APPENDIX 5

Hydrology modelling summary

BROWNHILL KESWICK CREEK STORMWATER PROJECT - HYDROLOGY COMPONENT

INTRODUCTION

The hydrology of the catchment of Brownhill and Keswick Creeks upstream of Tapleys Hill Road has been extensively studied, firstly for providing hydrological data input (flow estimates at various location for various average recurrence intervals (ARIs)) for floodplain mapping and secondly to assess the hydrological effect of various flood mitigation strategies proposed.

All hydrologic modelling has been carried out using the RRR model. Two earlier separate creeks models have been combined and extended to cover the entire catchment and the complete model reviewed to ensure that information gained since the development of the two individual models is taken into account.

THE RRR MODEL

The RRR model has been developed as a result of the limitations that have been identified in runoff routing models normally used in Australia, such as RORB and RAFTS. One of the most important of these is that RORB and RAFTS can deal with only one runoff process.

The RRR model makes provision for separate channel storage and hillside (or process) storage. This represents a major change to existing runoff routing models that assume that only surface runoff is being modelled and that the total storage within the catchment can be represented by a series of storages along the watercourses.

The model is named RRR (or Rainfall Runoff Routing) model because like rainfall runoff models, it models hydrological processes and like runoff routing models these processes are represented by a series of concentrated storages.

The hillside storage must be able to be split to allow for the contributions from the different processes occurring. Since each process on the hillside is assumed to enter the channel by a separate flowpath, it is allowable to have non-linear storage in the hillside part of the model.

The channel storage is assumed to be linear (ie. the travel time does not vary with the amount of flow in the channel), as a result of evidence obtained from earlier investigations of channel travel times.

In its simplest form the model can be used with a single sub-area. The model structure for a single sub-area is as follows;

- The model has ten equal channel reaches of length d/10, where d is the longest flow path length in the catchment (km). It is assumed that the area contributing to each reach is also equal (ie. total catchment area/10).
- Channel storage for each channel reach is modelled as a linear storage of the form $S = 3\,600\,k\,Q$.
- Contributions from any number of separate hydrological processes can be added at the downstream end of each channel reach before routing through the channel storage.
- Each of these processes is modelled as per Laurenson's Runoff Routing Model, as used in the RAFTS model ie. with ten equal storages each with a storage $S = 3\,600\,k_p\,Q^m$, kp being a lag related to runoff process. The total area of each process model is the total catchment area/10, so that the area of each sub-catchment is the (total catchment area/100). The exponent m is taken to be 0.8.
- Each of the hydrological processes has an initial and continuing or proportional loss associated with it.

The use of ten storages for both the process and channel components follows the Laurenson Runoff Routing Model. The catchment is not however delineated with equal travel times, but with equal areas, as per the RAFTS model.

The RRR model is not a computer package as such, but a structure that can be set up and run using the industry standard XP-RAFTS graphical user interface.

Figure 1 shows diagrammatically the structure of a single sub-area of the model.

Although the model may initially look complicated with 100 sub-catchments it is in effect simple as all sub-catchments are the same size and storage parameters and losses need be input only once for each process modelled.

It has been found that for rural catchments three runoff processes are identifiable, and for ease of identification these are termed process 1 to 3. Process 1 is equivalent to the base flow found in most catchments and process 2 is the runoff normally modelled by Runoff Routing models such as RORB and RAFTS.

Note: input to each process storage is (rainfall – losses) over an area = total catchment area / 100, Initial loss IL, Proportional loss PL or Continuing loss CL

Ten process storages for each process (2 shown)
Each with $S = 3600k\ Q^m$

Only one input to channel node shown

Outfall hydrograph

Nine channel storages,
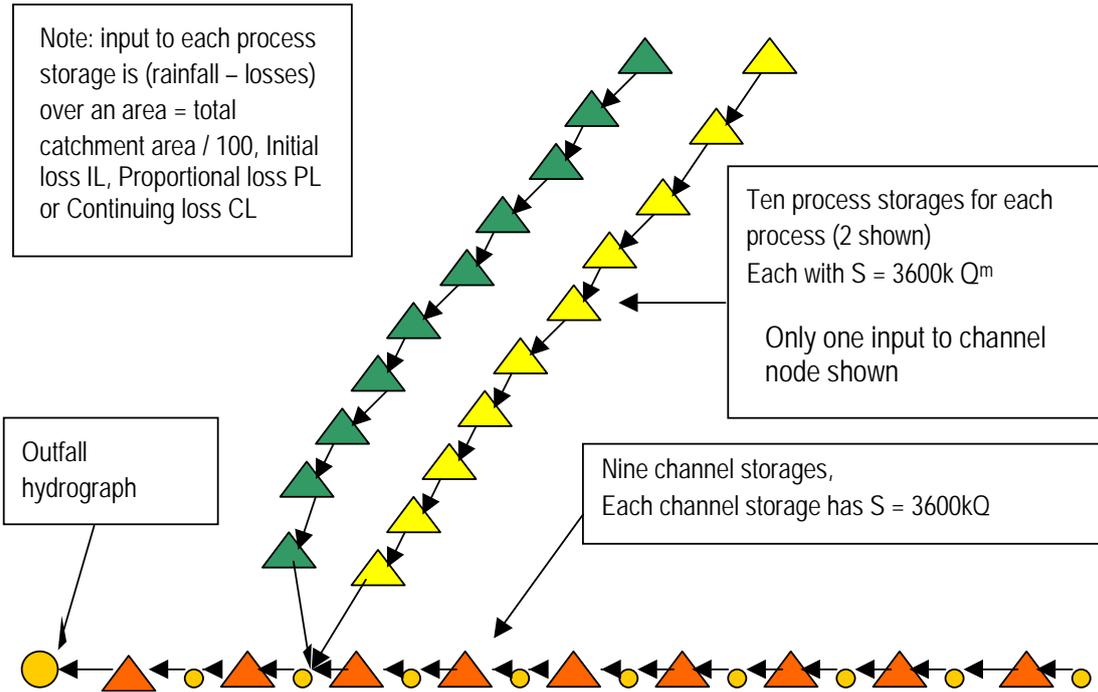Each channel storage has $S = 3600kQ$

Figure 1. Structure of the single sub-area RRR model

Process 3 is most likely to be true surface runoff. Process storage in this case is zero, with the catchment lag for this process being the same as the channel lag.

The RRR model can also be used with multiple sub-areas, with channel reaches connecting sub-area outlets.   With more than one sub-area generalised parameters have to be introduced for application to any catchment.

Two generalised parameters are required, being the *channel characteristic velocity, v_c* defined as:

$$ v_c \;=\; \frac{d}{(36\ k)} \tag{1} $$

Where v_c is the channel characteristic flood wave velocity (m/sec)
  d is the longest flow path length in the catchment (km)
  k is the channel storage parameter (hrs)

and the *catchment characteristic lag parameter, Cp*, where:

$$ Cp \;=\; k_p\ A^{m-1} \tag{2} $$

where A is the catchment or sub-area area (km^2)
       m is the exponent in the storage equation
          $S = 3600k_pQ^m$

There are normally two catchment characteristic lag parameters, designated Cp1 and Cp2.

In general the hydrograph from upstream sub-areas is translated according to the characteristic flood wave velocity to the next sub-area outlet.

In urban areas two processes contribute to the outflow, being the directly connected impervious and the unconnected area (composed of supplementary paved and pervious areas) contributions. In addition allowance is made for a separate but parallel overflow path to be modelled in conjunction with the normal flow path in each urban sub-area. Flows in excess of the pipe system capacity, at each channel storage, are passed to the parallel overflow path, where flows are routed through storages with a different storage delay time, representing the greater amount of storage available in the street system. Other features such as storage basins can also be incorporated in the model.

For the calibration of the RRR model in the Brown Hill and Keswick Creek catchment flows in excess of the urban channel capacity are transferred to a separate overflow path having a series of storages to represent the greater delay of flows outside the channel system. The RRR model used for the production of floodplain mapping do not have these overflow paths as overflows are dealt with by the hydraulic model. In this mode the RRR model is used only to provide inflows to the hydraulic model. For this purpose inflow hydrographs were provided at the upstream boundaries of the hydraulic model and at a number of locations along the main channel system.

The RRR model has been subject to verification on gauged urban catchments at Glenelg and the Paddocks in South Australia and at Jamison Park in New South Wales, with good results. It has also been verified on six gauged rural catchments, four in the Mount Lofty Ranges in South Australia, one in New South Wales and one in the Northern Territory.

On independent peer review, prior to undertaking this current study, the flood flow estimates being produced by the RRR model were considered to be "suitable for design purposes".

THE ADVANTAGES OF THE RRR MODEL

There are several features of the RRR model as described above that make it ideal for application on the Brown Hill and Keswick Creeks catchment.

Firstly the model can deal with a hydrological system that behaves differently for small and large events. Flows in excess of the pipe network capacity in urban areas will travel through the street network. These will travel much more slowly than the pipe network and thus must be modelled differently. The RRR model

as developed deals with this by having essentially two layers, with different storage relationships for each layer.

Secondly the model can be calibrated to any number of individual locations, without affecting the predicted flows at other parts of the model, which would not be expected to change as a result of the calibration. This is part of model self-consistency, which does not exist in models such as RORB and RAFTS. In addition there is no single catchment wide storage parameter in RRR as there is in RORB. Different storage parameters and losses can be applied to different parts of the model that have different land use characteristics. For instance hydrological differences between rural and urban areas can be readily accommodated.

In addition because the RRR model treats the in-channel and process storages separately (or in-channel and pipe system storage routing) the RRR model will intrinsically give a better indication of flood peak travel times than RORB.

MODEL CALIBRATION

The model was developed based on estimated contributing percentages of directly connected impervious areas and sub-area response time in urban sub-areas. The storage and loss parameters for the rural catchment to Scotch College were based on calibrated parameters for other rural catchments in the Mount Lofty Ranges. All these parameters were verified and adjusted where necessary by the application of the model on a number of flood events in the catchment.

SUMMARY

The RRR model has been developed to overcome a number of limitations in runoff routing models such as RORB and RAFTS, and as such it is an appropriate model for the catchment. On independent peer review, prior to undertaking this current study, the flood flow estimates being produced by the RRR model were considered to be "suitable for design purposes".

The model parameters have been adjusted based on the application of the model to a range of monitored flood events, and it can thus be used as a basis for the prediction of flood hydrographs.

Brownhill and Keswick Creeks
Location of Calculated Hydrographs

Brook I

MileEndl

Goodl

Parkl

(2)I

USJuncl

(3)I

Vic Park

Keswickl

PKupJl

Parklands Creek

Glenside

Rich I

PKupJl

(4)I

(1)I

504580l

GOupJl

Charlesl

Full I

Osmond Creek

Anzacl

Windl

Morphl

Tapleysl

Hawthl

Ridge

Belairl

Scotchl

Brownhill Creek

Not to Scale

Location of Hydrographs
Creeks
Suburbs
Subcatchments
Roads