

# Documentation of flow and salinity routing methods used by various modellers

## 1. Introduction

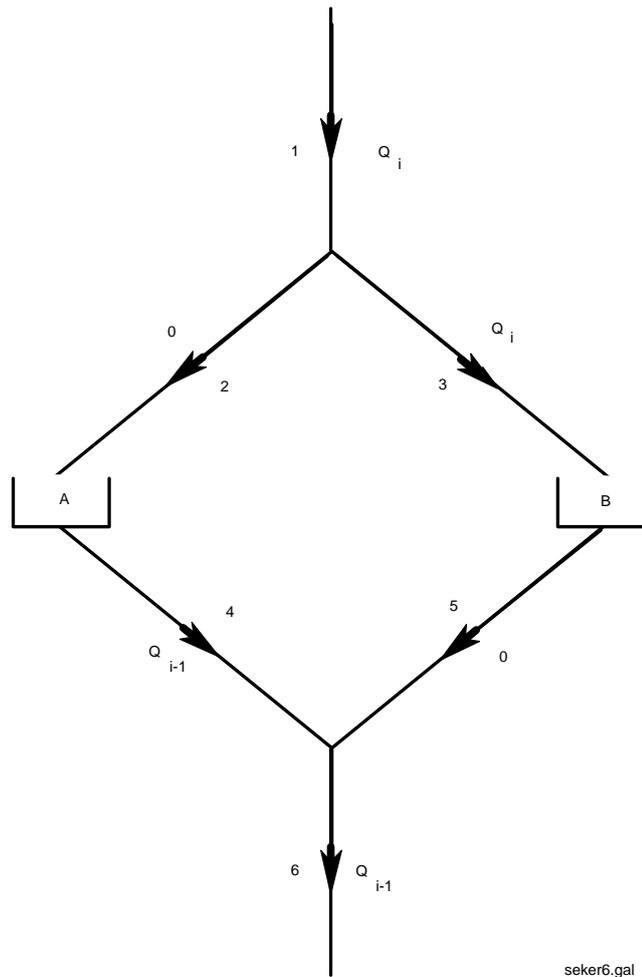
This document describes various methods of lagging and or attenuating flow which have been applied in a number of different REALM models. The different methods are listed below in sub sections according to which models they have been included.

In summary, the main methods are:

- Use of one storage to lag and/or attenuate flow including mixing of salinity;
- Use of two or more storages in parallel to lag flow without mixing or attenuating;
- Combination of above two approaches;
- In cases where lags and/or attenuation is required in upstream parts of the model, manipulation of inputs;
- In cases where lags and attenuation are required in downstream reaches before output to another model, using carriers to calculate the flow and salinity to be output.

## 2. Goulburn Daily Model

This REALM model does not directly account for travel time between nodes, however, time lags have been incorporated into the model. The following is a method by which the model can be lagged by one time step to simulate travel time between any two nodes whilst maintaining quality. The process may be repeated as often as necessary until the required delay is achieved. This method can not be used to model travel time less than one day because minimum simulation time step in REALM is one day. Figure 2-1 below illustrates the method used to introduce lag time in the model.



■ **Figure 2-1 Schematic showing flow at time step i**

At time step  $i$  the capacity of Carrier 3 is unlimited and Carrier 2 capacity is zero. Therefore, flow  $Q_i$  with salinity  $EC_i$  from Carrier 1 travels via Carrier 3 and is stored in Storage B. In the same period Carrier 5 capacity is zero but the capacity of Carrier 4 is equal to the volume of Storage A which is the previous time step flow rate  $Q_{i-1}$  with salinity  $EC_{i-1}$  at Carrier 1. The downstream Carriers 4 and 5 have large negative costs forcing REALM to release water at a rate up to the carrier capacity. Each carrier capacity alternates daily from unlimited capacity to zero capacity using a function of the previous day capacity.

The disadvantage of this method is that parts of the network downstream of the lagging storages will not be “seen” as part of the linear programming solution to be solved with the parts of the network above the lagging storages. This can be overcome by including carriers in the upper part of the network with a high negative penalty to “force” the flow downstream of the lags. It should be noted that the benefits of using a linear programming model for this situation is reduced.

### 3. Murray Model

The description below is described in the document “Murray REALM Model User Guide” (DSE, 2005).

The procedure for calculating the order on Hume has to take into account that some of the water in river storage will not be effective in terms of meeting demand. The concept is now described in detail.

Reach storage volume is related to reach flow rate. As flow rates drop, reach storage volumes drop correspondingly. Flow rates are set by releases from reservoirs to meet demands. As demand drops releases are adjusted downwards. Because of the travel times involved this adjustment cannot be made sufficiently quickly to prevent the reach storage drop volume being surplus to demand. This surplus volume is termed **waste of reach store**. It represents water which is not effective in meeting demand. It may still be able to be captured in Lake Victoria or be used to meet SA demand.

More specifically it is assumed in the RMSM (and MSM) that waste of reach storage occurs in the reaches Hume to Yarrawonga, Yarrawonga to Torrumbarry, Torrumbarry to Wakool and on the Edward Wakool. Reductions in these reach storages is assumed to be surplus to demand upstream of the Wentworth Junction. The waters may still be used to meet demands downstream of Wentworth or captured in Lake Victoria if there is capacity (inlet & storage) to meet SA demand.

From an accounting viewpoint, the increase in Hume order due to waste of reach store needs to be attributed to the states. The accounting rules state (as coded in the MSM) that a state's waste of reach store is given by

States (positive waste of reach store) =  $\max(0, \text{States reach store this time step} - \text{States reach store last time step})$

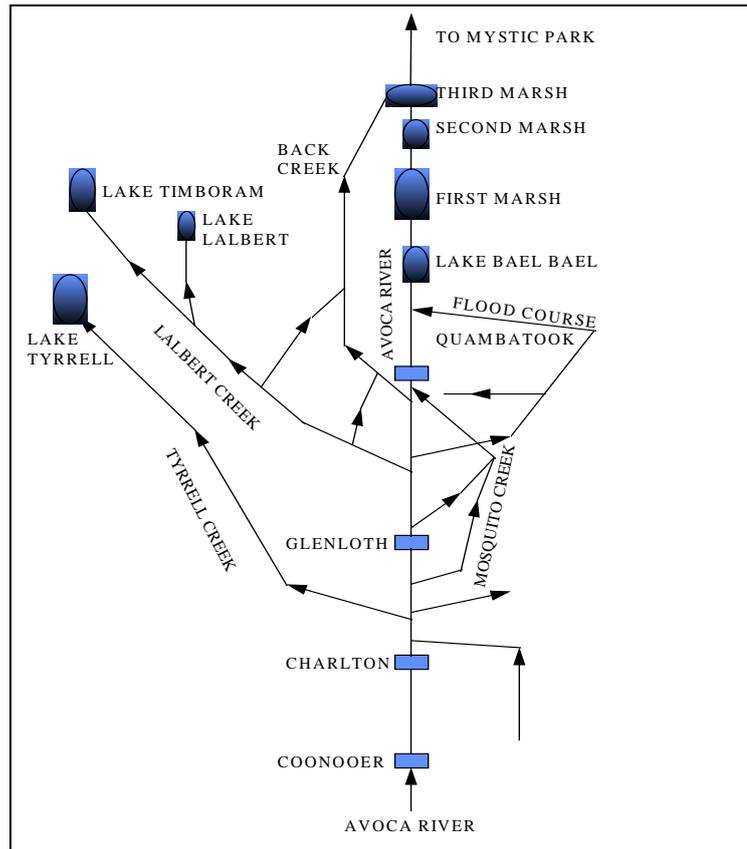
i.e. the reduction in that states reach store.

Occurrences arise when, for the integrated system, there is a drop in reach store made up of one states rise in reach store and the other states fall. Using the above formula alone, one state would have a reach store greater than the integrated system reach store while the other would have a zero waste of reach store.

A negative waste of reach store is introduced to ensure that the total of states waste of reach store is equal to the integrated systems waste of reach store. A states negative waste of reach store is given by

States (negative waste of reach store) = Other states (positive reach store) - Integrated systems waste of reach store

#### 4. Avoca River



■ **Figure 4-1 Schematic Diagram of the Avoca River System**

Functional relationships representing the flow attenuation and divergence in the Avoca River were created in a series of carriers upstream of Lake Bael Bael. From Coonooer Bridge, flow diverges to various anabranches at different flows in the Avoca River. Flow attenuation and in-stream losses were also incorporated in the flows in various branches. Simple one reservoir - one carrier attenuation systems were used on each branch, which resulted in mixing of flows in each branch over time. However, branch flows would be at least partially mixed due to the in-stream storage and stream meandering, particularly in the branches. The downstream carrier from the reservoir would have a smaller capacity than the upstream carrier, thus water would accumulate in the storage until inflow ceased. Outflow from the reservoir would continue until it was empty, thus the flow would be attenuated.

The attenuated flow in the Avoca River main stream ( $Q_a$ ) was estimated by CMPSF (1985) as:

$$Q_a = Q_c \times (Q_r / Q_u)$$

■ **Equation 4-1**

Where,

$Q_r$  = recorded flow at Quambatook;

$Q_c$  = flow at Coonooer Bridge; and

$Q_u$  = the unattenuated flow at Quambatook

In summary:

- The attenuated flow in the Avoca River main stream ( $Q_a$ ) was estimated by CMPSF (1985) based on Equation 4-1. This relationship was used for the main stream flows, using the historical measured flow at Quambatook. Because the relationship developed by CMPSF (1985) only considered peak flows, some adjustments had to be made. Because there were frequent occurrences when flow continued at Quambatook after flow had ceased at Coonoor Bridge, the attenuated flow was equal to  $2 Q_c Q_r$  to release the remainder of the attenuation reservoir storage.
- The attenuation on the Mosquito Creek assumed that flow was stored in the floodplain while the main peak passed Coonoor Bridge. Once flow had ceased into Mosquito Creek, the flow out of the attenuation storage was equal to a proportion of the storage volume.
- The Back Creek flow attenuation was based on a straight 10-day lag and it was assumed that the maximum flood flow from the Back Creek to the Third Marsh is 300 ML/day.
- A 6-day lag was placed on the Avoca River flow before it entered Lake Bael Bael.
- Attenuation in flow through Lake Bael Bael and the Avoca Marshes was incorporated by applying a factor to flows between Lake Bael Bael and the Avoca Marshes.
- A 6-day non-mixed lag was applied on outflow from Third Marsh before it enters the Kerang-Swan Hill area. This was achieved by placing six lag storages in parallel, each delaying one day's flow for six days.
- The Avoca outfall from the Third Marsh flows to the Channel 6/7 (via Channel No. 7) based on whether supply to Woorinen and Tresco was occurring or not. The remaining flows to Lake Boga via floodway, with 8 days lag for flows greater than 200 ML/day. Since there is a low flow channel through the floodway which takes smaller flows straight through, no lag was placed on flows less than 200 ML/day.

## 5. Loddon River

Time lags and flow attenuations in the Loddon River system have been included in the Wandella Creek model using variable capacity carriers as follows:

- The travel time of 2 to 4 days was adopted for the Loddon River from Appin South to Kerang Weir. Therefore the Loddon River flows at Appin South have been lagged by 2 days and attenuated over three days. The attenuated Loddon River flow is calculated as:

$$Q_{att} = \frac{\sum_{i=n}^m (Q_{t-i})}{m - n + 1}$$

■ **Equation 5-1**

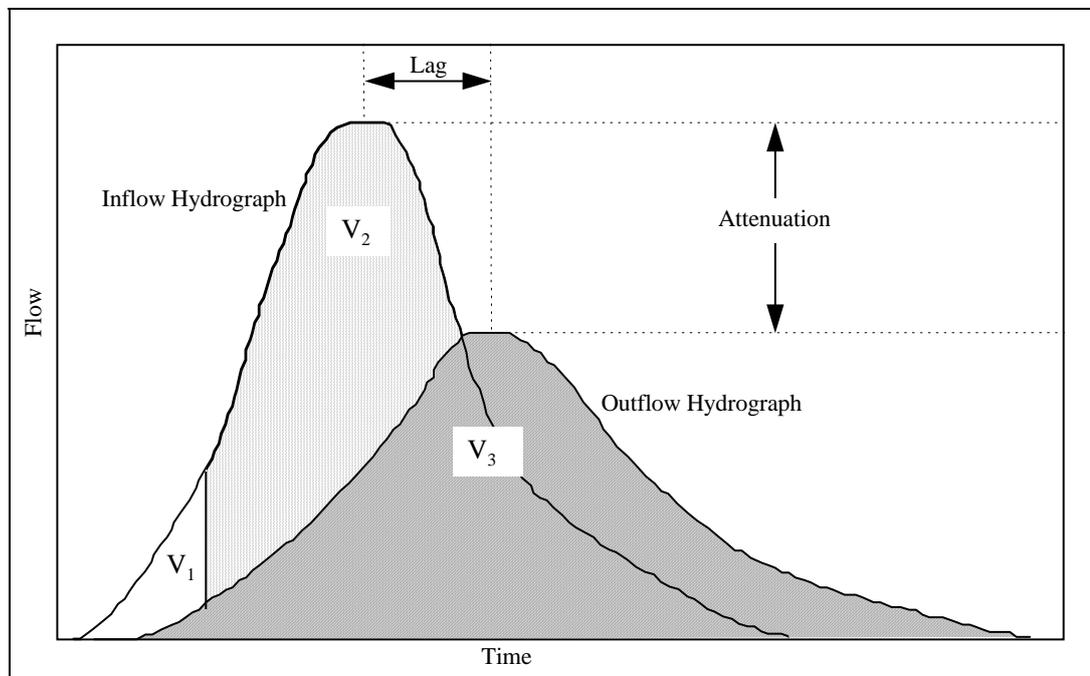
Where:

$Q_{att}$  = the actual Loddon River flow upstream of Kerang Weir;

$Q_{t-i}$  = the Loddon River flow at Appin South on day t-i (t is the current day);  
 n = minimum days travel time = 2; and  
 m = maximum days travel time = 4.

## 6. Wandella Creek

The significant storage within the Wandella Creek system has the effect of lagging and attenuating flood peaks. In addition to storage in large lakes and wetlands, there is a substantial volume of storage available within stream reaches, in surface depressions and in the soil profile. At the beginning of a flood event, this reach storage must be filled as the flow advances through the system. This filling process produces high reach travel time, and also attenuates the peak of events. Similarly, after the flood peak has passed this storage drains progressively, producing a very long recession curve. Some of the depression storages will become isolated from the receding floodwater and this water, along with that which infiltrated into the soil profile, is thus lost from the flood event. This residual storage is eventually depleted by vertical drainage, evaporation and evapotranspiration. The effect of reach storage and loss processes on a flood hydrograph are illustrated in Figure 6-1.



■ **Figure 6-1 Effect of Reach Storage and Loss Processes on Hydrograph Shape**

The volume which enters the reach is  $V_1+V_2$ .  $V_1$  represents the volume which goes into reach storage and is lost, either because it infiltrates, or is isolated from the main drainage line during the recession.  $V_2$  is the volume which eventually passes downstream, and is equal to  $V_3$ . The lag and the attenuation are clearly shown.

Loss and lag are very simple to model. An initial loss can simply be modelled as a reservoir with no spill capacity below full. The maximum capacity of the reservoir is then an initial loss, which must be satisfied before any water will pass further downstream. A continuing loss is modelled as a carrier leading to a stream terminator. Flow in this loss carrier can either be a constant, or can be made a function of other variables such as the volume in a storage, or flow in another carrier.

Two different type of lags have been included in the model as follows:

- Type 1 – Simple one-reservoir lag element with full mixing effect; and
- Type 2 – Multi reservoirs and parallel flow paths lag element with no mixing effect.

Type 1 lag element includes a single reservoir and only one flow path. It has the effect of fully mixing successive days' flow over the period of the lag. Simple lag of  $x$  days can be modelled by using a reservoir whose outflow is equal to inflow  $x$  days previously. To specify a four-day lag, a reservoir is created whose outflow is equal to the sum of the inflows over the previous four days less the sum of the inflow over the previous three days.

The type 1 lag element can have an undesirable effect on the simulated salinity of the water leaving the reach. This effect is most apparent at the beginning of flood events when there is often a short spike of highly saline water lasting only a day or so. A simple lag element will operate so as to spread this spike out over a number of days. This effect was found to significantly impair the ability of the model to adequately represent stream salinities near the beginning of flow events. Therefore a slightly more complex modelling approach (Type 2 lag elements) were adopted at some locations. This was designed using two parallel flow paths with a reservoir on each flow path for each day's lag. Each day, flow is made to switch from one flow path to the other so that successive days' inflow do not mix.

Attenuation is far more difficult to model, and a number of approaches were tried as part of earlier study (SKM, 1995), all using reservoirs in some way. The approach chosen for use in the model is not simple, and does have some limitations. It was chosen because it is extremely flexible. It has a number of calibration parameters, and by careful consideration of these, it is possible to use the same model element in many different instances where attenuation is evident, and tailor the process to the particular conditions encountered.

The approach uses only one reservoir, and works by treating the rising and falling limbs of an event in different ways, loosely representing the physical processes that are occurring. On the rising limb, a small proportion of each day's flow is taken into storage, representing the filling up of depression storages and the soil profile. Once the inflow hydrograph begins to fall again, a proportion of this water is released from storage at each time step, and this proportion increases as the recession continues. Details of these can be found in SKM, 1995.

## **7. Glenelg River**

Lag included in the upper reaches of the model through manipulation of inputs.

## **8. Bet Bet Creek**

Bet Bet Creek catchment was required to be split in the daily GBCL REALM model to give greater resolution of the catchment. In order to simulate flow in the upper reach of Bet Bet Creek being routed to the lower reach, this was achieved by manipulation of the inputs. In essence, the input in the REALM model of upper Bet Bet Creek at Lillicur (407288) was attenuated to the point where it entered the REALM model at the downstream gauging point (Bet Bet Creek at Bet Bet - 407211).

The flow at 407288 was routed to 407211 using the Muskingum method (external to the REALM model). The flow from the intermediate catchment area between the two gauges was calculated as the difference between the routed flow from upstream and the recorded gauged flow at 407211. The parameters for routing was decided by fitting the hydrographs by eye then minimising the total negative inflows in the intermediate reach. The adopted Muskingum parameters was:  $K = 20$ ,  $x = 0.15$ ,  $T = 24$ . Following this process, negatives accounted for 1% of the total estimated flow.

In order to preserve the mass balance at 407211, any remaining negatives were removed by a process of carrying forward negative flow to following time steps.

## **9. References**

DSE (2005), Murray REALM Model User Guide. Department of Sustainability and Environment, 2005.

CMPS&F (1985), Avoca Flood Plain Management Study for Rural Water Commission of Victoria, Camp Scott Furphy, Final Report, March 1985.

SKM (1995), Wandella Creek Catchment Study – Progress Report on Model Development, Unpublished Consulting Report for GMW, SKM, Melbourne. RC077:RC077A.doc