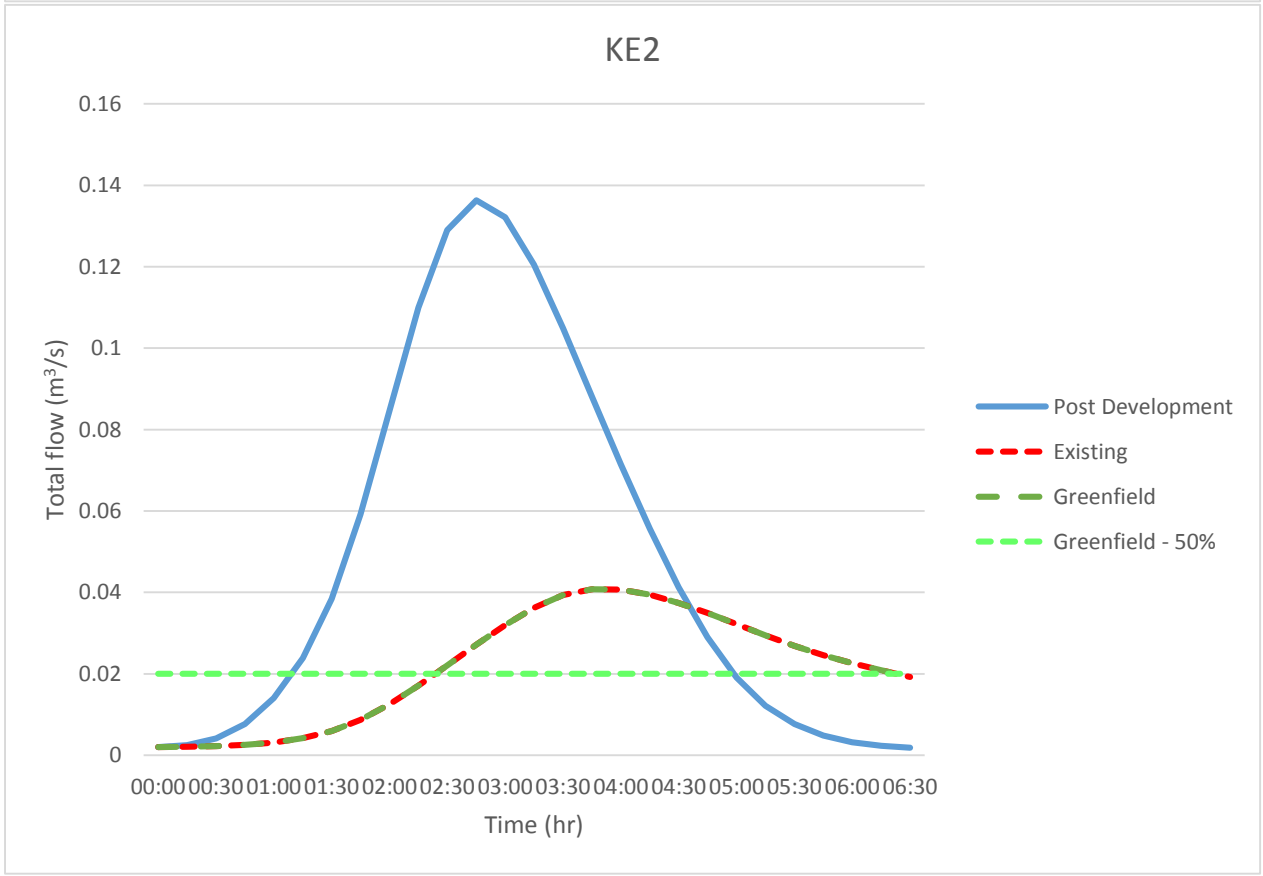

CH4
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

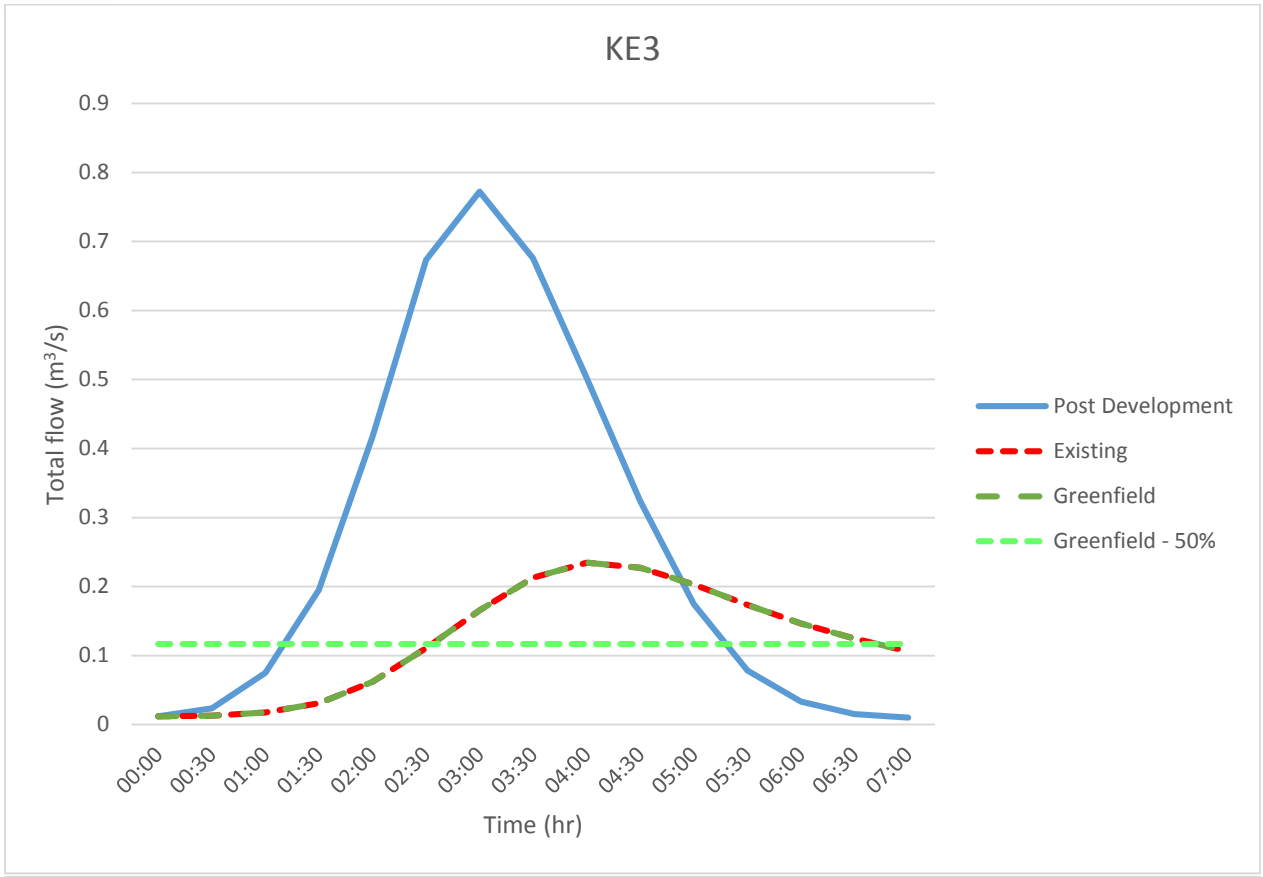

CH17
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

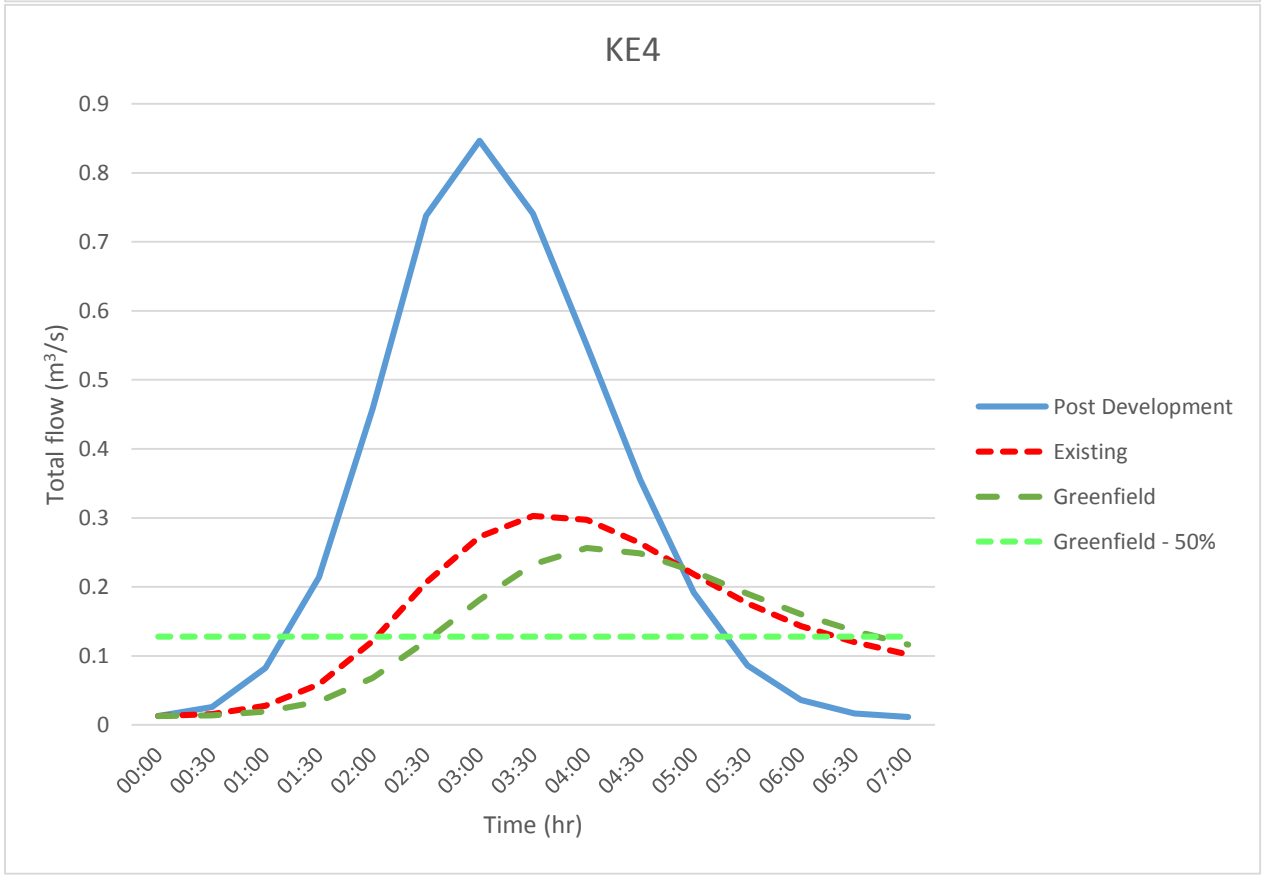

DW6
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

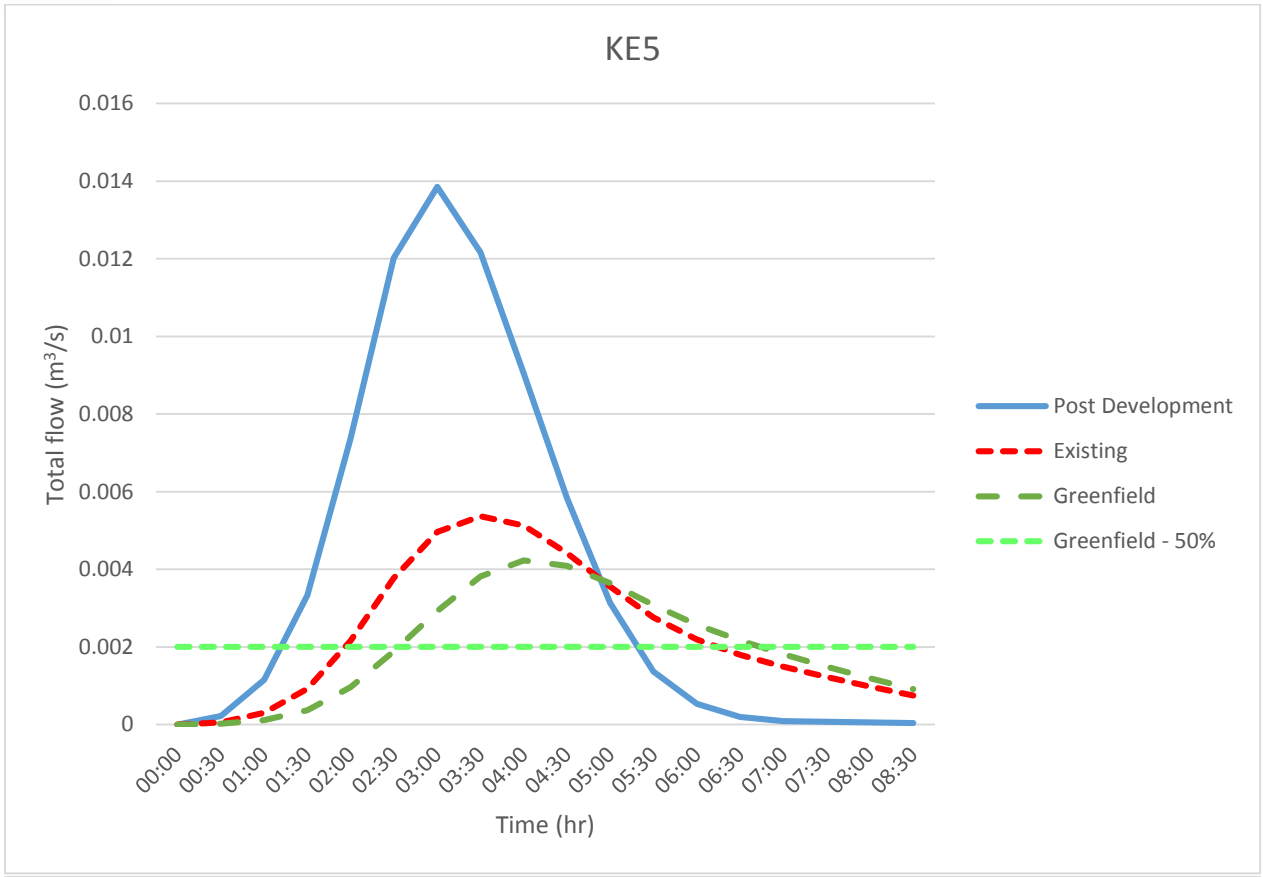

HG3 HG4
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

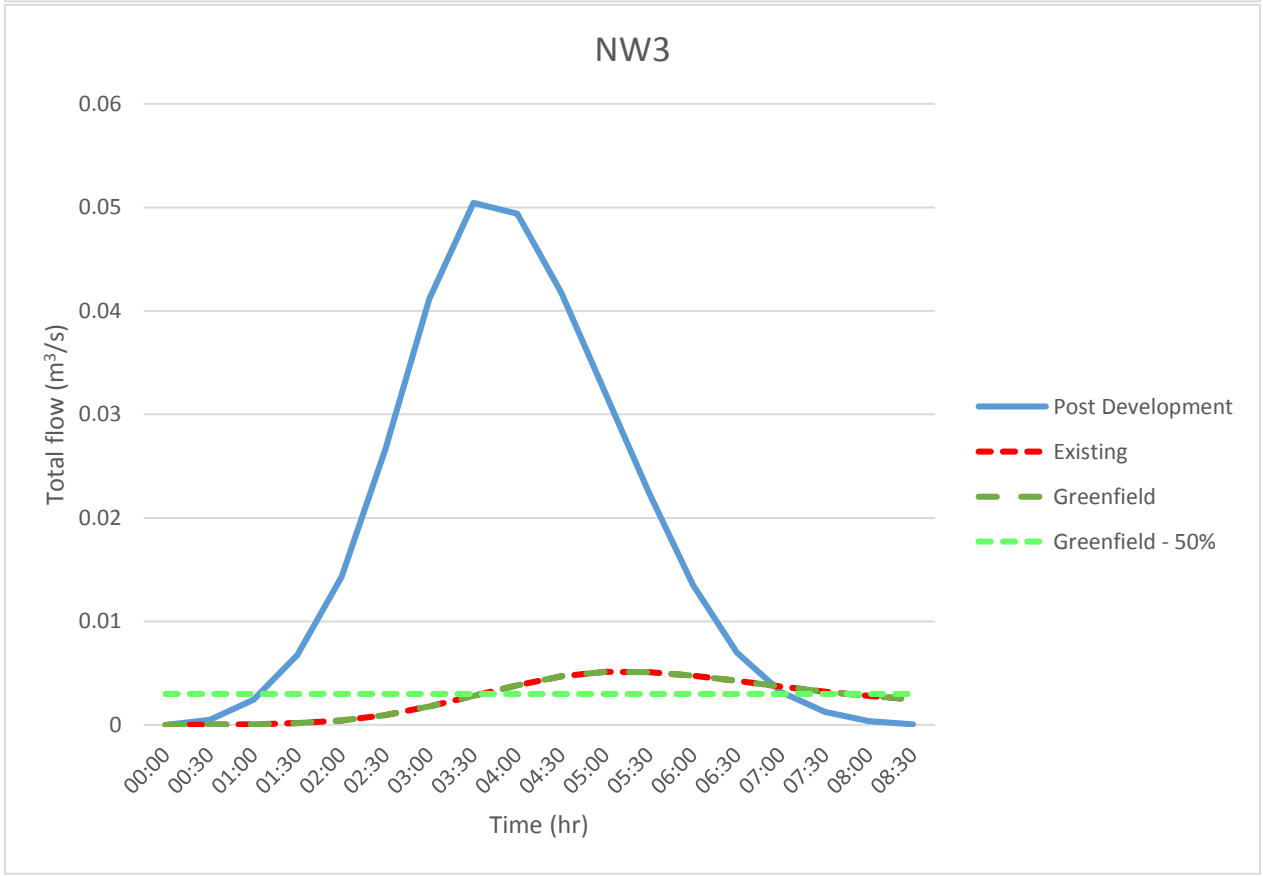

IO2
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
12:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

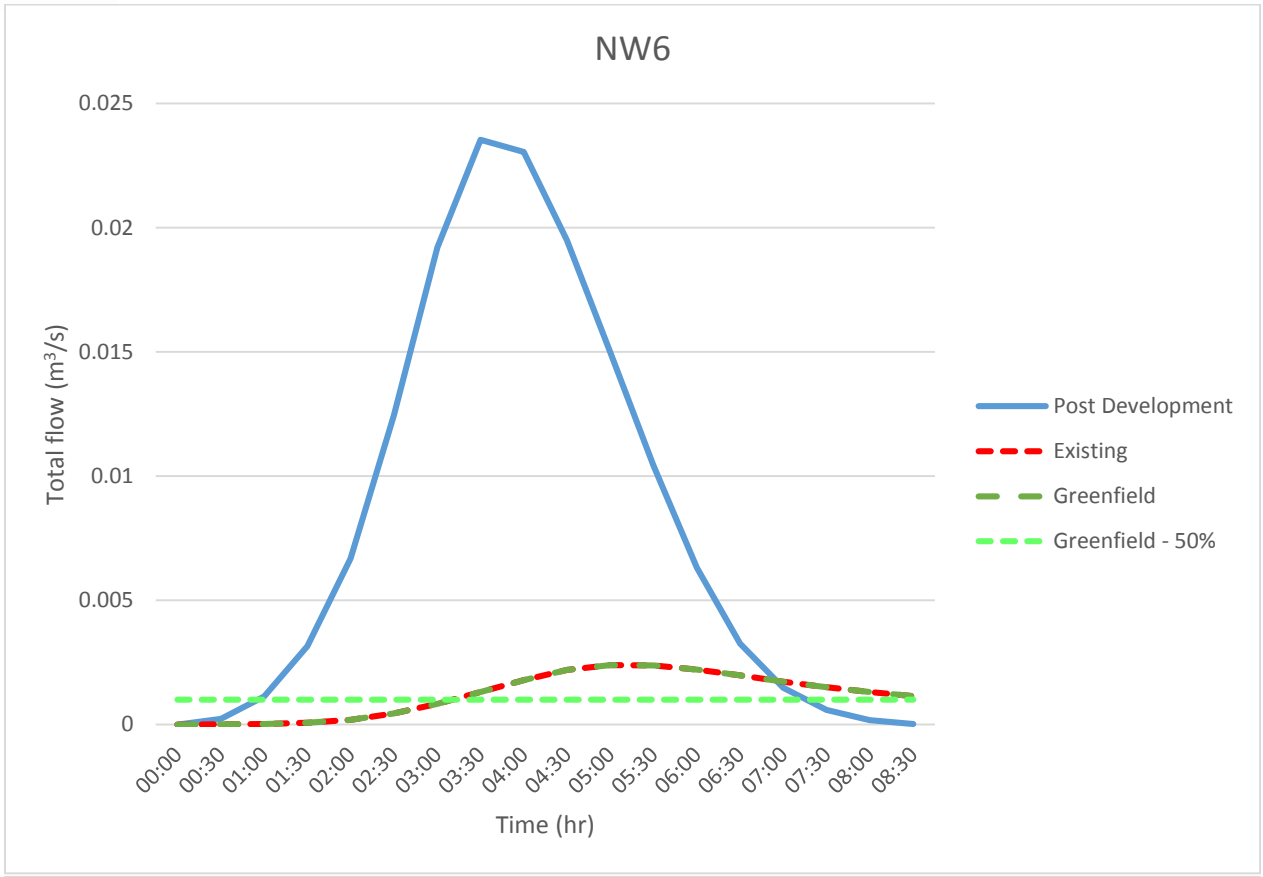

KE2
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

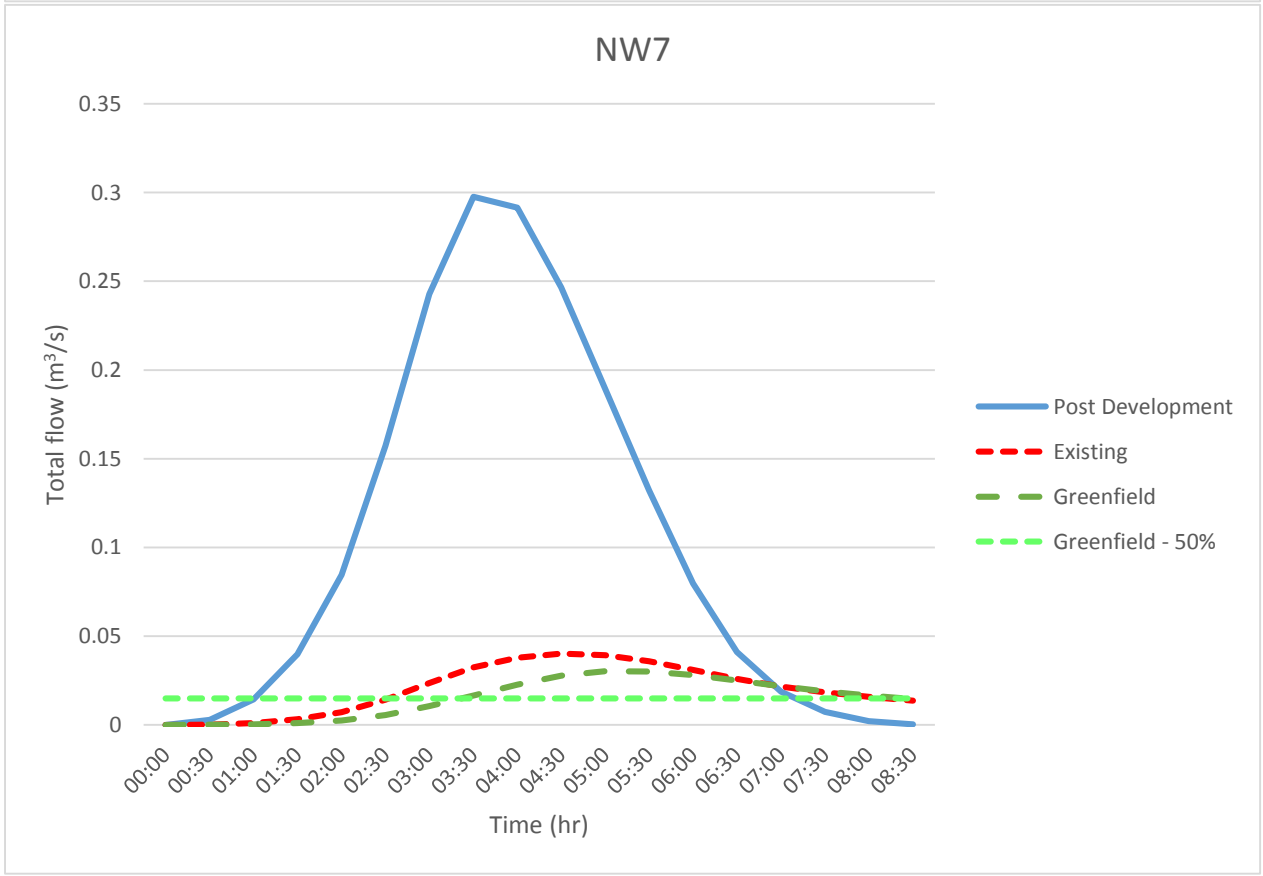

KE3
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

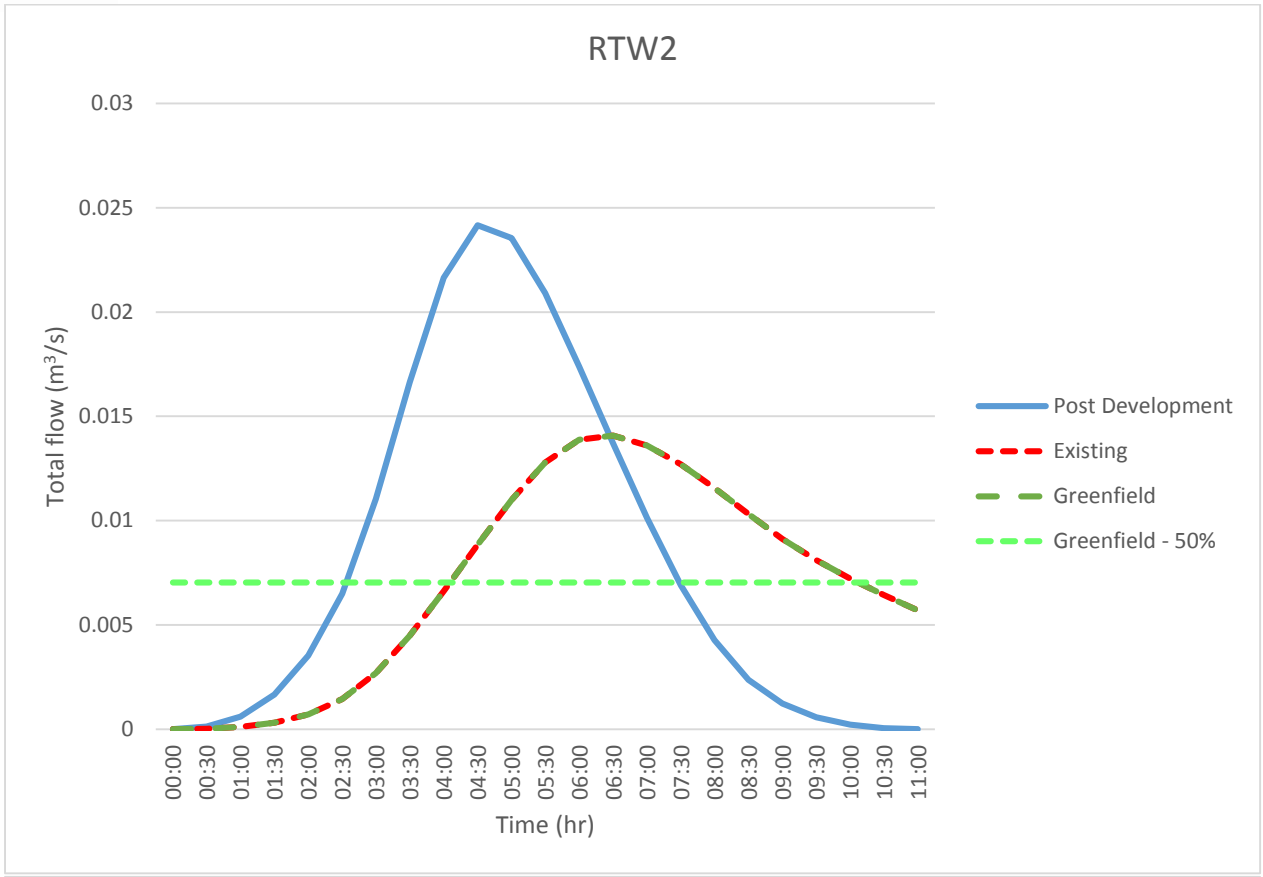

KE4
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


KE5
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

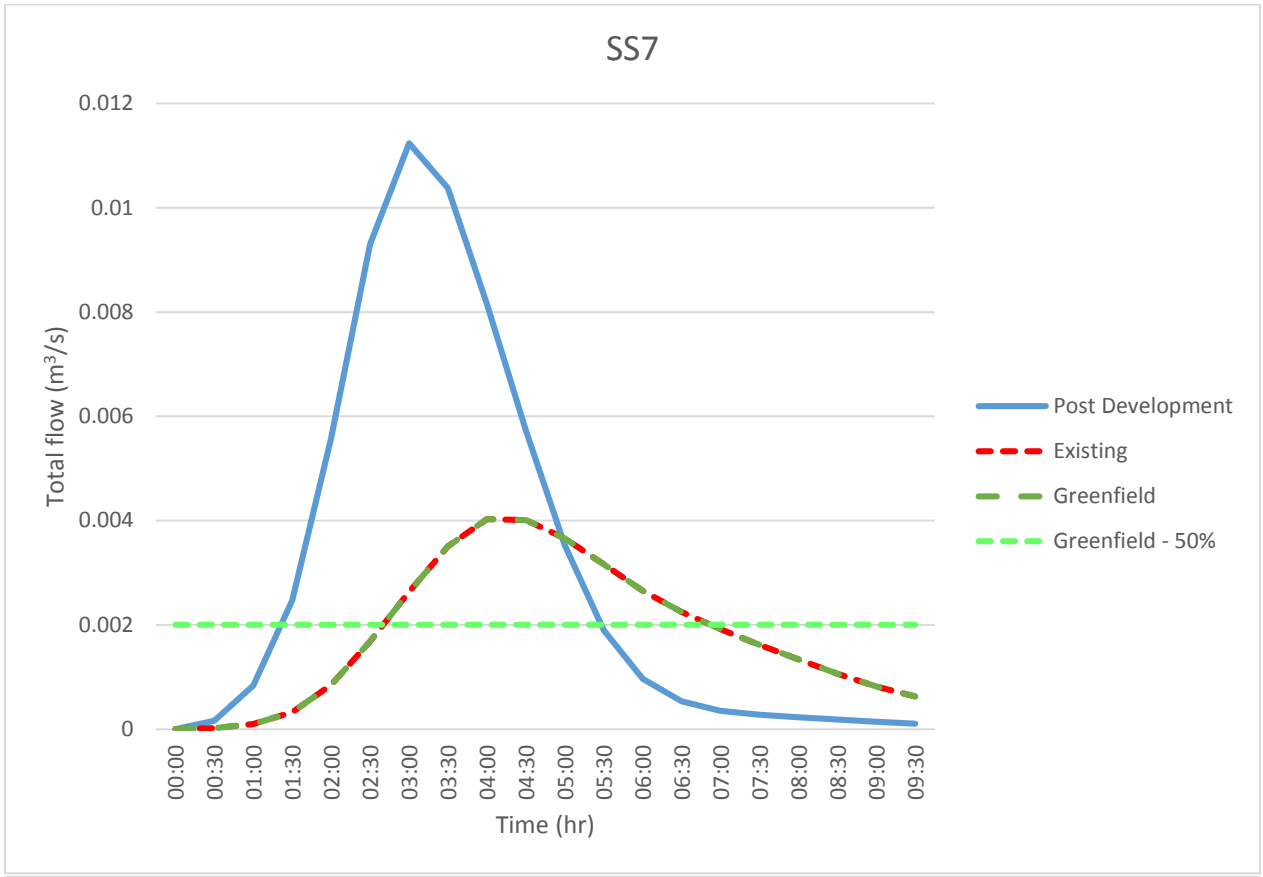

NW3
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

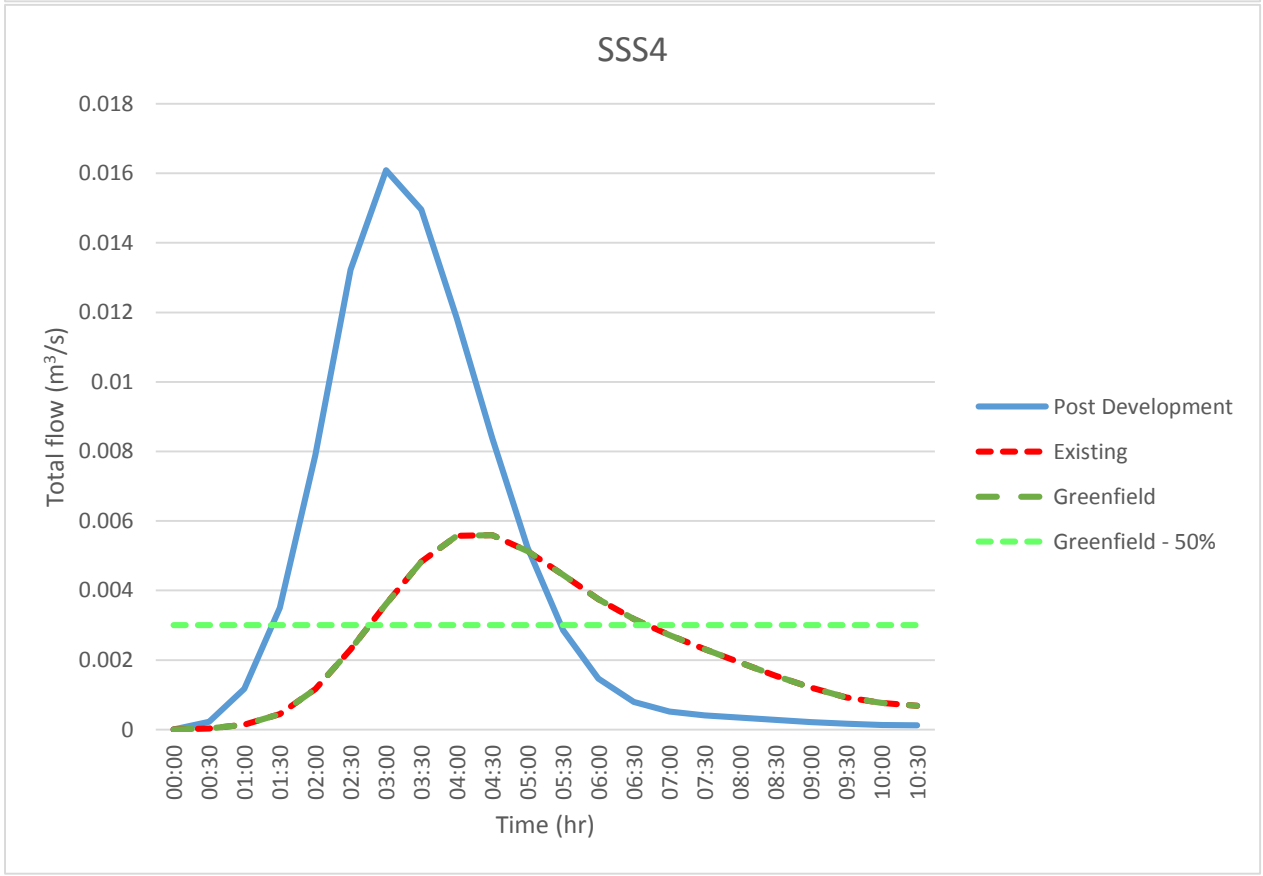

NW6
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

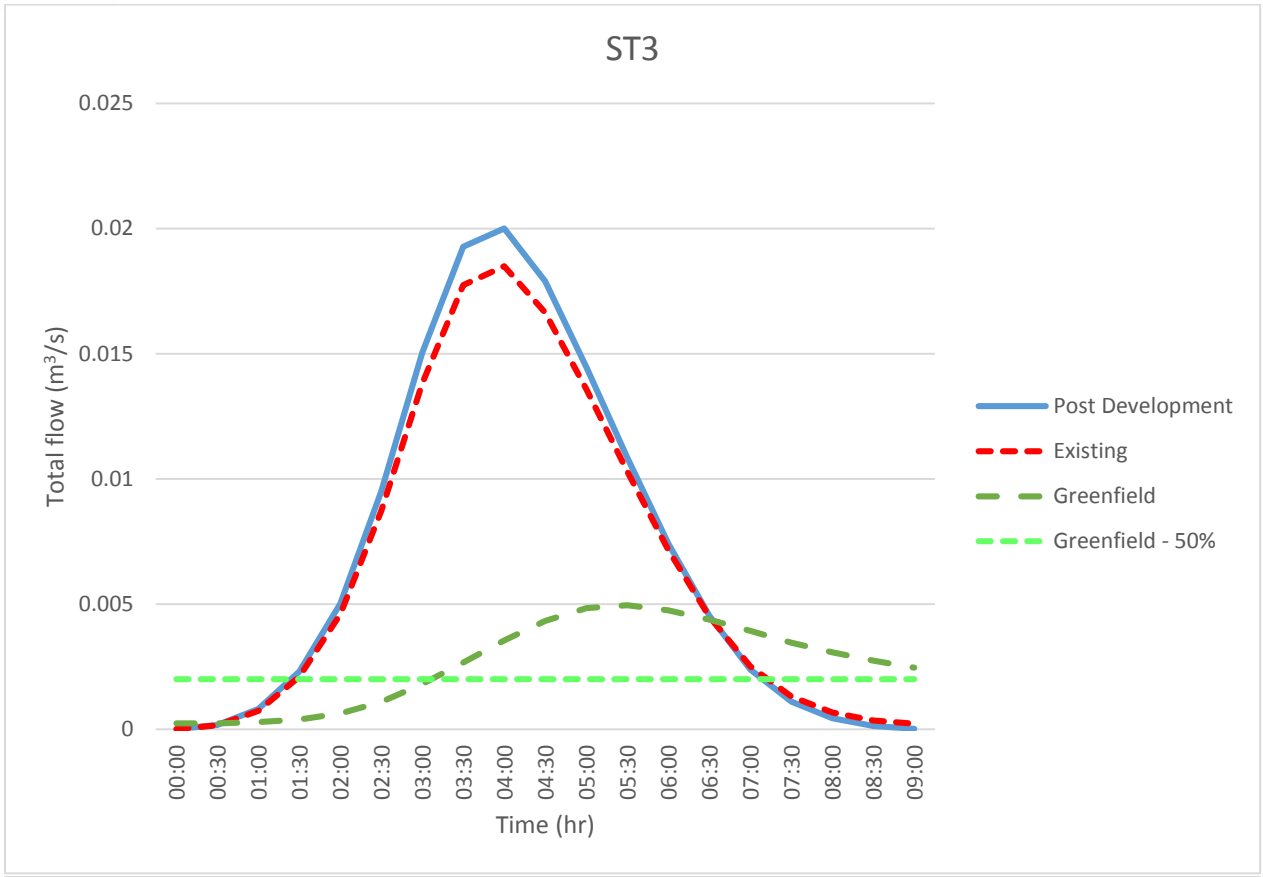

NW7
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

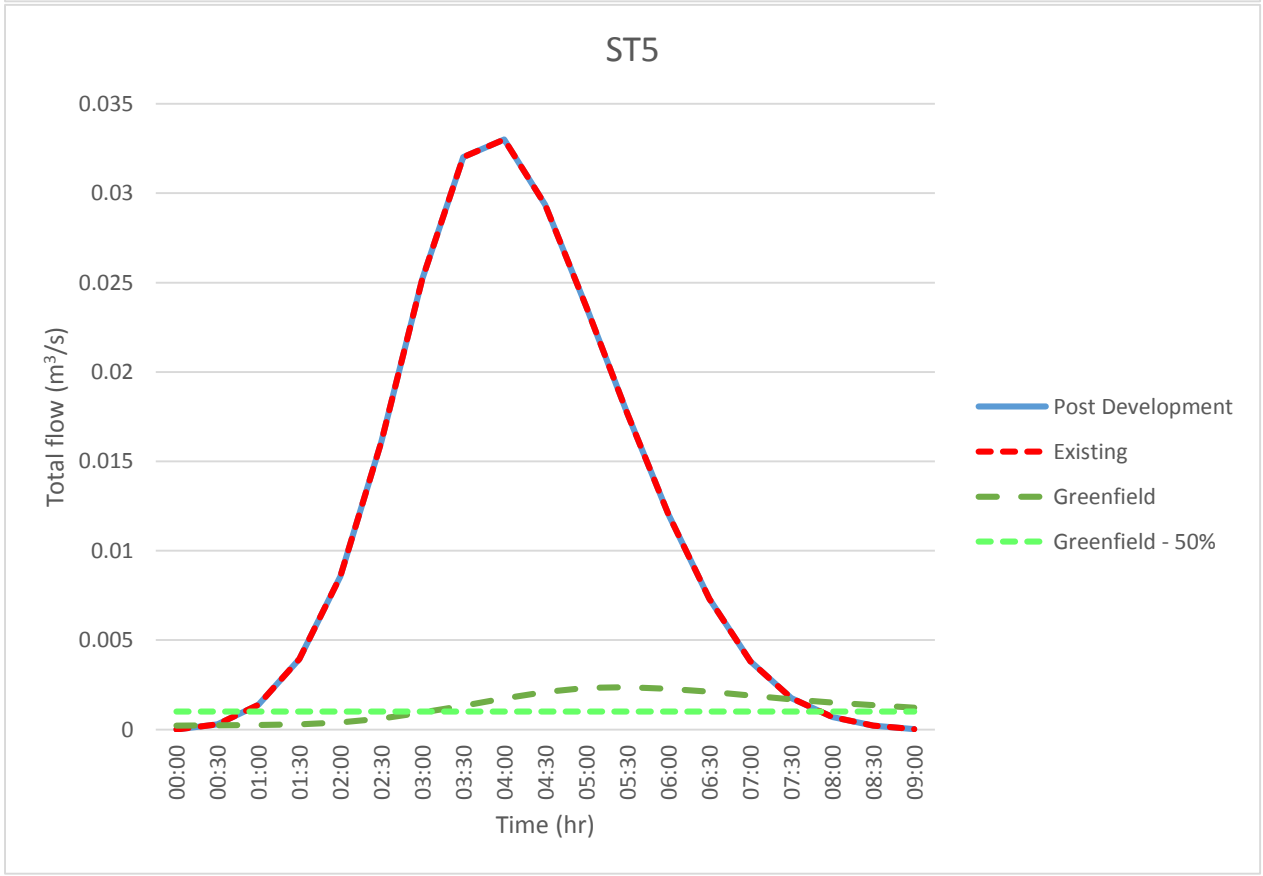

RTW2
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

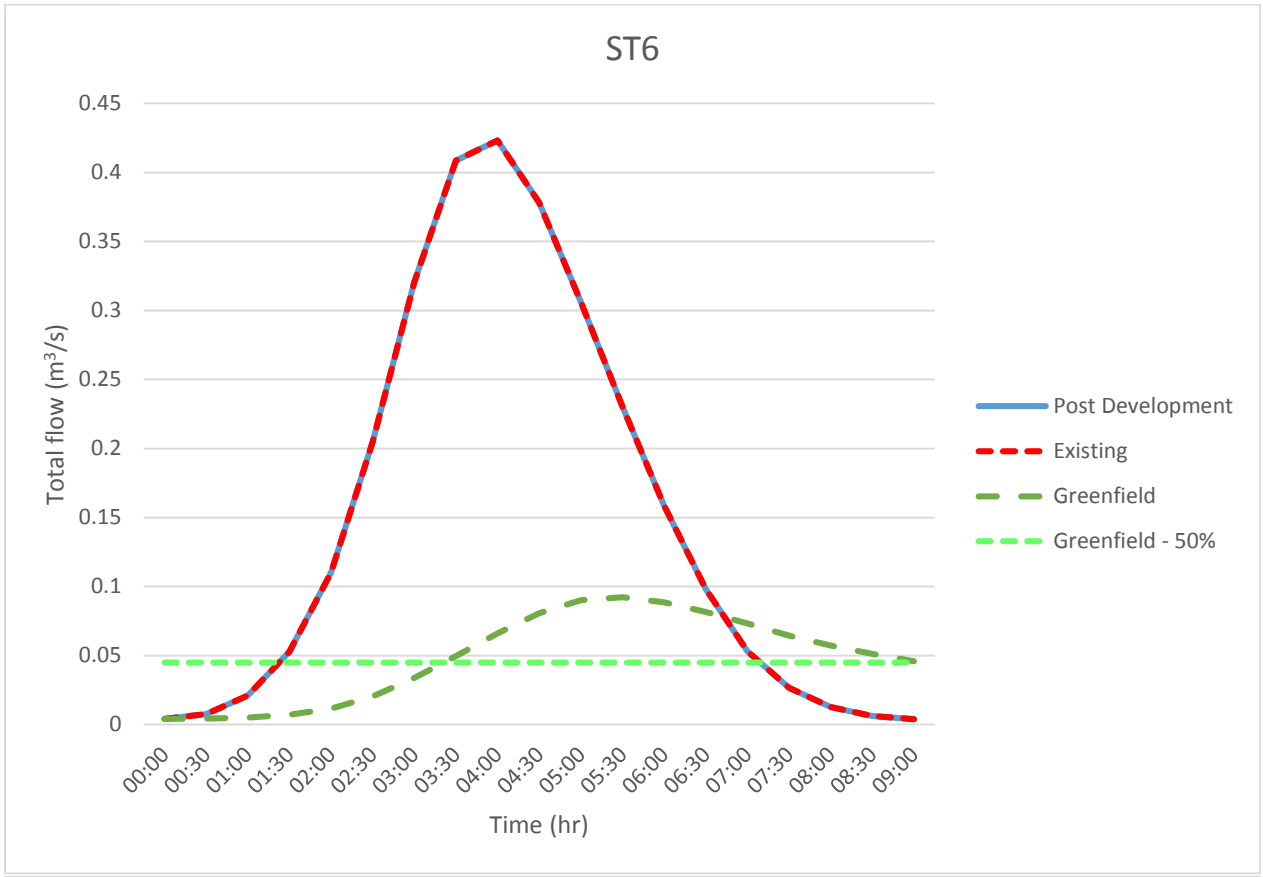

SS3
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

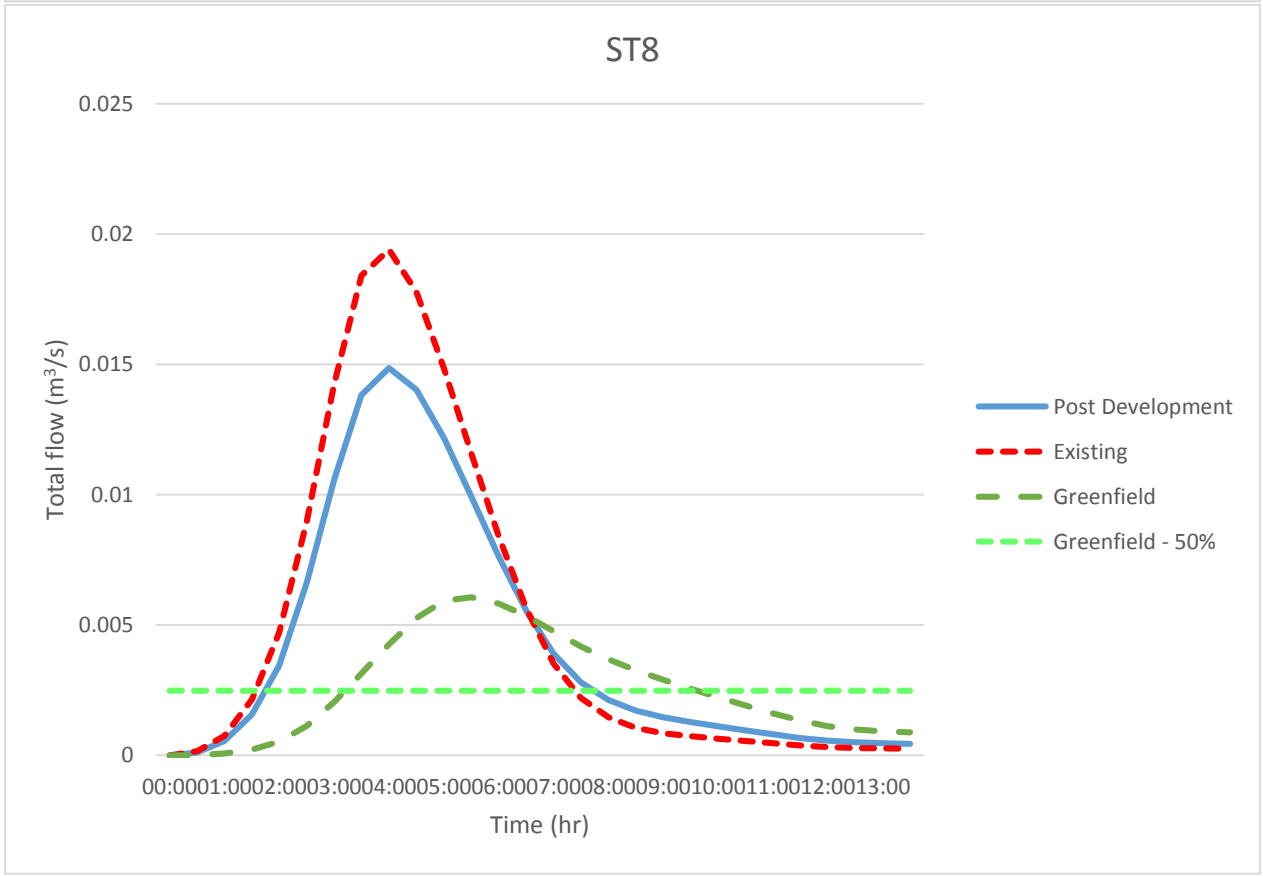

SS7
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

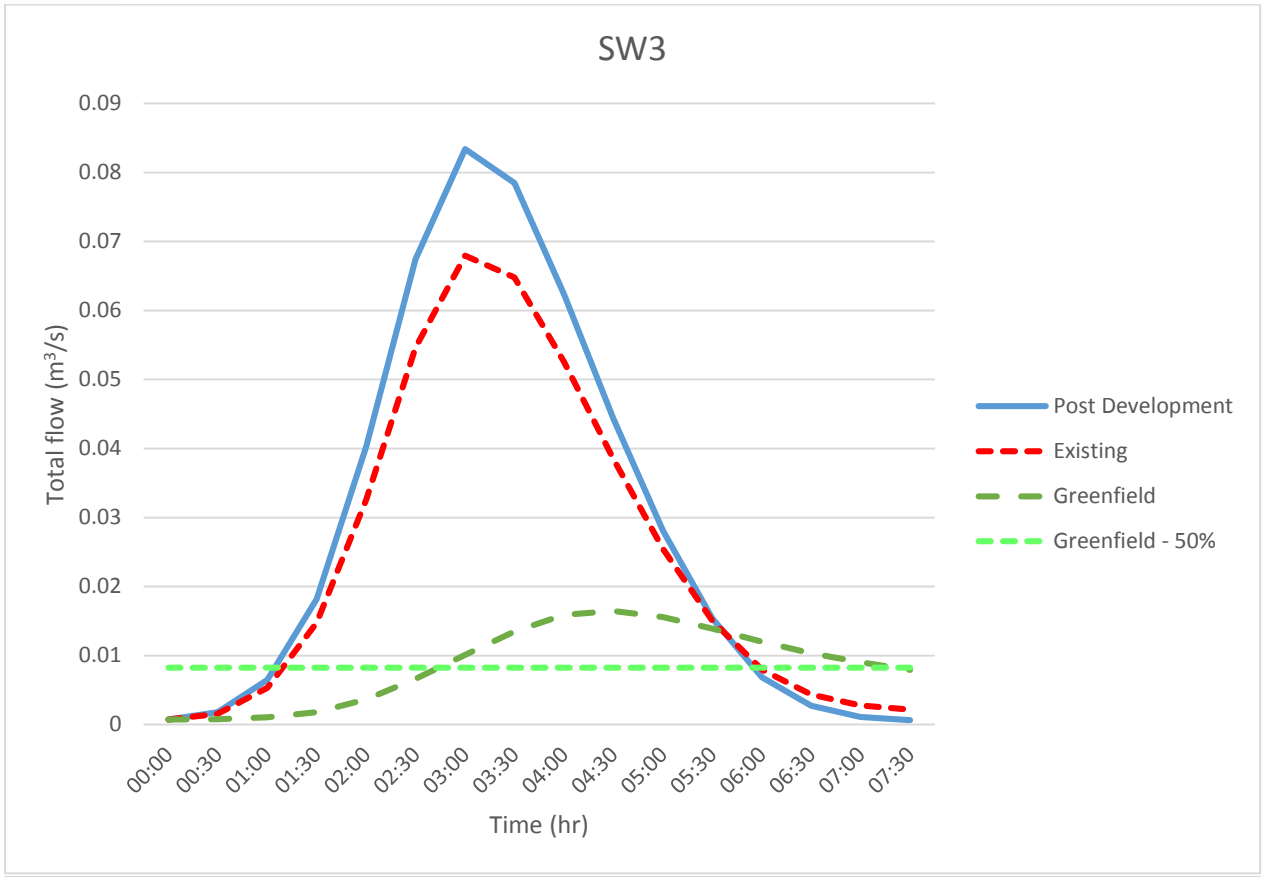

SSS4
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

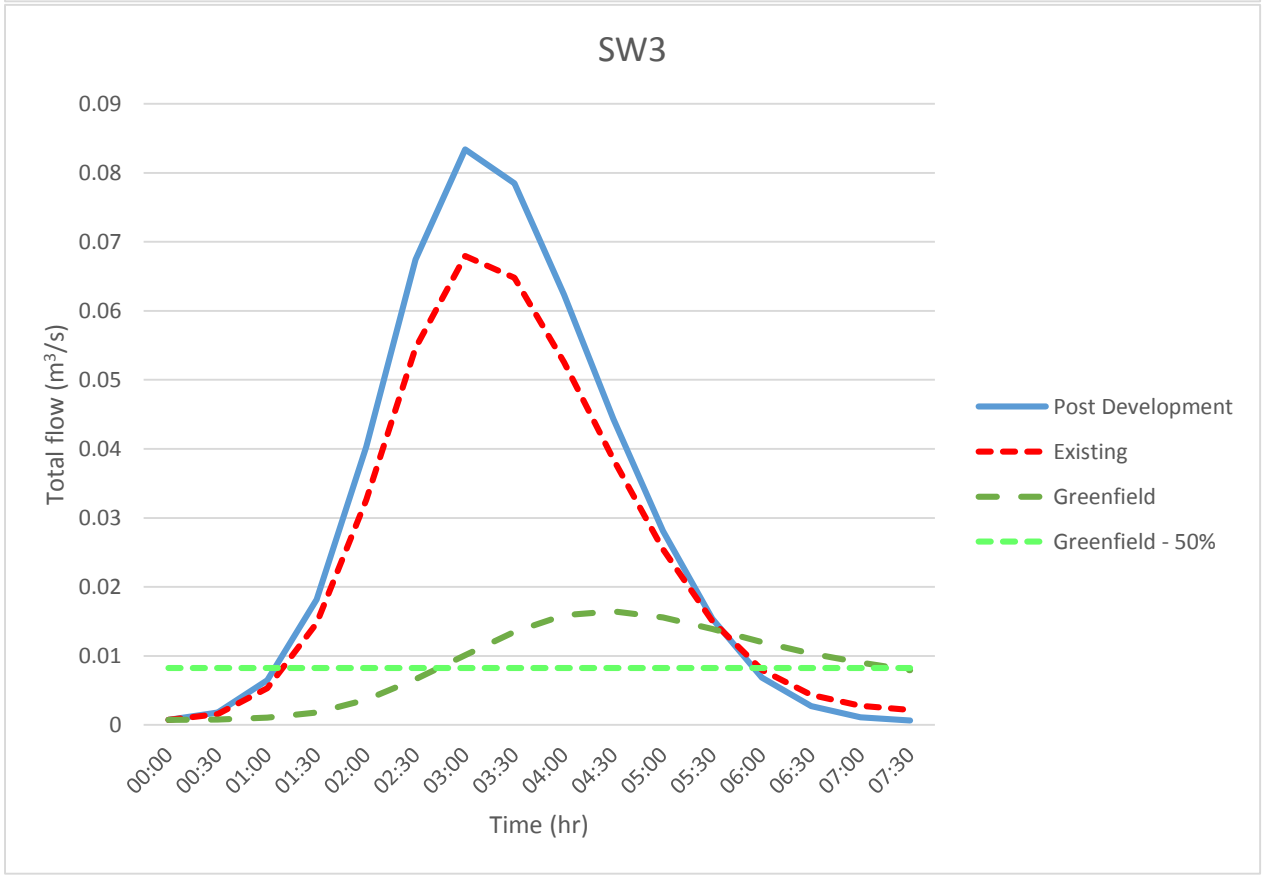

ST3
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

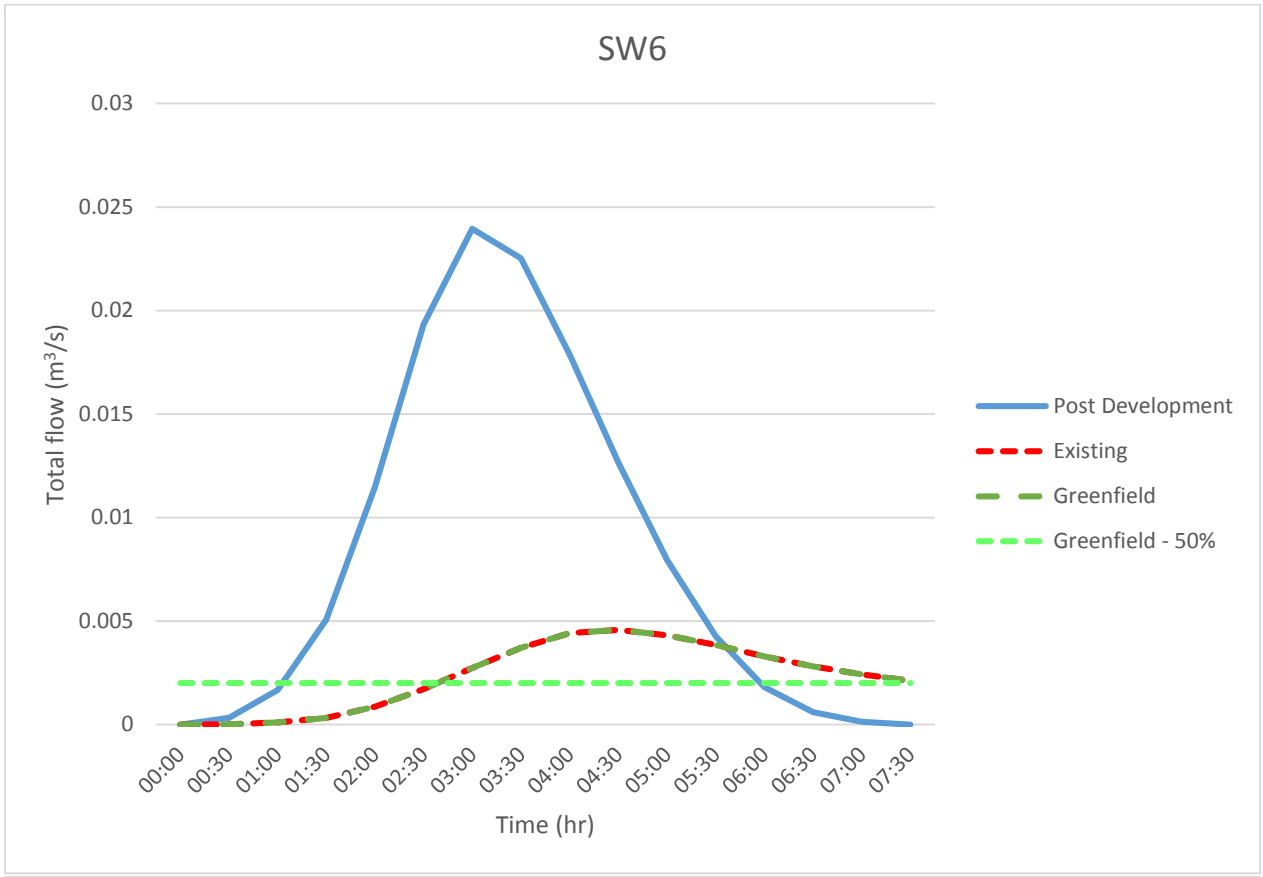

ST5
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

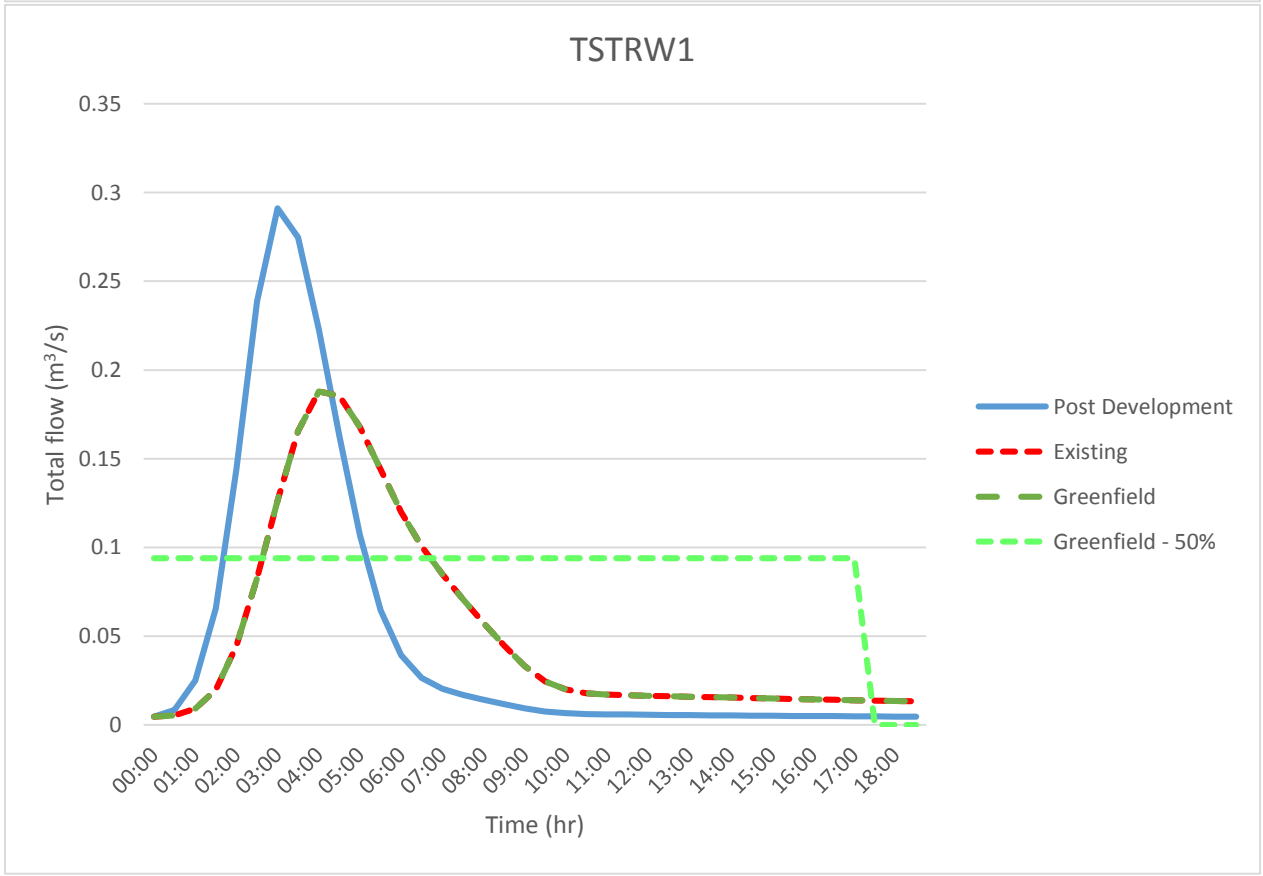

ST6
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

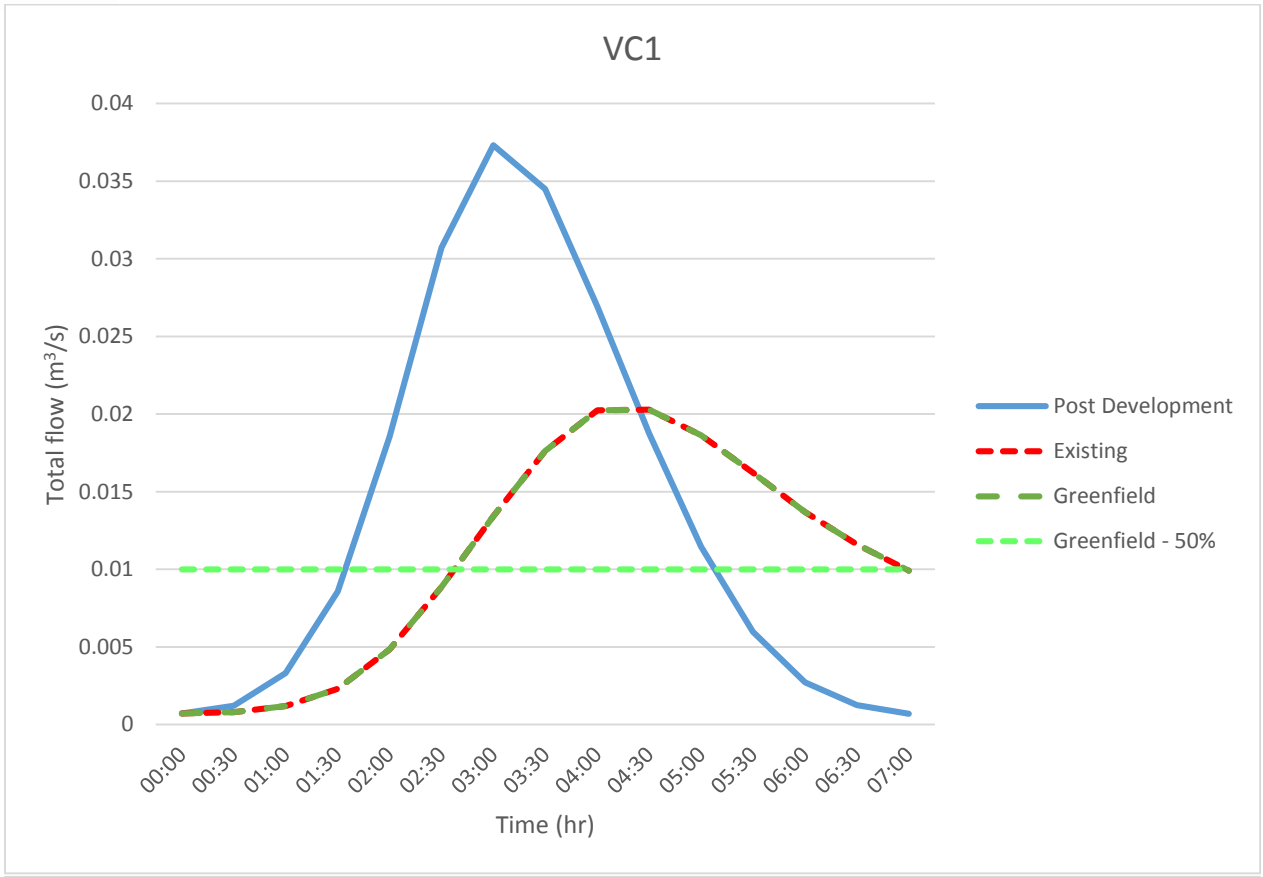

ST8
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:0001:0002:0003:0004:0005:0006:0007:0008:0009:0010:0011:0012:0013:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

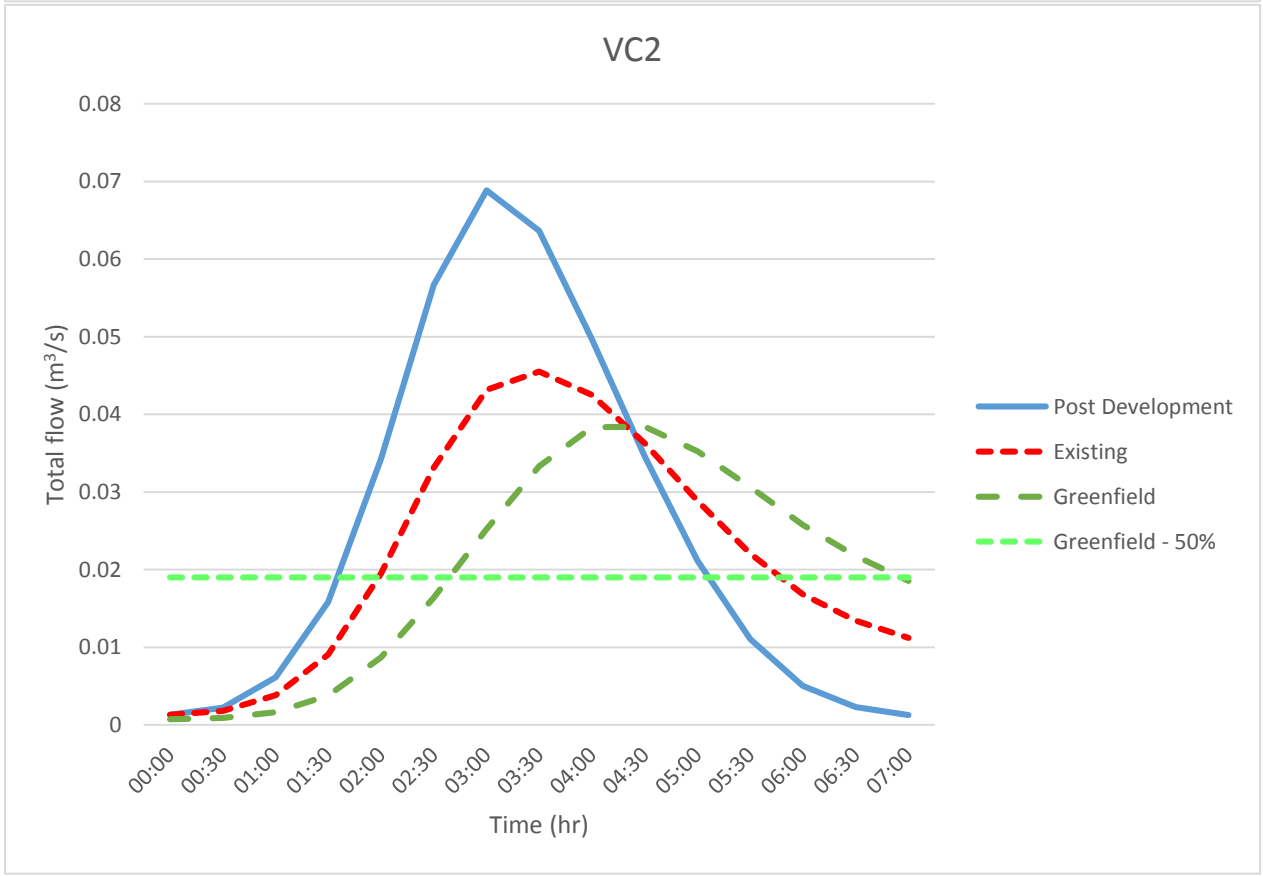

SW3
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

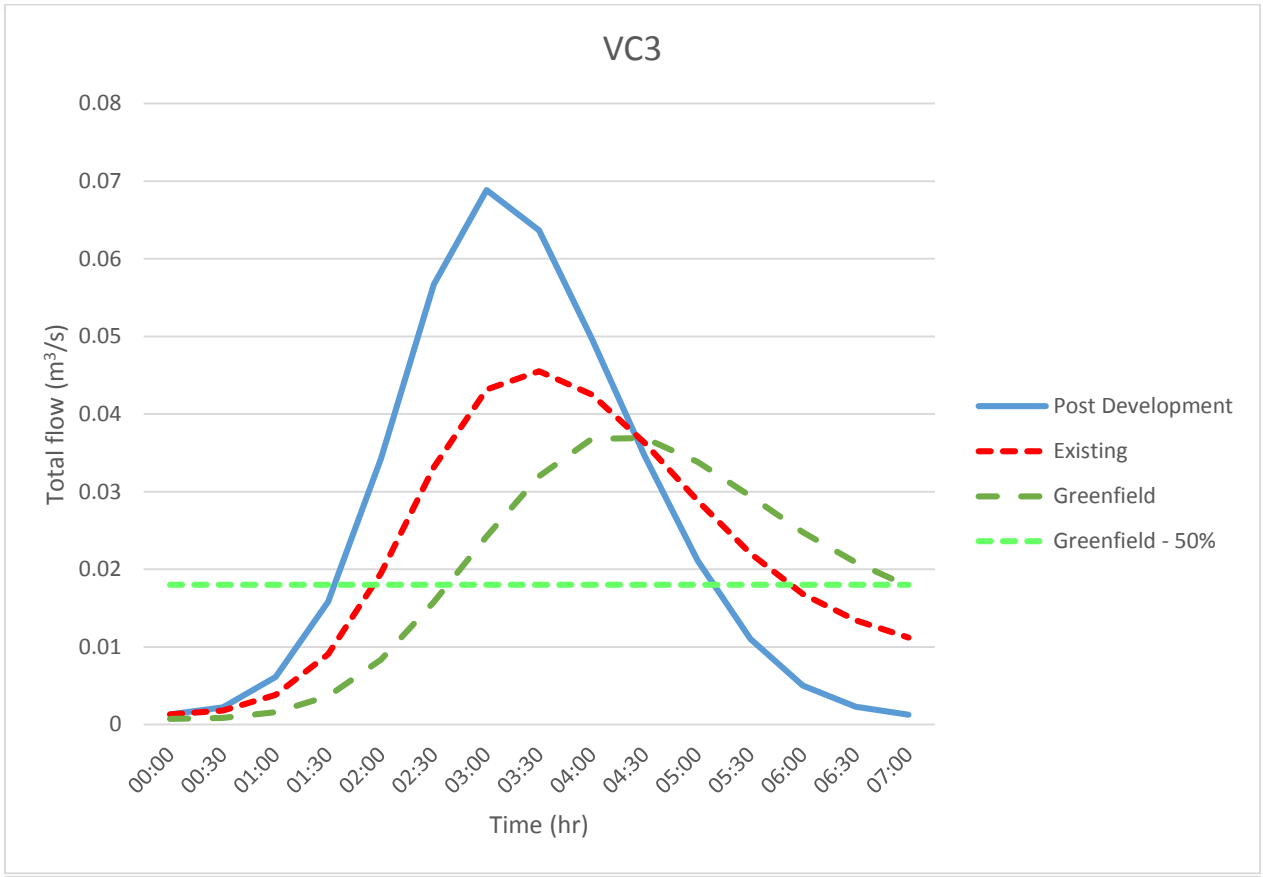

SW3
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

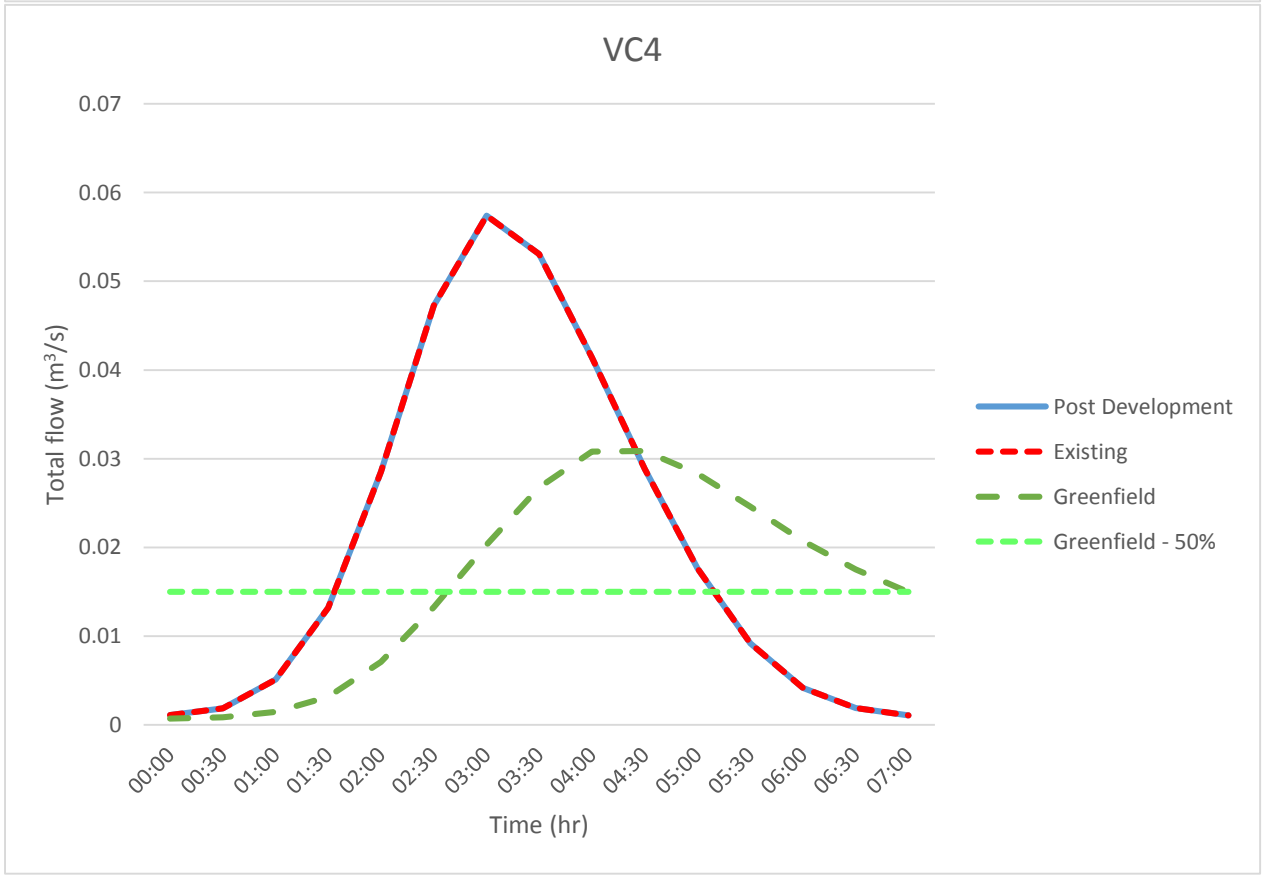

SW6
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

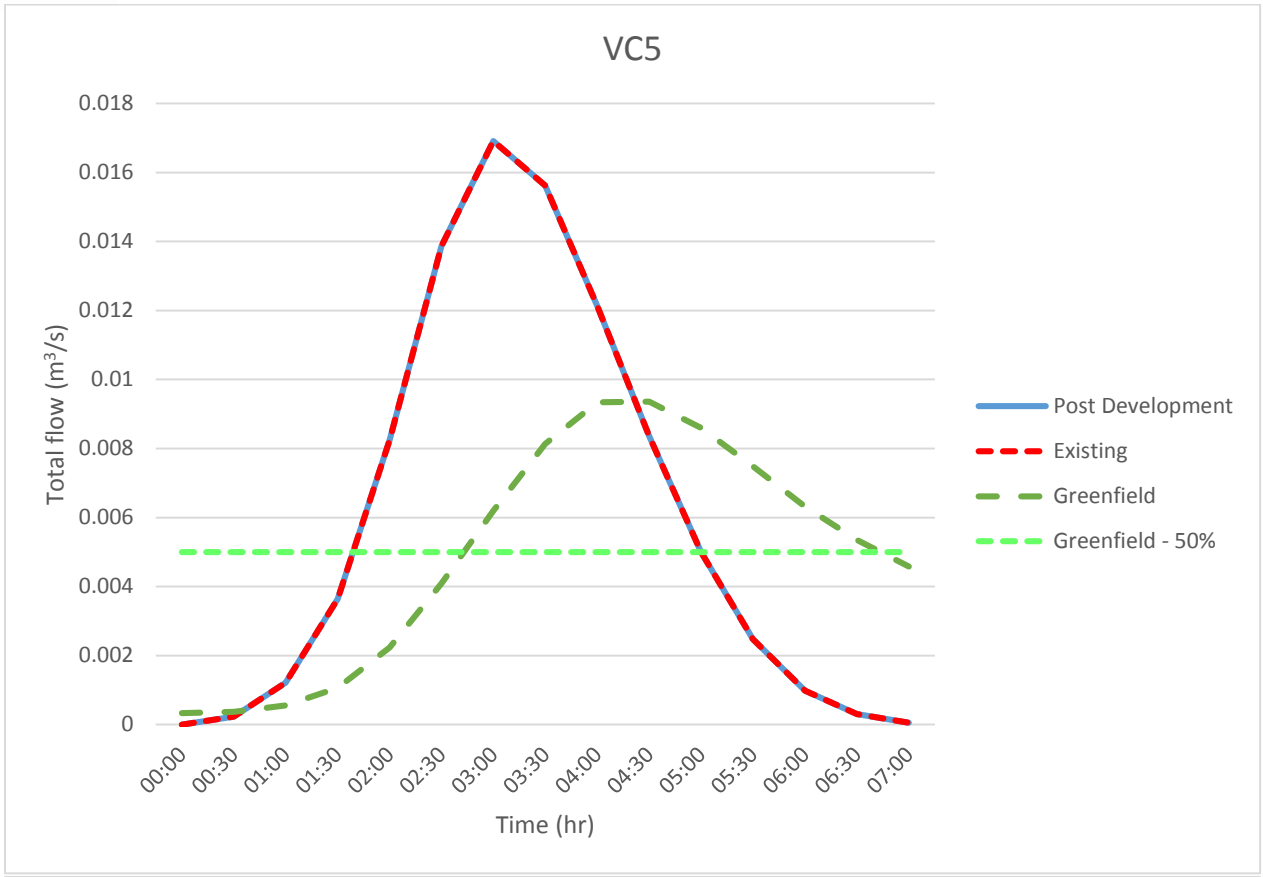

TSTRW1
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

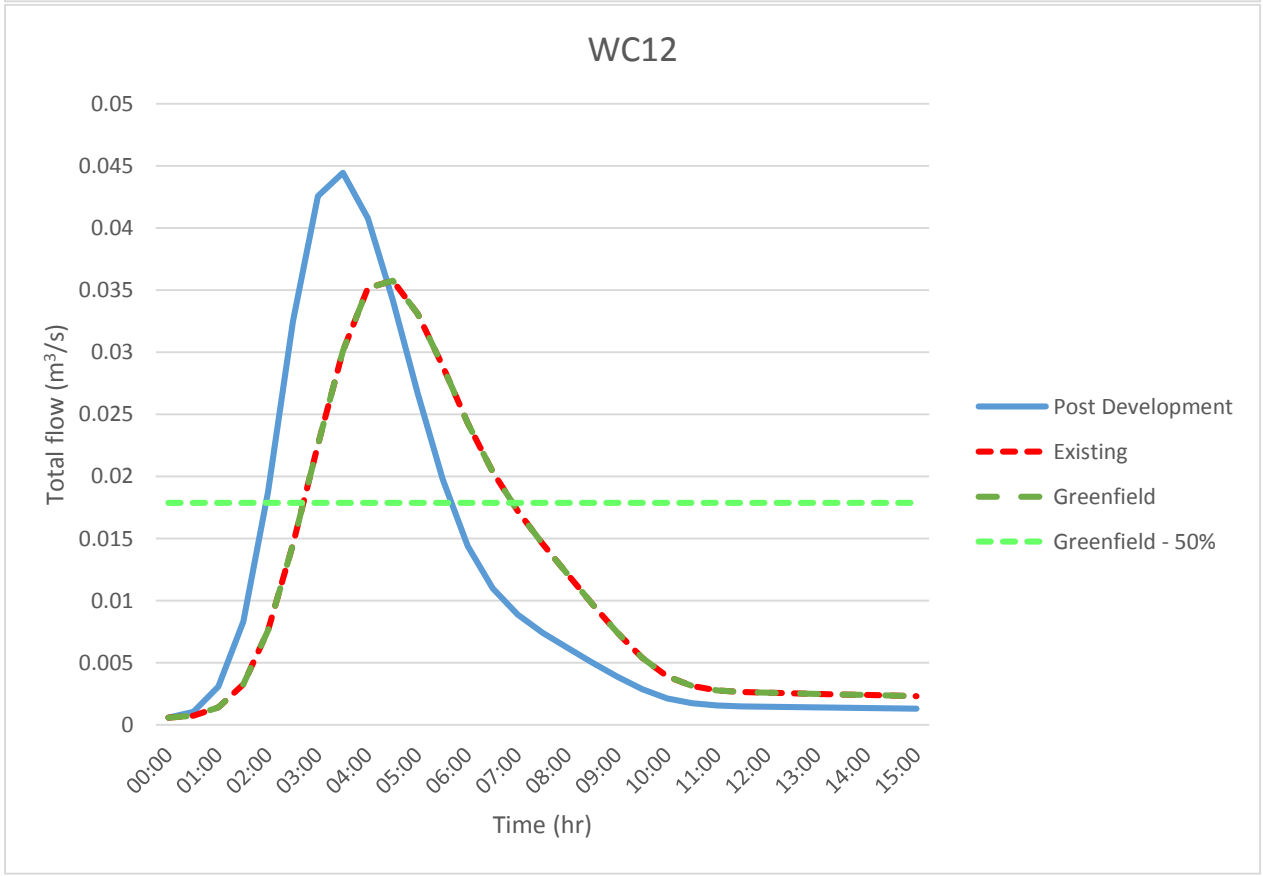

VC1
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

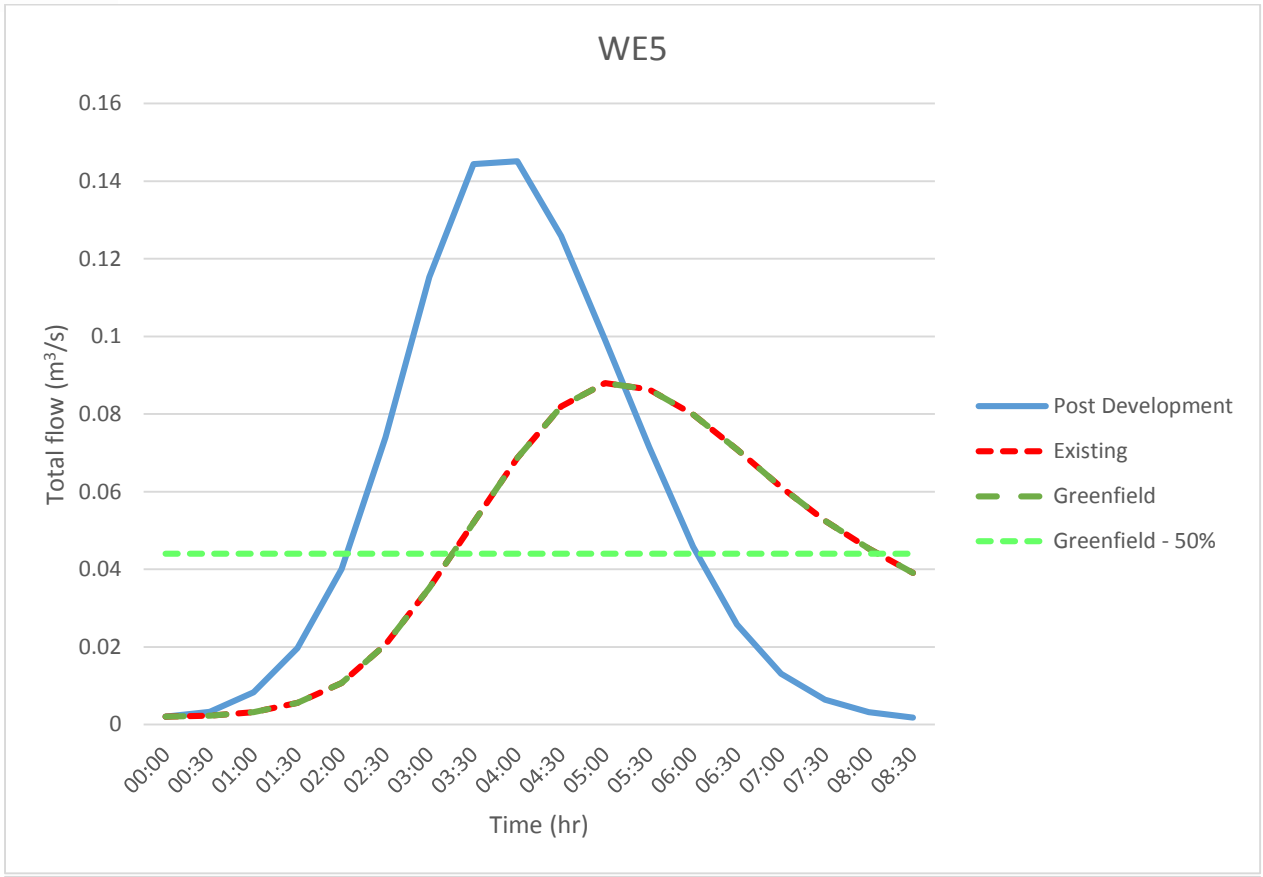

VC2
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

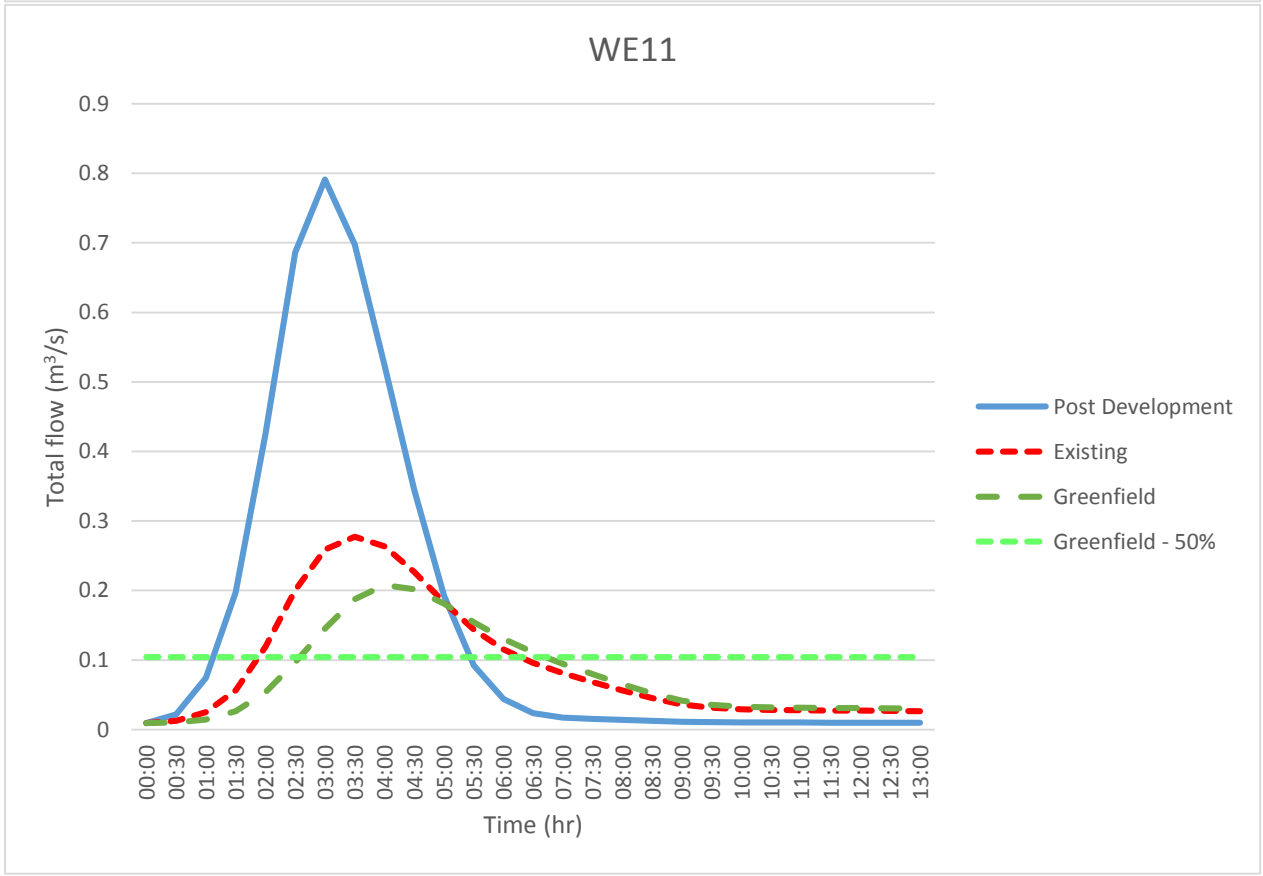

VC3
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

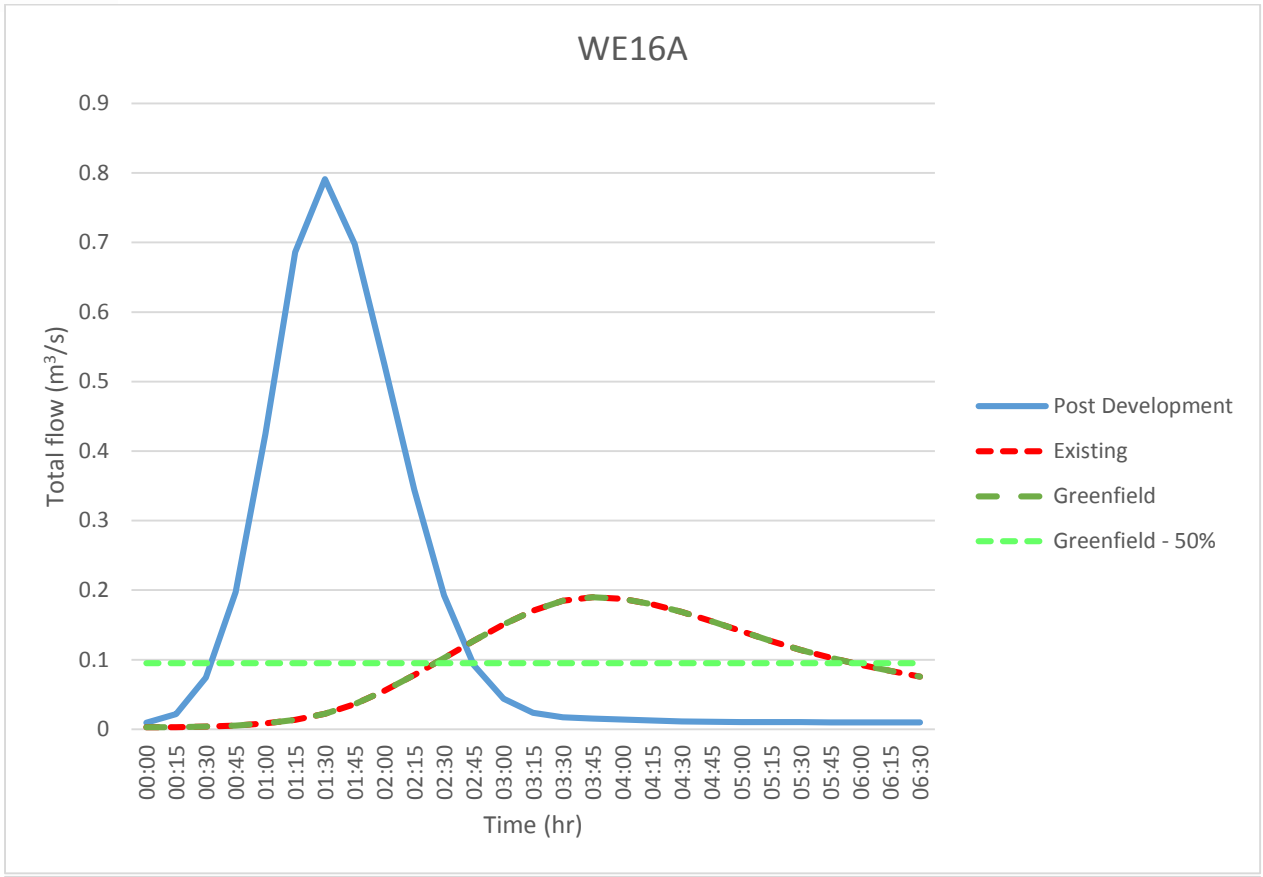

VC4
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

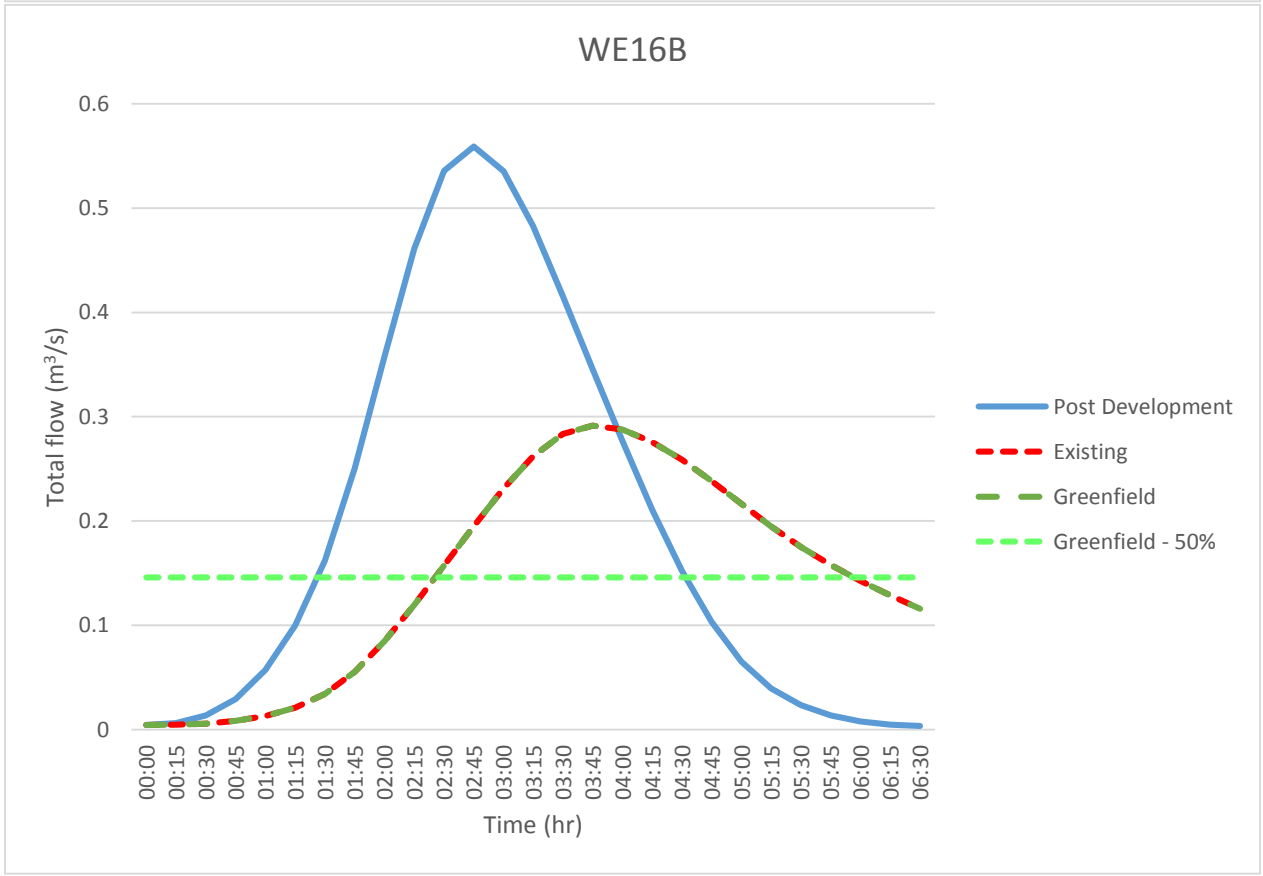

VC5
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

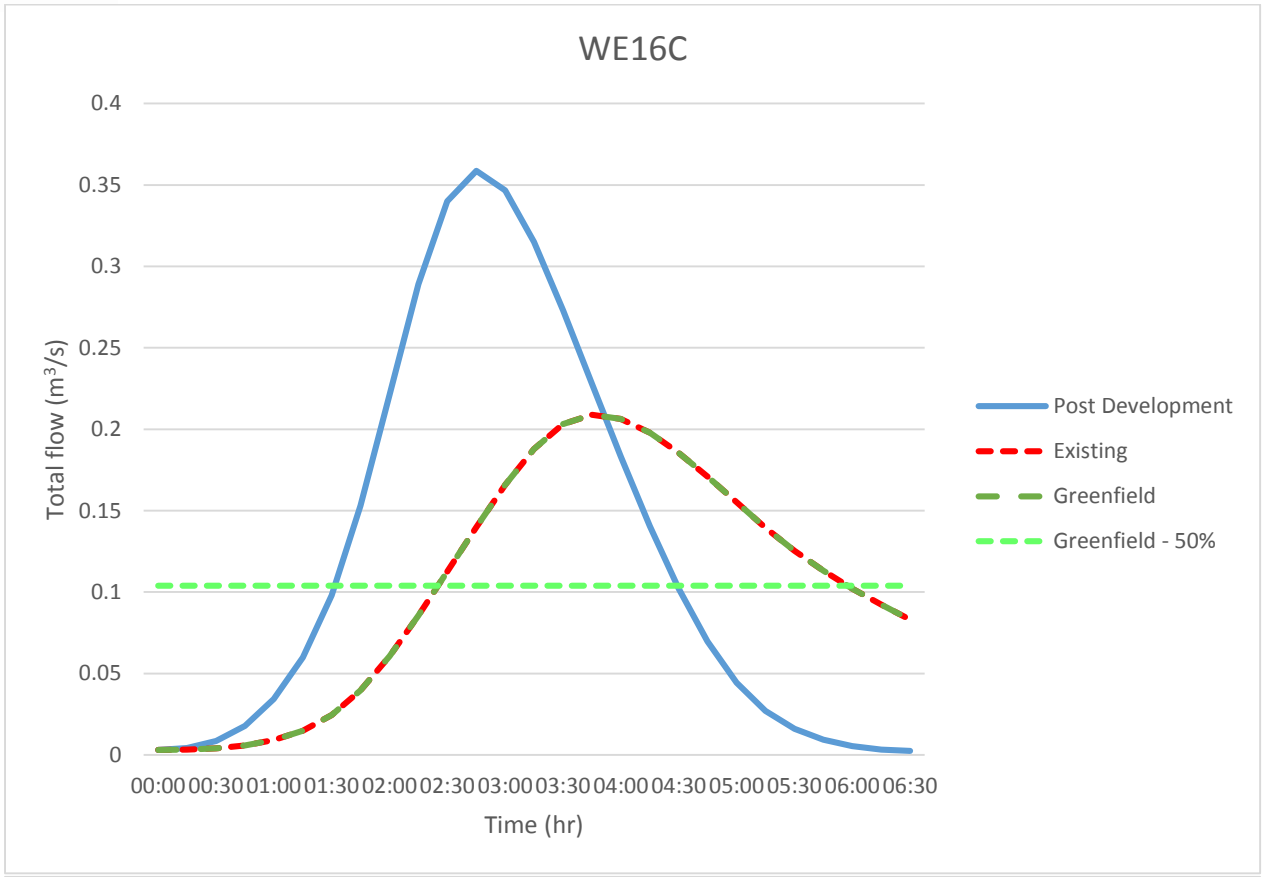

WC12
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

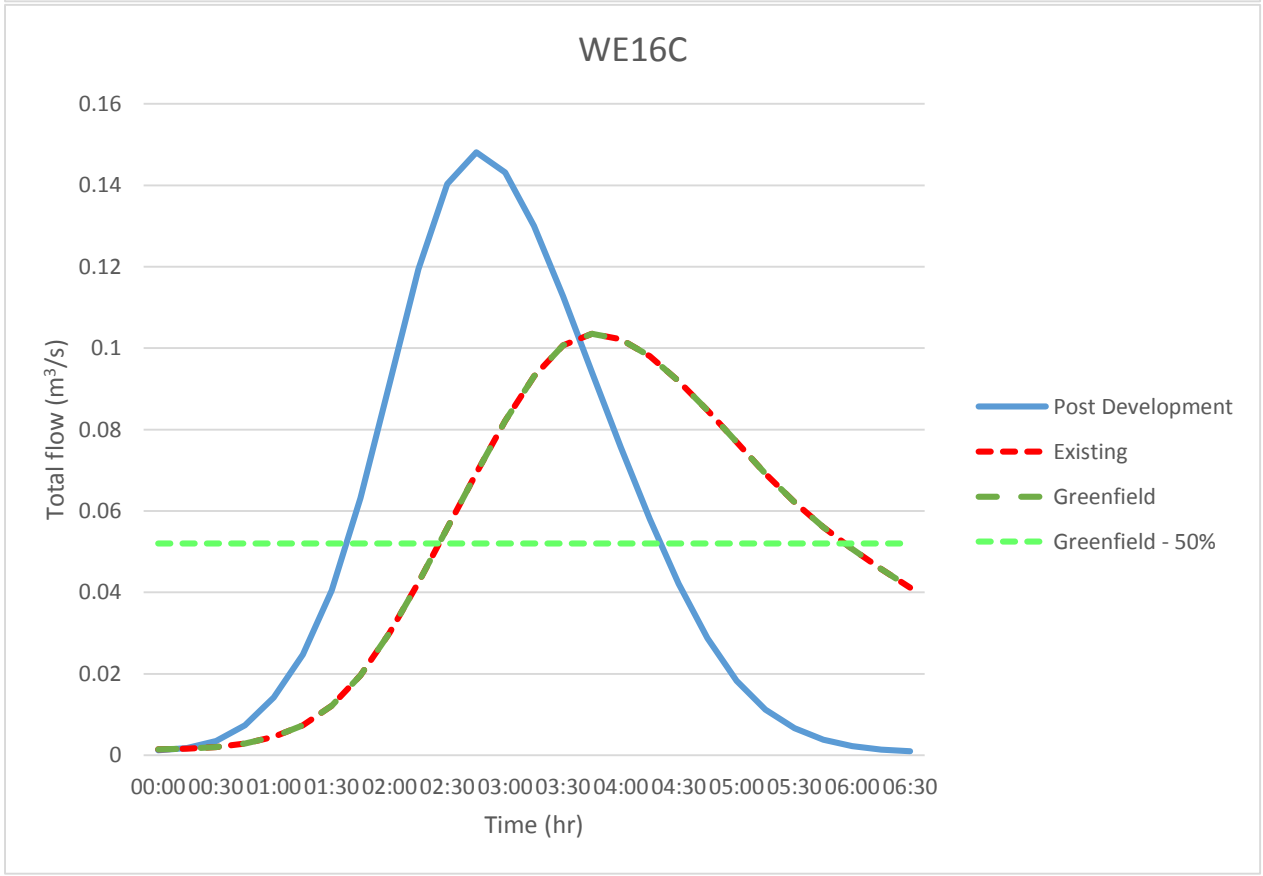

WE5
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

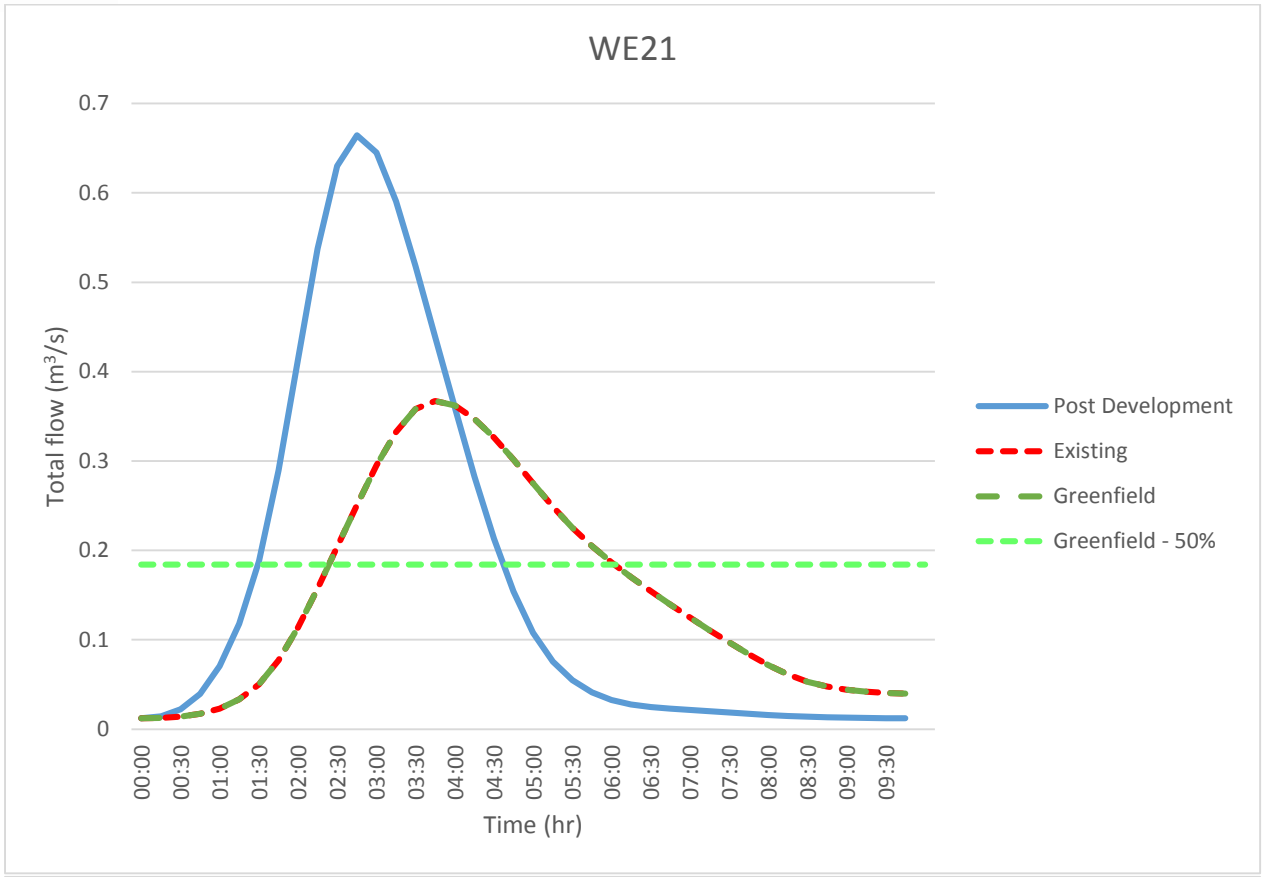

WE11
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

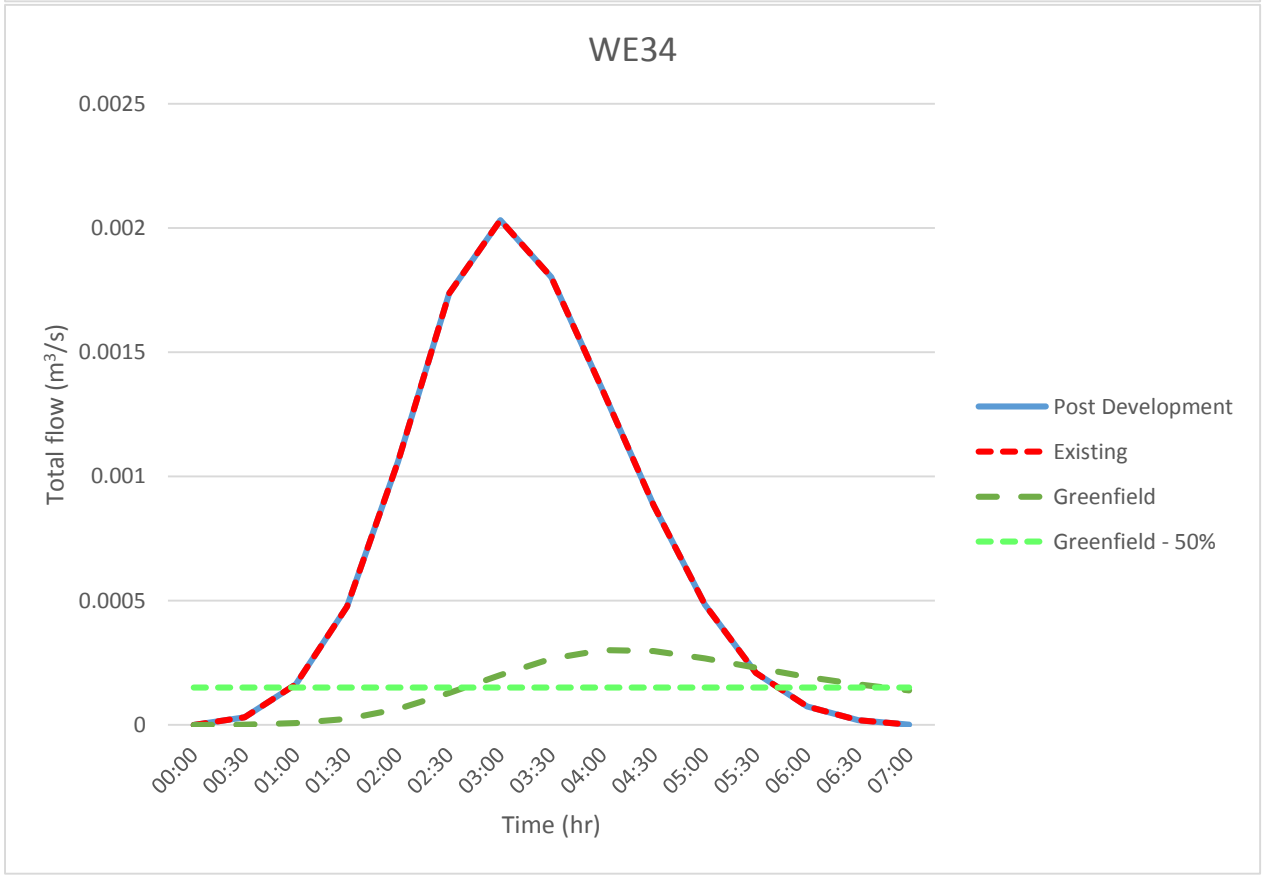

WE16A
Total flow (m³/s)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00
02:15
02:30
02:45
03:00
03:15
03:30
03:45
04:00
04:15
04:30
04:45
05:00
05:15
05:30
05:45
06:00
06:15
06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

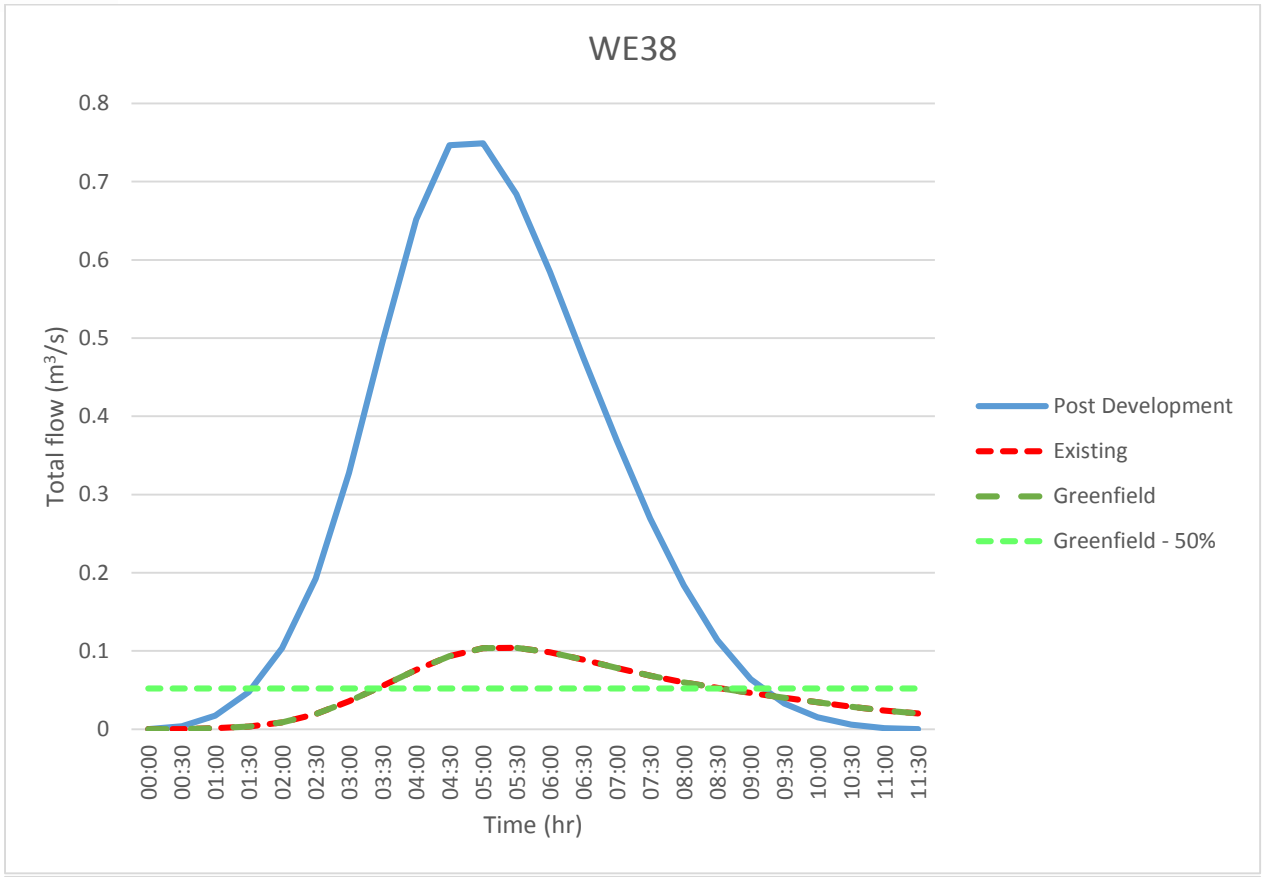

WE16B
Total flow (m³/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00
02:15
02:30
02:45
03:00
03:15
03:30
03:45
04:00
04:15
04:30
04:45
05:00
05:15
05:30
05:45
06:00
06:15
06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

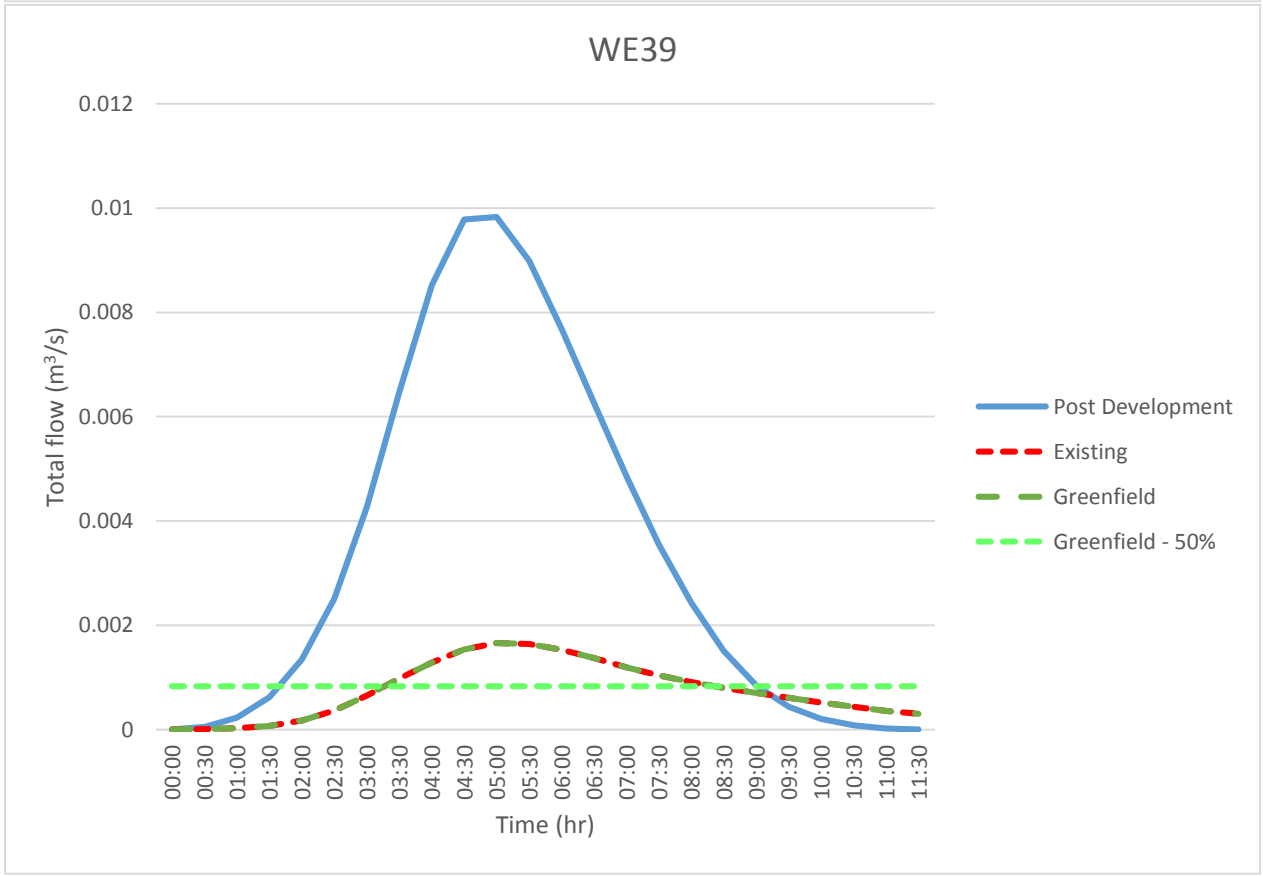

WE16C
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total flow (m³/s)
00:00 00:30 01:00 01:30 02:00 02:30 03:00 03:30 04:00 04:30 05:00 05:30 06:00 06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

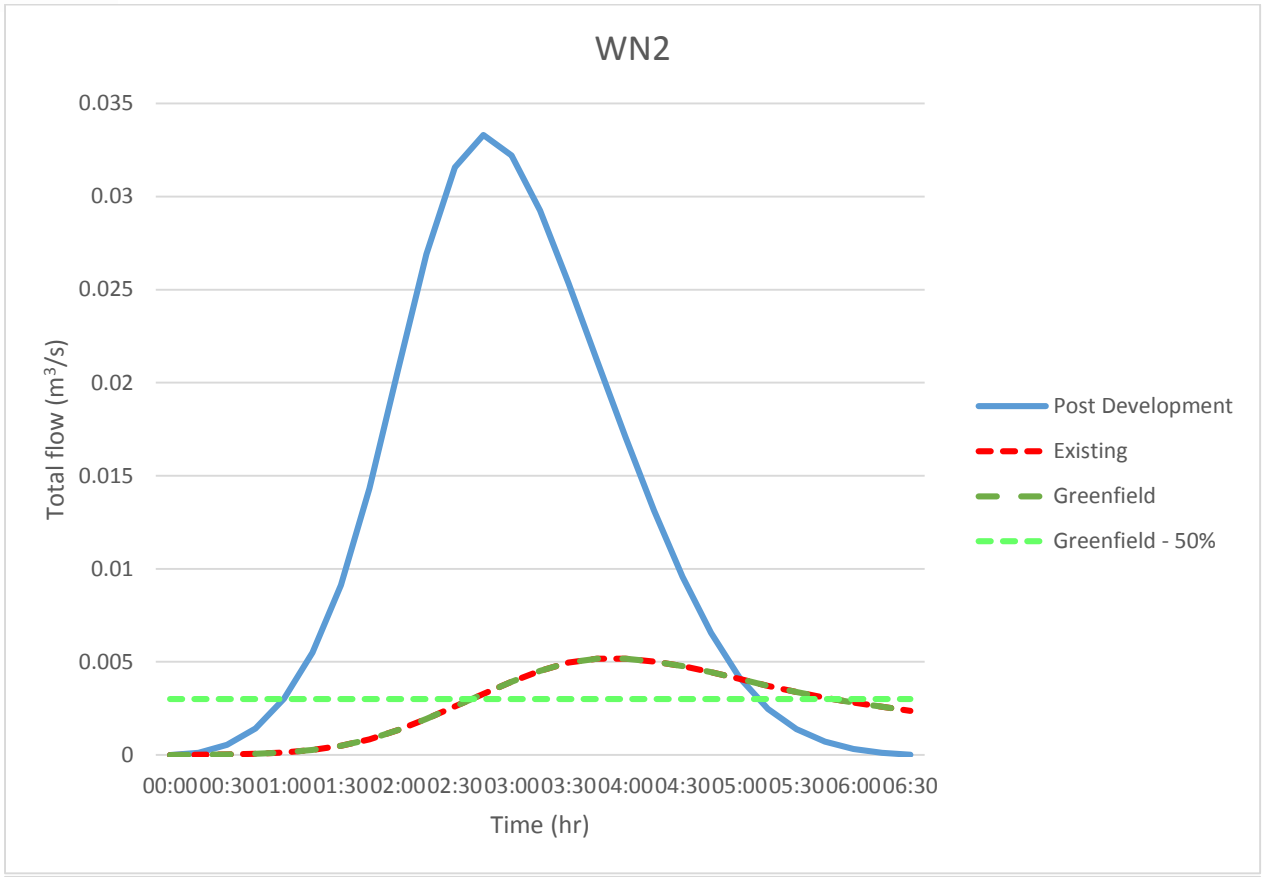

WE16C
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Total flow (m³/s)
00:00 00:30 01:00 01:30 02:00 02:30 03:00 03:30 04:00 04:30 05:00 05:30 06:00 06:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

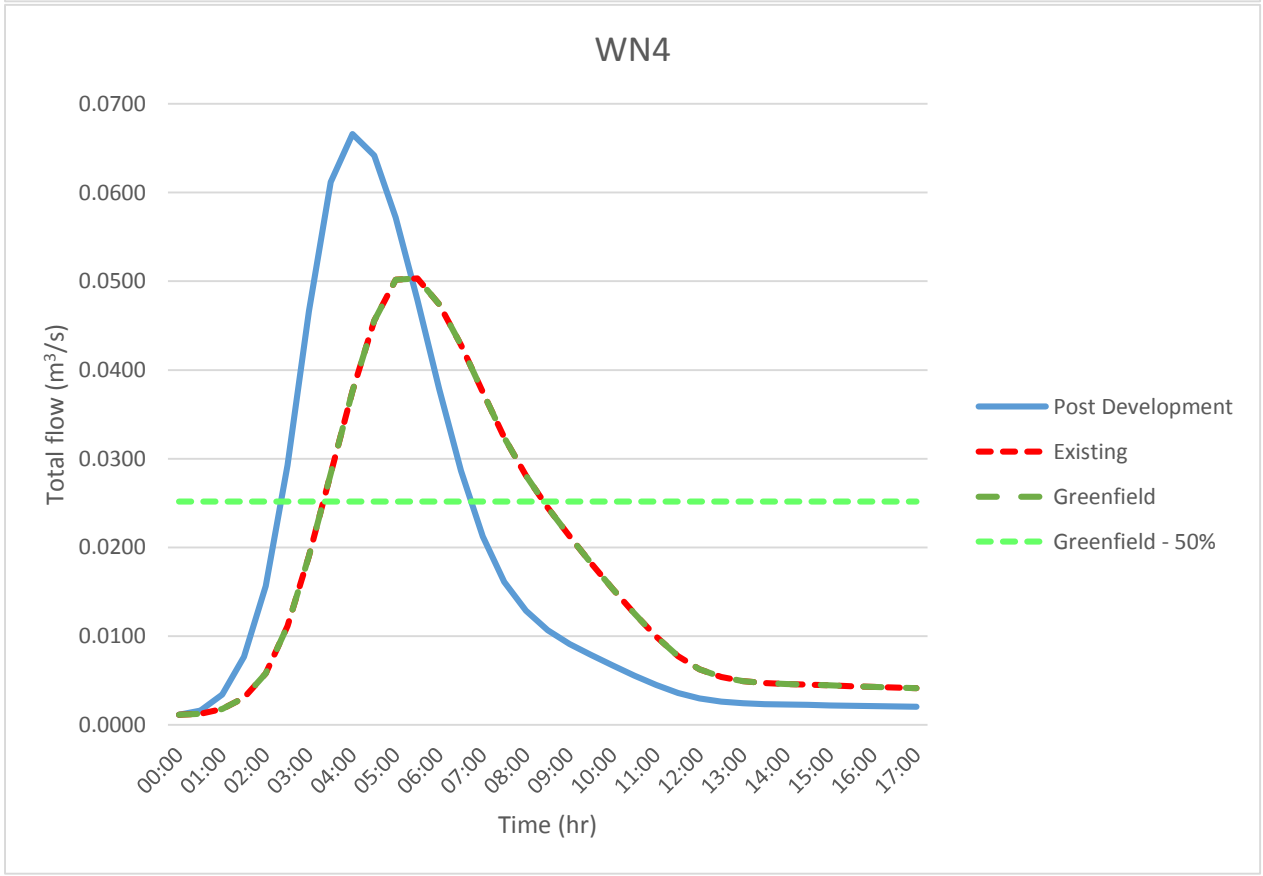

WE21
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WE34
0.0025
0.002
0.0015
0.001
0.0005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

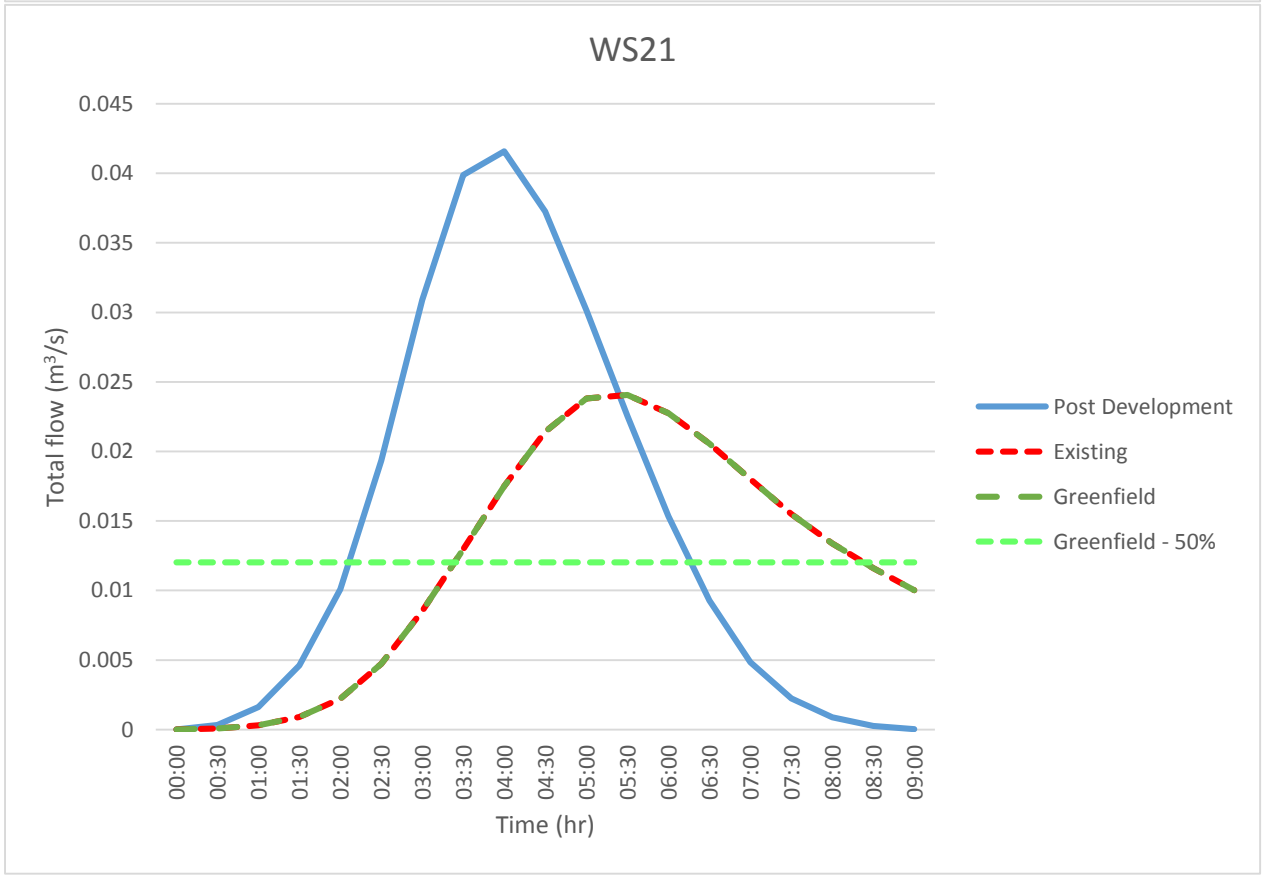

WE38
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WE39
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

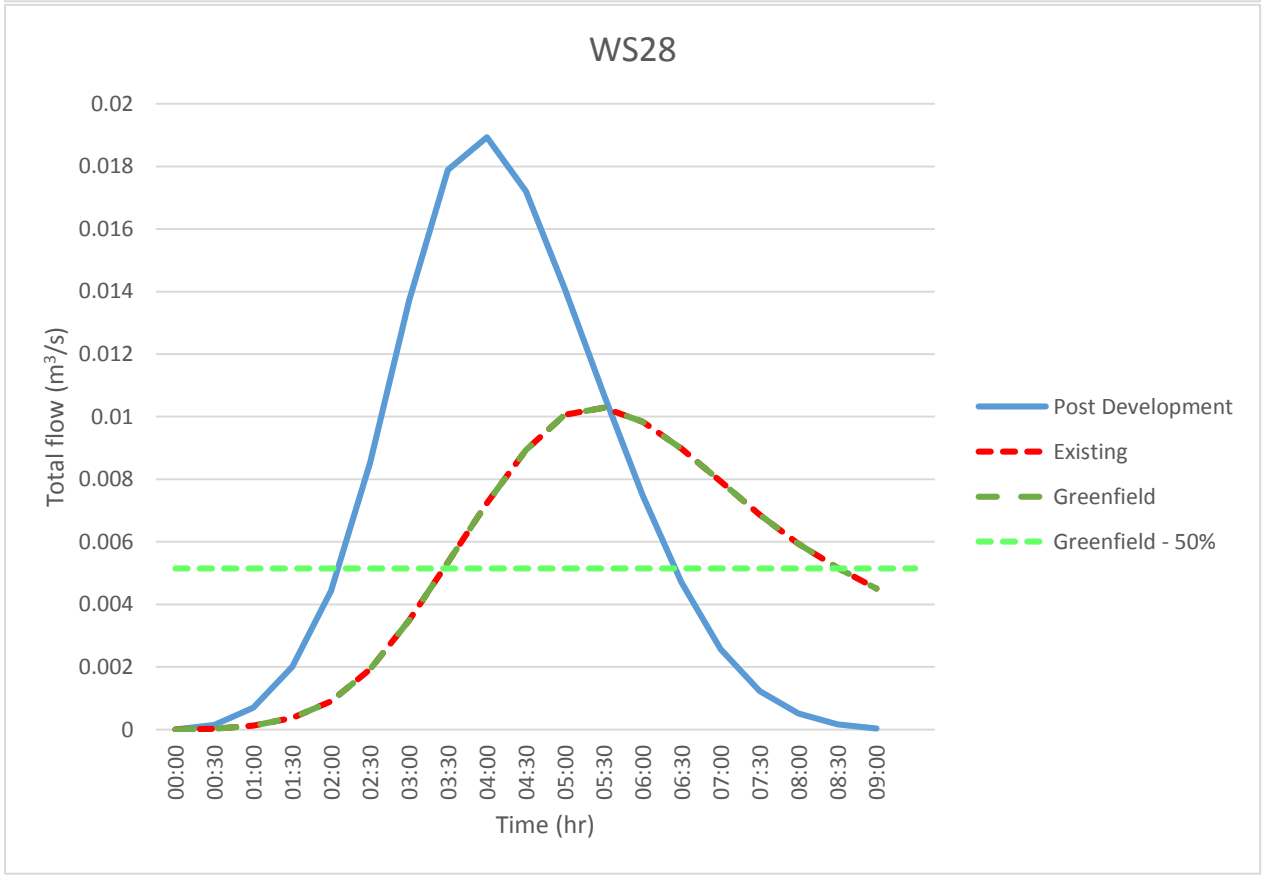

WN2
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:0000:3001:0001:3002:0002:3003:0003:3004:0004:3005:0005:3006:0006:30
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

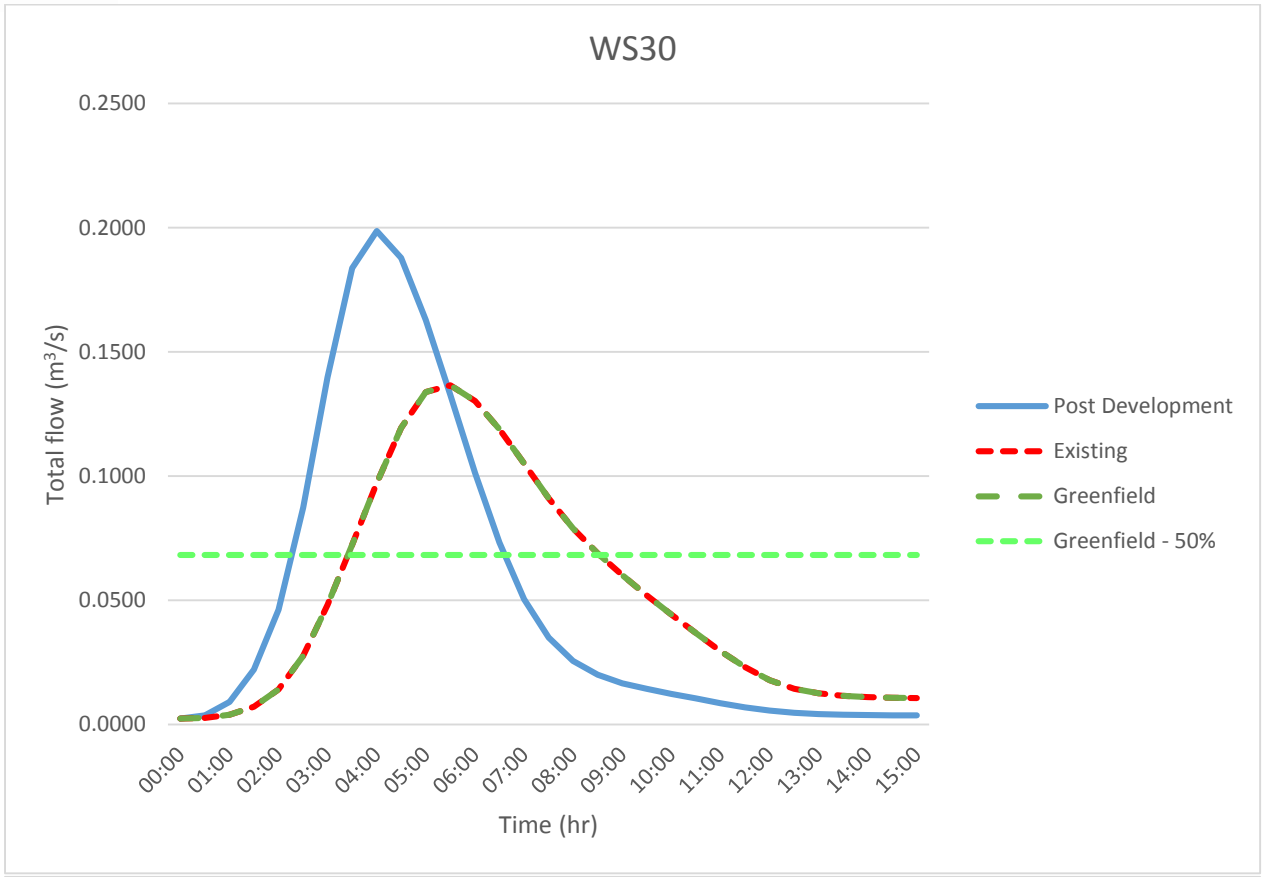

WN4
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

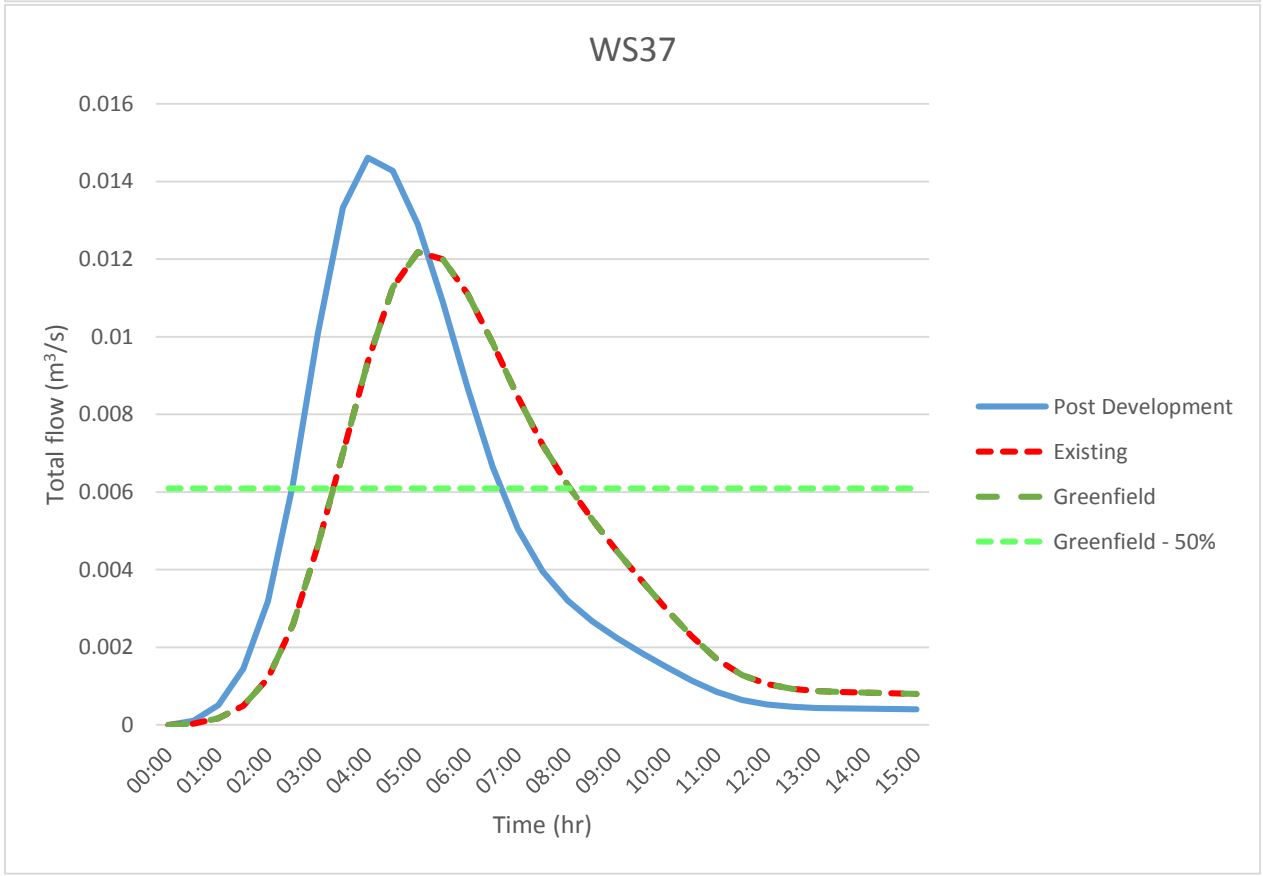

WS11
2.5
2
1.5
1
0.5
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WS21
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WS25
0.03
0.025
0.02
0.015
0.01
0.005
0
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time (hr)
Post Development
Existing
Greenfield
Series4


WS28
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WS30
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%


WS37
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Total flow (m³/s)
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
Time (hr)
Post Development
Existing
Greenfield
Greenfield - 50%

A.4 Modelled Flood outline

Figure A-1: 1% AEP + Climate change flood extent for Ashford for area 1

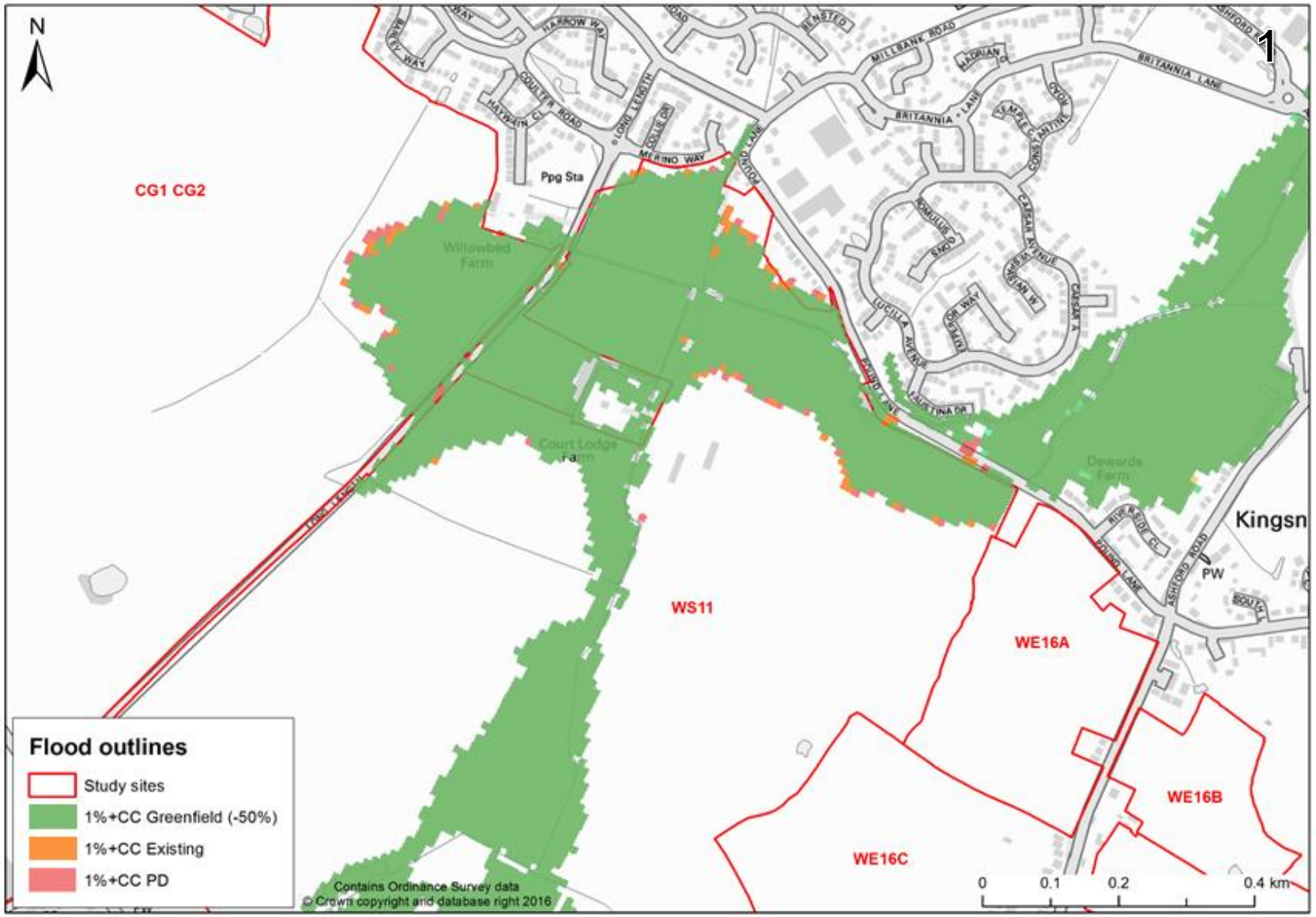


Figure A-2: 1% AEP + Climate change flood extent for Ashford for area 2

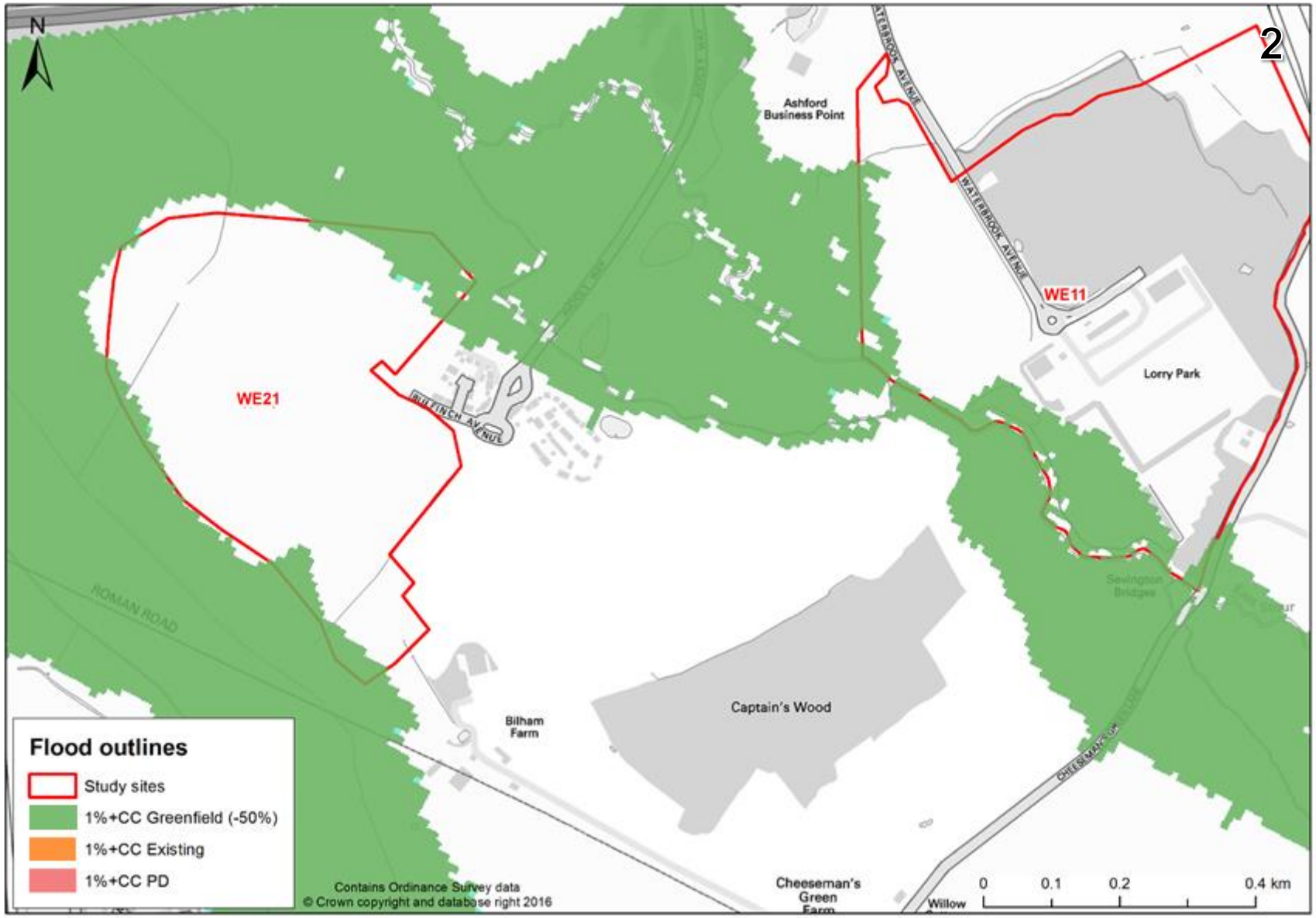


Figure A-3: 1% AEP + Climate change flood extent for Ashford for area 3

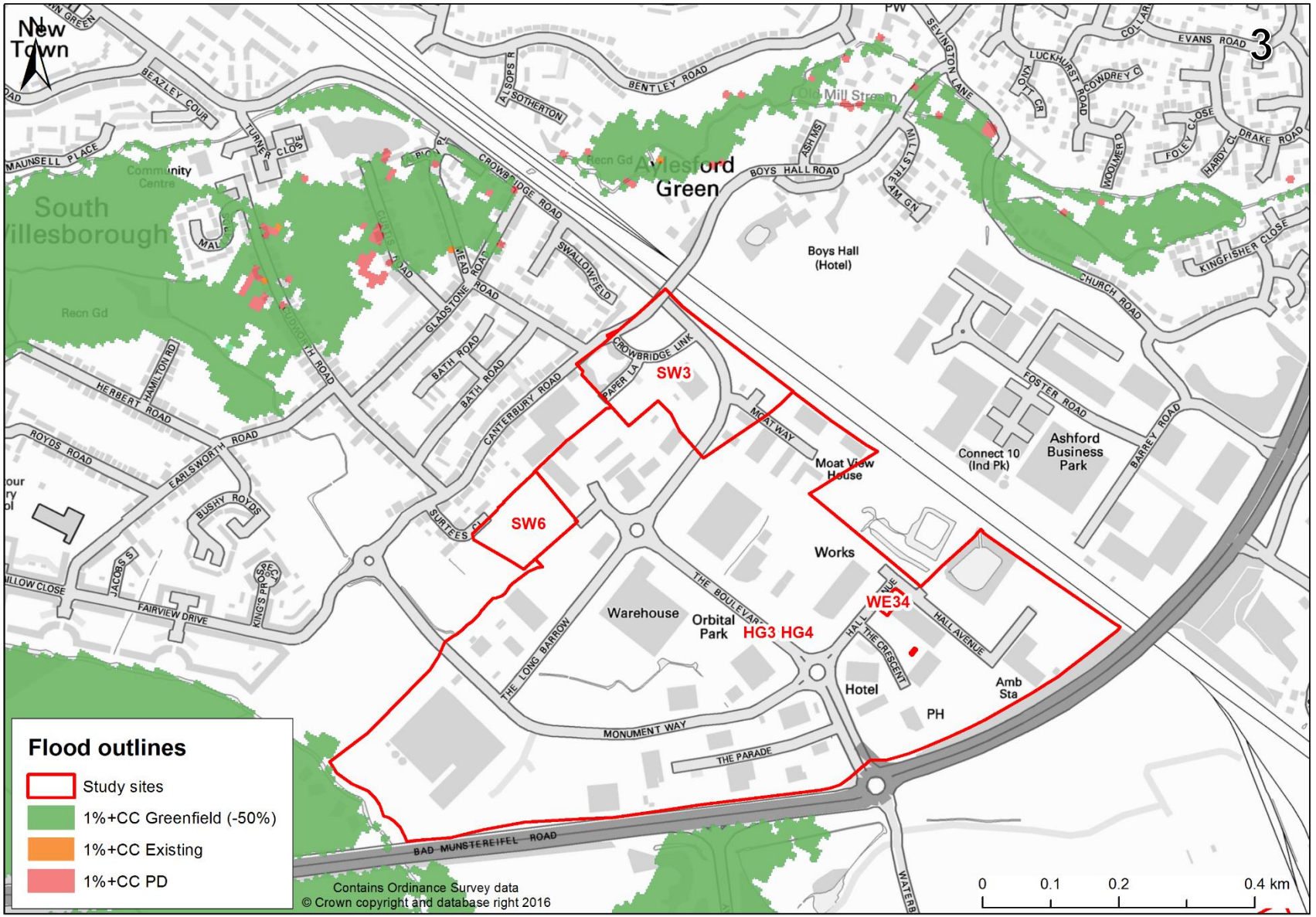


Figure A-4: 1% AEP + Climate change flood extent for Ashford for area 4

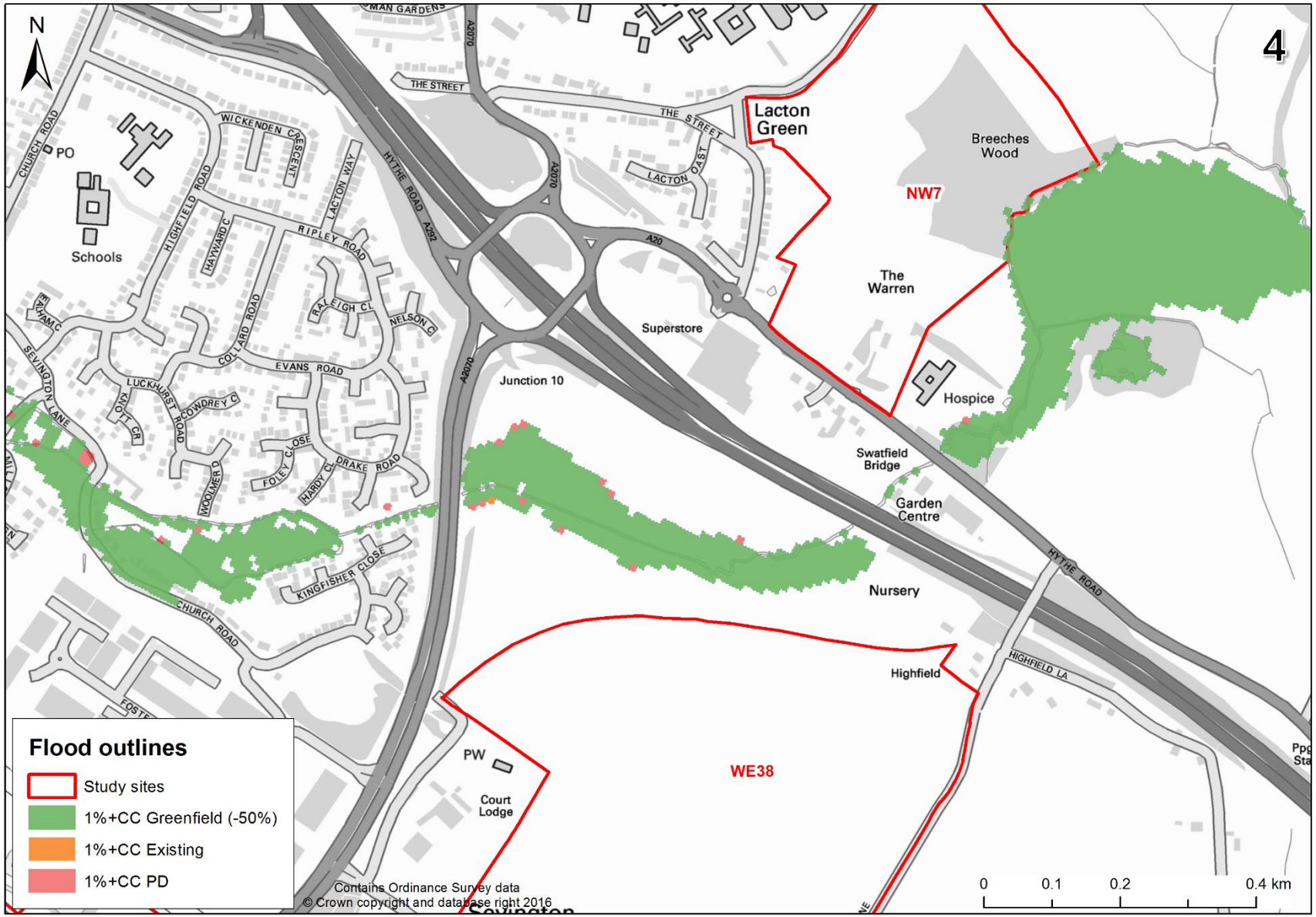


Figure A-5: 1% AEP + Climate change flood extent for Ashford for area 5

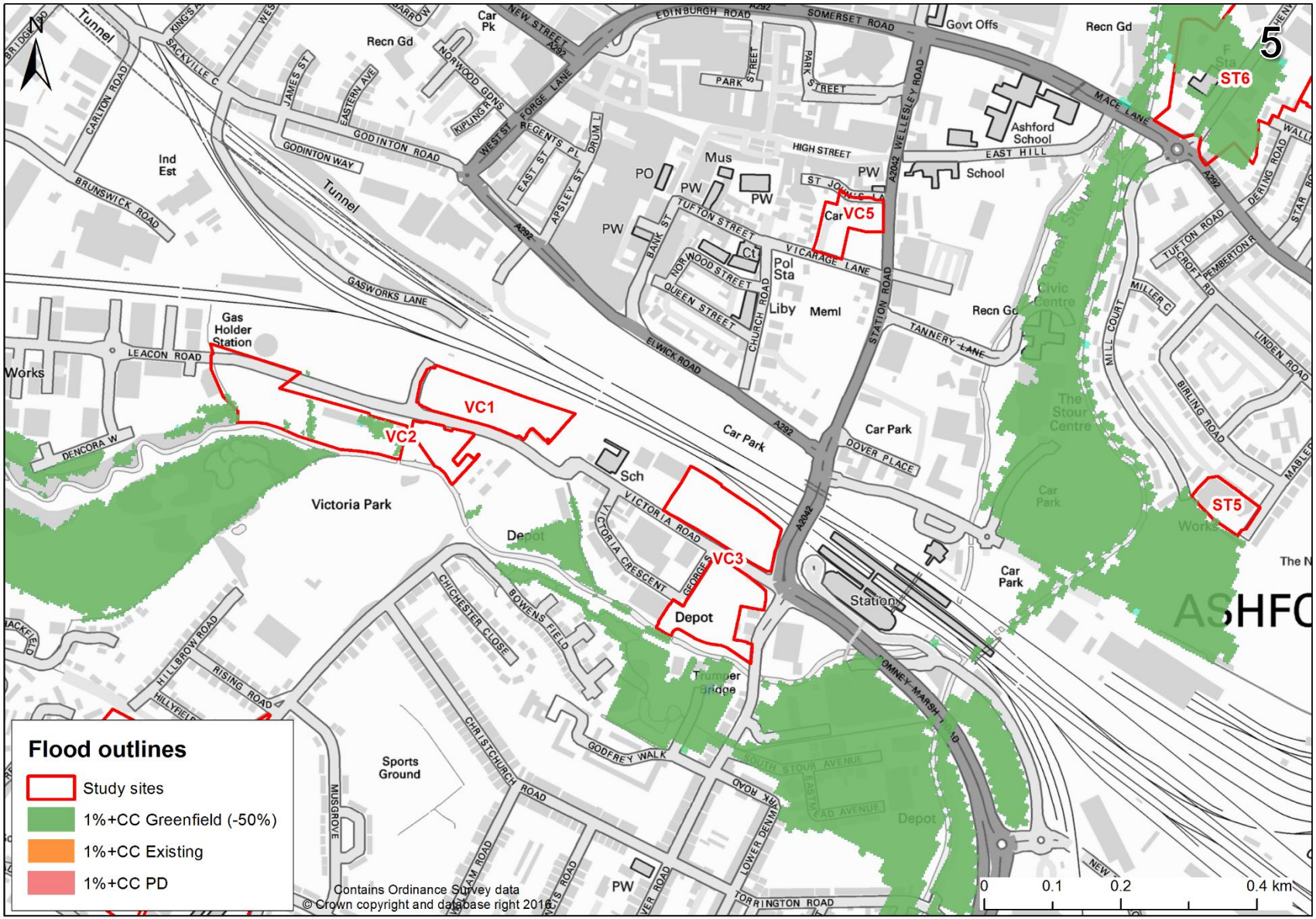


Figure A-6: 1% AEP + Climate change flood extent for Ashford for area 6

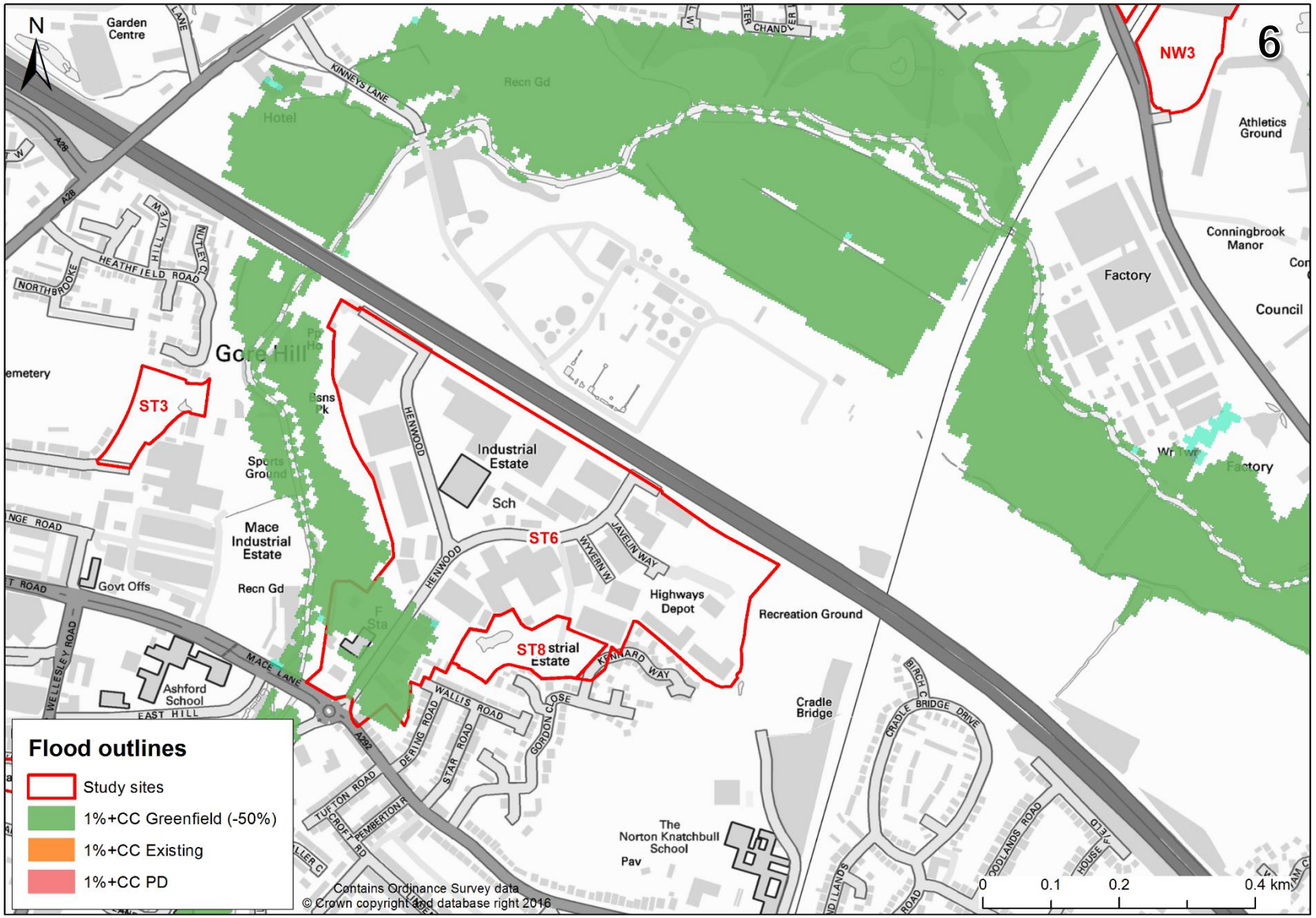
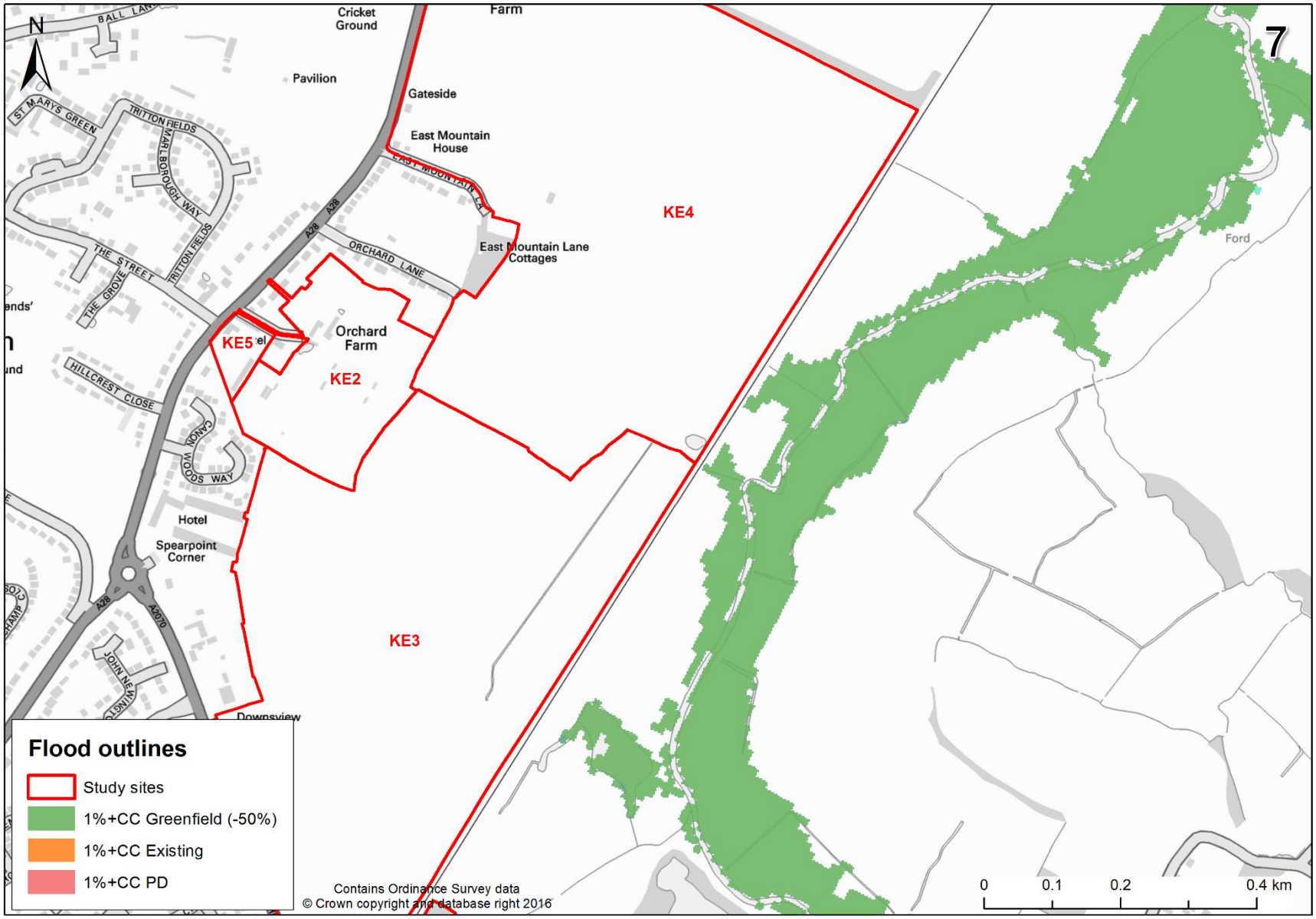
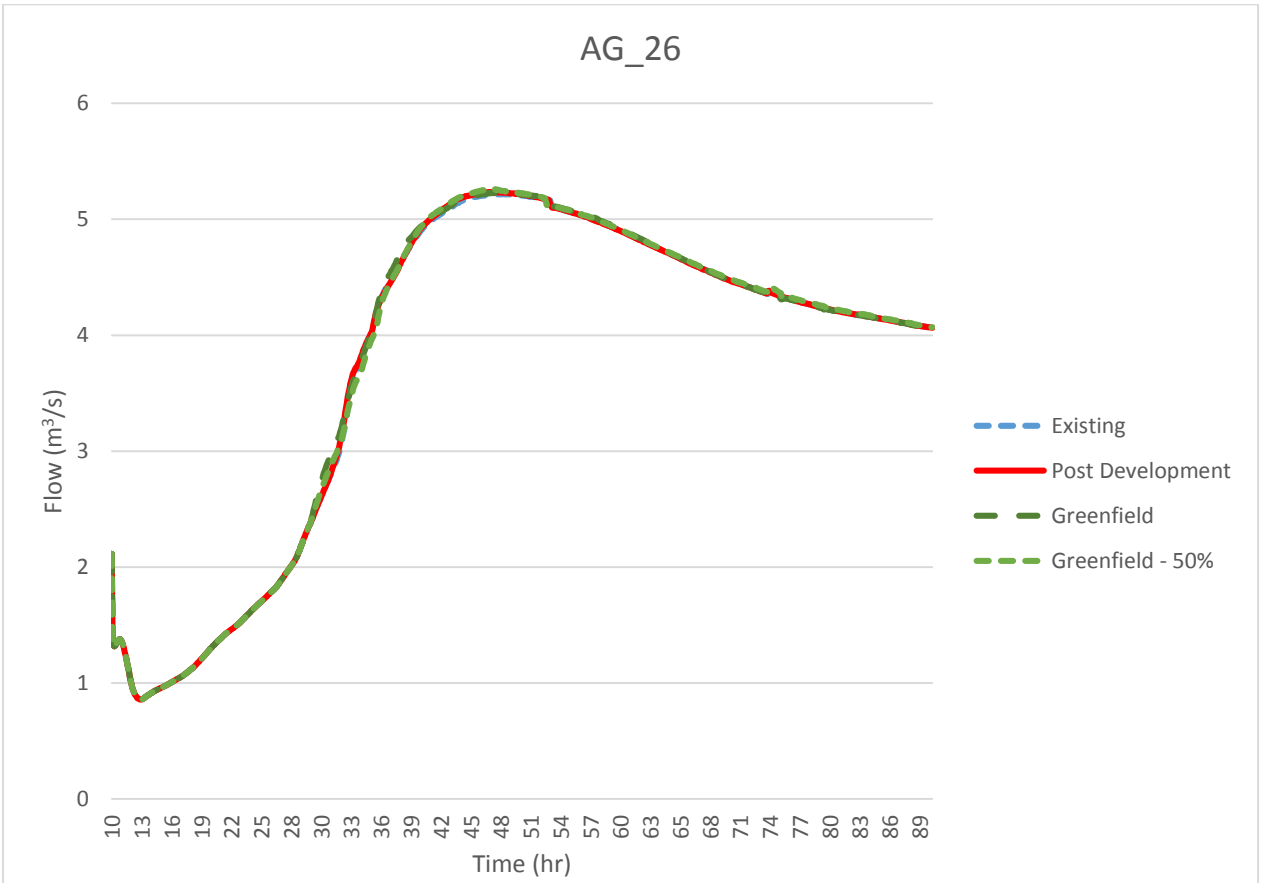


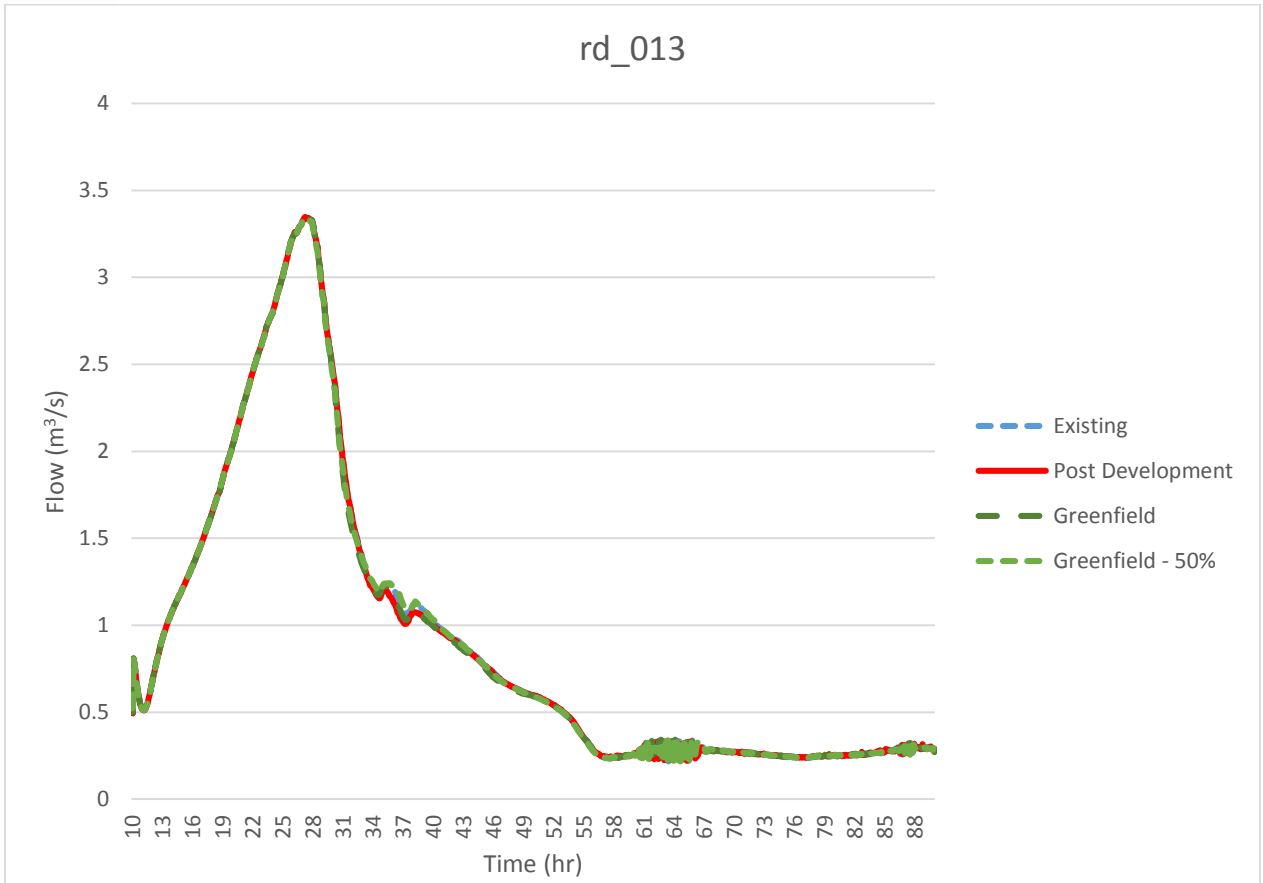
Figure A-7: 1% AEP + Climate change flood extent for Ashford for area 7

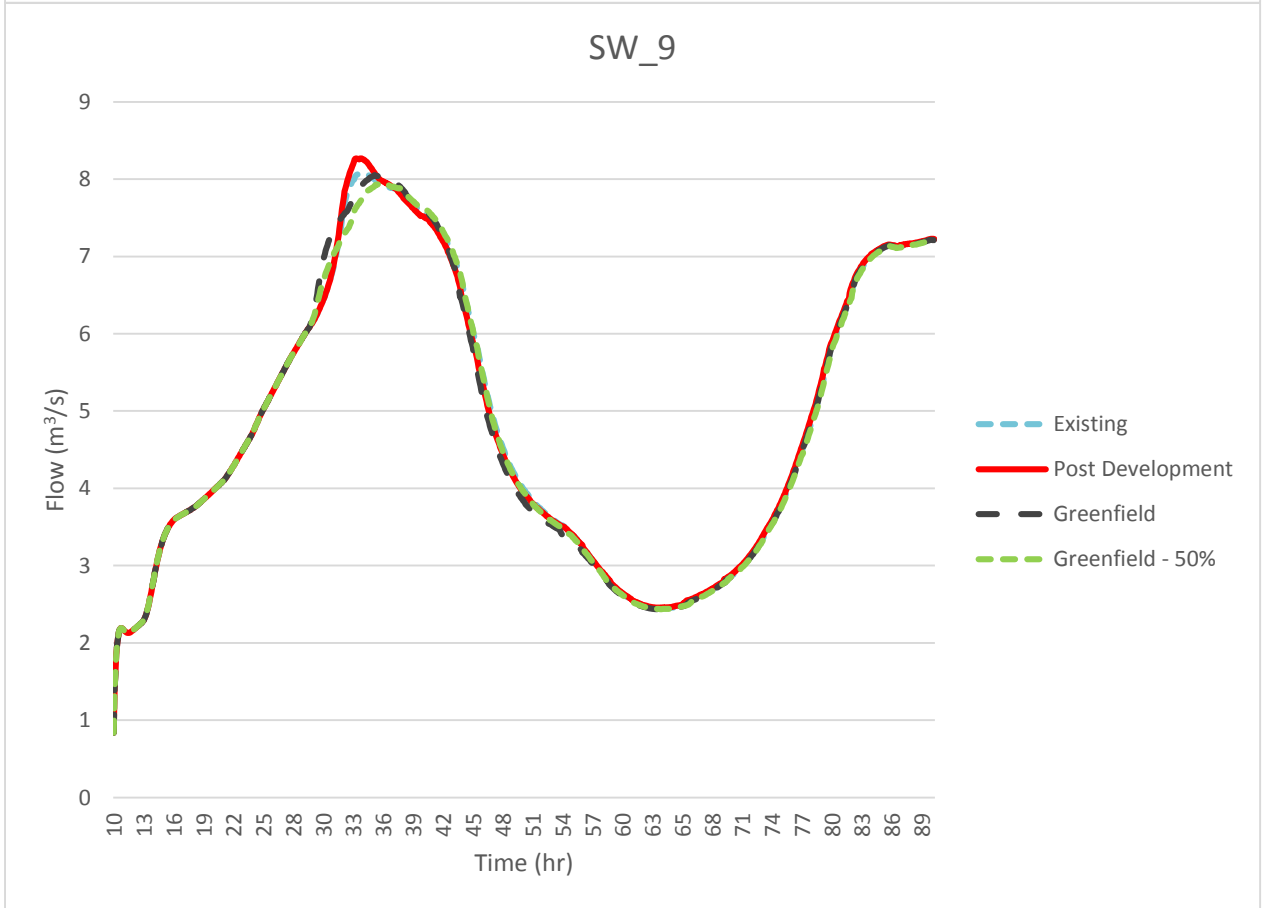


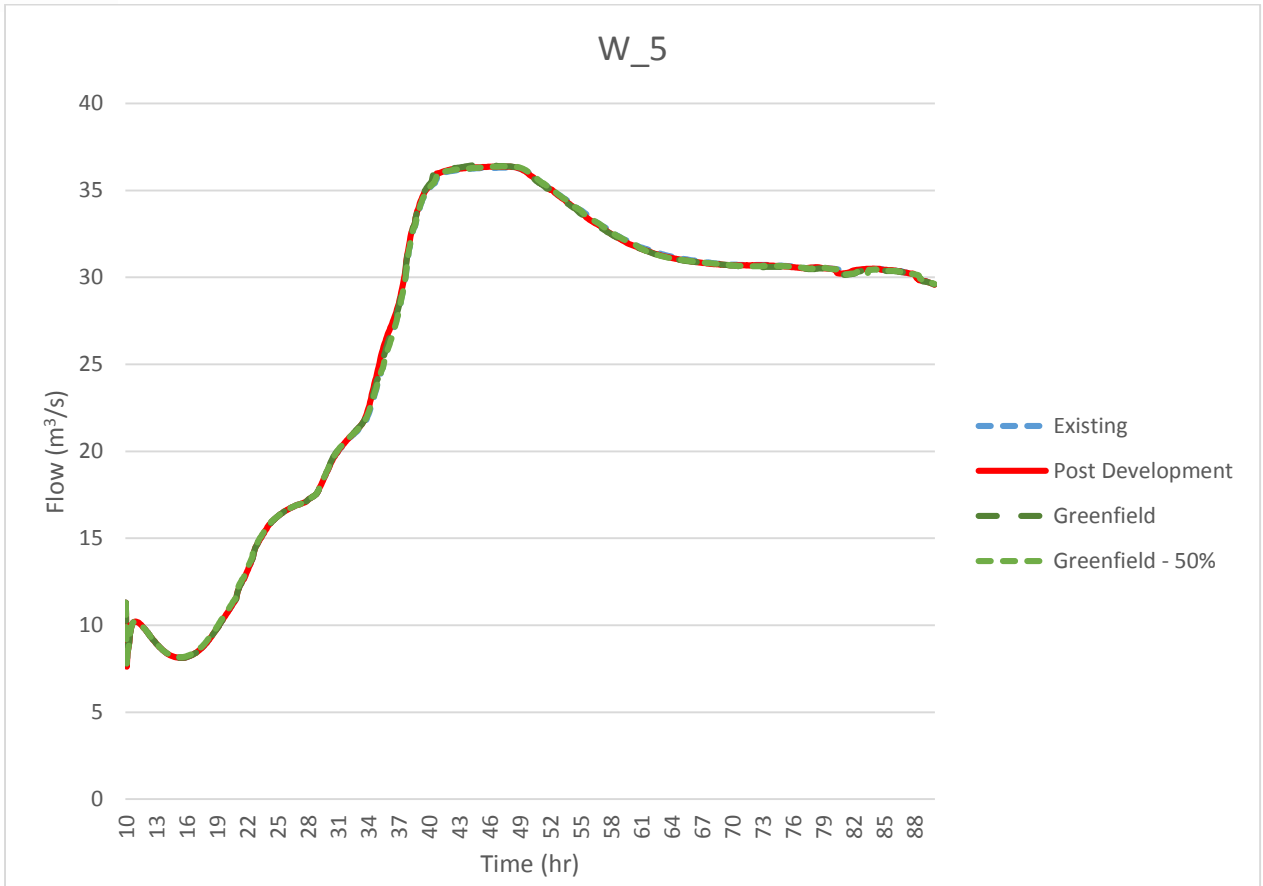
A.5 ISIS 1D flow hydrographs for nodes of the Great Stour model

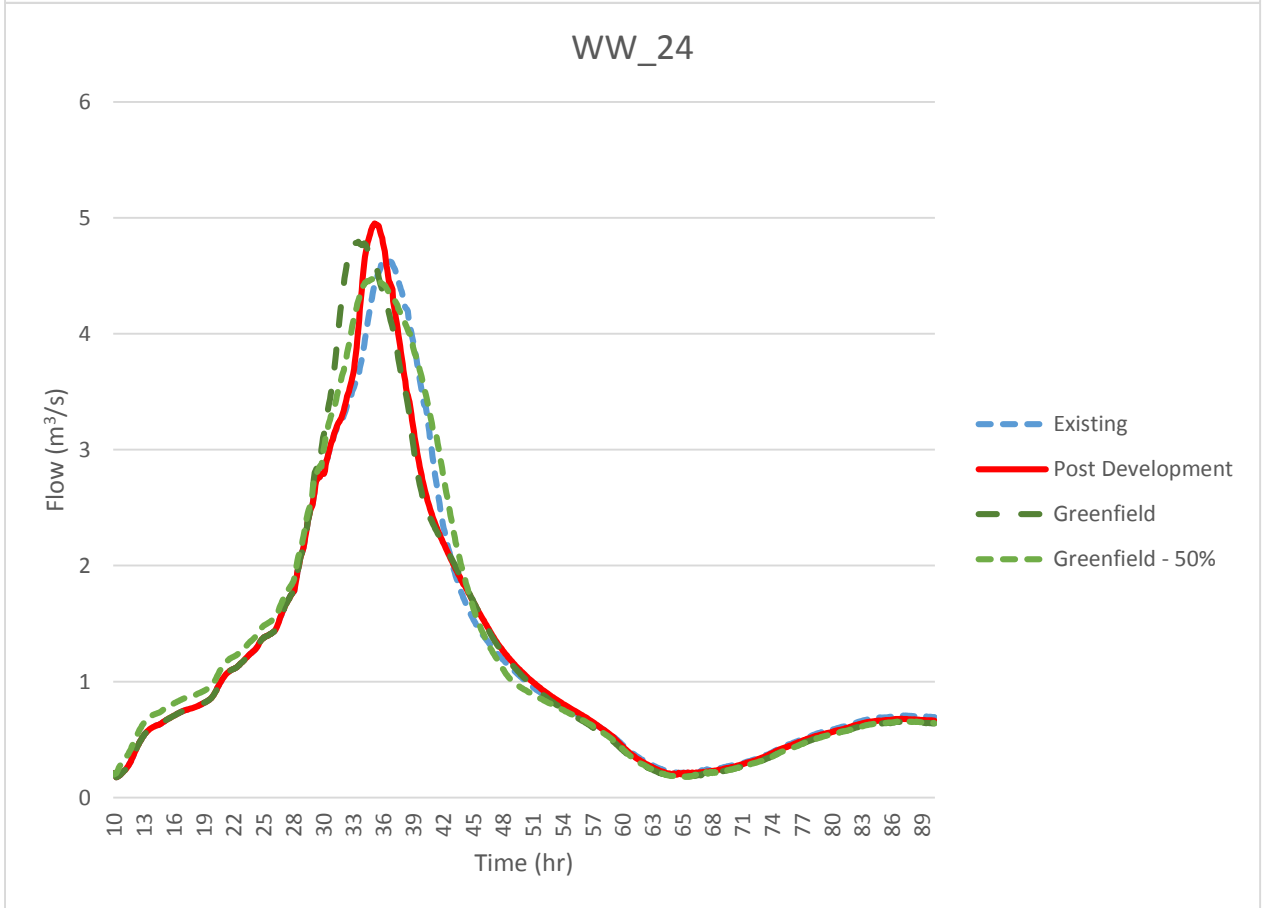





rd_013
Flow (m³/s)
Time (hr)
Existing
Post Development
Greenfield
Greenfield - 50%


SW_9
Flow (m³/s)
Time (hr)
Existing
Post Development
Greenfield
Greenfield - 50%


W_5
40
35
30
25
20
15
10
5
0
Flow (m³/s)
10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88
Time (hr)
Existing
Post Development
Greenfield
Greenfield - 50%


WW_24
6
5
4
3
2
1
0
Flow (m³/s)
10 13 16 19 22 25 28 30 33 36 39 42 45 48 51 54 57 60 63 65 68 71 74 77 80 83 86 89
Time (hr)
Existing
Post Development
Greenfield
Greenfield - 50%

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