MOUSE TRAP

Technical Reference
Surface Runoff Quality Module

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[1] DHI is a private, non-profit research and consulting organization providing a broad spectrum of services and technology in offshore, coastal, port, river, water resources, urban drainage and environmental engineering.

Contents

1 THE BUILD-UP/WASH-OFF OF SEDIMENTS

1.1 Accumulation of Particles on the Catchment

During dry weather periods sediments accumulate on the surface of urban catchments. The most common formulations of this process are to assume that the build up is a linear or an exponential function of time. Both formulations have been implemented in the model. The choice between the two formulations is not straightforward, due to insufficient experimental results.

The linear build up function is given as:

$$\frac{dM}{dt} = A_c \quad \text{for } M < M_{\max}$$

$$\frac{dM}{dt} = 0 \quad \text{for } M \geq M_{\max} \tag{1}$$

where:

M is the accumulated mass of particles at time t (kg),
M_{max} is the maximum accumulated mass of particles on the catchment (kg),
t is the time in days,
A_c is the daily accumulation rate (kg/ha/day).

The exponential build up function is given as:

$$\frac{dM}{dt} = A_c - D_{rem} \cdot M \tag{2}$$

where:

M is the accumulated mass of particles at time t (kg),
t is the time in days,
A_c is the daily accumulation rate (kg/ha/day),
D_{rem} is the removal coefficient (d^{-1}).

The coefficient D_{rem} represents the removal of particles from the surface by various mechanisms (e.g by wind, traffic, street sweeping, biological and chemical degradation) - all except wash off. The accumulated mass M will increase until a limit A_c/D_{rem} is reached.

An example of the two build up formulations is shown in Figure 1.

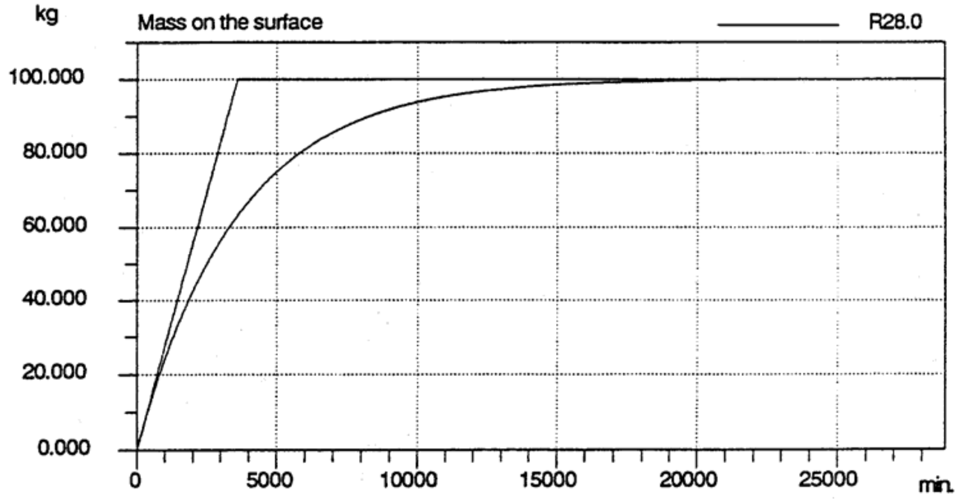

Figure 1 *The linear and the exponential build up function. Maximum value = 100 kg and Build up rate = 40 kg/ha/day.*

1.2 Wash Off of Particles by Rainfall

Wash off of sediment particles during a rain event can be divided into two processes: erosion by raindrops and erosion by overland flow. Only the erosion by raindrops is taken into account in the model. Erosion by raindrops is governed by several parameters. The most important are: rainfall intensity, rainfall depth, rainfall duration, raindrop size, catchment topography, particle characteristics and vegetation. However, parameters such as raindrop size and rainfall depth are rarely available so a simpler approximation has been adopted in the model. This approximation states that the rain drop erosion is a function of the rain intensity and a detachment rate. The equation for the detachment by rainfall can be written as, (Ref. /1/):

$$V_{sr} = D_r \left(\frac{i_r}{i_d} \right)^{\exp} LW(1-\varepsilon)A_s \qquad (3)$$

where:

V_{sr} sediment volume detached by the rain per unit of time (m³/h),
D_r detachment coefficient for rainfall (m/h),
i_r rainfall intensity (mm/h),
i_d rain intensity constant (=25.4 mm/h),
exp exponent (default value 2),
L length of the catchment (m),
W width of the catchment (m),

ε porosity of the sediment,
A_s fraction of surface area covered with sediment.

It is important to note that the erosion rate is independent of the diameter of the particles, hence the transport of the fine fraction is independent of the particle diameter. The transport of the coarse sediment is limited by the transport capacity of the overland flow, whilst the transport of the fine sediment only is limited by the rain erosion rate and the mass available on the surface. The transport capacity for the coarse fraction is calculated as the sum of the bed load and the suspended load transport capacity. The transport capacity for bed load and suspended load is calculated from the van Rijn formula (see MOUSE TRAP Technical Reference, Sediment Transport).

2 THE SEDIMENT AND ATTACHED POLLUTANTS

The description of the attachment of pollutants to sediment is based on the PPC concept, as described in MOUSE TRAP Technical Reference, Water Quality Module. The mass attached to each fraction is determined as:

$$M_{fine} = TP \cdot S_{fine} \cdot FL$$
$$M_{coarse} = TP \cdot S_{coarse} \cdot CL \qquad (4)$$

where:

TP is the pollutant in grams per litre wet sediment
M_{fine} is the load of pollutants attached to the fine sediment fraction (kg/s),
M_{coarse} is the mass of pollutant attached to the coarse sediment fraction (kg/s),
S_{fine} is the sediment transport of the fine fraction (m^3/s),
S_{coarse} is the sediment transport of the coarse fraction (m^3/s),
FL is the percentage of the total pollutant load (TP) attached to the fine fraction,
CL is the percentage of the total pollutant load (TP) attached to the coarse fraction.

3 THE GULLY POTS

3.1 The Processes in Gully Pots

The purpose of a gully pot is to trap particles and prevent them from entering the pipe system. Also, it prevents the release of odour from the pipe system. A sketch of a gully pot is shown in Figure 2.

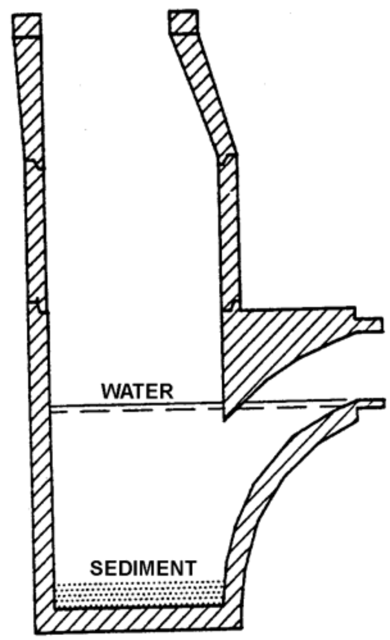

Figure 2 Sketch of a gully pot.

The gully pot acts as a sediment trap during dry weather flow. During storms either deposition or erosion of sediment will take place depending on the flow conditions in the gully pot. Whether sediment will deposit or erode during storms depends on many different factors e.g.: the geometry of the gully pot, the depth of sediment in the gully pot, the level of turbulence in the gully pot and the sediment size and density. Furthermore, the removal of sediment from the gully pot by cleansing is an unknown factor.

Dissolved pollutants will build up in the gully pot liquid during dry weather. The build up is dependent on the type of pollutant, the biological/chemical conditions in the gully pot and the temperature.

3.2 Transport of Particles Through the Gully Pots to the Sewer System

During storms, the volume of liquid and sediment will remain unchanged in the gully pots. Thus, it is assumed that all sediment, which enters the gully pot is transported straight through the gully pot. This assumption is a necessary simplification, since the efficiency of trapping of sediment depends to a large degree on the local conditions in the gully pot. The amount trapped in the gully pot can be represented by a reduced detachment coefficient for rainfall or, for the fine fraction, by reducing the volume of sediment available on the surface.

3.3 The Build-up and the Release of Dissolved Pollutants in Gully Pots

The build up of pollutants in the gully pot is assumed to be a linear function with a threshold value for the maximum concentration. The release of the polluted water during storm events is assumed to be a simple mixing process of the incoming water with the gully pot liquor as follows:

$$c_{out} = \frac{q_i \cdot c_i \cdot dt + V_{gully} \cdot c_{gully}}{V_{gully} + q_i \cdot dt} \qquad (5)$$

where:

c_i is the concentration of pollutants in the inflow water,
c_{gully} is the concentration of pollutants in the gully pot,
c_{out} is the concentration of pollutants in the outflow water,
dt is the time step,
q_i is the inflow discharge,
v_{gully} is the volume of the gully pot.

4 NOMENCLATURE

A_c	daily accumulation rate (kg/ha/day)
A_s	surface area fraction covered with sediment
CL	percentage of the total pollutant load (TP) attached to the coarse sediment fraction
D_r	detachment coefficient for rainfall
D_{rem}	removal coefficient (d^{-1})
FL	percentage of the total pollutant load (TP) attached to the fine sediment fraction
i_r	rainfall intensity (= 25mm/h)
i_d	rain intensity constant (mm/h)
L	length of the catchment (m)
M	accumulated mass of particles at time t (kg)
M_{coarse}	mass of pollutant attached to the coarse fraction
M_{fine}	mass of pollutants attached to the fine fraction
M_{max}	maximum accumulated mass of particles on the catchment
S_{coarse}	sediment transport of the coarse fraction
S_{fine}	sediment transport of the fine fraction
TP	pollutant in grams per litre wet sediment
t	time in days
V_{sr}	sediment volume detached by the rain per unit of time (m^3/h)
W	width of the catchment (m)
ε	porosity of the sediment

5 REFERENCES

/1/ Svensson, G., "Modelling of Solids and Metal Transport from small Urban Watersheds". Chalmers University of Technology, Göteborg, Sweden, 1987.