WaPUG Spring Meeting 1990

New Hydrology Model

J.C.Packman, Institute of Hydrology
Work performed while seconded to Hydraulics Research Ltd

A new hydrology model has been discussed at the last two WaPUG spring meetings, this time a proposed new model is presented for your consideration. The model is currently being tested by WRc and if satisfactory will be developed only a little further before being included in WALLRUS. Although the new model is more flexible than the old, and makes better engineering sense, it is based on a (severely) restricted database which might alarm users.

The original WASSP hydrology model was not designed to model long duration storms or large catchments, including extensive undeveloped areas. Inflow to each manhole and flow in each pipelength was intended to be modelled explicitly. The PR equation was based on a regression approach which did not seem intuitively correct, and its application beyond the range of observations was unwise.

The new model (as requested by users) should be able to:

(i) model above-ground response, but also (optionally) pipe flow (with surcharging), thereby allowing lumped areas (~10ha) to be input to trunk sewers

(ii) allow greater flexibility in runoff generation by different surface types, and also allow for inlet restrictions and bypassing.

(iii) allow time series applications with rainfall losses varying in time with catchment wetness, but unaffected by splitting long events into shorter bursts (ie. seamless).

These requirements were originally to be met with, for each subarea in the catchment, up to three separate modules in parallel to represent the surface types (eg. paved, roof, pervious, undeveloped). Each module comprised a rainfall loss model, a runoff routing model, and a storage-diversion model, and a sewer routing model. The structure was undoubtedly flexible and the repetitve structure made for easy implementation. However, as indicated at last year's meeting it involved up to 45 parameters per subarea, and it would be impossible to determine stable values for the more hydrological of these.

It is worth noting at this point that while WASSP/WALLRUS users have been requesting a more detailed hydrological model, Prof.Harremoes (influential in MOUSE, the major international competitor to WALLRUS) predicted in his keynote lecture to the 1988 Urban Water conference in Duisburg a return to simple volumetric coefficients with stochastic error modelling (very much as in WASSP). This was due to (i) the difficulty of fitting detailed hydrological models, and (ii) the relatively small impact the extra detail has on design decisions. His argument however is concerned with design decisions and not with the confidence a model user derives from good simulation/verification results.

With this in mind, the structure of the new model has been simplified and is now a more obvious development of the original WASSP model (fig 1). In each subarea, up to three surface types may be defined, one of which MUST be pervious. Initial depression storage loss depends on slope (as in WASSP), but is abstracted before the continuing loss. Paved/roof area runoff is derived from the EFFECTIVE impervious area via a factor, the residual area is treated as pervious. Runoff from pervious area depends on accumulated moisture, varying both between and during storms. Runoff routing uses the current WALLRUS linear-reservoir model, which depends on subarea size and slope. All pervious area runoff in the subarea is routed via the one store, but taking a proportion (eg parks or undeveloped area) more slowly is a possible development. The storage- bypass model deflects output from one surface's routing model for input to another. The sewered subarea model is not yet defined.

Effective impervious area factors can vary from subarea to subarea, but the pervious moisture store contents are tied to the respective rainfall hyetograph (with potentially parallel computations for different SOIL types). This expedient ensures 'seamlessness' without needing to specify initial moisture conditions for each subarea (which would only be guessed!), just for each hyetograph/SOIL combination. The small negative impact is that non-EFFECTIVE paved/roof runoff and bypass flows do not surcharge the pervious area store (but would this be measured anyway?).

The model therefore requires (a) for each subarea, up to 3 depression storage values (dependent on SLOPE), 2 effective area factors, 3 routing delays (dependent on SLOPE and AREA), and storage-bypass data (b) for each hyetograph/SOIL combination, various soil moisture parameters (depending on model adopted), plus (c) global parameters for the routing model's dependence on rainfall intensity. From most user's point of view, the effective area factors are the only additional requirement (and these will avoid the need to FORCE bad paved/roof areas to obtain a verified model!).

Various forms of soil-moisture model have been tried in the model. It was hoped a proper 'accounting' model could be derived, with PR depending only on the cumulative balance of infiltration and evaporation. (Evaporation has been estimated throughout using an annual sinewave, Calder, Harding & Rosier (IH) showed this was as good as anything where soil-moisture was concerned). The PR:Soil-moisture dependence was modelled in linear and SCS forms. However these models were no more accurate than a simpler PR:API model, and gave unrealistic parameter values when optimised. Basically the models had been oversimplified, and more detailed parameterisation was needed - this did not fit with the philosophy!

Table 1 shows the development from a simple constant PR model to the recommended API model, together with the mean error at each stage. The recommended model is of the form

PR = IF*PIMP + (100-IF*PIMP)*NAPI/PF

where IF is the effective impervious area factor
PF is a moisture depth parameter (mm)
and NAPI is API derived from net rainfall after subtraction of running depression storage.

Depression storage, limited to 2mm, is evaporated according to a sine wave fitted to regional data published by MAFF. A constant PF value of 200mm is recommended (cf the 150mm root constants in MORECS), but the API decay constant (0.5 in WASSP) is given values of 0.1, 0.5, 0.7, and 0.9 for SOIL types 1, 2, 3 and 4 respectively; (faster reduction of soil moisture in lighter soils is something I've wanted for some time!). The remaining parameter is the effective impervious area factor. Recommended values are 0.45, 0.6, and 0.75 for surfaces in poor, fair, and good condition.

The recommended parameter values presented above were derived by manual smoothing of best fits (in terms of RMS volume error) for individual catchments. Some may be relieved that regression has not been used, though I am worried. Regression is only a mathematical way of drawing a straight line through data points. In this case, there are only 9 data points, the 9 catchments (cf 112 events) used in the analysis. The catchments all have their own idiosyncrasies, and make too small a sample for satisfactory regression (or maybe any) work.

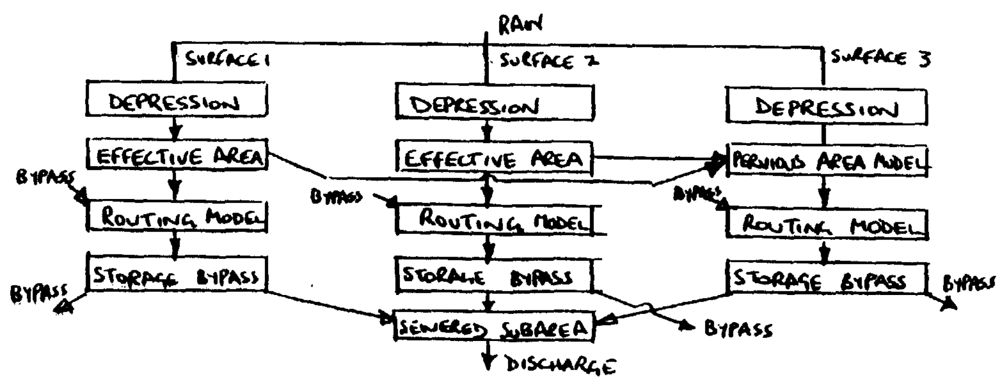
In developing the original PR equation, 17 catchments and 510 events were used. Less data were used in this study because (i) some data were insufficient, (ii) some data could not be reconstituted with the resources available, (iii) some events were recombined as multiple events, and (iv) only events with maximum 5-minute intensities of 20mm/h or more were used.

As can be seen, the data are all for small catchments. None include the effects of storage tanks, overflows, pumping stations, sea outfalls, or large undeveloped areas. In most cases only a single raingauge is available. The data predate electronic logging, and timing errors from clock drift are present. The data were collected typically over a period of 3 years, and flows were usually estimated using flume structures.

The variation in runoff from impervious area shown by the data is remarkable, ranging from 45% at WFRL to 100% at Oxhey Rd. The tarmac at WFRL was recognised by RRL as in bad condition, and resurfacing increased the runoff considerably. Oxhey Rd was a single length of new road with 6 gulleys and a catchment boundary tight to the road area. The only SOIL type 1 catchment was Kidbrooke, the yard of a government training centre, subject to random building activity! Pervious areas lay outside the surrounding buildings.

	Black-pool	Donc-aster	Kidb-rooke	Oxhey Rd	WFRL	Brac-knell	Derby 3A	Southampton 1	Southampton 2
1. Catchment Data									
AREA	4.82	5.14	3.42	0.78	1.39	11.60	8.55	0.80	0.60
PIMP	42	30	68	60	50	46	51	41	42
SOIL	0.45	0.45	0.15	0.45	0.30	0.45	0.45	0.40	0.40
EVENTS	13	15	25	23	8	5	10	6	7
Nov-Apr	0	0	2	2	0	3	1	0	0
2. Constant PR model									
PRimp	84.7	69.0	54.9	98.7	46.0	75.5	56.9	62.6	64.0
RMS%	16.0	24.6	16.9	13.6	10.8	32.7	16.9	33.2	13.6
3. Constant storm PR, varies between storms with API (DK=0.9)									
PRimp	69.3	34.3	53.3	97.1	43.4	49.0	47.3	40.0	56.2
PFapi0	339	280	1028	1035	1999	113	277	192	630
RMS%	13.1	21.1	16.8	13.7	10.5	7.1	13.0	17.4	11.2
4. Varying PR with API (DK=0.9)									
PRimp	67.8	22.8	53.0	96.5	42.2	39.4	43.6	37.4	54.8
PFapit	344	242	1027	880	1574	113	253	193	588
RMS%	12.8	19.8	16.7	13.6	10.3	7.3	12.0	17.0	10.9
5. Varying PR with Net-rain-API (DK=0.9)									
PRimp	75.2	49.3	59.8	98.8	43.0	48.7	52.0	48.8	59.8
PFnapi	247	201	2000	362	875	108	226	157	502
RMS%	12.4	18.9	13.1	14.6	8.1	3.5	11.3	18.4	6.3
6. Varying PR with Net-rain-API									
PRimp	67.8	47.4	59.2	96.4	39.9	47.1	47.2	50.2	61.0
PFnapi	324	202	332	97	185	119	541	96	232
DK	.956	.910	.500	.569	.500	.925	.986	.819	.500
RMS%	10.3	18.8	13.0	14.1	5.2	2.5	10.2	13.9	5.8
7. Varying PR with Net-rain-API (PF=200mm)									
PRimp	65.4	48.8	59.9	100.	43.9	54.6	52.9	55.8	62.7
DK	.940	.920	.100	.790	.596	.960	.910	.885	.391
RMS%	11.6	19.1	12.9	14.8	7.2	11.3	12.3	19.4	6.0
8. Varying PR with Net-rain-API (PF=200mm, DK=.1,.5,.7,or .9)									
PRimp	74.5	53.4	59.9	100.	44.7	65.2	53.4	62.6	60.5
RMS%	12.9	19.4	12.9	14.8	7.4	16.3	12.4	23.2	7.3

FIGURE 1.



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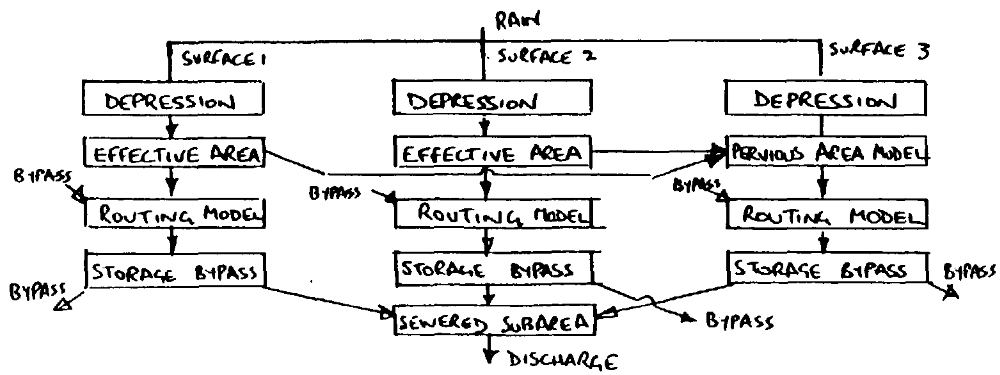

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Spring Meeting Discussions

NEW HYDROLOGY MODEL - J PACKMAN (IOH) / M OSBORNE (HRL)

R Dew - Yorkshire Water
After section (4) of Table 1 (refer to paper) the changes in "RMS %" were very small.

Ans: It is true that for all the effort, the variation is small. However, the confidence in the model is important and if this is increased, even though by a small margin, it is valuable to the engineer.

R Ashley - Dundee Institute of Technology

1) Whilst the approach is correct is there a danger of too much flexibility which will not be fully understood by users?

2) The lack of resources and limited data used is disappointing. There must be other information available from other WASSP users and from overseas.

3) How will such a hydrology model fit in with WALLRUS?

4) Will the information produced by this research be disseminated widely?

Ans: Regarding WALLRUS, the engineer will be able to classify paved surfaces within the SSD file - although this could be dangerous. It is of concern that a more flexible model will encourage force fitting during verification.

The lack of resources is also of concern. The original investment in WASSP was £0.5M, but for this model it is presently only £0.05M.

It is not true that plenty of information is available elsewhere. Even if this were so, more money would need to be spent to research each individual catchment thoroughly.

O Leonard - Howard Humphries
How would you like to see extra data collection handled?

Ans: All existing data was collected "non-electronically" using flumes/paper charts. Modern methods of flow-recording should be used. I must emphasise that data collection alone is inadequate, there must be a commitment to use it!

D Beale - Howard Humphries
You have only presented % volume runoff - what about peak-flow runoff?

Ans: As yet still inconclusive - we are concentrating on the loss model at present.

D Wright - Applied Research
So everything done so far is based on volumes and not on shapes of hydrographs?

Ans: Yes.