5. Scenario runs

An objective of the groundwater flow model was to generate various scenarios for aquifer management purposes. ‘Dry’, ‘wet’ and ‘medium’ scenarios were formulated to examine the aquifer behaviour under “no pumping”, “current development” and “entitlements” conditions. It is hoped that the results of these scenarios will aid in the formulation of an appropriate aquifer management strategy for the Upper Lachlan Aquifer system.

The selection of ‘dry’, ‘wet’ and ‘medium’ conditions is based on the historical rainfall pattern going back about 100 years. These data sets identified as C\text{dry}, C\text{wet} and C\text{med} were supplied by CSIRO. Each set of climate data was used to prepare relevant MODFLOW recharge and evapotranspiration packages.

For the MODFLOW river package, Integrated Quantity and Quality Model (IQQM) model generated monthly flow data for the chosen period were converted to corresponding monthly river stage at gauging stations along the Lachlan River, Belubula River, Goobank Creek and Back Creek for each climatic variation (C\text{dry}, C\text{wet} and C\text{med}).

For the ‘wet’ scenario five flood events were applied over the 100 year period, based on exceedance of the river stage height of 5.7 metres at the gauging stations 412004 and 412002 in Figure 3-11. With the same criterion, three flood events were applied for the ‘dry’ and ‘med’ climatic variations. Floods were applied over the area inundated by the 1990 flood.

Irrigation recharge was maintained at the 2000/2001 level in the absence of any other irrigated area spatial distribution data.

Heads at outflow CHD boundaries were fixed at long–term average values.

The three different climatic variation scenarios were run for three different groundwater extraction limits: ‘no pumping’, ‘current development’ and ‘maximum allocation’. The combination of three climate scenarios and three pumping scenarios yielded nine scenarios in total.

The ‘no pumping scenario’ represents the natural condition where zero pumping occurs. The ‘current development scenario’ corresponds to the 2006-2007 water year in which the highest groundwater usage (84.6 GL) was recorded. These data sets were applied from the end of the calibration period to June 2108. In order to assess the current development situation. The ‘entitlements’ scenario corresponds to the maximum allocation limit of 174.6 GL/year. These data were recycled 100 times to allow simulation to year 2108.

All nine scenarios (‘dry_no pumping’, ‘dry_current development’, ‘dry_max_allocation’, ‘wet_no pumping’, ‘wet_current development’, ‘wet_max_allocation’, ‘med_no_pumping’, ‘med_current development’ and ‘med_max_allocation’) were applied from the end of the calibration period (July 2008), finishing at June, 2108.

5.1 Scenario water balance

Scenario results are provided in Figures 5-1 to 5-3. These diagrams show water balance components (GL/yr) averaged over the 100 year period.

The major differences in the dry, wet and medium scenarios relate to groundwater pumping.

Comparison of the ‘dry_current development’ with ‘dry_max_allocation’ scenario result show river leakage is greater by 5 GL/yr and evapotranspiration deplete from 138 to 120 GL/yr. The ‘dry_no pumping’ scenario shows that evapotranspiration was increased to 171 GL/yr and net river leakage decreased from 100 GL/yr to 62 GL/yr (Figure 5.1). For the wet scenario recharge (rainfall+flood+irrigation) is 146 and net river leakage is 106 GL/yr in wet_max_allocation scenario,
however in the wet current development river net leakage declined to 101 and evapotranspiration rose up to 178 GL/yr. Wet no pumping scenario net river leakage is 67 GL/yr in Figure 5.2.

These illustrate that if there was no pumping in the region, water levels would have risen causing river leakage to decrease and evapotranspiration to increase. If there was high pumping, water level would have depleted causing evapotranspiration to decrease and river leakage to increase.

Evapotranspiration is the dominant discharge process over each scenario run.

In the early stages of each scenario run, it was noted that some of the bores failed to maintain the pumping rates specified in the model and as a result of those pumping locations became dry (as shown in Figures 5-4 to 5-6). Water levels in these areas can exhibit gradually declining trends. In the dry, wet and med scenarios with the maximum allocation, the groundwater system reaches a new equilibrium after year 55 and the system maintains groundwater pumping rates at approximately 96-99 GL/yr.

Net river leakages over the one hundred year period from 1895 to 1995 in each scenario are shown in Figure 5-7 to 5-9. As expected river leakage increases with pumping in all three scenarios.
Figure 5-1 Average Annual water balance over dry scenario run June 2008 to July 2108

**Dry_No_Pumping**

Rain+Flood+Irr: 108
Riv in: 78
Riv out: 16
ET: 171
Well: 0

Storage In: 186
Storage Out: 189

**Dry_Current_Development**

Rain+Flood+Irr: 108
Riv in: 98
Riv out: 3
ET: 138
Well: 69

Storage In: 206
Storage Out: 212

**Dry_Max_Entitlements**

Rain+Flood+Irr: 107
Riv in: 103
Riv out: 3
ET: 120
Well: 102

Storage In: 210
Storage Out: 226
Figure 5-2 Average Annual water balance over medium scenario run June 2008 to July 2108

**Medium_No_Pumping**

<table>
<thead>
<tr>
<th>Rain+Flood+Irr</th>
<th>Riv in</th>
<th>Riv out</th>
<th>ET</th>
<th>Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>82</td>
<td>17</td>
<td>192</td>
<td>0</td>
</tr>
</tbody>
</table>

**Medium_Current_Development**

<table>
<thead>
<tr>
<th>Rain+Flood+Irr</th>
<th>Riv in</th>
<th>Riv out</th>
<th>ET</th>
<th>Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>126</td>
<td>103</td>
<td>4</td>
<td>157</td>
<td>70</td>
</tr>
</tbody>
</table>

**Medium_Max Entitlements**

<table>
<thead>
<tr>
<th>Rain+Flood+Irr</th>
<th>Riv in</th>
<th>Riv out</th>
<th>ET</th>
<th>Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>126</td>
<td>107</td>
<td>3</td>
<td>137</td>
<td>104</td>
</tr>
</tbody>
</table>
Figure 5-3  Average Annual water balance over wet scenario run June 2008 to July 2108

**Wet_No_Pumping**

- Rain+Flood+Irr: 147 GL/yr
- Riv in: 85
- Riv out: 18
- ET: 214 GL/yr
- Well: 0
- Storage In: 231
- Storage Out: 234

**Wet_current_Development**

- Rain+Flood+Irr: 147 GL/yr
- Riv in: 105
- Riv out: 4
- ET: 178 GL/yr
- Well: 70
- Storage In: 252
- Storage Out: 255

**Wet_Max_Entitlements**

- Rain+Flood+Irr: 146 GL/yr
- Riv in: 110
- Riv out: 4
- ET: 156 GL/yr
- Well: 104
- Storage In: 256
- Storage Out: 267
Figure 5-4  Dry Scenario yearly groundwater extractions over the 100 year simulation

Figure 5-5  Med Scenario yearly groundwater extractions over the 100 year simulation
Figure 5-6 Wet Scenario yearly groundwater extractions over the 100 year simulation

Figure 5-7 Dry Scenario yearly net river leakage over the 100 year simulation
Figure 5-8 Mid Scenario yearly net river leakage over the 100 year simulation

Figure 5-9 Wet Scenario yearly net river leakage over the 100 year simulation
6. Conclusions and recommendations

A groundwater flow model for the Upper Lachlan Valley has been developed to improve the understanding of the regional flow system, assess the quantity of water within the system and the amount of recharge to the aquifer and to evaluate the impact of climate change on the water balance for the regional aquifers within the valley.

The model was developed using MODFLOW (McDonald and Harbaugh, 1988) with a non uniform grid for this study. Grid cell dimensions vary from 500 m in the vicinity of the Lachlan River and increase progressively to 2000 m at distance from the river to the north and south. The model grid is rotated 20 degrees anti clockwise. The model calibration period is July 1986 to June 2008. The model consists of four layers that correspond to each of the major aquifers:

- Layer 1: the unconfined Upper Cowra
- Layer 2: the confined/unconfined Lower Cowra
- Layer 3 the confined/unconfined Lachlan Formation
- Layer 4 the confined/unconfined fractured rock (inactive layer)

The groundwater flow model identified the main recharge components as rainfall recharge, river leakage, flood recharge and irrigation recharge, whilst evapotranspiration is the major discharge component followed by groundwater usage. The aquifer outflow is to the west.

Non linear parameter estimation (PEST) was used to aid calibration of the model based on water levels from observation bores. Assessment of the model's performance, based on comparison between observed and simulated groundwater levels for the entire calibration period, indicates that, for all model layers, a good match was generally achieved except in zone 7. Low SRMS (scaled root mean square) values (less than 5%) were achieved for all three layers which confirm that the model is well calibrated.

This groundwater model simulates monthly stress periods and requires usage data at a monthly frequency. However from 1998 onwards groundwater usage data in the model have only annual frequency. There is little usage data available prior to 1998. This shortcoming in the groundwater usage data set constrained the model calibration in some cases.

The water balance summary for the 22 year period of the model (July 1986 to June 2008) shows an annual average total recharge of 186.48GL. This figure represents an average over the model spatial domain and calibration period. It is not representative of recent conditions and takes no account of spatial variability. In practice, pumping is concentrated in small areas and has increased significantly in recent years. This pattern of usage is likely to affect local water levels and may diminish local extraction potential unless sufficient recovery occurs. The model will be of value in investigate local usage scenarios. The total annual average outflow is 156.30 GL. The evapotranspiration is about 76% of this total. Therefore evapotranspiration is the dominant output over the calibration period.

Three climate scenarios (dry, wet and med) were undertaken to evaluate the aquifer’s response to different levels of groundwater pumping. The ‘no pumping scenario’ water budget revealed the likelihood of rising water levels, reduced river leakage and increased evapotranspiration in the absence of pumping for all climatic scenarios. The increased pumping scenario showed, water level depleted causing evapotranspiration to decrease and river leakage to increase in all scenarios.
It is recommended in future attempts to revise this model the following aspects are given consideration:

- Poor calibration of bores in Zone 7 is attributed to the complexity of the groundwater system in this area. More geological investigations are needed to obtain a proper understanding of the hydrogeological framework of the area.

- Review the hydrogeological framework of the alluvial's in zone 1 and 2.

- Independent studies of the groundwater recharge process (for example, hydrochemical characterisation) could enhance calibration of the groundwater model particularly Zone 1, 2 and 7.

- Annual monitoring of groundwater production bores constrains the integrity of groundwater usage data. The requirement for monthly usage data for groundwater modelling purposes necessitates assumptions regarding temporal distribution of production. Therefore, it is recommended that, particularly in critical areas of groundwater usage, selected landholders be requested to provide monthly meter readings of production with additional data such as pumping on/off times and a log of associated management decisions.

- Some discrepancies between observed bore data and corresponding model-simulated data are attributed to the likelihood that a few existing groundwater extraction sites are not represented in the model. Future model enhancement should seek to assess the veracity of this suspected cause.

- Improved estimate of irrigation recharge based on landuse, crop patterns and combined usage of surface and groundwater.

- Verification of this model has not been undertaken. Since almost all suitable observation data sets were used to calibrate this model, spatial verification is not possible. However, temporal verification remains an available option at a future time since over two years of observation data have accumulated since the end of the calibration period of this model.
7. References


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Murray Basin Hydrogeological Map Series CARGELLIGO scale 1:250 000


