Integrated Urban Drainage Modelling Guide

Appendix G

Modelling Road Gulleys

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G1. Introduction

With integrated catchment modelling it is frequently necessary to understand and replicate how the highway drainage system operates in storm conditions when there may also be overland flow along the streets. This appendix is intended to provide guidance on how and when modelling of road gulleys should be contemplated.

G2. Modelling Approach

Except for relatively small models it is likely to be unrealistic to model all of the road gulleys in a catchment as the model would become unnecessarily complex and slow to run. Therefore, a more targeted approach is recommended which may involve a degree of iteration.

The standard approach is just to model manholes as computational nodes in both 1D and coupled 1D-2D models. Whilst head-discharge relationships can be applied it is more common for manholes to be simulated as simple open pits. With 1D-2D models this may be unrealistic as overland flows generally enter the piped systems via road gulleys; in these circumstances there can be benefits in modelling the road gulleys and the manholes in a more realistic manner. Therefore, in those portions of a coupled 1D-2D model where the road gulleys are modelled the simple open pit approach to modelling manholes is no longer suitable; the manhole modelling needs to be more sophisticated.

The locations where there are benefits in modelling road gulleys are likely to be one or more of the following:-

- Where there is significant overland flow (also referred to as ‘exceedance flow’) along the road;
- At dips or low spots in the road where floodwater can accumulate;
- Where an assessment is required whether additional road gulleys would alleviate a problem;
- Where it is thought that road gulleys contribute to a flooding problem by allowing water to escape from overloaded pipes and sewers.

In the circumstances where road gulleys are modelled it is imperative that the flooding characteristics of the manholes in those areas are modelled in the more sophisticated manner as described below.

G3. Modelling Manholes

The actual mechanism of flooding from manholes is a progressive one starting with water escaping via key holes (Figure G1) which in effect is a series of small orifices with the manhole cover remaining in place. As the internal pressure increases the manhole cover is lifted and the floodwater escapes from under the cover (Figure G2) which is akin to weir flow around that portion of the opening from which the cover is lifted. The pressure at which the cover starts to be lifted out of the frame depends on the weight of the cover and whether it is jammed or stuck in place.

If the pressure increases further the cover is lifted completely out of the frame (Figure G3) at which point the manhole opening effectively becomes an orifice acting in a horizontal manner.

When there is overland flow across a manhole but the head within the manhole is below ground level the cover will remain in place but it is only via the key holes that water can get into the manhole. This is again similar to a series of small orifices.

Figure G 3- orifice flow

Figure G 1 - orifice flow

Figure G 2 - weir flow

The flooding mechanism can be simulated as a head-discharge relationship which is a composite of orifice flow (blue line) followed by weir flow (red line) followed by orifice flow (green line)as shown in Figure G4.

In the negative direction (ie flooding into the manhole) the composite line follows the orifice line (blue line).

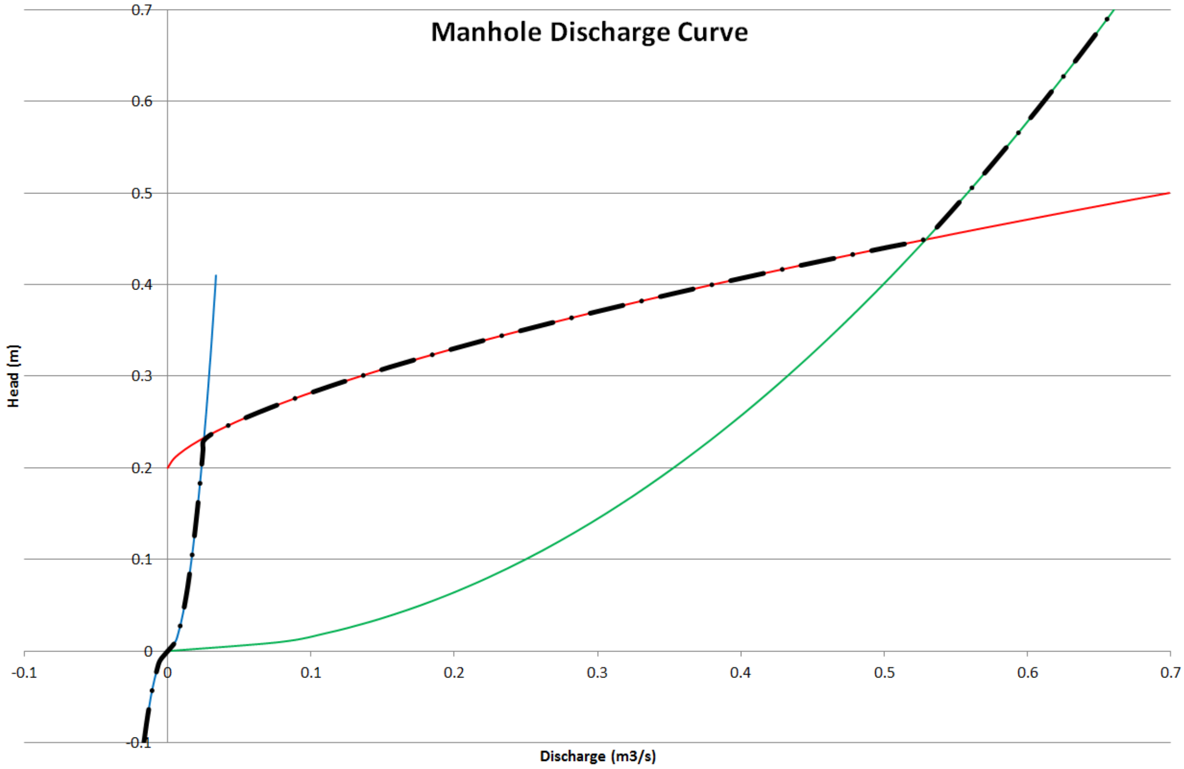

Figure G 4 - Composite head-discharge curve

G4. Modelling Road Gulleys

To model road gulleys in InfoWorks the head discharge relationship of the gully in question needs to be identified. The data needed for this comes in three categories, the gully itself, the road on which it is located and the hydraulic characteristics defined by these properties;

Gully:
- Grating
- Pot

Road:
- Longitudinal slope
- Cross-sectional slope

Hydraulic characteristics:
- Kerb channel flow
- Gully collection efficiency

Gully

For British gulleys, there are five categories of gully grating, P, Q, R, S and T. These are named in decreasing hydraulic capacity, which is judged on their total size, the number and orientation of the slots and the total waterway area provided by the slots [1]. Kerb inlets are also commonly used in Britain in specific situations. An example of this is opposite T-junctions, where they are well positioned to collect the flow running down the joining road.

Figure G5: Standard type R gully

Figure G6 shows a cross-section through a typical British gully pot. The flow through a gully pot comes down through the grating and around the trap, circled in red, which is designed to stop odours coming back up from the sewer system. It then flows into the pipe where it discharges into the network. The route the flow takes around the trap limits the discharge from the gully pot to 10 l/s. This limit is effective in both directions, so any amount of negative head on the gully would create at maximum a -10 l/s flow back up flow through the gully and flood onto the road.

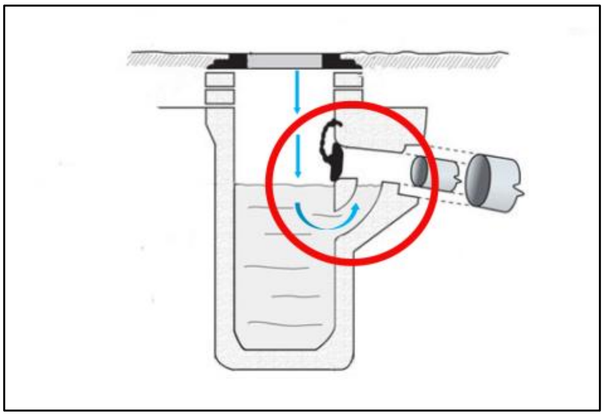

Figure G6: Cross-section of British gully pot

Road

The longitudinal slope of the road is an important factor as it affects the velocity of the flow in the kerb channel, which directly affects the width of flow. The longitudinal slope is defined as the average gradient over a 3m distance upstream of the gully [1]. This value could be measured and used accurately, but it has been judged sufficient to simplify this parameter. It can be put into one of two categories, saving time in both the modelling and the assessment, as it can be observed rather than measured. The cross-sectional slope of the road is also known as the crossfall or camber. Again, this can be measured, but for ease and efficiency of modelling, this too can be put into categories of either steep or shallow. The crossfall directly affects the width of the flow in the kerb channel. A steeper crossfall creates a narrower width of flow for a given depth at the kerb. Figure G7 shows the values allocated to the two categories, for both longitudinal slope and the crossfall.

	Shallow	Steep
Longitudinal, S_L	1/100	1/20
Crossfall, S_C	1/50	1/15

Figure G7: Typical slope values

Hydraulic Characteristics

The hydraulic characteristics of standard British gulleys for a full range of road slopes are given in the 'Spacing of Road Gulleys' design manual[1]. The design tables in appendix C of the manual give both the discharge in the kerb channel, which is irrespective of the gully grating, and also the gully efficiency, which is dependent on the size and style of grating.

It should be recognised that the hydraulic characteristics and modelling parameters set out in this appendix are based in the road gulleys being clear. The Modeller will need to make a judgement about the likelihood of gulley gratings being blinded (as shown on the cover photograph) and make adjustments accordingly. The Modeller will also need to make a judgement about the likely condition of the gulley pots as gulleys located where there is on-street car parking may not have been cleaned for a considerable time.

Creating Modelling Parameters

A table has been developed to aid the process of converting the raw data collected on gulleys into the format required for modelling software. This is shown in Figure G8. The "Gully Description" box should be replaced with the type of gully grating and the road slopes. The "Highway (longitudinal), S_L" and "Crossfall, S_C" values can be taken from Figure G7 above. Then the "highway flow" and "collection efficiency" can be populated from the design tables in appendix C (1) of the manual. Figure G8 is set up to calculate the flow to gully automatically by multiplying these values and filling the "Nett flow to gully" row. Figure G9 presents an example of a completed table. An important point to note at this point is that in this example, the flow to the gully at a flow width of 1.5 m is 11.37 l/s. It is known that the flow from a gully cannot be more than 10 l/s due to the trap. When the data is transferred to the modelling software, any value greater than 10 l/s must be reduced to 10 l/s.

	Gully Description			
	Highway (longitudinal), S_L			
	Crossfall, S_C			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)				
Collection Efficiency %				
Nett flow to gully (l/s)	0.00	0.00	0.00	0.00

Figure G8: Conversion table

	R_STEEP_SHALLOW			
	Highway (longitudinal), S_L			1/20 (Steep)
	Crossfall, S_C			1/50 (Shallow)
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	0.95	2.8	6.02	17.76
Collection Efficiency %	94	87	82	64
Nett flow to gully (l/s)	0.89	2.44	4.94	11.37

Figure G9: Example of populated conversion table

Now that the discharge properties of the gully have been established, the only parameter left to be calculated is the head (m). This is done using Equation 6 from the design manual(1) as shown below;

$$H = BS_C$$ ***Equation (6)***

Where;

H = head in meters
B = Flow width in meters
S_C = Cross sectional slope

With the values of head calculated, the data can be inputted into the modelling software as shown in Figure G10. Two important things to note at this point are;

1. The discharge in the modelling software may be in cubic meters per second in which case the values must be converted from litres per second;
2. Some negative heads must be included, and as previously mentioned, these should be done at a value of -10 l/s.

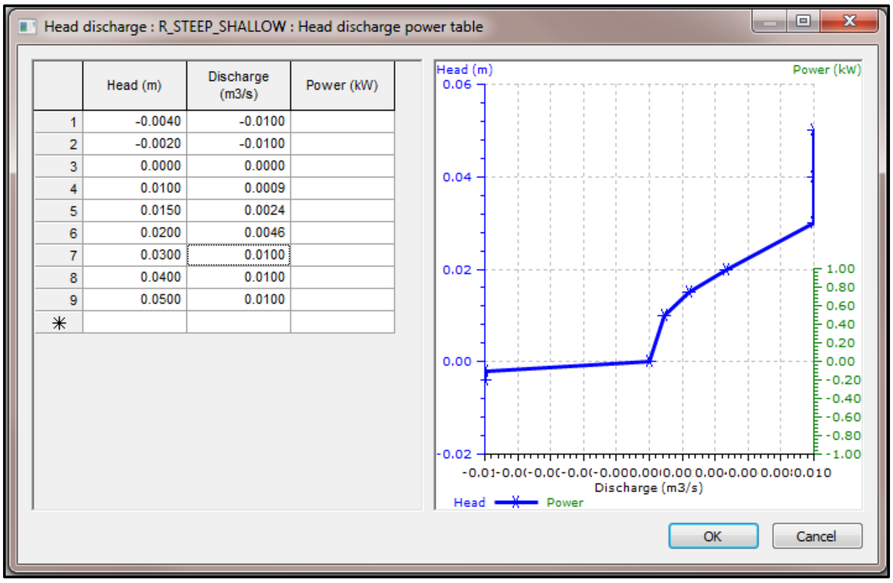

Figure G10: Modelled Head/Discharge relationshop

Discharge conversion tables

Discharge conversion tables have been populated for types R, S and T gulleys, and these are shown on the next pages with an example image of the gully type.

References

1. **Highways Agency.** Design Manal for Roads and Bridges, Volume 4: Geotenchics and Drainage, Section 2: Drainage, Part 3: HA 102/00 Spacing of Rad Gullies. November 2000.

Type R

R_STEEP_STEEP				
	Highway (longitudinal) 1/20 (steep)			
	Crossfall 1/15 (steep)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	6.84	20.17	43.44	128.07
Collection Efficiency %	88	76	61	Not eff
Nett flow to gully (l/s)	6.02	15.33	26.50	Not eff

R_STEEP_SHALLOW				
	Highway (longitudinal) 1/20 (steep)			
	Crossfall 1/50 (shallow)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	0.95	2.8	6.02	17.76
Collection Efficiency %	94	87	82	64
Nett flow to gully (l/s)	0.89	2.44	4.94	11.37

R_SHALLOW_STEEP				
	Highway (longitudinal) 1/100 (shallow)			
	Crossfall 1/15 (steep)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	3.06	9.02	19.43	57.28
Collection Efficiency %	94	89	83	66
Nett flow to gully (l/s)	2.88	8.03	16.13	37.80

R_SHALLOW_SHALLOW				
	Highway (longitudinal) 1/100 (shallow)			
	Crossfall 1/50 (shallow)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	0.42	1.25	2.69	7.94
Collection Efficiency %	99	97	96	92
Nett flow to gully (l/s)	0.42	1.21	2.58	7.30

Type S

	S_STEEP_STEEP			
	Highway (longitudinal)			1/20 (steep)
	Crossfall			1/15 (steep)
	Flow Width, B (m)			
	0.5	**0.75**	**1**	**1.5**
Highway flow (l/s)	6.84	20.17	43.44	128.07
Collection Efficiency %	88	76	61	Not eff
Nett flow to gully (l/s)	6.02	15.33	26.50	Not eff

	S_STEEP_SHALLOW			
	Highway (longitudinal)			1/20 (steep)
	Crossfall			1/50 (shallow)
	Flow Width, B (m)			
	0.5	**0.75**	**1**	**1.5**
Highway flow (l/s)	0.95	2.8	6.02	17.76
Collection Efficiency %	94	89	82	64
Nett flow to gully (l/s)	0.89	2.49	4.94	11.37

	S_SHALLOW_STEEP			
	Highway (longitudinal)			1/100 (shallow)
	Crossfall			1/15 (steep)
	Flow Width, B (m)			
	0.5	**0.75**	**1**	**1.5**
Highway flow (l/s)	3.06	9.02	19.43	57.28
Collection Efficiency %	94	89	83	66
Nett flow to gully (l/s)	2.88	8.03	16.13	37.80

	S_SHALLOW_SHALLOW			
	Highway (longitudinal)			1/100 (shallow)
	Crossfall			1/50 (shallow)
	Flow Width, B (m)			
	0.5	**0.75**	**1**	**1.5**
Highway flow (l/s)	0.42	1.25	2.69	7.94
Collection Efficiency %	97	95	92	84
Nett flow to gully (l/s)	0.41	1.19	2.47	6.67

Type T

T_STEEP_STEEP				
	Highway (longitudinal) 1/20 (steep)			
	Crossfall 1/15 (steep)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	6.84	20.17	43.44	128.07
Collection Efficiency %	77	56	Not eff	Not eff
Nett flow to gully (l/s)	5.27	11.30	Not eff	Not eff

T_STEEP_SHALLOW				
	Highway (longitudinal) 1/20 (steep)			
	Crossfall 1/50 (shallow)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	0.95	2.8	6.02	17.76
Collection Efficiency %	90	79	67	50
Nett flow to gully (l/s)	0.86	2.21	4.03	8.88

T_SHALLOW_STEEP				
	Highway (longitudinal) 1/100 (shallow)			
	Crossfall 1/15 (steep)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	3.06	9.02	19.43	57.28
Collection Efficiency %	90	80	68	Not eff
Nett flow to gully (l/s)	2.75	7.22	13.21	Not eff

T_SHALLOW_SHALLOW				
	Highway (longitudinal) 1/100 (shallow)			
	Crossfall 1/50 (shallow)			
	Flow Width, B (m)			
	0.5	0.75	1	1.5
Highway flow (l/s)	0.42	1.25	2.69	7.94
Collection Efficiency %	95	91	85	71
Nett flow to gully (l/s)	0.40	1.14	2.29	5.64