APPENDIX 6.7
SUDS WITHIN ASHFORD

1. SUSTAINABLE DRAINAGE AND FUTURE DRAINAGE TECHNIQUES

1.1 Introduction to SUDS

Considerable attention has been given to 'sustainable' drainage design in the UK in recent years, with the term 'SUDS', or sustainable urban drainage systems becoming common parlance in engineering literature. The move towards sustainable drainage recognises that conventional separately drained systems of greenfield or even brownfield sites may not be acceptable in the 21st century, as development generally increases the proportion of 'impermeable' surfaces through the roofs, roads and similar impermeable surfaces in any development. This results in a higher proportion of runoff being collected and conveyed to adjacent watercourses; this runoff also occurs more rapidly, resulting in 'peaky' runoff hydrographs. Such increases may result in large changes in drainage requirements locally, although these may become smaller catchment-wide

Research into the application of SUDS has culminated in the CIRIA design guides (CIRIA, 2000, 2001, 2003). This manual presents a palette of sustainable drainage systems that maximise natural drainage in a development and tries to maintain runoff peaks and volumes close to their natural, greenfield, values.

It should nevertheless be recognised that SUDS is not a 'magic bullet' for drainage. The CIRIA manual's strength is that it has drawn together new ideas with a range of techniques used worldwide for the last couple of decades (for example Japanese use of porous pavements and perforated pipes and Australian swales), and presented clearly their use and limitations.

All SUDS techniques essentially depend on the detention of runoff, whether it is in overlarge surface channels, swales, or in more conventional detention storage ponds, and its infiltration into the ground. The application of SUDS to Ashford will make best use of these techniques, but it must be recognised that their use will not presently allow 31,000 new homes and associated development to be developed around Ashford with zero impact on the surrounding watercourses.

1.2 Future developments in drainage

Ashford's accelerated development will continue for about 30 years. It is worth asking whether technological developments will be made to SUDS in the interim such that one can imagine a development with no impact on the surrounding watercourses. If so, it may be valid to assume a high degree of efficiency for SUDS. Ultimately, as noted above, SUDS can only use drainage techniques based on detention and infiltration. It is unlikely that these techniques can be radically improved in efficiency. However, it is likely that there will be improvements to:

- Maintenance; and
- Design methods.

Maintenance is a current concern as to the long term effectiveness of SUDS. SUDS requires more regular maintenance then a conventional piped system. In the longer term, systems such as porous pavements and soakaways may need partial or full replacement due to clogging up of flow paths. One might reasonably expect such problems to be adequately solved during the long-term development of Ashford's, either due to improved materials, or due to the establishment of proven maintenance regimes.

At present, there remain significant problems in calculating runoff quantities from small catchment areas (Cawley & Cunnane, 2003). To the practitioner, field runoff equations seem to give too low an answer, yet the Rational Method often seems to provide improbably high flows. Further, neither seem to be consistent with the results obtained from the methods contained in the Flood Estimaton Handbook (FEH), working at the lower end of their area range. With a general acceptance of SUDS, there will be pressure from practitioners for more research in this field, and one can expect improvements to design techniques for the quantification of urban runoff.

Finally, one must ask whether there could be any radically new ideas in drainage and flood management over the next decade or so. Flood management has long been accused of being a conservative science, but perhaps unfairly, as it is required to handle large volumes of water in a short period. One area that could bring considerable benefits would be an effective approach to aquifer recharge. This would allow a direct link to be drawn in the water systems map from flood flows to water supply and would impact both winter surpluses and summer shortages of water. However, it is unlikely that such a scheme could be implemented successfully in Ashford due to the prevailing geology (see below). Trial schemes elsewhere have had mixed success, and there is always the risk of contamination to the aquifer.

1.3 Geology of Ashford

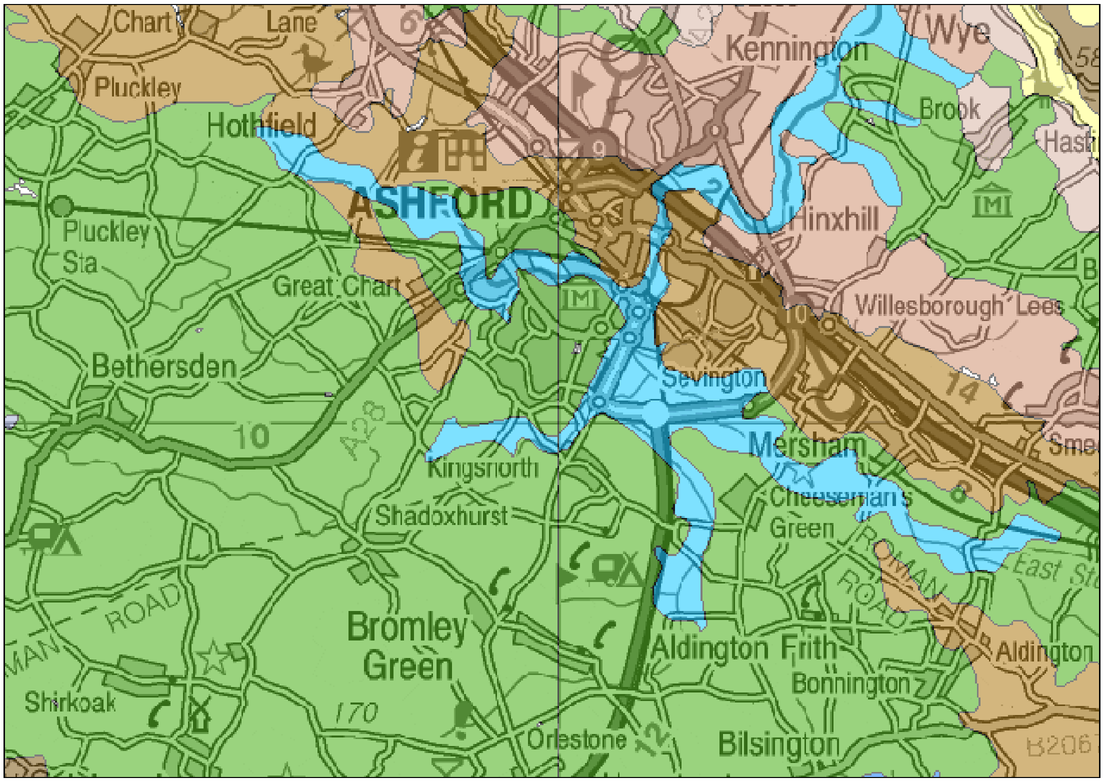
Having examined the principles of SUDS, this section applies these principles to Ashford. It is helpful to first examine the soil types. The Multi-Agency Geographic Information for the Countryside (MAGIC) project brings together definitive rural designation boundaries and information about rural land-based schemes into one place. A 'soilscapes' data set was added to MAGIC in June 2004. This provides a simple and accessible soils map for England and Wales, which amalgamates the 300 soil associations in the National Soil Map legend to 27 broad landscape types (being called 'soilscapes'). The 'soilscapes' for Ashford are shown on Figure 1.

It can be seen that for Ashford:

- The soils to the north of the M20 are generally Type 5, 'Freely draining lime-rich loamy soils.'
- The soils between the M20 and the Great and East Stour upstream of their confluence are generally Type 9, 'Lime-rich loamy and clayey soils with impeded drainage.'
- The soils to the south of the Great and East Stour upstream of their confluence are generally Type 17, 'Slowly permeable seasonally wet acid loamy and clayey soils.'
- The soils directly adjacent to the Great and East Stour upstream of their confluence are generally Type 20, 'Loamy and clayey floodplain soils with naturally high groundwater.'

Of these soil types, only Type 5 is clearly suitable for SUDS infiltration solutions. Type 9 may be variable in composition, and locally suitable for infiltration. Type 17 is slowly permeable, suggesting that detention storage may be the preferred SUDS option in these areas. Infiltration is unlikely to be effective to control runoff from large development areas. Type 20 is more permeable, but since it is on the natural floodplain, with high groundwater, again it suggests that detention storage should be preferred to infiltration in this area. In times of extreme storm events, however, they would become ineffective, being located within the floodplain.

Referring the above 'MAGIC' soil types back to the Soil Map of England and Wales (Soil Survey, 1993) allows one to relate the soil type to its HOST (Hydrology Of Soil Types) classification, and hence to its Standard Percentage Runoff (SPR) value. Table 1 links soil type, SPR, SUDS solution and the Ashford development areas.



Map produced by MAGIC on August 2 2004. © Crown Copyright. All rights reserved. Defra 100018880 2004

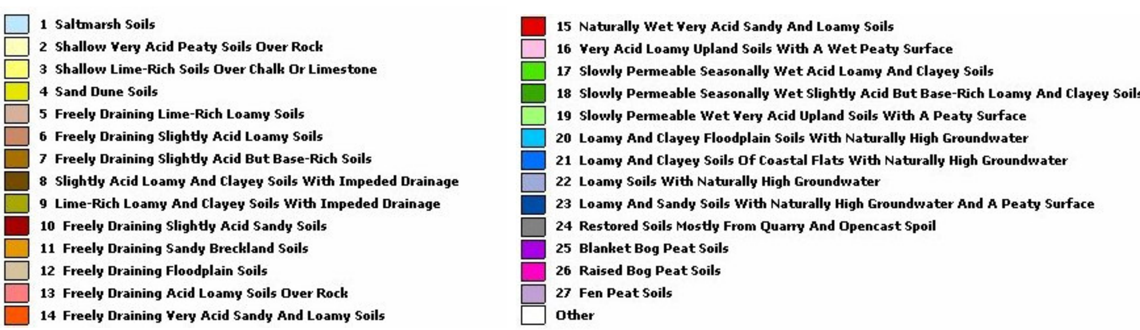


Figure 1 – Soil types around Ashford

Table 1 – Application of SUDS to development in Ashford

Soil type in Magic map	SPR	SUDS solution	Ashford development
5	14.5	Infiltration	Kennington 1, Kennington 2, Sandyhurst, Bockhanger, Bybrook Estate.
9	14.5 to 47.2	Infiltration/ Detention	Barracks, Town Centre, Alyesford Green, New Town Works, Orbital Park North, Sevington North
17	39.7 to 60.0	Detention	Cobb's Wood Estate, Chart Estate, Victoria Crescent, Sevington South, Goldwell, Chilmington Green, Stanhope, Stanhope West, Stanhope East, Kingsnorth, Park Farm, Cheeseman's Green, Canal South.
20	25.3	Detention	Town Centre South, Canal West, Canal North.

The conclusions from the above table are that in the most general terms, infiltration will only be effective to the north of the M20. Through the town centre and to the south, there may be local opportunities for infiltration, but the ruling soil types suggest that detention storage will be the only viable option. The use of detention storage means that:

- flood peaks may be controlled and maintained at their current magnitude; however
- flood volumes will increase.

The Ashford drainage system is sensitive to flood volumes as well as peak flows. This means that there may be some impact to flood levels, even when detention storage is used. There are also planning implications as to the land take required for the detention storage.

SUDS scenarios for Ashford

Figure 2 shows an outline drawing of proposed SUDS scenarios for Asford prepared by Urban Initiatives. It an be seen that the areas to the south of the M20 are generally shaded in green, and are labelled as being on Weladen Clay. The SUDS options proposed for these areas, on the drawing, are:

- 4a: Wet Meadow
- 4b: Reed bed/swale
- 4c: Wet woodland
- 4d: Dew ponds/reeds/willows
- 4e: Grassy/planted swale/hedge & ditch

It can be seen that these options are predominantly detention options. Although wet woodlands and wet meadows might be expected to retain and disperse water by evapo-transpiration and very slow infiltration into the clay, this will only be effective for minor events. For extreme design events such as a 100-year event, the above SUDS measures will effectively operate as detention storage ponds.

Overall, the above proposals are consistent with the conclusions of this Section, that the southern Ashford development areas are unsuitable for infiltration-based SUDS, and that detention storage techniques must be adopted.

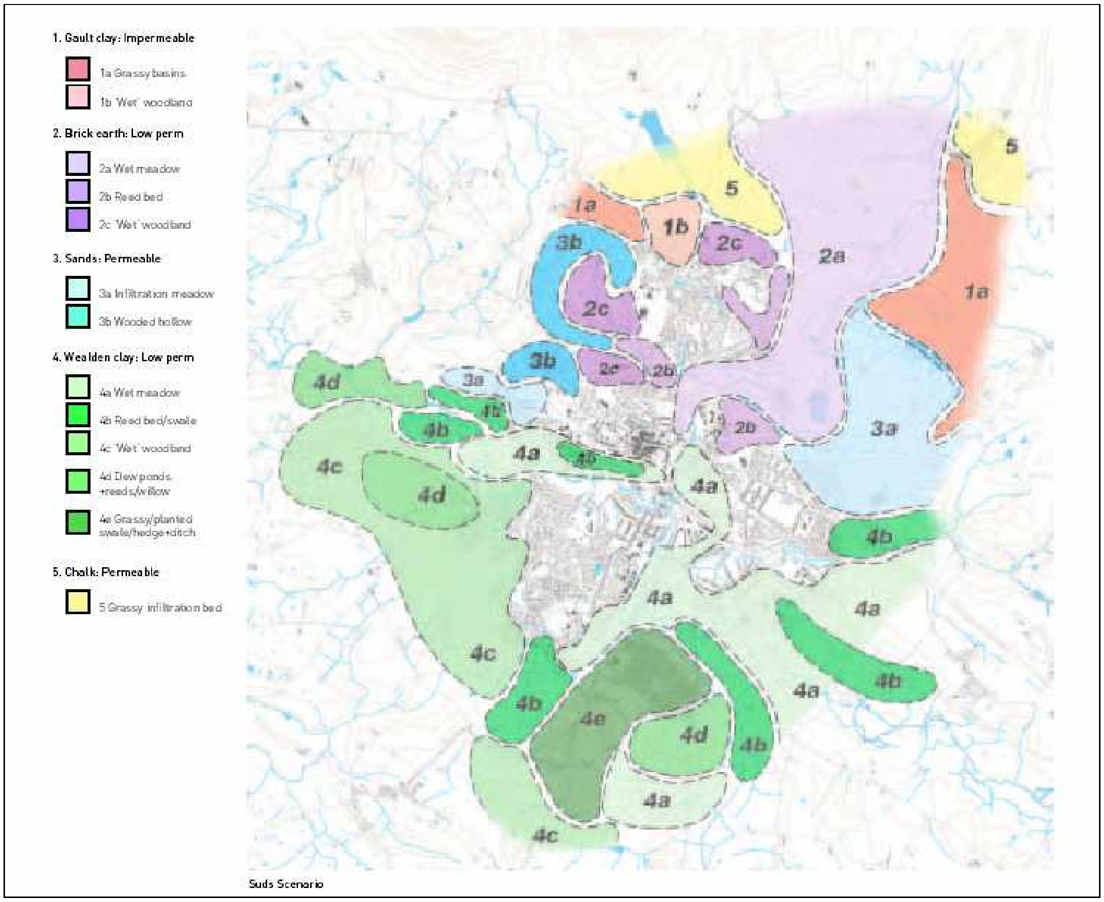


Figure 2 – SUDS scenarios for Ashford

(Source: Urban Initiatives)

1.4 SUDS in catchment design for Ashford

For use in the Stour catchment model, SUDS designs must be translated into equivalent changes to the FEH catchment descriptors used in the unit hydrograph rainfall-runoff models. In the model, adjustments will be needed to account for:

- Increased urban area;
- Infiltration; and
- Increased lake area (added detention storage).

It is most unlikely that SUDS techniques can be applied to all areas of new development. However, detention storage options are more likely to be effectively applied than infiltration options. Three scenarios have therefore been investigated:

- An 'optimistic' case, with full SUDS assumed.
- A 'realistic' case, assuming:
  - 50%, by area, of all infiltration is implemented, north of Ashford; and
  - 75%, by area, of all detention storage is implemented, south of Ashford.
- A 'pessimistic' case with no SUDS.

These cases must be translated into consistent parameter changes within the ISIS hydrodynamic model, being represented as changes to parameters in the FEH rainfall runoff model.

1.5 Modelling urbanisation

The impact of urbanisation on catchment runoff remains an area of some uncertainty. In general terms, urbanisation causes catchment flows to increase in volume and become 'peakier' in nature, due to the increase in impermeable area from roofs, roads and areas of hardstanding, and due to the storm sewer system, as illustrated on Figure 6.5. There are, however, questions as to whether flow from high return period events returns to its old overland flow path, having exceeded the capacity of the storm sewers, and to the extent that houses, roads and the like form barriers to that overland flow.

The rainfall-runoff method contained within the Hydrology Module of ISIS, includes allowances for urbanisation in the unit hydrograph time-to-peak and percentage runoff models. The parameter URBEXT represents the extent of urban and suburban land within a catchment. Modelling the impact of increased urbanisation is typically achieved by modifying the parameter URBEXT within the Hydrology Module of ISIS. This approach has been adopted for the current interim report.

The version of the rainfall-runoff method contained within the Hydrology Module of ISIS assumes that 61.5% of the areas represented by the parameter URBEXT are comprised of impermeable surfaces. Information received from GADF indicates that the proportion of 'pure green' space, and the density of urban developments on the remaining area, could vary markedly from one development area to the next. An allowance has been made for these different development densities by applying a factor to the various areas covered by each type of area to provide a consistent URBEXT value. The different types of development and the adjustment factors adopted for the developed areas to determine post development values of URBEXT are given in Table 2.

Table 2 – Proportions of 'urban' area

Type of area	'Pure green' area %	Developed area %	Green area in development %	Paved area in development %	URBEXT adjustment factor
Yellow (residential)	20	80	50	40.0	0.65
Orange (high-density)	10	90	40	54.0	0.88
Red (industrial)	5	95	25	71.2	1.16

Note: The colour coding of areas refers to those shown on Figures 6.1 and 6.2.

1.6 Modelling infiltration

Areas that are urbanised, and use infiltration methods to control runoff, are simply simulated by making no changes to the FEH catchment parameters: assuming that the developed runoff is identical to that from the greenfield site in both peak flow and volume.

1.7 Modelling flood detention ponds

The most difficult aspect of urbanisation to model is the provision of SUDS in the form of detention ponds. During the detailed design of the development areas, it may be possible to use detailed ISIS models of individual developments and their pond systems. At this macro-planning stage however, a more general approach is required.

To the best of our knowledge, no approach has been developed for the simulated of flood detention on a macro scale. However, it is important to evaluate the potential impact of SUDS detention techniques in the Ashford area. Ponds have therefore been looked at in two ways in order to gain some impression of this impact. It must be stressed that these approaches are totally arbitrary, and are not backed by rigorous hydrological theory. When the individual developments for Ashford come to be designed, each pond must be analysed to assess both its local impact and its interaction with other detention ponds. It must be realised that the interaction of poorly designed detention ponds can actually increase downstream flows and levels.

The first approach recognises that flood detention ponds are designed to limit flood peaks from a development to the same level as from the greenfield site. There is, however, an increase in total runoff volume. This is generally done by limiting outflow from the pond, so that there is a slow release of flow from the development into the receiving waters. Effectively this lengthens the time to peak of the flow (Tp) from the catchment development, that has been previously reduced by urbanisation. It is possible to simulate this design process on a macro scale within the ISIS FEH rainfall-runoff unit by the following process:

- Increase URBEX to represent the urban development within the catchment, with a corresponding increase in peak flow and reduction in Tp.
- Increase Tp of the unit hydrograph to the same value as the original, undeveloped catchment.

It must be again stressed that this is an approximate approach, but one that allows consistent comparisons of development options. Figure 6.5 shows this approach applied to the 15km^2 catchment at the head of the Aylesford stream, before and after urbanisation. It can be seen that the peak flow rises slightly above the natural catchment hydrograph, but this increase is small compared with the urbanised flow hydrograph, and the resulting hydrograph has additional volume on the falling limb, from the additional runoff from the urbanised area.

The second approach is simpler, and merely assumes that the detention ponds are simulated by assuming only 50% of the actual urbanisation adjustment to URBEXT. This is reflected by a limited increase in both flow and volume, as shown on Figure 3

Although adjustment to Tp gives a better 'aspirational' simulation of flood detention ponds, the simple adjustment to urbanisation is easier to apply, and has therefore been used for this paper. Combining the above discussion with the adjustments described earlier in this section, that assume it unlikely that SUDS techniques can be applied to 100% of the area of new developments. The three design scenarios therefore become:

- An 'optimistic' case, with full SUDS assumed – no adjustment to URBEXT.
- A 'realistic' case, assuming:
    - 50%, by area, of all infiltration is implemented, north of Ashford, with adjustment to URBEXT for 50% of area.
    - 75%, by area, of all detention storage is implemented, south of Ashford, with an adjustment to URBEXT of 0.75*0.5*100 = 37.5% of area.
- A 'pessimistic' case with no SUDS – full adjustment to URBEXT.

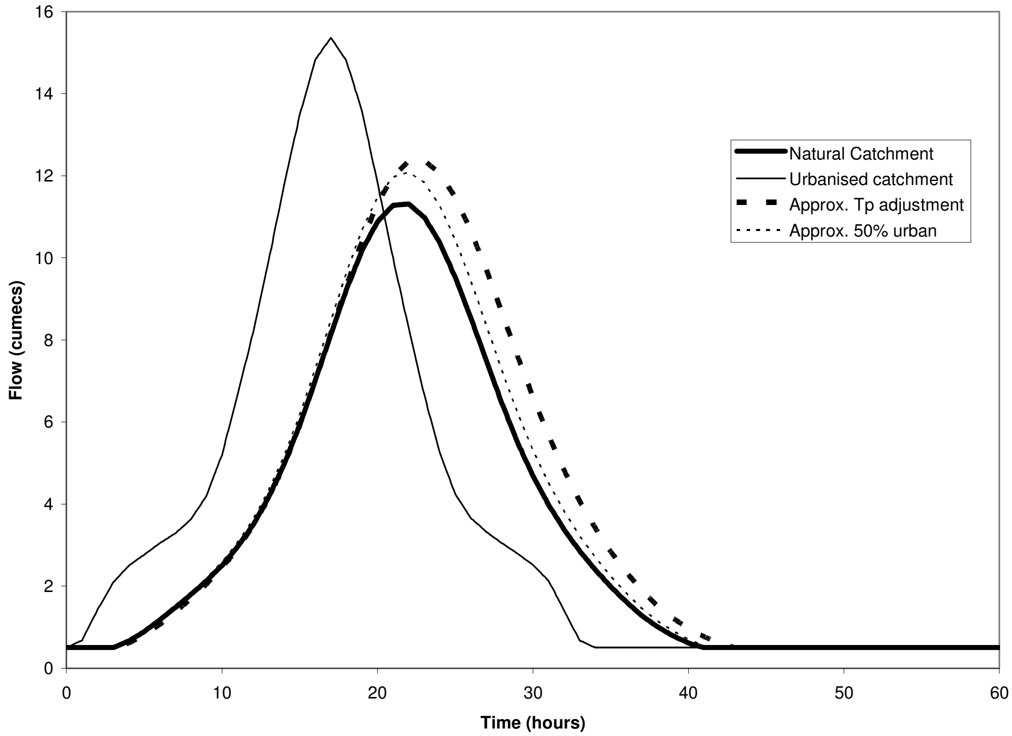
Table 3 shows the adjustment of URBEXT for the individual catchment areas within the study area, used in the simulations described in Section 7.

Table 3 – URBEXT values used in ISIS model, including SUDS options

	Green area 1) 'Pure'	Green area 1) In dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. No.			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
2. Sub-catchment name:			**ald_in**	**int_inflow**	**RD_054**	**MiddleEStour***	**WW_063**	**WW(2)***	**AYLS_55**	**AYLS(2)***	**LowerEStour***	**HOTH_IN**	**RAIL_IN**	**CHART_IN**	**LowerGtStour***	**ds_m20**	**Nackholt**	**Boughton**	**Brook**	**us_wye**
3. Area (A_{catch}) in km^2:			49.890	10.500	14.100	2.500	3.060	5.200	13.400	6.650	2.300	61.230	3.360	2.420	2.900	7.270	10.580	12.280	5.540	14.560
4. URBEXT$_{1990}$:			**0.009**	**0.015**	**0.003**	**0.010**	**0.002**	**0.125**	**0.006**	**0.115**	**0.292**	**0.010**	**0.009**	**0.147**	**0.388**	**0.156**	**0.062**	**0.008**	**0.004**	**0.002**
5. Urbanised area (A_{urb}) in km^2:																				
Type of area	**'Pure'**	**In dev.**																		
Yellow (residential)	20%	50%	0.000	1.681	1.500	0.376	0.981	0.782	0.000	0.526	0.356	0.000	0.105	0.122	0.740	0.288	0.289	0.000	0.000	0.000
Orange (high-density)	10%	40%	0.000	0.000	0.000	0.000	0.000	0.304	0.000	0.000	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red (industrial)	5%	25%	0.000	0.116	0.000	0.000	0.000	0.000	0.394	0.385	0.000	0.000	0.000	0.000	0.000	0.308	0.000	0.000	0.000	0.000
6. Contribution to URBEXT (km^2)																				
Yellow: 0.65 x A_{urb}			-	1.093	0.975	0.244	0.638	0.508	-	0.342	0.231	-	0.068	0.079	0.481	0.187	0.188	-	-	-
Orange: 0.88 x A_{urb}			-	-	-	-	-	0.268	-	-	0.058	-	-	-	-	-	-	-	-	-
Red: 1.16 x A_{urb}			-	0.135	-	-	-	-	0.457	0.447	-	-	-	-	-	0.357	-	-	-	-
7. Total contribution to URBEXT (km^2)			0.000	1.228	0.975	0.244	0.638	0.776	0.457	0.789	0.289	0.000	0.068	0.079	0.481	0.544	0.188	0.000	0.000	0.000
8. URBEXT$_{FUTURE}$ for no SUDS (4 + 7/3)			**0.009**	**0.132**	**0.072**	**0.108**	**0.210**	**0.275**	**0.040**	**0.233**	**0.418**	**0.010**	**0.029**	**0.180**	**0.554**	**0.231**	**0.080**	**0.008**	**0.004**	**0.002**
9. 'Realistic' SUDS (km^2)			0.000	0.614	0.488															
Infiltration areas 50% of 7																0.272	0.094	0.000	0.000	0.000
Detention pond areas 38% of 7			0.000	0.460	0.366	0.092	0.239	0.291	0.171	0.296	0.108	0.000	0.026	0.030	0.180					
10. URBEXT$_{FUTURE}$ for 'realistic' SUDS (4 + 9/3)			**0.009**	**0.073**	**0.038**	**0.047**	**0.080**	**0.181**	**0.019**	**0.159**	**0.339**	**0.010**	**0.017**	**0.160**	**0.450**	**0.193**	**0.071**	**0.008**	**0.004**	**0.002**

Notes:
1) Source: GADF
2) The colour coding areas refers to those shown on Figures 2.1 and 2.2 of the report.
3) URBEXT$_{FUTURE}$ is URBEXT post development (2004). URBEXT values between 1990 and present are not known.
4) * is denoted for additional area to the Section 105 model.

Figure 3 – Impact of urbanisation and detention ponds



1.8 Simulation of SUDS within IWMS

The use of SUDS technology is important and integral to the flood risk management for Ashford. The Interim Report on FRM looked closely at the use of SUDS within Ashford and brought out a number of issues as to its use:

- Firstly, the use of SUDS is fully included in the FRM components. All SUDS techniques essentially depend on infiltration into the ground and/or the detention of runoff, whether it is in overlarge surface channels, swales, porous car parks with underlying tanks, wet woodland or in more conventional detention storage ponds.
- Within Ashford, the surface geology suggests that infiltration will be effective north of the M20, and will be the predominant application of SUDS in this area.
- South of the motorway, infiltration will only be effective locally and for small areas. SUDS in the form of detention storage therefore has been assumed for all areas to the south of the motorway.
- The best use of SUDS techniques will manage the increased runoff from developments within Ashford to a large extent. However, it must be recognised that their use will not allow 31,000 new homes and associated development to be developed around Ashford with zero impact on the surrounding watercourses.
- A number of sketches have been seen by BV showing SUDS techniques, such as reed beds or wet woodland, within the limits of the floodplain. Indeed, the Option 6 Masterplan shows major water features located within the floodplain. It must be stressed that this is effectively double-counting FRM measures. Both the floodplain and many SUDS techniques are detention storage.

Subsequent to the consultant's review and upgrading of the S105 model, and with the release of Development Option 6, further investigations of the effectiveness of SUDS within Ashford have been carried out. Two important issues have emerged.

Firstly, an additional series of ISIS model runs have been carried out, based on GADF Option 6. They have also used the alternative method for simulating SUDS to that described in the Interim Report on FRM. In this method, the time to peak of the sub-catchment runoff hydrographs are lengthened *so that the <u>peak</u> flow after urbanisation is the same for the Greenfield site before development.* This is, of course, the aim of most SUDS measures.

Having carried out these ISIS runs on this basis, it was perhaps surprising to find that, after the application of SUDS, the peak levels in the watercourses around Ashford do not return to the baseline (pre-development) levels, even assuming full application of SUDS to the urban areas. Full model results are presented in Appendix 7.3. For a key location, just downstream of the confluence of the Great and East Stour, for the 100-year flood, urbanisation (without SUDS or loss of floodplain due to the Canal District) raises water levels by 70mm, but the application of SUDS only reduces this by 35mm.

On reflection, this is due to the drainage system within Ashford being both *peak* and *volume* sensitive. Water levels are not just controlled by the peak flood flows in the river. They are also controlled by the storage of volume within the flood plain in the Ashford area. SUDS based on detention storage can reduce the *peak flow* entering the rivers, but the *peak volume* will always be higher due to the increased impermeable areas due to urbanisation.

Is it possible to reduce the impact of urbanisation in a volume controlled system further? The residual increases in level are very small, typically 35mm. Nevertheless, the Environment Agency's target is for as low a residual as possible. The ISIS model runs also showed that further increasing the time to peak of flows from the sub-catchment could reduce the residuals to less than 10mm. In reality, this will require Ashford BC to set the outfall rate of developed runoff to be *less than* the greenfield value. The above is only an issue in the areas of the catchment using only detention storage, rather than the infiltration.

The above statements have allowed SUDS options to be modelled on a basin-wide scale. However, the work also highlighted limitations as to the use of SUDS. For both SUDS and the rural equivalent - land use management techniques, described below - UK practitioners require a coherent set of design methodologies. There are real problems in estimating runoff from small areas in the UK. A range of methods may be used, such as:

- field drainage by ADAS' approach, often used by the EA;
- urban runoff approaches using Hydroworks/InfoWorks CS methodology;
- small catchment procedures such as researched by IoH124.
- the Flood Estimation Handbook (FEH); or
- the Rational Method.

Each of these methods will give a different value. At this time, the Environment Agency's usual method of defining Greenfield runoff by ADAS' methodology would appear to be as good as any. Typical values might be 6 l/s/ha for the south of Ashford, and 2 l/s/ha for the infiltration areas to the north. In view of the volume effects of SUDS runoff described above, values of 4 l/s/ha for the south of Ashford and and 2 l/s/ha for the infiltration areas to the north are suggested. Definitive values need to be agreed by the Environment Agency and Ashford Borough Council based on their more detailed experience of the area.

Defra/EA have recently released interim guidance as to the calculation of greenfield runoff. This is included as Appendix 7.4. The approach described can only be interim, as it uses a number of outdated approaches. However, essentially it allows the designer to set the allowable runoff from a development site.

The long term maintenance and efficiency of SUDS technology may also be questioned, as to the performance of some options in high return period storms.

1.9 References

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