Green Infrastructure Valuation Toolkit

Supplementary notes: revised tool 2.1

Energy and carbon emissions savings from reduced stormwater volume entering combined sewers

Underlying model

The underlying model was used by The University of Manchester in the ASCCUE project where it was applied to Greater Manchester (Gill, 2006; Gill et al, 2007). It had previously been developed and used in Merseyside (Whitford et al, 2001).

The surface runoff model is based upon the US Soil Conservation Service approach (Soil Conservation Service, 1972). It takes a daily rainfall amount, and then calculates how much of this rainfall will not be converted to surface runoff; this could be because this rainfall is intercepted (e.g. by plants and vegetation), infiltrated (e.g. into the soil), or stored (e.g. on surfaces). The remaining rainfall is converted to surface runoff.

The method is based both on theory as well as on the results of empirical studies into precipitation runoff from many small watersheds in the US. It assigns 'Curve Numbers' to a range of different surface types, depending on the hydrological properties of the soil, and how wet it has been in the preceding 5 days. The more impervious the surface (e.g. built and sealed surfaces) the higher the curve number is; whilst the less impervious the surface (e.g. vegetated surfaces), the lower the curve number is. A combined 'Curve Number' can then be applied to the area of interest by weighting all of the individual curve numbers according to the area they cover.

As it is used in the STAR tools, the model:

- Calculates the percentage of the rainfall that becomes surface runoff, and the volume of this surface runoff.
- Has few input requirements (surface cover, precipitation, antecedent moisture conditions, and hydrological soil type) and is straightforward to use. Models vary greatly in their complexity and data requirements. Whilst there is a temptation to use the most complex model available, there can often be much uncertainty in the values given to parameters.
- Allows the role that different vegetated surfaces can play within urban areas to be considered. Other models do not necessarily do this. For example, in the UK, the method used in the Flood Estimation Handbook distinguishes between urban (mostly covered by concrete and other impervious surfaces) and suburban (a mixture of paved areas and vegetation) development.
- Considers direct surface runoff; it does not consider the case when high ground water levels contribute to runoff.
- Does not calculate the speed or rate of the runoff.

- Does not include slope as an input parameter. This is because runoff volume is not highly dependent on slope whereas runoff speed is. Runoff volume is determined mainly by "the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention" (Natural Resources Conservation Service, 1986, p1-1). However, the infiltration capacity is altered by slope, as larger slopes provide less opportunity for infiltration (Mansell, 2003). Slope is also not included in the UK Flood Estimation Handbook method for estimating effective rainfall, but is used to estimate the time taken to reach peak flow (Mansell, 2003).

- Does not include storage in depressions in the ground.

- Has been applied in Merseyside and Greater Manchester, but has not been validated. However, the model was developed from experimental studies of small watersheds and is widely used in the United States (Natural Resources Conservation Service, 1986).

More information on the surface runoff model can be found in chapter 6 of Susannah Gill's PhD thesis.

As used in the valuation toolkit, the antecedent moisture conditions are assumed to be normal. Also, note that the way the model is used in the toolkit assumes that any vegetation is mature at the beginning of the 50-year valuation period. Results should therefore be used with caution if, for example, trees are being planted as whips.

Land cover

Ideally, these figures should be derived from an aerial or birds-eye view of your study area. So, for example, a tree over a small residential road counts towards the percentage of trees, rather than the percentage of other impervious surfaces.

By default the figures are estimated based upon information entered into the Project Data sheet. It is recommended that more detailed land cover data and data from tree audits should be used wherever available.

If such data is not immediately available, it can be derived in GIS from aerial imagery using one of the following methods:

- Estimating the percentages of the different land cover types
- Digitising the different land cover types
- Placing a grid over your study area and assigning the predominant land cover type in each cell
- Placing random points (400 points recommended) within your study area and identifying the surface cover under each (this approach was used in the ASCCUE project and is explained in chapter 3.3 of Gill, 2006).

The underpinning model assigns 'curve numbers' to the different land cover types; and surface runoff is calculated from this. It is therefore advised that, when collecting land cover data you try to distinguish between those land covers that are the most different in terms of their curve numbers.

Curve numbers for the land cover types required for surface runoff tool (for hydrological soil type A under normal antecedent moisture conditions; Gill, 2006)

Land cover type	Curve number
Trees	25
Rough grass	30
Mown grass	39
Shrubs	45
Cultivated surfaces	67
Bare soil or gravel surfaces	74
Buildings and other impervious surfaces	98
Water	n/a

Annual rainfall

Use of the annual rainfall figure gives a significant underestimate of the water diverted from sewers. If daily rainfall figures are available, these can be entered near the bottom of the sheet, which will give more accurate results. For example, one experimental run of the tool using daily figures gave a final value of about £1m, whereas the equivalent using an annual figure gave a final value of only about £30k.

The daily figures can be automatically populated for UK regions by selecting the Met Office region. This uses data from http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html for the years 1988 – 2017.

Alternatively within the UK, data for a specific location (rather than a generalised area) can be purchased from the Met Office. Another source, with global coverage, is http://www.ncdc.noaa.gov/cdo-web/search ('Daily Summaries').

Note that if the location is a significant distance from the study area, it may experience very different weather, in which case significant error may be introduced into the final outputs.

A value of -99.99 is used to represent a non-existent day.

Hydrological soil types

Soils are classified into four hydrologic soil groups (A-D) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The infiltration rate is the rate at which water enters the soil at the soil surface and is controlled by surface conditions. The hydrologic soil type also indicates the transmission rate of water through the soil, controlled by the soil profile (Natural Resources Conservation Service, 1986). In practice, soil profiles may be considerably altered as a result of urbanisation; in such cases the classification should be made according to the texture of the new surface soil, providing that significant compaction has not occurred (see disturbed soil profile in table 1). In addition, some soils will be classed as group D because of a high water table that creates a drainage problem; once these soils are effectively drained they are classified differently (Natural Resources Conservation Service, 1986).

US Soil Conservation Service hydrologic soil classification, with recommendations for disturbed soil profiles (after Natural Resources Conservation Service*, 1986)*

Soil Type	Description	Disturbed soil profile texture
A	Soils having low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 7.62 mm/hr).	Sand, loamy sand, or sandy loam
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (3.81-7.62 mm/hr)	Silt loam or loam
C	Soils having low infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (1.27-3.81 mm/hr).	Sandy clay loam
D	Soils having a high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-1.27 mm/hr).	Clay loam, silty clay loam, sandy clay, silty clay, or clay

By default, it is assumed that the whole study area is on soil of type C – a moderate and conservative assumption. However, more accurate results will be obtained if the true figures are entered. LandIS data from the National Soil Resources Institute at Cranfield University, which classifies soils into seven runoff potential classes, is suitable for this purpose. The Cranfield categories can be translated: S_1, S_2, P_1 and P_2 to hydrological soil type D, S_3 to type C, S_4 to type B, and S_5 to type A.

Runoff potential and soil classes

Runoff potential	Soil class
Peat very high	P_1
Peat high	P_2
Very high	S_1
High	S_2
Moderate	S_3

Low	S_4
Very low	S_5

UK data used can be purchased from the National Soil Resources Institute at Cranfield University www.landis.org.uk/data/index.cfm. It may also be useful to look at the Soilscapes online mapping which, although it does not contain runoff potential classes, has free information which could be useful in determining a hydrological soil type www.landis.org.uk/soilscapes.

References

Gill, S.E. (2006). Climate change and urban greenspace. PhD thesis, University of Manchester. http://www.ginw.co.uk/resources/Susannah_PhD_Thesis_full_final.pdf (see chapters 5 and 6 in particular).

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Mansell, M.G. (2003). Rural and urban hydrology. Thomas Telford, London.

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