018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project

Global Change and Ecosystems

DELIVERABLE 2.3.2a: A GIS DATA INTEGRATION TOOL FOR ASSESSING STORMWATER MANAGEMENT OPTIONS: USER GUIDE

Due date of deliverable: January 2009

Actual submission date: June 2009

Start date of project: 1 February 2006 Duration: 60 months

Organisation name of lead contractor for this deliverable: Middlesex University

Prepared by Christophe Viavattene, Middlesex University

Revision: Final

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SWITCH Deliverable Briefing Note Template

SWITCH Document

A GIS Data Integration Tool for Assessing Stormwater Management Options: User Guide (Deliverable 2.3.2a).

Audience

This deliverable describes a stormwater decision support (DSS) tool designed to assist practitioners (drainage engineers, urban decision-makers, private developers, city planners, water managers, environmental legislators/regulators, environmental modelers) in the selection and location of BMPs for a defined catchment area. The tool will be initially applied and tested by the Birmingham Learning Alliance and to the Birmingham Eastside development area. It is also aimed at the wider SWITCH consortium, specifically those with an interest in stormwater management in the Demonstration cities.

Purpose

The purpose of the user guide is to describe the structure of a GIS model, which has been developed to assist in the identification and location of sites within a catchment that are appropriate for the installation of stormwater BMPs for the control of wet weather flow and associated water quality. The presented report directs the user through the different stages and use of the tool and highlights how the benefits can be best achieved.

Background

The user guide is organized into the following sections which initially outline the operating principles of the GIS-based tool and then instruct the user on how to derive the optimum information regarding the identification and location of BMPs.

- Introduction
- Procedure for downloading the program
- File requirements
- Launching the Tool
- The GIS interface
- The user-friendly interface
- Conclusion
- References

The 'user-friendly interface' identifies the important operational components of the tool and is divided into the following sections:

1. Project properties
2. Symbology
3. Unit operation process and pollutant removal

4. Multi-criteria analysis (MCC)
5. Site criteria
6. Potential areas (for BMP location)
7. Site by site analysis
8. Add stormwater BMP

The 'Project properties' and the 'Symbology' interfaces allow the user to effectively manage the current project. The 'Parameter' interfaces (3, 4 and 5) relate to the unit operating processes within the BMPs, the pollutant removal potentials, the scores within the multi-criteria analysis, and/or the site characteristics) and allow the user to change values which influence the decision process within the tool. Finally, there are three interactive interfaces identified as 'Potential areas', 'Site-by-site' and 'Add stormwater BMP' which can be used to assess potential BMPs appropriate for a site.

By addressing a range of site characteristics (such as soil type and depth to groundwater) the tool identifies those sites where a selected BMP could be feasibly installed. Alternatively, individual sites can be examined sequentially to determine which BMPs are practicable at that location. The derived list of BMPs can be further discriminated in terms of either pollutant removal ability or by consideration of a range of influencing criteria. These criteria are described within the tool by a series of indicators relating to technical, environmental, operation and maintenance, social and community, economic, and legal and urban planning factors which are assessed using a multi-criteria analysis approach. The pollutant removal capabilities of the BMPs are assessed through a scoring system which combines a consideration of the unit operating processes within BMPs with the behaviour of different pollutants towards these processes.

Potential Impact

The GIS-based tool works in two directions by matching BMPs to sites and by indicating which BMPs are feasible at an identified site. The additional capacity to consider the pollutant removal capability of a BMP as well as its scientific, social, economic, operational and planning requirements makes this a powerful tool for practitioners involved in either designing a new urban drainage system or retro-fitting an existing one. It is particularly appropriate for analysis of the mitigating controls required for extreme event conditions.

Issues

The GIS-based methodology provides an integrated, sub-catchment/site planning approach to offer a high sustainability ethos for high density urbanization. The presented report is designed as a guide to highlight how the benefits of the tool can be best achieved. If the user of the tool has a particular preference for a specific BMP, the tool can search for sites where this BMP could be installed by dragging an icon across the search area. When a positive match is found, the characteristics of the site are displayed. It is possible to amend some of these characteristics to

assess the impact on BMP selection.
Recommendations The developed tool has the capability of identifying and locating those sites within a catchment where a particular BMP could be installed or, for a particular site, it can identify the different BMPs which are feasible. Where several BMPs are possible, they can be compared in terms of pollutant removal capacity or through a range of technical and non-technical criteria and indicators. Currently, within the SWITCH project, the tool is being linked with the STORM model. This will provide a more fully comprehensive approach to the prediction of the stormwater attenuation benefits which can be achieved by incorporating appropriately designed and positioned BMPs into a conventional urban drainage system. Stormwater practitioners will be able to use the extended tool to assist with the design of new drainage systems or the retro-fitting of existing systems involving the incorporation of BMPs for the control of extreme event flooding.

Table of Contents

Table of Figures

Summary

This deliverable, which has been developed in WP2.3 of the SWITCH project, describes the operating structure of a decision support (DSS) tool designed to assist practitioners in the selection of stormwater BMPs for a defined catchment area. The objective of the task associated with this deliverable was to develop a GIS-based model with the capacity to identify sites within a catchment which are appropriate for the installation of stormwater BMPs. In addition, it was planned to identify the most relevant type of BMP for use at a particular site in relation to site-specific conditions, such as soil type and depth to groundwater. By addressing a range of site characteristics the tool identifies those sites where a selected BMP could be feasibly installed. Alternatively, individual sites can be examined sequentially to determine which BMPs are practicable at that location. The derived list of BMPs can be further discriminated in terms of either pollutant removal capability or by consideration of a range of influencing criteria. These criteria are described within the tool by a series of indicators relating to technical, environmental, operation and maintenance, social and community, economic, and legal and urban planning factors which are assessed using a multi-criteria analysis approach. The pollutant removal capabilities of the BMPs are assessed through a scoring system which combines a consideration of the unit operating processes (OUPs) within BMPs with the behaviour of different pollutants towards these processes.

If the user of the tool has a particular preference for a specific BMP, the tool can search for sites where this BMP could be installed by dragging an icon across the search area. When a positive match is found, the characteristics of the site are displayed. It is possible to amend some of these characteristics to assess the impact on BMP selection.

The presented report is designed as a guide to highlight how the benefits of the tool can be best achieved. Because of current licence requirements associated with the GIS component of the tool it can only be made available to members of the SWITCH consortium on request. The tool works in two directions by matching BMPs to sites and by indicating which BMPs are feasible at an identified site. The additional capacity to consider the pollutant removal capability of a BMP as well as its scientific, social, economic, operational and planning requirements makes this a powerful tool for practitioners involved in either designing a new urban drainage system or retro-fitting an existing one.

1. Introduction

The contribution that stormwater BMPs (also known as Sustainable Urban Drainage Systems ; SUDS) can make to sustainable urban development through their potential to address the needs and concerns of a diverse group of stakeholders, has been widely recognised (Revitt et *al.*, 2008). These systems include a wide range of structures having different impacts in terms of water quantity and quality, posing different technical constraints and entailing variable costs. However, unfamiliarity with these techniques, and in many cases, the lack of technical knowledge held by stakeholders, could influence the decision-making process when selecting appropriate systems.

Urban stormwater models such as SWMM, MIKE II, MOUSE, Hydroworks or STORM (for a review of these models see Balmforth *et al.*, 2006; Elliott *et al.*, 2007; Ellis *et al.*, 2008) are now widely used to assess the impact of control devices on the urban drainage system. Such models provide a good representation of the physical and hydraulic phenomena but, because of their complexity, they are usually non-user friendly and are generally limited to technical issues (Balmforth *et al.*, 2006).

Geographic Information Systems (GIS) are commonly used to collect and manage the spatial data required as an input for such models. More recently they have also been used as post-processors to accept the output and enable a user-friendly representation of the results (Heaney *et al.*, 2001). In the context of a typical urban development scenario of multiple stakeholders drawn from a wide variety of backgrounds, there is clear potential for the use of such a central data integration and communication tool to act as a precursor to analytical modelling. The development of this type of specific GIS tool which will enable stakeholders to identify possible sites for the location of urban BMPs on a catchment-scale represents an obvious step-forward. Currently there are only a few examples of such dedicated tools (Makropolous *et al.*, 2001; Cappiella *et al.,* 2005; Lai et *al.*, 2007).

The Stormwater BMP DSS tool described in this deliverable has been developed with the objective of achieving the following requirements for users:

- Providing support for the identification of appropriate BMPs
- Supporting the integration of data (quantitative and qualitative) from a variety of sources to enable the investigation of the potential benefits of BMPs
- Incorporating user-friendly tools to ensure simplicity and ease of communication
- Requiring relatively few skills in GIS (once the spatial data are ready to use)

The current tool incorporates and extends the previously developed MCC approach (EU 5th Framework DayWater project) (Ellis *et al.,* 2008) which in addition to site characteristics, also benchmarks the performance of BMPs against a range of technical, environmental, economic, operation and maintenance, and social and legal criteria. In addition, an up-dated methodology for assessing the comparative pollutant removal potentials of different BMPs (Scholes *et al.*, 2008) has been included.

The current tool does not link directly to a stormwater model. The output from such a model could be imported as a shapefile layer and on-going developments within the SWITCH project are investigating the coupling of the described approach with the STORM model

(http://www.sieker.de/english/). This coupled GIS-based tool will provide a powerful tool for the analysis of pluvial flooding and pollution arising from extreme events in impermeable urban catchments.

An important output of the Stormwater BMP support tool is a GIS layer identifying appropriate positions for the installation of selected storm-water BMPs. This layer supports the creation of alternative land-use scenarios which, in turn, could be used in storm water modelling for comparative analysis and evaluation by stakeholders.

2. Procedure for downloading the program

The tool has to be downloaded on the root C:\ of the computer.
The folders should follow the respective pathways:

C:\ BMP_DSS_TOOL
C:\ BMP_DSS_TOOL\datalayer
C:\ BMP_DSS_TOOL\guidance
C:\ BMP_DSS_TOOL\icone
C:\ BMP_DSS_TOOL\paramdata
C:\ BMP_DSS_TOOL\picture

The BMP_DSS.exe is in the BMP_DSS_TOOL folder

3. File requirements

When the tool starts, it automatically uploads the different files; without these files the tool cannot work.

The two different types of files required are shapefiles (.shp) and text files (.txt). These are described in more detail below.

3.1. Shapefiles

A shapefile is a digital vector storage format, used within GIS, for storing geometric location and associated attribute information. Shapefiles are simple because they store primitive geometrical data types of points, lines, and polygons, which could for example represent wells, rivers and lakes, respectively. Together with attributes to specify what they represent they can create a large number of representations relating to geographical data.

In the described tool, the shapefiles (.shp) are produced using GIS software and can be saved anywhere on the computer. An "Open file" Dialog box is available within the tool to select these files.

Any shapefile (and raster) can be used in the tool to add spatial information and to support the decision-making. However, at least two shapefiles are required and there are specific constraints.

3.1.1. Site Characteristic – Polygon

In GIS terminology, a polygon is a two-dimensional shape that is modelled and stored within the database. It may be coloured, shaded and/or textured, and its position in the database is defined by the co-ordinates of its vertices (corners). In the described tool, this type of shapefile contains geographic information relating to the site characteristics in which the basic unit is at the scale of a parcel of land e.g. road, car park, house, park, etc.

A variety of site-specific aspects which have the potential to influence the use of various BMPs have been widely reviewed in the literature (CIRIA, 2007; Daywater, 2005; Jin *et al.*, 2006; Scholz *et al.*, 2006; Woods–Ballard *et al.*, 2007). Based on a consideration of their criticality and ease of utilisation within a GIS format, the following indicators have been selected:

- Type of land use :

The value is a string and identifies whether the land use is open space, railway, car park, building, pavement, road, verge, water body, other.

- Soil type:

The value is a string and identifies whether the soil is clay, silt, loam, sand, gravel which have different permeability/impermeability characteristics.

- Slope :

The value is a number and defines the slope as a percentage (%).

- Depth to groundwater:
The value is a number identifying the depth to groundwater in m.

- The presence of ‘flat’ roof:
The value is a binary number; 0 for no flat roof and 1 for the presence of a flat roof.

- Drainage Area:
The value is a number. Although no specific unit of area is required, the value in ha is preferred

- Area of the surface:
The value is a number. Although no specific unit of area is required, the value in m^2 or ha is preferred

- Pollutant:
The value is a string and identifies the type of pollutant (e.g. TSS, lead, oil etc.) found within the studied area.

- An Identification Number:
This is a unique number associated with each feature (in this case a created polygon) which serves as a record of where a stormwater BMP location is created in the stormwater BMP location shapefile.

The order of the columns in the database is not constrained but has to be known (see Fieldcriteria Text File in Section 3.1.2).

3.1.2. Stormwater BMP location - Point

This shapefile contains geographic information about the location of the stormwater BMP. It can be used to add a new stormwater BMP into the tool (see Section 6.8) but can also contain existing stormwater BMP data. The following columns in the database are required:

- Identification number:
This is a unique number associated with each feature (in this case a created point) which serves as a record of the feature. (It is not used in the current version of the tool).

- Type of stormwater BMP:
A string describing a particular BMP e.g. swale, wetland etc.

- Surface of the BMP:
The value of the area (m^2)

- The related parcel ID:
This ID number can be used to search for more information concerning an identified parcel of land in the site characteristic shapefile.

- The related parcel land use:
A string describing the type of land use at the parcel site.

- The related parcel surface:
A value of the area (m^2/ha)

- Comments:
String – enabling any required comments to be made.

The order of the columns is important and has to be as illustrated in Figure 1.

FID	Shape	Id	Type	Surface	IdOS	TypeOS	SurfOS	Comments
7	Point	22	Green roof	1.06178	1562	Carpark	1.06178	
8	Point	9	Porous asphalt	4.5501	3036	Road	4.5501	None
9	Point	10	Green roof	2.96547	990	Building	2.96547	None
10	Point	11	Porous pavement	1.24273	3434	Pavements	1.24273	None
11	Point	12	Porous asphalt	9.1705	2886	Pavements	9.1705	None

Figure 15: Example of stormwater BMP location within the database.

3.2. Text files

Text files are used for the storage of information and in the desctibed tool they contain the initial parameters which are used in the different matrices when the tool is loaded. There is no open file dialog associated with the text files and therefore their locations, structures and names have to be strictly preserved.

All the text files are stored in the C:\ BMP_DSS_TOOL\paramdata folder.

All the text files follow the same rules:
- Separator: a comma (,)
- First line: number of rows in the matrix (15 for instance)
- Second Line: the name of each column
- 15 next lines: name of the row with the specific values

The four text files, which are required, are outlined below.

3.2.1. Field criteria

This file is used in the project properties interface. It provides information on the relationship between the criteria used within the tool and the structure of the site characteristic shapefile (see Section 3.1.1). For instance the criteria ‘flat’ is associated with the 8th column named ‘roof’ (Figure 2). Once the tool is open, the relationship can be updated.

Criteria	Fieldname	FieldPosition
Landuse	Landuse	7
Soil Type	soil	4
Area	area	9
Slope	Slope	3
Watertable	watertable	5
Drainage Are	Drainarea	10
Pollutant	Pollutant	6
Flat	Roof	8

Figure 2: Name (Fieldname) and position (FieldPosition) of the columns in the site characteristics shapefile for the related criteria

3.2.2. Site criteria

This file is used in the site criteria interface. It provides information on the default values which relate BMP type to the indicators, effectively establishing a set of rules which determine which BMPs can be located at a particular site.

3.2.3. BMP UOP matrix and pollutant UOP matrix

These two files are used in the unit operation process (UOP) interface. The BMP UOP matrix contains the default values which relate a BMP to pollutant removal processes (see Section 6.3). The pollutant UOP matrix contains the default values which relate pollutant removal processes to a pollutant type.

3.2.4. Performance matrix

This file is used in the MCC criteria interface to provide information on the default values which relate BMP type to the multi-criteria indicators (see Section 6.4).

4. Launching the tool

To start the tool, it is only necessary to double click on BMP_DSS.exe in C:\BMP_DSS_TOOL. A first dialog window appears facilitating the uploading of the two working shapefiles (site characteristics and stormwater BMP location; see Section 3.1)

The tool is immediately available for use. It consists of two main interfaces which are viewed simultaneously (the GIS interface and the user-friendly interface) as shown in Figure 3.

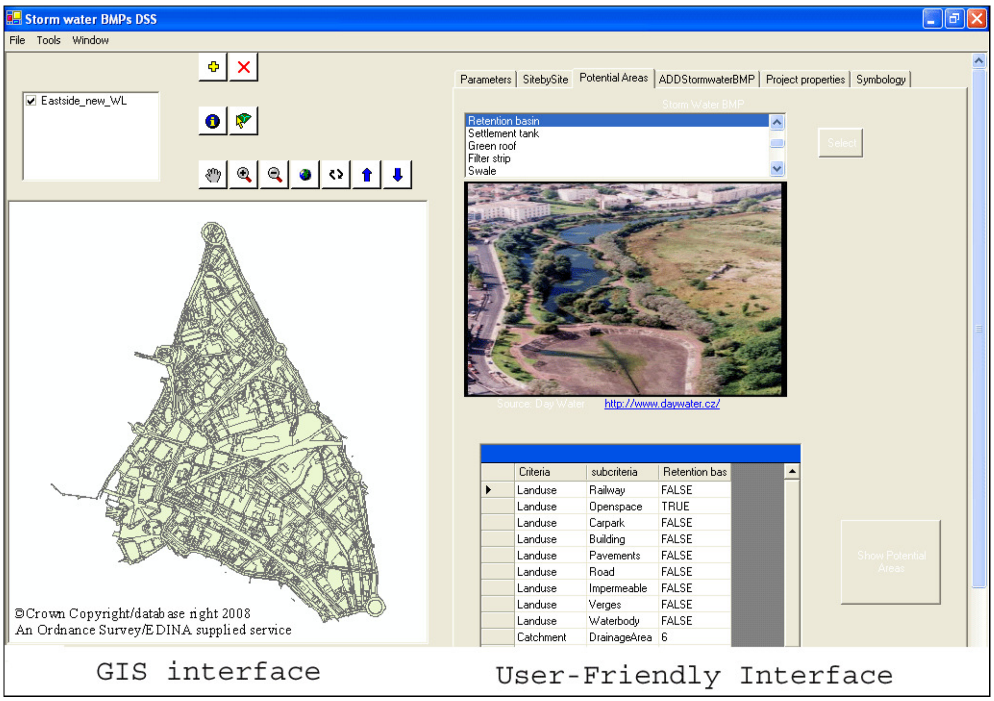
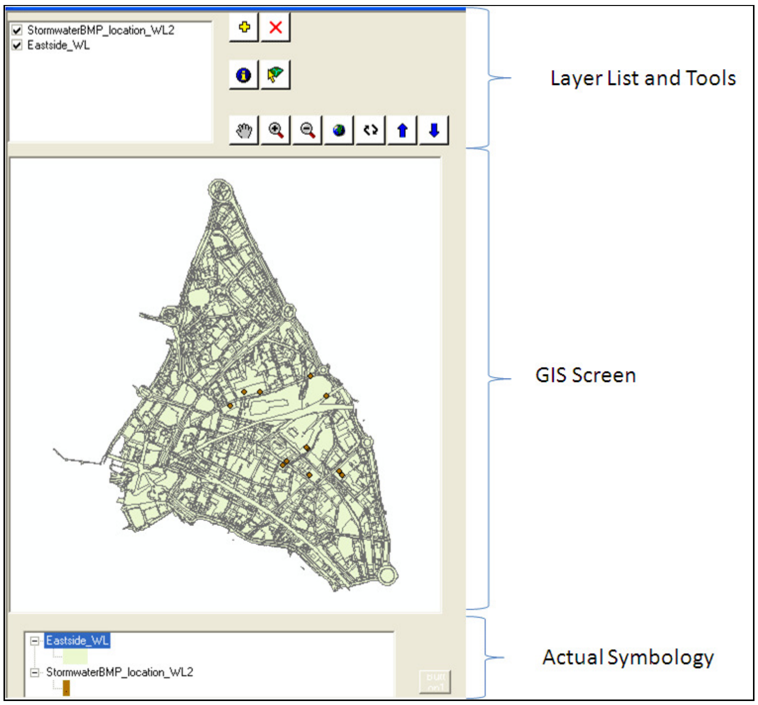


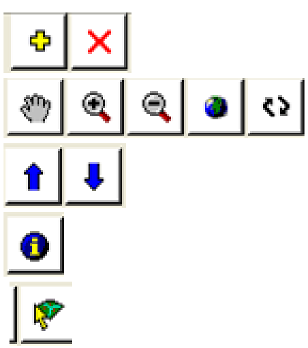
Figure 3: The opening window of the stormwater BMP DSS tool

5. The GIS interface

Four components are available on the GIS interface screen as shown in Figure 4. These are the 'layer' list, the 'tools' button, the GIS screen, and the 'actual symbology' display.

Different shapefiles and raster layers can be viewed on the GIS screen. The name of the layer is listed on the top right screen (the 'layer' list). Each layer can be selected within this box and can be selected to be visible or not on the screen. The 'actual symbology' is displayed at the bottom of the screen. Current map tools (e.g. zoom, pan, refresh, up and down layer, add and remove layer) enable users to interact with the map.





Add or remove layers (.shp or .raster)

Pan, zoom in, zoom out, zoom full extent, refresh

Move up/down the layer on the screen

Identify

Site by site tool (see Section 6.7)

Figure 4: The GIS interface screen together with operating symbol explanation.

6. The user-friendly interface

The user-friendly interface is a multiple-page dialog box enabling users to access information, databases and pictures relating to 15 different stormwater BMPs. The different interfaces are:

- Project properties
- Symbology
- Parameters – Unit operation processes
- Parameters – Pollutant removal
- Parameters – MCC criteria
- Parameters – Site criteria
- Potential areas
- Site by site
- Add stormwater BMP

The 'Project properties' and the 'Symbology' interfaces allow the user to manage the current project.

The four 'Parameter' interfaces allow the user to change values which influence the decision process within the tool. These parameters can relate to the unit operating processes within the BMPs, the pollutant removal potentials, the scores within the multi-criteria analysis, and/or the site characteristics).

Finally, there are three interactive interfaces identified as 'Potential areas', 'Site-by-site' and 'Add stormwater BMP' which can be used to assess potential BMPs for a site.

The individual components of user friendly interface are discussed in more detail in the following sections.

6.1. Project properties

The structure of the 'Project properties' interface screen is shown in Figure 5. It consists of a 'Working shapefile' and a 'Criteria and Fields relation' component. The shapefile is composed of two working layers which are displayed on the top of the page together with their names and paths.

Within the 'Criteria and Fields relation' there are 2 boxes; the top box (Box A) lists the fields of the site characteristics database and the bottom box (Box B) lists the different criteria used in the tool. The criteria and field have to be correctly related within the tool and this is done through the 'Fieldcriteria.txt' file shown in Figure 5. The information contained within this file can be corrected using this interface by selecting the criteria and related field in each box and by clicking the 'relate' button.

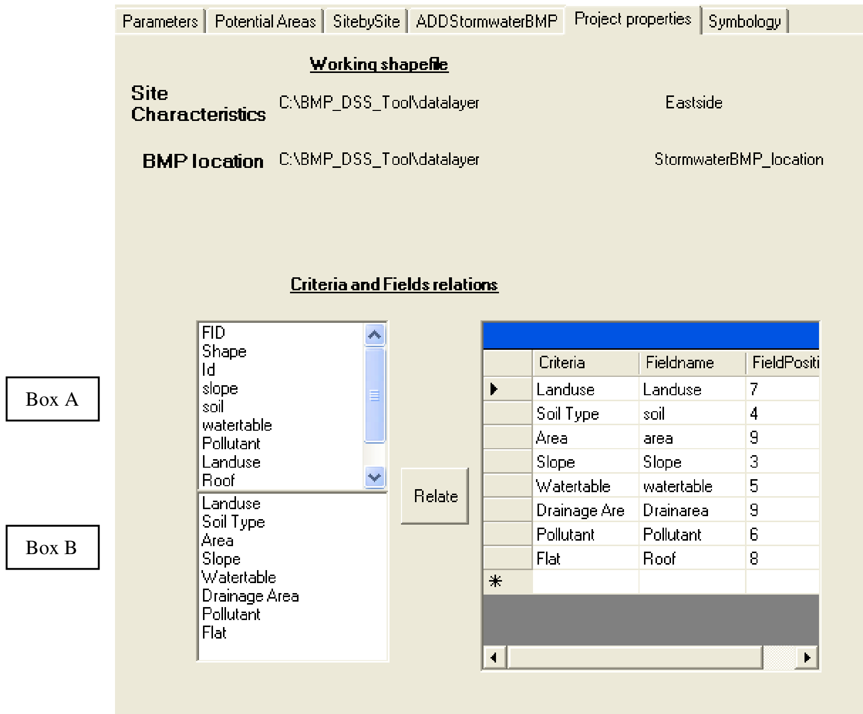


Figure 5: Details of the ‘Project properties’ interface screen

6.2. Symbology

The symbology interface allows the user to amend the display characteristics of each layer. This is achieved by first selecting the layer and then applying a unique colour or value.

- Unique colour:

The user can change both the outline and the back colour by double-clicking on the colour box to trigger the colour box pop up. In the case of point or line polygon, the size can be changed. The transparent box allows the user to have a transparent polygon. Changes are initiated by clicking on ‘Apply’.

- UniqueValue

The user has first to select the appropriate field in the list box and click on ‘class’. The different values are then listed and the user can change the colour by double clicking on the value. The change is actioned by clicking on ‘Apply’.

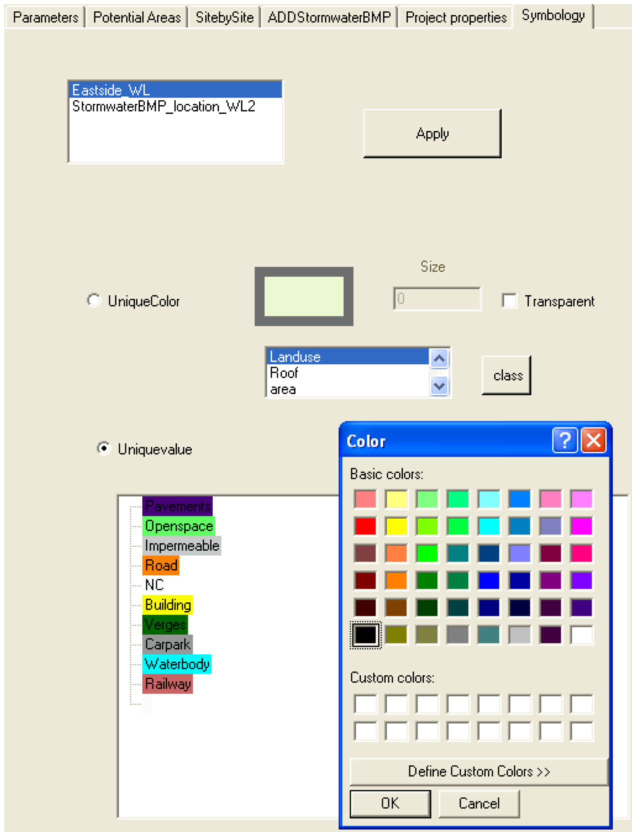


Figure 6: Details of the 'Symbology interface' screen

6.3. Unit operation process – pollutant removal

To address concerns relating to water quality aspects, the systematic BMP pollutant removal assessment approach developed by Scholes *et al.* (2008) has been incorporated within the decision support system. The developed BMP pollutant removal assessment framework involves the combination of field data and expert judgement to determine the potential for seven pollutant removal processes (adsorption, settling, microbial degradation, filtration, plant uptake, volatilisation and photolysis) to occur within a range of BMPs (Figure 7; top matrix). In addition, an assessment has been made of the potential for the identified processes to remove pollutants of concern (Figure 7; bottom matrix). The information pertaining to this process is contained in two text files which are loaded at the launch stage of the tool see Section 3.2.3).

The default values currently assigned can be changed by clicking on the appropriate cell. The relative importance of removal processes to either a BMP or a pollutant are represented by six classes; high, high/medium, medium, low/medium, low and NA (not applicable). The user can export the matrix in a .txt file to save the introduced change(s).

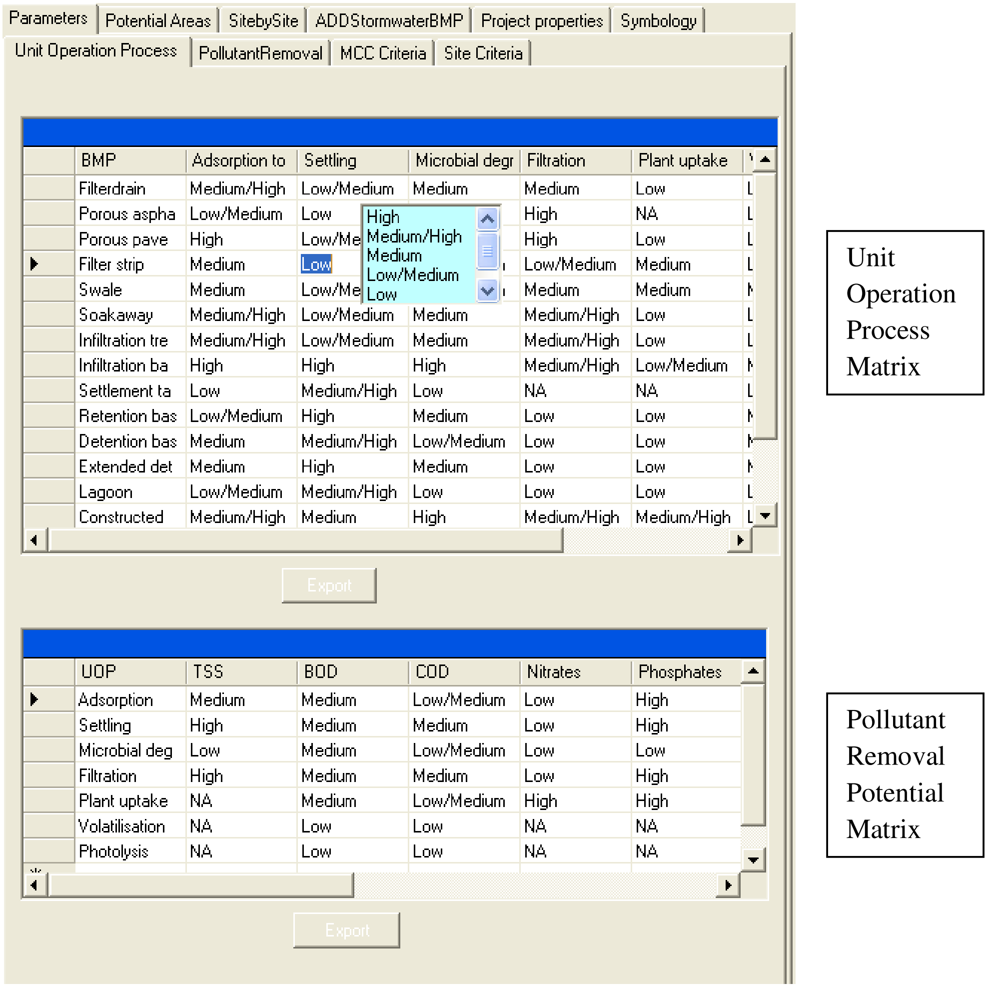


Figure 7: Details of the 'Unit Operational Process interface' screen.

The two sets of information shown in Figure 7 are combined to develop a single unit value which identifies the relative potential for a particular pollutant or pollutant group to be removed by specific BMPs. This is achieved by allocating values to each category of relative importance as shown in Figure 8 (top left-hand table). In addition, each process is assigned a weighting (Figure 8; top right-hand table). It is possible for a user to change the default values by clicking on the appropriate cell.

The 'calculate' button updates the central table in Figure 8 to produce an overall score representing the pollutant removal potential within each BMP. By selecting a specific pollutant and clicking the 'ranking' button, a hierarchy of BMPs is generated for that pollutant with the most efficient system at the top. Figure 8 illustrates this list for COD showing that infiltration basins are predicted to possess the highest removal capacity for this pollutant. It is important to note that the scores shown in this list are not representative of relative efficiencies which can be demonstrated by the different BMPs but merely denote the order of preference for the specific site and criteria under consideration.

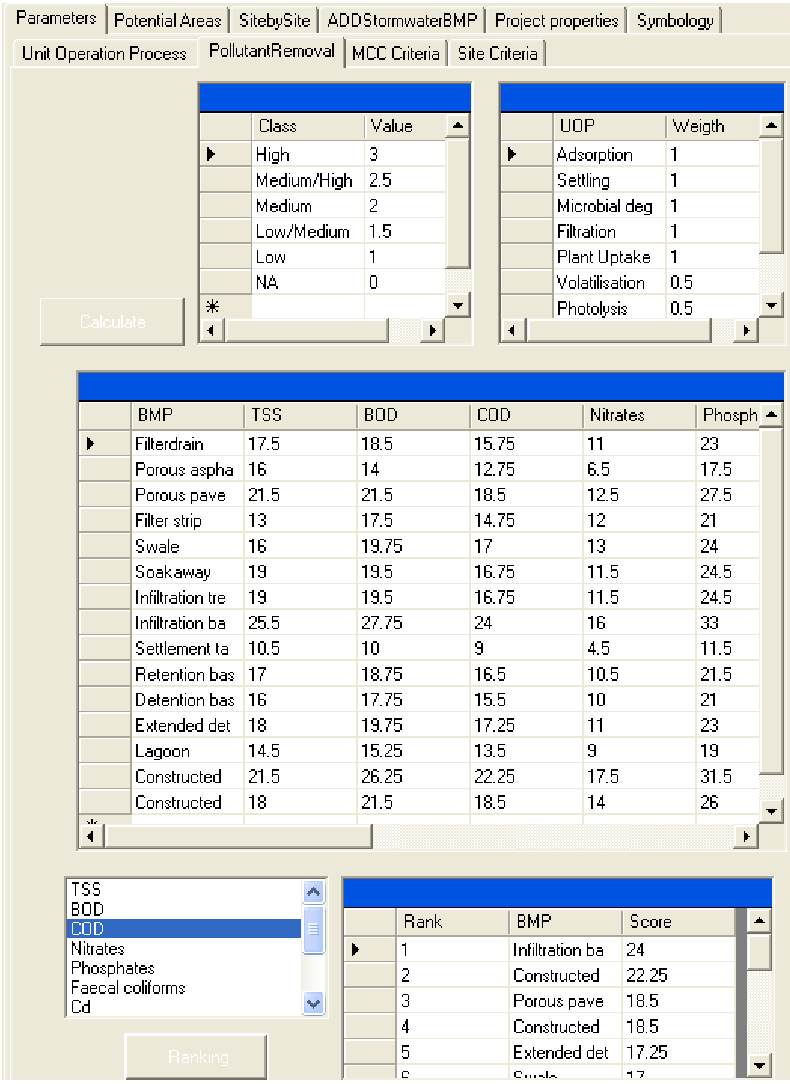


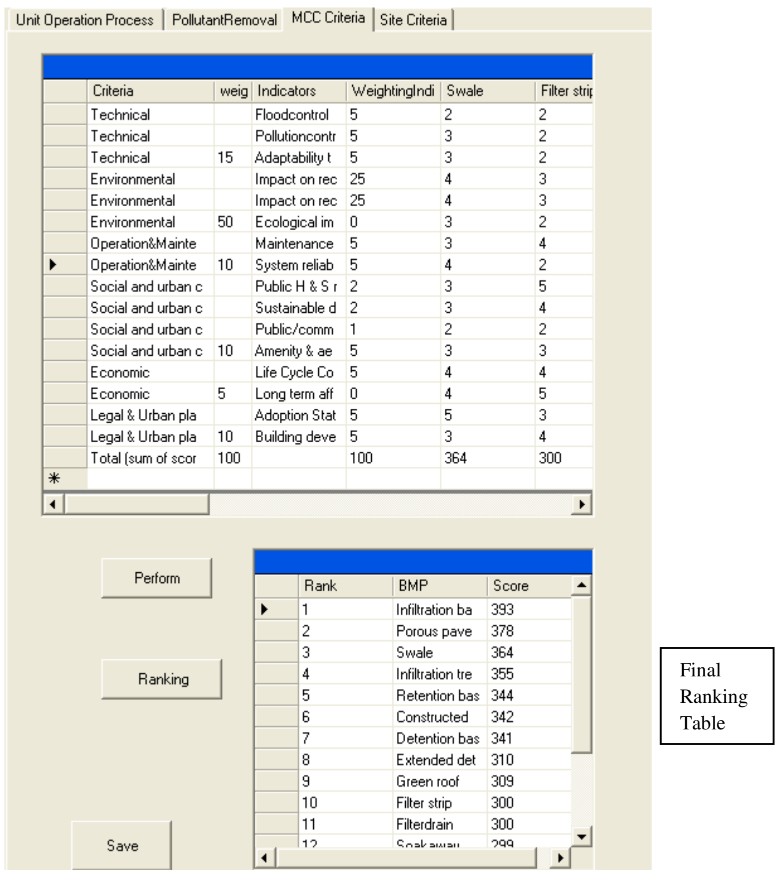
Figure 8: Details of the 'Pollutant Removal interface' screen.

6.4. MCC Criteria

Using the MCC interface, stakeholders are able to assess the performance of BMPs against the following criteria (and indicators) based on the EU 5th Framework DayWater Multi-Criteria Comparator (MCC) (Ellis *et al.,* 2008):

- Technical: Flood control, pollution control, adaptability to urban growth
- Environmental: Impact on receiving water volume, impact on receiving water quality, ecological impact
- O&M: Maintenance and servicing requirement, system reliability and durability
- Social and urban community benefits: Public health and risk, sustainable development, public/community information and awareness, amenity and aesthetics
- Economic : Life cycle cost, long term affordability
- Legal and Urban planning: adoption status, building development issues and stormwater regulation

The performance of each of 15 BMPs has been benchmarked against each indicator using default scores (developed during the DayWater project (Ellis *et. al*., 2008)). The default scores are imported from a text file when the tool is launched and are partially shown in Figure 9. It is also possible for users to enter their own scores (per BMP) by clicking on the cell of the main matrix (Figure 9). Different weightings (column 4) can also be applied by the user to express the relative importance that they attach to the different indicators (and thus criteria) for the BMPs. By pressing the 'perform' button the applied weightings are combined with the scores to generate a total score for each BMP. This is then converted into an order of preference for the BMPs by clicking on the 'ranking' button as shown in Figure 9 (lower table).



Criteria	weig	Indicators	WeightingIndi	Swale	Filter strip
Technical		Floodcontrol	5	2	2
Technical		Pollutioncontr	5	3	2
Technical	15	Adaptability t	5	3	2
Environmental		Impact on rec	25	4	3
Environmental		Impact on rec	25	4	3
Environmental	50	Ecological im	0	3	2
Operation&Mainte		Maintenance	5	3	4
Operation&Mainte	10	System reliab	5	4	2
Social and urban c		Public H & S r	2	3	5
Social and urban c		Sustainable d	2	3	4
Social and urban c		Public/comm	1	2	2
Social and urban c	10	Amenity & ae	5	3	3
Economic		Life Cycle Co	5	4	4
Economic	5	Long term aff	0	4	5
Legal & Urban pla		Adoption Stat	5	5	3
Legal & Urban pla	10	Building deve	5	3	4
Total (sum of scor	100		100	364	300

Rank	BMP	Score
1	Infiltration ba	393
2	Porous pave	378
3	Swale	364
4	Infiltration tre	355
5	Retention bas	344
6	Constructed	342
7	Detention bas	341
8	Extended det	310
9	Green roof	309
10	Filter strip	300
11	Filterdrain	300
12	Soakaway	299

Figure 9: Details of the 'MCC Criteria interface' screen.

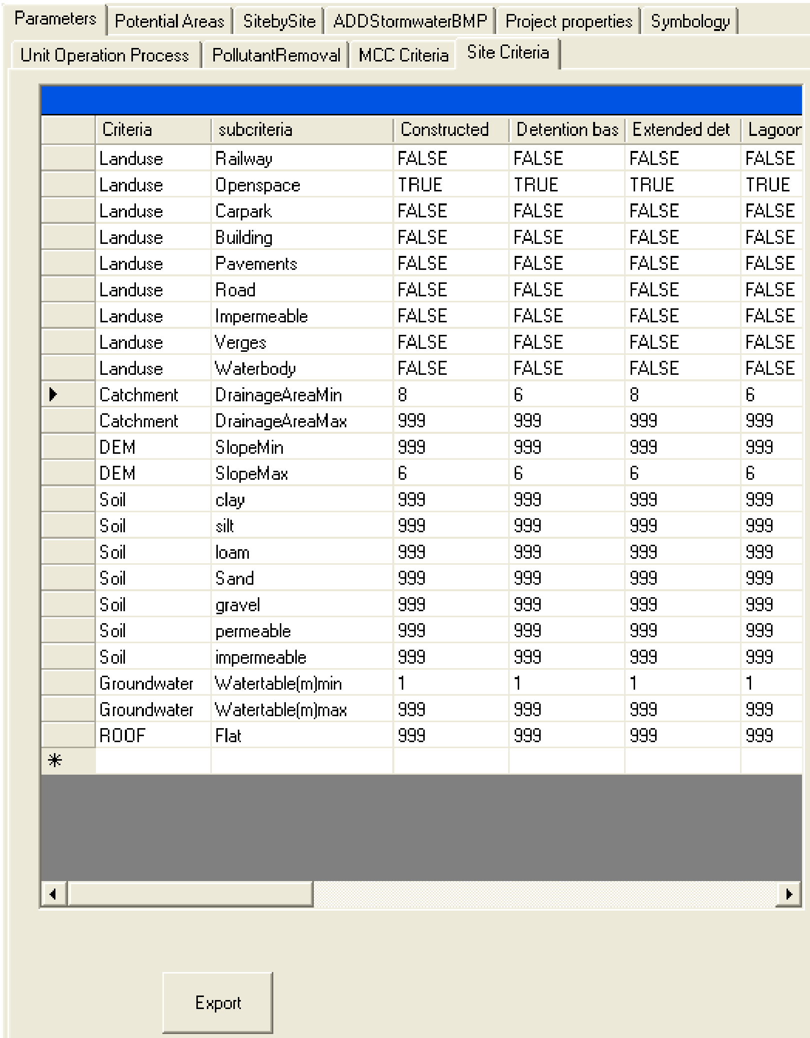
6.5. Site criteria

This interface establishes a set of default values which relate the different types of BMPs to indicators which define those site characteristics which are important in determining whether it is feasible or not to locate a BMP at a particular site (Figure 10). The default values are imported from a text file when the tool is launched (see Section 3.2.2).

The user is able to change the default settings based on their own knowledge of a site and depending on the control/treatment requirements. Changes can be saved by clicking on

‘export’. Depending on the criteria, the assigned values are allocated according to the following rules:

- For all criteria: 999 is the default value used to indicate that a specific criterion has not been considered. It could be that non-consideration was because the criterion was not specific for the BMP or that no value could be collected in the .shp file (add 999 for all BMPs)
- Land use: **False** if the BMP is not appropriate for a particular land use; **true** if the BMP could be located within the land use.
- Catchment : a number (area) in the same units as the drainage area in the site characteristics in the shapefile (see Section 3.1.1)
- DEM: the minimum and maximum slope (expressed as a percentage) requirement
- Soil: **False** if the soil is not appropriate for a particular BMP; **true** if the BMP characteristics and the soil type are compatible.
- Groundwater: the depth to groundwater (m)
- Roof: a unique value (1 or 0). A value of one indicates that the roof sloop is considered as slight enough to support vegetation. A value of 0 means that the roof cannot support the vegetation. The value allocated is subject to the expertise possessed by the end user.



Criteria	subcriteria	Constructed	Detention bas	Extended det	Lagoor
Landuse	Railway	FALSE	FALSE	FALSE	FALSE
Landuse	Openspace	TRUE	TRUE	TRUE	TRUE
Landuse	Carpark	FALSE	FALSE	FALSE	FALSE
Landuse	Building	FALSE	FALSE	FALSE	FALSE
Landuse	Pavements	FALSE	FALSE	FALSE	FALSE
Landuse	Road	FALSE	FALSE	FALSE	FALSE
Landuse	Impermeable	FALSE	FALSE	FALSE	FALSE
Landuse	Verges	FALSE	FALSE	FALSE	FALSE
Landuse	Waterbody	FALSE	FALSE	FALSE	FALSE
Catchment	DrainageAreaMin	8	6	8	6
Catchment	DrainageAreaMax	999	999	999	999
DEM	SlopeMin	999	999	999	999
DEM	SlopeMax	6	6	6	6
Soil	clay	999	999	999	999
Soil	silt	999	999	999	999
Soil	loam	999	999	999	999
Soil	Sand	999	999	999	999
Soil	gravel	999	999	999	999
Soil	permeable	999	999	999	999
Soil	impermeable	999	999	999	999
Groundwater	Watertable(m)min	1	1	1	1
Groundwater	Watertable(m)max	999	999	999	999
ROOF	Flat	999	999	999	999

Figure 10: Details of the 'Site Criteria interface' screen.

6.6. Potential areas

This interactive interface assesses all the potential sites in the site characteristics shapefiles for a specific BMP based on the site criteria interface and displays the results on a map. To initiate this procedure the user has, first of all, to select a stormwater BMP from the list provided at the top of the screen (Figure 11; top right-hand box) and click 'Select'. This results in a picture of the selected BMP and the related criteria being displayed. Figure 11 shows the results for green roofs.

In order to illustrate where this BMP could feasibly be installed in a studied catchment area, the user can click on 'Show potential area'. The relevant areas are highlighted on the map as shown in Figure 11. The number of feasible sites and the corresponding surface covered by these sites appears in the bottom right-hand corner of the screen as indicated by the **true** returns.

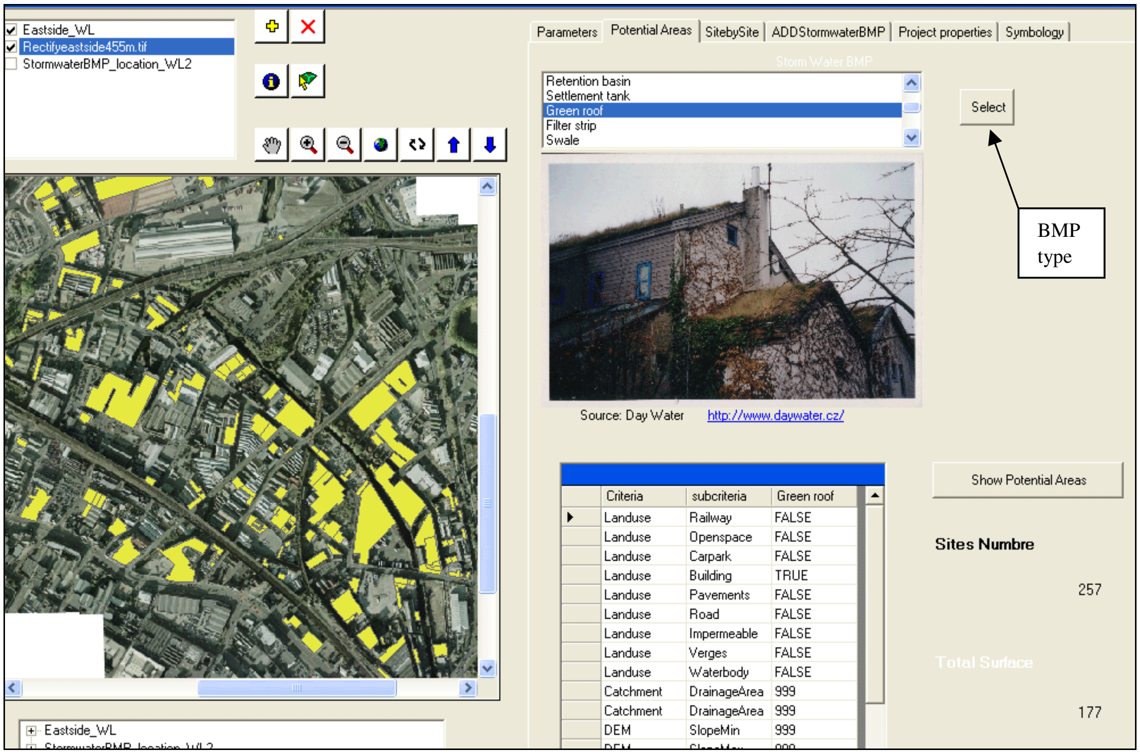


Figure 11: Details of the 'Potential Areas interface' screen.

6.7. Site by site

This interactive interface assesses all the potential BMPs which can be used within a specific site based on all considered criteria (site criteria, MCC and pollutant removal interface). By choosing the icon representing the selection tool, , the user can click on a specific site on the map. Once selected, the site is identified by a black grid. The site characteristic values are displayed (Figure 12; top left-hand table) and the potential BMPs appear in the top right-hand box (based on the site criteria value). The user can then select a specific pollutant in a list and show the score for each BMP calculated by the pollutant removal interface (Figure 12; bottom left-hand table). Those BMPs highlighted in red are not available or not appropriate) for the selected site. The user can also display (using the 'Show' button) the score of each BMP regarding the previously described MCC criteria (see Section 6.4). As before, those BMPs in red are not available or appropriate for the site.

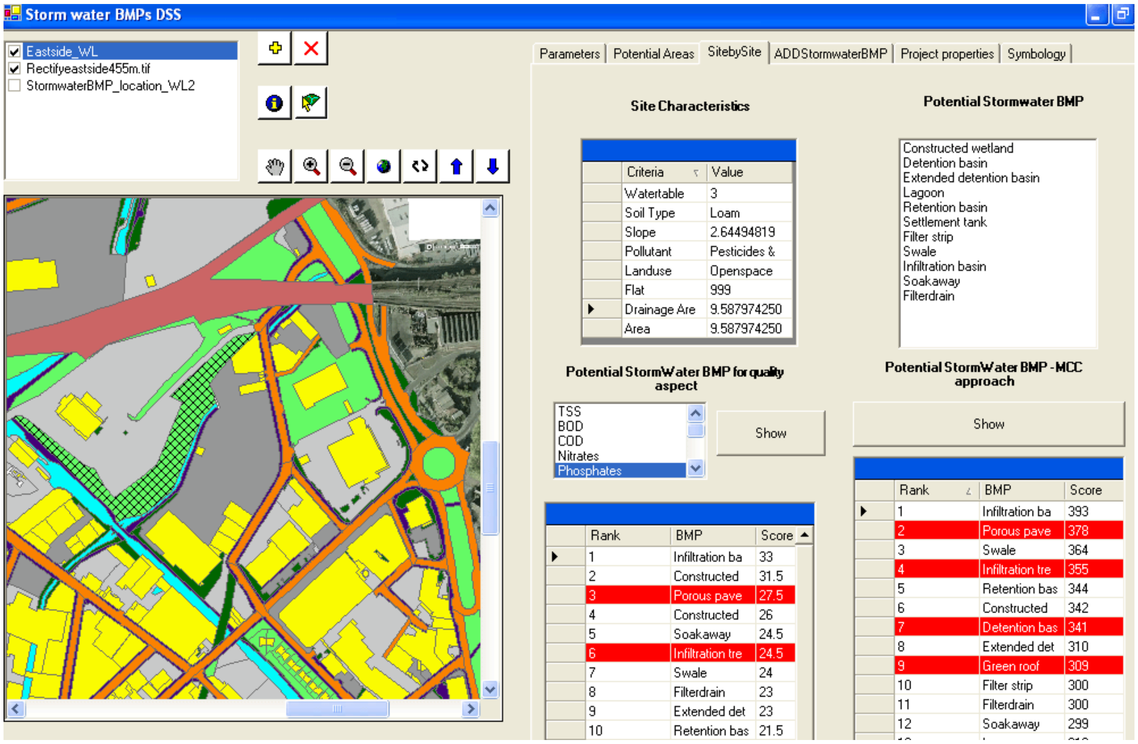


Figure 12: Details of the 'Site by site interface' screen.

6.8. Add stormwater BMP

Using this interface (Figure 13) the user can add a new stormwater BMP, based on the site criteria values, to the map located in the Stormwater BMP location working layer (see Section 3.1.2). The user has first to *select* a BMP from the list at the top of the screen. In the example shown in Figure 13, green roofs have been selected and as a consequence two icons (representing this BMP) can be seen adjacent to the BMP list. One of these will indicate that green roofs are feasible and the other (with a red circle and line through it) identifies that this BMP is not appropriate.

Clicking on 'Add BMP on the map' and moving the cursor over the map, results in the icon being dragged into different positions and according to whether or not the proposed BMP is feasible at a particular location, the symbol changes to the 'settlement' icon or to the 'no settlement' icon.

The characteristics of the site identified by the cursor are displayed in the table at the bottom of the screen and, if the BMP is not feasible, the failing criterion is highlighted in red. In addition, a message is displayed explaining why the BMP could not be installed at that particular site. A site ID appears on the right of the 'Site Characteristics' heading.

Clicking on the site causes the dialog Box shown in Figure 14 to pop up. The user can add specific attributes to the stormwater BMP location shapefiles (see Section 3.1.2) e.g. revised surface together with any required comments. The type of BMP, site ID, site type and site surface are automatically added. By clicking OK the BMP details are added to the shapefiles. The user can also cancel this operation.

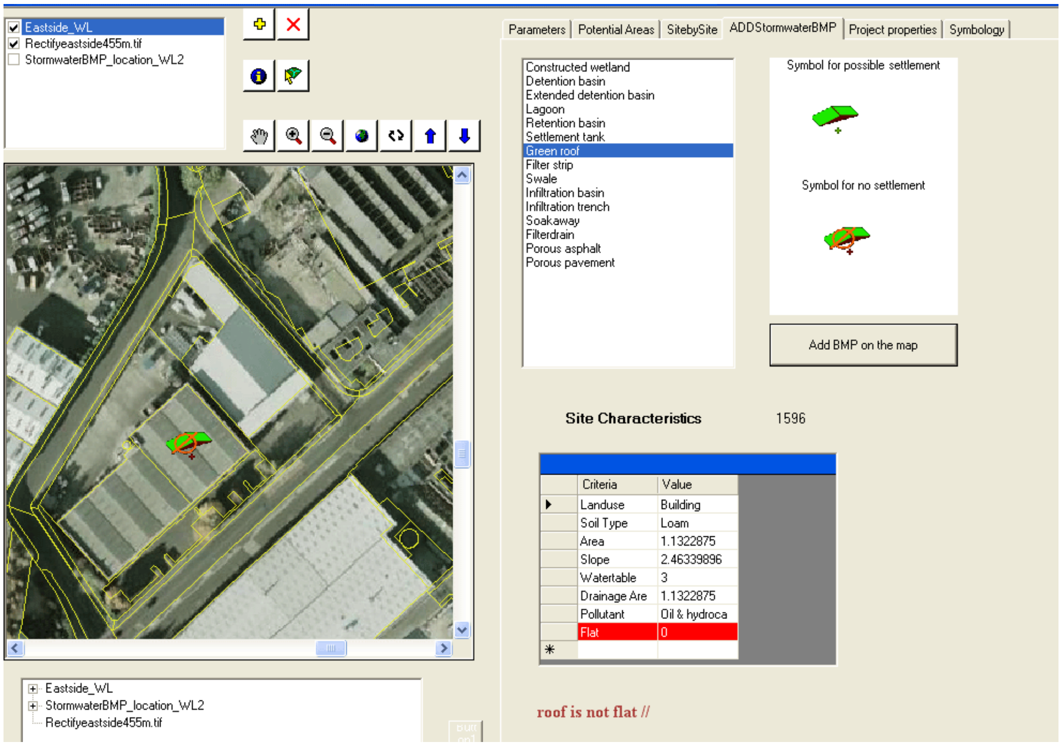


Figure 1316: Details of the 'Add BMP interface' screen.

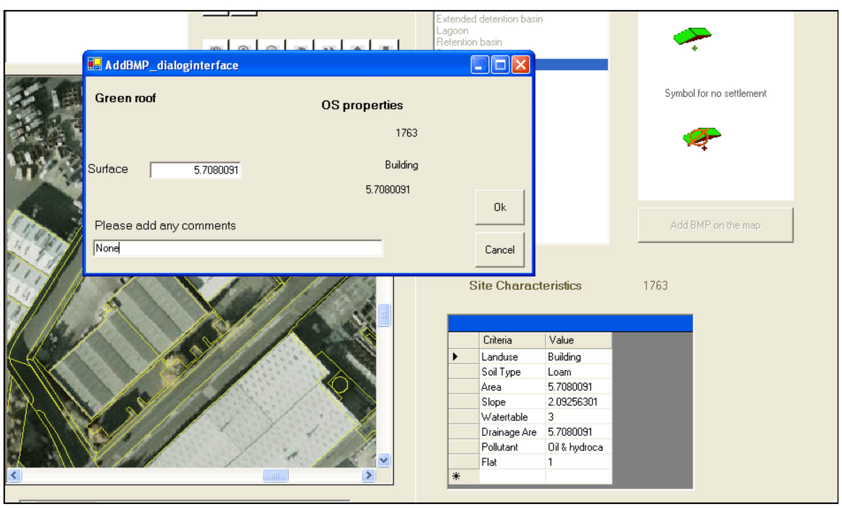


Figure 14: Dialog box linked to 'Add BMP interface' screen enabling BMP attributes to be changed.

7. Conclusions

A GIS-based tool has been developed which has the capability of locating and identifying those sites within a catchment where a particular BMP could be installed. Alternatively, for a

particular site, the tool can identify the different BMPs that are feasible. Where several BMPs are possible, they can be compared in terms of pollutant removal capacity or through a range of technical and non-technical criteria and indicators. Within the SWITCH project, the developed tool is currently being linked with the STORM model to provide a more comprehensive approach to the prediction of the benefits, in terms of stormwater attenuation for extreme event pluvial flooding, which can be achieved by incorporating appropriately designed and positioned BMPs into a conventional urban drainage system. This will extend the current scope of the tool in assisting stormwater practitioners with the design of new or the retro-fitting of existing drainage systems.

8. References

Balmforth D., Digman C.J., Butler D.and Shaffer P. (2006). *Integrated Urban Drainage Pilots: Scoping Study*. DEFRA.London

Capiella K., Schueler T. and Wright T. (2005). *Urban Forestry Watershed Manual Part1: Methods for increasing forest cover in a watershed.* US Department of Agriculture, Forest Service, North Eastern Area, State and Private Forestry, Pennsylvania, USA. NA-TP-04-05.

CIRIA (2007). Internet site. http://www.ciria.org.uk/suds/. Visited 25 February 2008.

DayWater (2005). *An Adaptive Decision Support System (ADSS) for the Integration of Stormwater Source Control into Sustainable Urban Water Management Strategies*. Internet Website. http://www.daywater.org. Visited 25 February 2008.

Ellis J.B., Deutsch J-C., Legret M., Martin C., Revitt D.M., Scholes L., Seiker H., and Zimmerman U. (2006). The DayWater decision support approach to the selection of sustainable drainage systems. *Water Practice and Technology,* 1 (1), (doi:10.2166/wpt.2006.0002) (ISSN 1751-231X).

Ellis, J.B., Shutes, B., Nascimento, N., Sieker, H., Peters, C. and Beuchat, X. (2008). Deliverable 2.1.2. A design manual incorporating best practice guidelines for stormwater management options and treatment under extreme conditions. Part A: Review of design guidelines for stormwater management in selected countries. Deliverable 2.1.2 of the SWITCH project. http://www.switch.watsan.net/page/766/offset/10. Visited 5 August 2009.

Elliott A.H., Trowsdale S.A. (2007). A review of models for low impact urban stormwater drainage. *Environmental Modelling & Software,* 22, 394-405.

Sample D.J, Heaney J.P., Wright L.T. and Koustas, R. (2001). Geographic Information Systems, Decision Support Systems, and Urban Stormwater Management. *J. Water Resource Planning. and Management*, 127(3), 155-161.

Jin Z., Sieker F., Bandermann, Sieker H. (2006). Development of a GIS-based expert system for on-site storm water management. *Water Practice and Technology,* 1 (1),

Lai F-H., Dai T., Zhen J., Riverson J., Alvi K.and Shoemaker L. (2007). SUSTAIN – An EPA BMP Process and Placement Tool for Urban Watersheds. *Proceedings of the Water Environment Federation, TMDL*, 946-968.

Makropolous, C., Butler, D and Maksimovic, C. (2001). GIS-supported stormwater source control implementation and urban flood risk mitigation. 95–105 in Marsalek, J (Edit): *Advances in Urban Stormwater and Agricultural Runoff Source Controls*. Kluwer, London. (ISBN 1402001533).

Revitt, D.M., Ellis J.B. and Scholes L. (2008). The DayWater Multi-Criteria Comparator. In D R Thevenot (Edit.): *DayWater: an Adaptive Decision Support System for Urban Stormwater Management*. Chapter 9, 87-96, IWA Publishing (ISBN: 1843391600).

Scholes L., Revitt D.M., Ellis J.B. (2008). A systematic approach for the comparative assessment of stormwater pollutant removal potentials. *Journal of Environmental Management*; 88(3), 467-478.

Scholz M., Corrigan N.L., Yazdi S.K. (2006). The Glasgow Sustainable Drainage System Management project: Case studies (Belvidere Hospital and Celtic FC Stadium Areas). *Environmental Engineering Science,* 23 (6), 908-922.

Woods-Ballard B., Kellagher R., Martin P., Jefferies C., Bray R., Shaffer P. (2007). The SUDS Manual. CIRIA, London. C697, pp 606. ISBN: 978-0-86017-697-8.