Case study - below average April to June 2011 rainfall but above median April to July streamflows

Between April and June 2011, our seasonal streamflow forecast catchments in the South-east Murray–Darling drainage division experienced below average rainfall (Figure 1). However, very much above average soil moisture resulted in quick streamflow responses to any rainfall and the area experienced below average temperatures (Figure 2) and evapotranspiration. In addition, antecedent streamflows were high. Hence most of our forecast locations reported above median April to July streamflows (Figure 3), despite below average April to June rainfall.

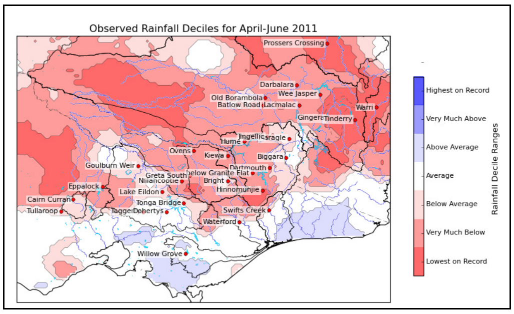

Figure 1: April to June rainfall deciles.

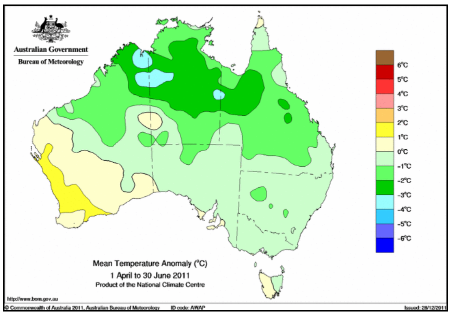

Figure 2: April to June mean temperature anomaly.

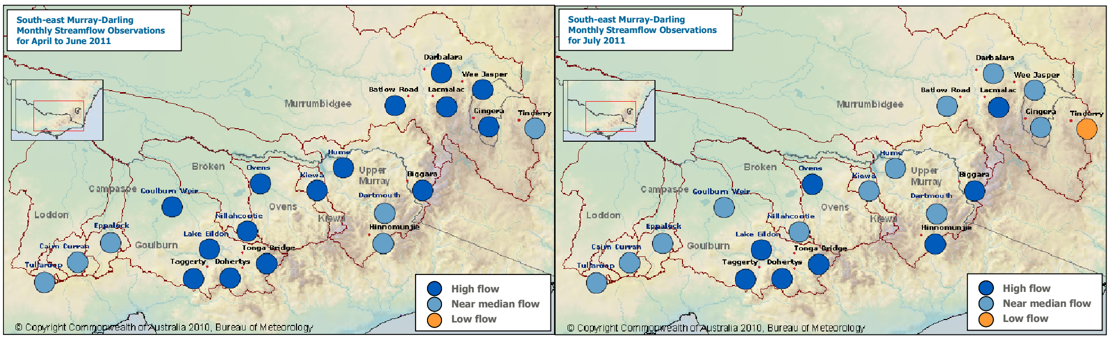

Figure 3: April to June streamflow observations (left) and July streamflow observations (right).

The volume of runoff, and consequently streamflow, occurring in a catchment as a result of the rainfall events during a month are strongly dependent on the initial catchment conditions, such as soil moisture levels, and the characteristics of the rainfall events. The volume of water that hydrologists generally refer to as runoff is made up of: surface runoff, which is the portion of rainfall, snowmelt, and/or irrigation water that runs over the soil surface towards the stream rather than infiltrating the soil; and interflow, which is the water that makes its way relatively quickly to the stream channel just below the surface (The COMET® Program, 2006).

Streamflow is made up of baseflow and quickflow. Quickflow is the direct and short-term response to rainfall that includes surface runoff, interflow and direct precipitation onto the stream surface (this immediately adds to streamflow so could contribute to a rapid increase in discharge, however usually the area of the stream is a small proportion of the total catchment area, so the volume of water involved is small). Baseflow is the longer-term discharge into a stream from natural storages, sustaining flow between rainfall events (Australian Government, 2006). Recognising that there can be multiple natural storages in a catchment, the discharge of groundwater (water held in saturated soils below the water table) to the stream is termed the groundwater component of baseflow.

The relative contribution of quickflow and baseflow components changes through the stream hydrographic record. The flood or storm hydrograph (Figure 4) is the classic response to a rainfall event and consists of three main stages:

i. initially low-flow conditions in the stream consist entirely of baseflow at the end of a dry period;
ii. then rainfall occurs, resulting in an increase in streamflow with input of quickflow dominated by runoff and interflow. This initiates the rising limb towards the crest of the flood

hydrograph. The rapid rise of the stream level relative to surrounding groundwater levels reduces or can even reverse the hydraulic gradient towards the stream. This is expressed as a reduction in the baseflow component at this stage;

iii. then the quickflow component passes, expressed by the falling limb of the flood hydrograph. With declining stream levels timed with the delayed response of a rising watertable from infiltrating rainfall, the hydraulic gradient towards the stream increases. At this time, the baseflow component starts to increase. At some point along the falling limb, quickflow ceases and streamflow is again entirely baseflow. Over time, baseflow declines as natural storages are gradually drained during the dry period up until the next significant rainfall event.

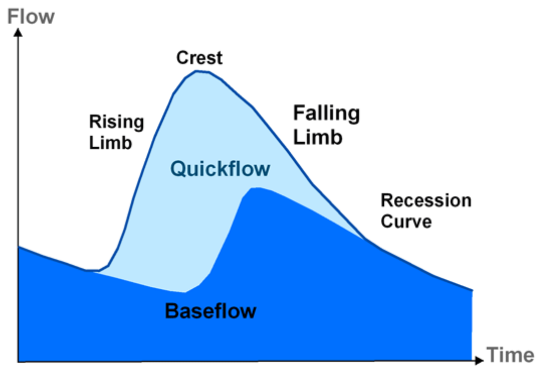

Figure 4: Components of a typical flood hydrograph.

Studies in agricultural areas of south-eastern Australia suggest interflow is not a significant flow pathway in terms of the proportion of total runoff volume, but can be important in saturating areas of the catchment that will then have high runoff rates (Ladson, 2008).

The mass balance for water in a river system can be written as (Raupach et al., 2009):

$$\underbrace{Q_{River}}_{\text{River flow}} = \underbrace{R_{Land}}_{\substack{\text{Total runoff}\\\text{from land}\\\text{surfaces}}} - \underbrace{E_{River}}_{\substack{\text{Evaporation}\\\text{from water}\\\text{surfaces}}} - \underbrace{D_{River}}_{\substack{\text{Diversion for}\\\text{irrigation and}\\\text{urban use}}} - \underbrace{G_{River}}_{\substack{\text{Flux from}\\\text{river to}\\\text{groundwater}}} - \underbrace{dS_{River}/dt}_{\substack{\text{Storage}\\\text{changes}}}$$

In which:

$$\underbrace{R_{Land}}_{\substack{\text{Total runoff}\\\text{from land}\\\text{surfaces}}} = \underbrace{P_{Land}}_{\substack{\text{Precipitation}\\\text{from land}\\\text{surfaces}}} - \underbrace{E_{Land}}_{\substack{\text{Evapotranspiration}\\\text{from land}\\\text{surfaces}}} - \underbrace{dW_{Land}/dt}_{\substack{\text{Soil water}\\\text{storage change}}}$$

Groundwater flow can either add to or reduce the flow of water in a stream (Ladson, 2008). The Ovens River, for example, has a section that is gaining (groundwater adds to streamflow), a section that is losing and a section that is seasonally varying. The upper Ovens River is a gaining stream, with steep hydraulic gradients between the river and aquifers (CSIRO Murray-Darling Basin Sustainable Yields Project, 2008). Groundwater contributes approximately 5 GL/year of streamflow at Myrtleford (mid-catchment), which is approximately 6 percent of the median annual Ovens River streamflow.

It is possible to record high streamflows in a catchment that receives median rainfall when the catchment is saturated and conversely, it is possible to record low streamflows in a catchment that receives median rainfall if the catchment is very dry. Rainfall intensity also influences changes in soil moisture and runoff, for example a season with many rain days and low daily rainfall totals may record a high three-monthly rainfall total but still not provide high runoff. In addition, some catchments require heavy rainfall to produce runoff, depending upon physical catchment characteristics such as vegetation cover, slope etc.

During January and February 2011, Australia continued to feel the effects of one of the strongest La Niñas on record (which peaked between late 2010 and early 2011) and catchments remained saturated. Victoria experienced its wettest January on record and its wettest February since at least 1973, while southern parts of New South Wales experienced over four times their February average rainfall. High streamflows continued, with seven forecast locations reporting record flows for January, including the total inflows to Tullaroop Reservoir, Cairn Curran Reservoir and Lake Eppalock, and thirteen for February, including the total inflows to Dartmouth and Hume Dams. Major and moderate flooding spanned north, west and central Victoria, including the Loddon and Campaspe River systems in January. During March, the La Niña event in the Pacific continued to weaken but above average rainfall occurred over New South Wales and Victoria and many catchments remained saturated. Most forecast locations reported above average streamflows in March and six had record March streamflows.

During April and May 2011, catchments experienced some drying, however soil moisture levels remained high (Figure 5), particularly in the lower layer (0.2 to 1.5 m).

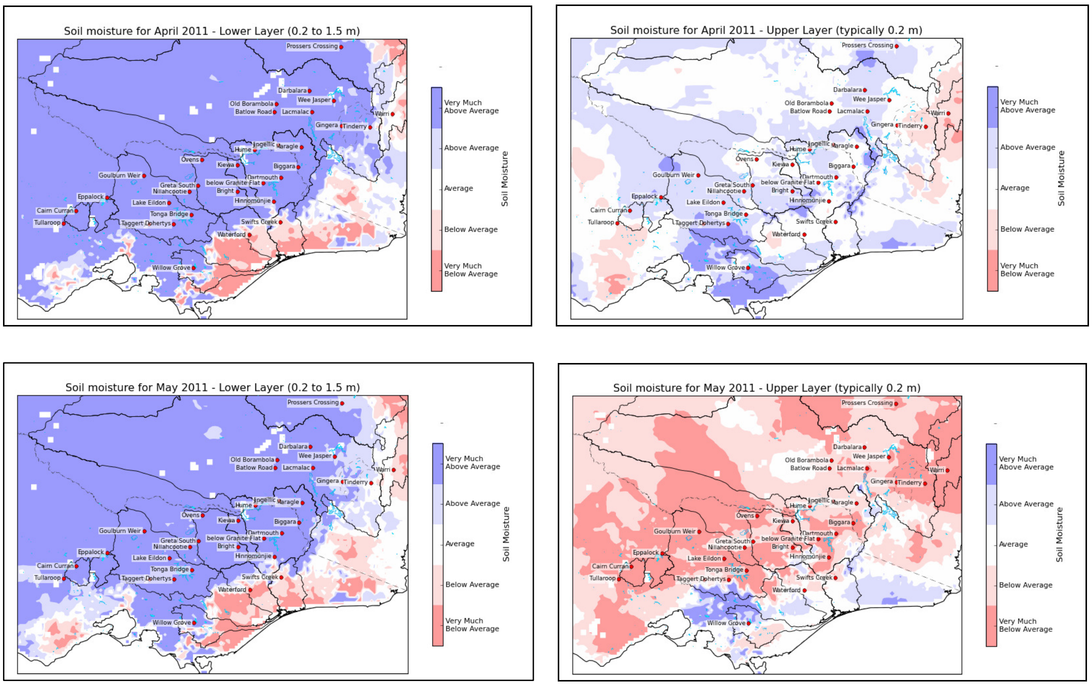

Figure 5: Lower and upper layer soil moisture for April and May 2011.

In addition, streamflows leading into April were high (see Figure 6 as an example).

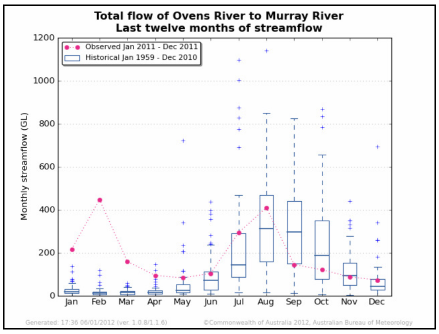

Figure 6: Total flow of the Ovens River to the Murray River 2011 streamflow.

Hence, although average to below average rainfall occurred in April and May over most of our forecast catchments (Figure 7), very much above average soil moisture resulted in quick streamflow responses to any rainfall and most forecast locations reported well above median streamflows for these months.

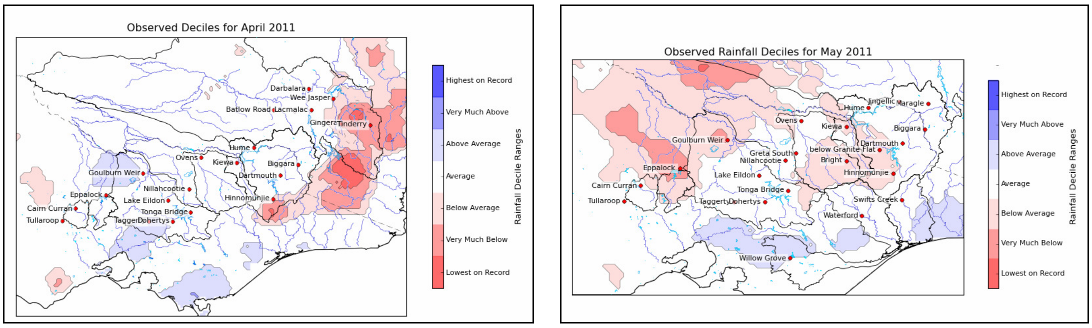

Figure 7: April and May rainfall deciles.

Heading into winter 2011, conditions in the tropical Pacific Ocean were neutral and generally below to very much below average rainfall occurred over our forecast catchments in June (Figure 8). Catchments continued to experience drying but soil moisture levels remained generally above to very much above average in the lower layer (Figure 8).

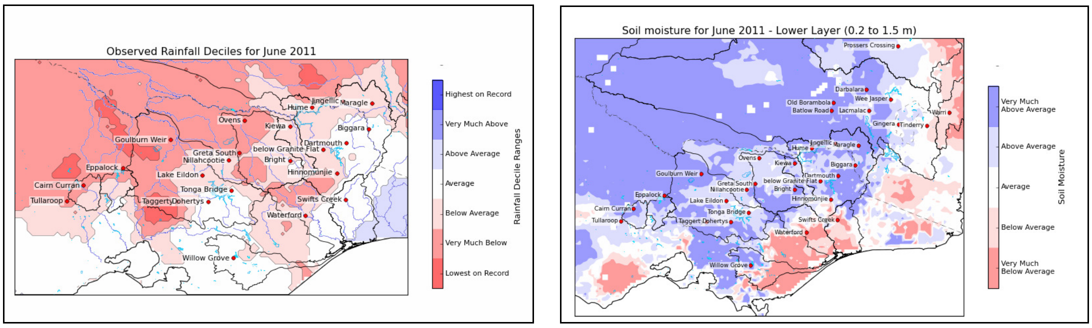

Figure 8: June rainfall deciles and lower layer soil moisture.

In June and July the majority of forecast locations reported streamflows that were above median, but closer to median than during May.

In summary, seasonal streamflows at the forecast sites are a function of several factors, including initial catchment conditions, such as soil moisture, antecedent streamflows due to some level of autocorrelation in the streamflow series, and the characteristics of catchment rainfall events during the season. Even though rainfall was below average during April to June 2011, most of our forecast locations reported above median streamflows during April to July as a result of above to very much above average catchment soil moisture and high antecedent streamflows.

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