Department of Water
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Capel River Hydrology Summary

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Surface Water Hydrology Series

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Subject of cover photograph: Capel River at Capel Railway Bridge (by Richard Pickett)

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1 Introduction

The Capel River was proclaimed for surface water licensing in 1969 under the *Rights in Water and Irrigation Act 1914*. The Department of Water is developing a management plan for the Capel River to guide water allocation and licensing.

This report discusses the hydrology of the Capel River and will be used to assist with the development of ecological water requirements for the Capel River catchment. Characteristics of surface-water hydrology were assessed at two gauging stations, Yates Bridge (610219) and Capel Railway Bridge (610010).

2 Catchment description

The Capel River catchment is located south of Bunbury and covers an area of approximately 635 km^2 (Figure 1). The river flows in a north-westerly direction, originating at the Darling Scarp (west of Kirup) and crossing the northern part of the Blackwood Plateau, the Whicher Scarp and the Swan Coastal Plain before discharging into the Indian Ocean (White & Comer 1999).

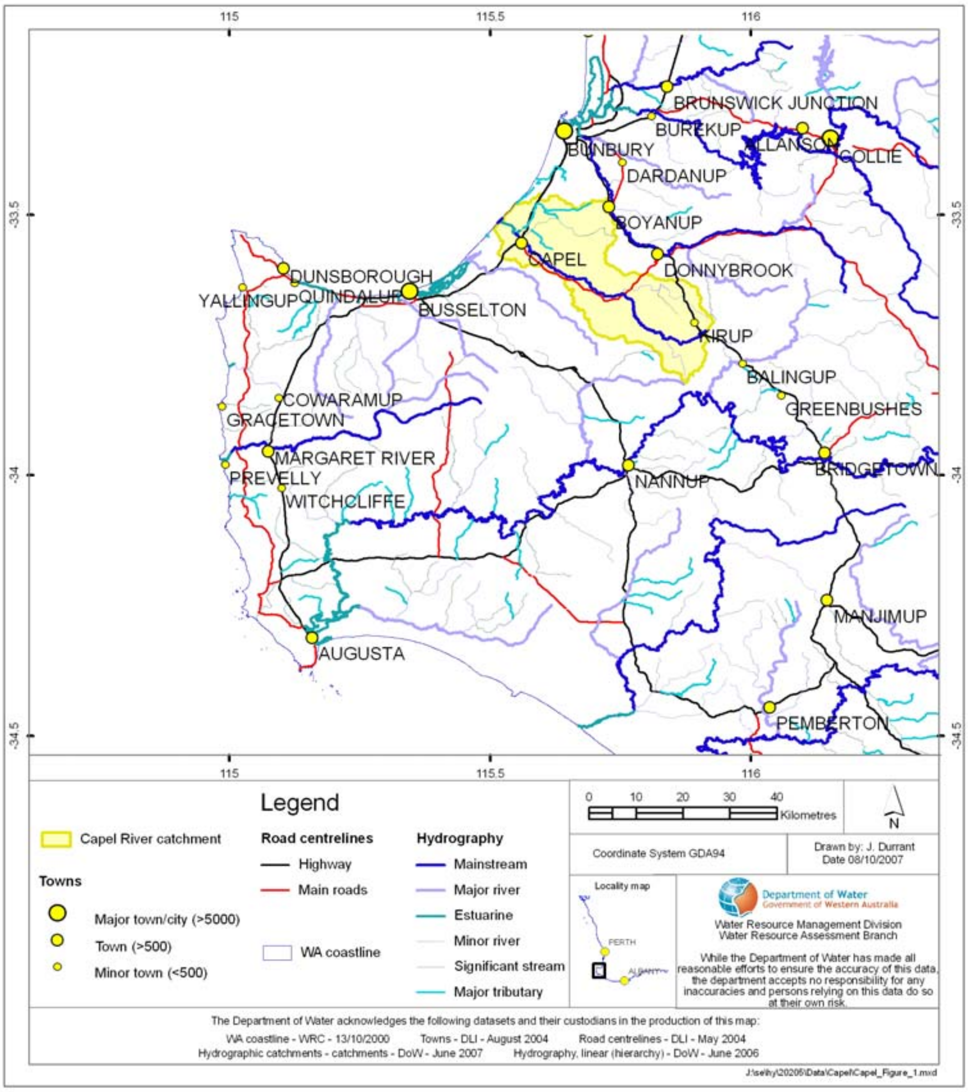

Figure 1 Location of Capel River

Historically, the Capel River discharged into the Vasse–Wonnerup Estuary via the Stirling Wetlands. In the late 1980s the river was diverted from the estuary to discharge directly into Geographe Bay by way of an artificial river mouth cut through the coastal sand dunes (Pen 1999). In order to prevent salt-water intrusion into the Stirling Wetlands, levee banks were built along the Capel River. A sand bar seasonally forms across the mouth of the river, and is broken under high-river-flow conditions.

The lower reach of the Capel has been modified as part of an artificial drainage system to drain the Swan Coastal Plain, enabling its use for dairy farming and other forms of agriculture (Pen 1999). Land use within the catchment consists primarily of agriculture, including dairy and beef production, orchards and viticulture. The mining of mineral sands in the Capel region is also a primary land use. As well, there is an increase in urban development across the catchment. The Water Corporation operates the Kirup Dam, located in the upper catchment, north-east of the south branch, to supply drinking water to the towns of Kirup and Mullalyup (Beckwith 2006).

A number of meteorological stations and streamflow gauging stations have operated periodically on the Capel River (Figure 2). The gauging stations at Yates Bridge (610219) and Capel Railway Bridge (610010) are currently in operation and are analysed further in this study. The Capel River catchment is approximately 60 per cent cleared (Figure 2). Upstream of the Yates Bridge gauging station, the level of catchment clearing is approximately 35 per cent, predominantly on the north branch.

The upper portion of the catchment includes several areas of State forest and is typical of the intermediate-rainfall-zone jarrah-forest catchments found in the south-west of WA. To the west of the Darling Scarp the vegetation is primarily eucalypt (tuart) and banksia woodlands (Beard 1990).

The Yarragadee Formation largely covers the extent of the Capel River, bounded on the east by the Darling Fault. It is overlain by the Leederville Formation and areas of Bunbury Basalt. The Yarragadee aquifer is high yielding and used for water supply at Capel and for the mineral sands industry in the area. The Leederville aquifer is overlain by the superficial formations on the Swan Coastal Plain. The part of the aquifer between the Whicher Scarp and the Darling Fault is not overlain by the superficial deposits (Figure 2) (Department of Water n.d.).

Groundwater salinity ranges from less than 200 milligrams per litre to about 400 milligrams per litre (Department of Water n.d.). Salinity levels in the Capel River vary between the upper portion of the river and the townsite. The upper Capel is considered fresh (0–500 mg/L), whereas downstream the water quality is classified as marginal (501–1100 mg/L) (Water and Rivers Commission 2003).

The north and south branches of the Capel River converge where the Darling Scarp meets the Swan Coastal Plain and the terrain changes from rolling hills to flat plains. In the upper catchment there is a large amount of surface-water storage, most of it in the form of on-stream dams. As the topography changes to plains in the central branch of the river, the ability to store water diminishes and direct pumping is the primary method used to obtain water. In the lower catchment, there is a greater reliance on abstraction from groundwater rather than surface water (CRLWUG n.d.; Beckwith 2006).

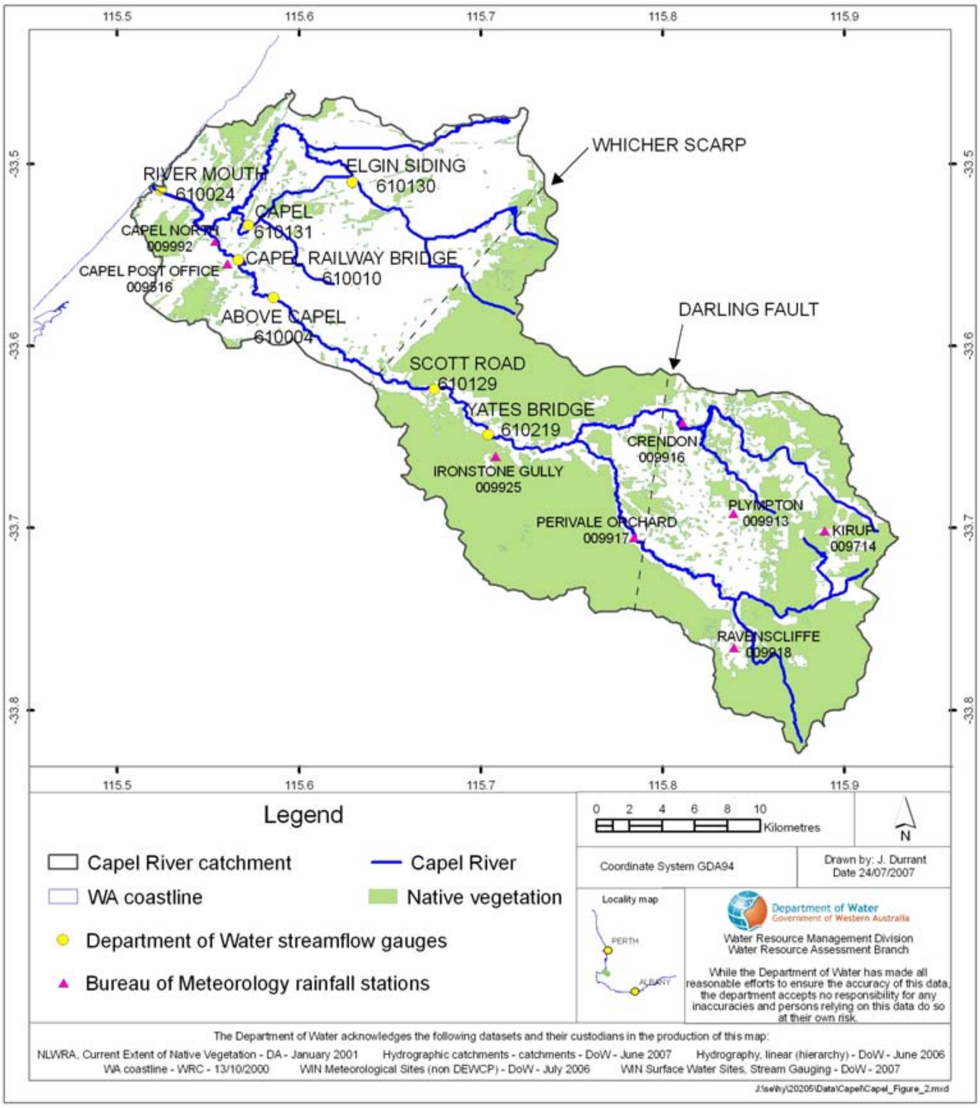

Figure 2 Capel River catchment, showing streamflow gauges, selected rainfall gauges, extent of clearing, and location of the Darling and Whicher Scarp

3 Climate

The Capel River catchment has a temperate climate (based on the Köppen classification system) with a marked wet and cold winter and a distinctly dry and warm summer (Bureau of Meteorology 2006). Winter rainfall is typically generated from rain-bearing low-pressure systems (cold fronts) crossing the coast. High-intensity summer storms may occur as a result of thunderstorms or ex-tropical cyclones.

A number of Bureau of Meteorology rainfall gauges are located throughout the catchment with varying periods of record. Long-term SILO derived/modelled rainfall and evaporation data (from 1899) are available at the Capel Post Office (009516) and Kirup (009714) gauges (Figure 2).

A centroidal daily rainfall series was developed for the upper part of the catchment by using the Thiessen weighted polygon method to combine information from six of the gauges selected for use in this study. Evaporation for the upper catchment was described by the gauge at Kirup (009714).

The rainfall gauge at Capel Post Office (009516) operated from 1914 to 2003 and has since been replaced by Capel North (009992). The Capel Post Office gauge was selected to describe rainfall and evaporation in the lower catchment. The rainfall was combined with the daily rainfall series generated for the upper catchment in order to provide a single input for the modelling.

Consistent with the pattern for many other locations in the south-west of WA, the mean annual rainfall in the catchment has shown a noticeable decrease since the 1970s from the long-term mean (Figure 3). For the period 1900 to 1974 the average annual rainfall at Capel Post Office was 870 mm, while for 1975 to 2003 the average was 735 mm, a decrease of 16 per cent.

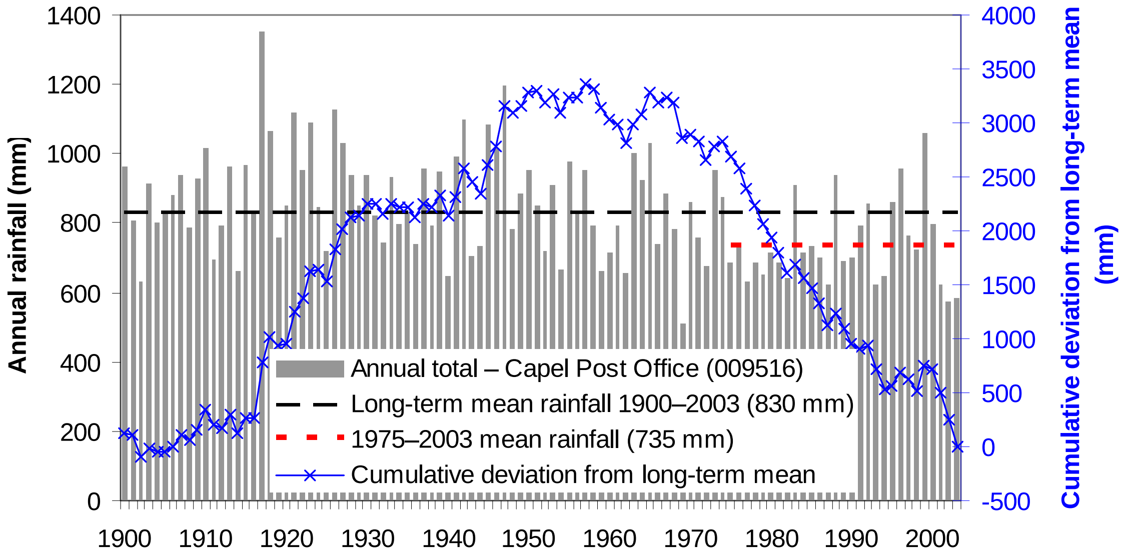

Figure 3 Annual rainfall at Capel Post Office (009516)

Mean annual rainfall varies throughout the catchment, increasing with distance from the coast towards the scarp. The decreasing trend in annual rainfall is evident across the whole catchment, with an average annual rainfall at Kirup for the period 1900 to 1974 of 1040 mm while for the period 1975 to 2003 the average was 955 mm. Although the change is not as pronounced as near the coast, it is still a reduction of 8 per cent.

Rainfall is highly seasonal, with 79 per cent and 77 per cent of the annual rainfall at Capel Post Office and Kirup respectively occurring between May and September for the period 1975 to 2003 (Figure 4). The peak-rainfall month at Capel Post Office is June, but in the upper Capel catchment at Kirup the peak month is July. The monthly rainfall record for the period 1975 to 2003 at Kirup displays a small shift in seasonality from the long-term record, with June being the peak-rainfall month over the period 1900 to 1974. However, 77 per cent of the annual rainfall still occurred between May and September.

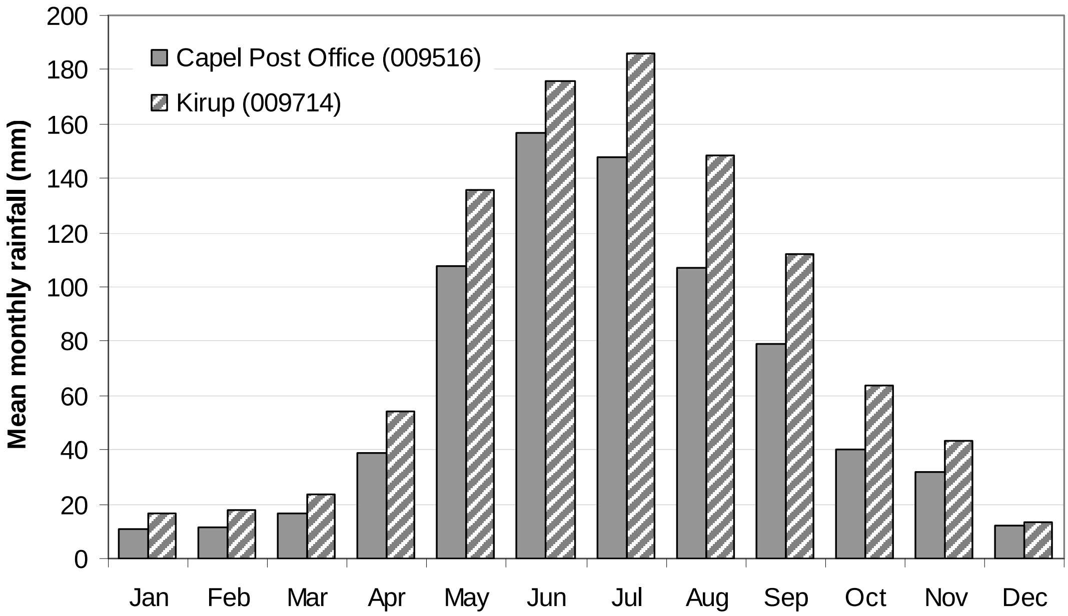

Figure 4 Mean monthly rainfall for Capel Post Office and Kirup for the period 1975 to 2003

Average annual evaporation for the period 1975 to 2003 was 1460 mm and 1320 mm at Capel Post Office and Kirup respectively. There has been a very slight increase (2 per cent) in evaporation over the long term (comparison of the period 1900 to 1974 and 1975 to 2003).

4 Streamflow

Five streamflow gauging stations have operated periodically on the Capel River (Figure 2). Two historical stations operated on Gynudup Brook, which joins with the lower Capel before flowing into the Indian Ocean. The streamflow records produced at these sites are not useful in this study due to the short periods of record. The Capel River North and South branches have never been gauged. Two main gauges, Yates Bridge (610219) and Capel Railway Bridge (610010), are currently in operation and are analysed further in this study (Figure 5).

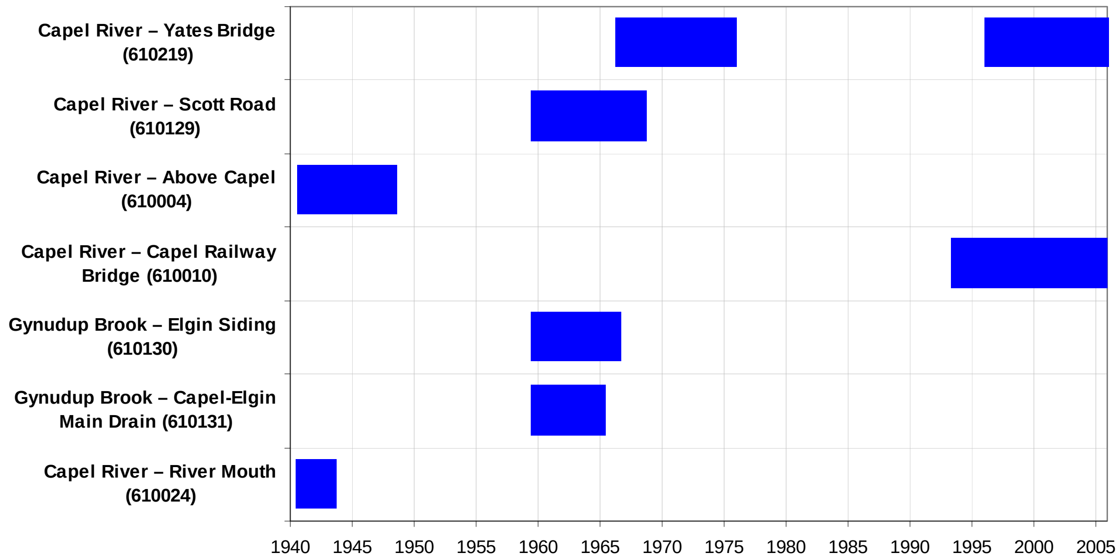

Figure 5 Streamflow gauging stations in the Capel River catchment

The Yates Bridge gauging station records flow from 315 km^2 of the upper Capel catchment (~50 per cent of entire catchment). The gauge was in operation from 1966 to 1976 and was reopened in 1996, resulting in an approximate 20-year period of missing data. The flow record was complete from 1997 onwards, with no gaps. The stage-discharge relationship has been developed from 94 discharge measurements ranging from 0.01 m^3/s to 39.5 m^3/s. In the period of record since 1975, only one flow was recorded above these measured flows (53.4 m^3/s). The flows at Yates Bridge are therefore considered relatively reliable.

The Capel Railway Bridge gauging station, located approximately 20 km downstream of Yates Bridge, records flow from 395 km^2 of the upper and middle Capel catchment (~62 per cent of entire catchment) and has been in continuous operation since 1993. The stage-discharge relationship is developed from 45 discharge measurements ranging from 0.02 m^3/s to 45.6 m^3/s. One flow was recorded above these measured flows (50.7 m^3/s). A degree of uncertainty surrounds the rating curve, as there is no stable control at the gauging station site. As a result, a large amount of the flow record has had corrections or estimations applied.

5 Rainfall runoff modelling

There is a significant gap in flow data from the mid-1970s to the mid-1990s for the Capel catchment, with no gauges recording flow during this time. To complete the hydrologic analysis, the records for Yates Bridge and Capel Railway Bridge needed to be extended to cover the period 1975 to 2003. A lack of hydrologically similar catchments with long gauged records meant that the data could not be extended using correlation techniques.

The AWBM daily rainfall runoff model, within the CRC for Catchment Hydrology Rainfall Runoff Library, was therefore run in order to extend the data sets. The rainfall runoff model calculates surface runoff and baseflow from inputs of rainfall and evaporation.

Calibration results were assessed using several methods, including the coefficient of efficiency (E) (Nash & Sutcliffe 1970), the mean absolute error (MAE) and the root mean square of the error (RMSE). The final parameter sets and statistical assessments of fit can be found in the Appendix.

5.1 Yates Bridge (610219)

For Yates Bridge gauging station (610219) the AWBM daily rainfall runoff model was prepared and calibrated from 1997 to 2003 and verified for the years 1975 and 2004. The centroidal rainfall derived using the Thiessen weighted polygon method was used as the catchment rainfall series and the evaporation record at Kirup as the catchment evaporation series.

The calibration produced a reasonable fit to the observed data. Monthly and annual model efficiencies (E) for the calibration period were calculated at greater than 0.9 (Figure 6). At a daily timestep the model did not perform as well, with an efficiency of 0.71. Hydrographs for the calibration and verification periods further illustrate the fit to the observed data (Figure 7).

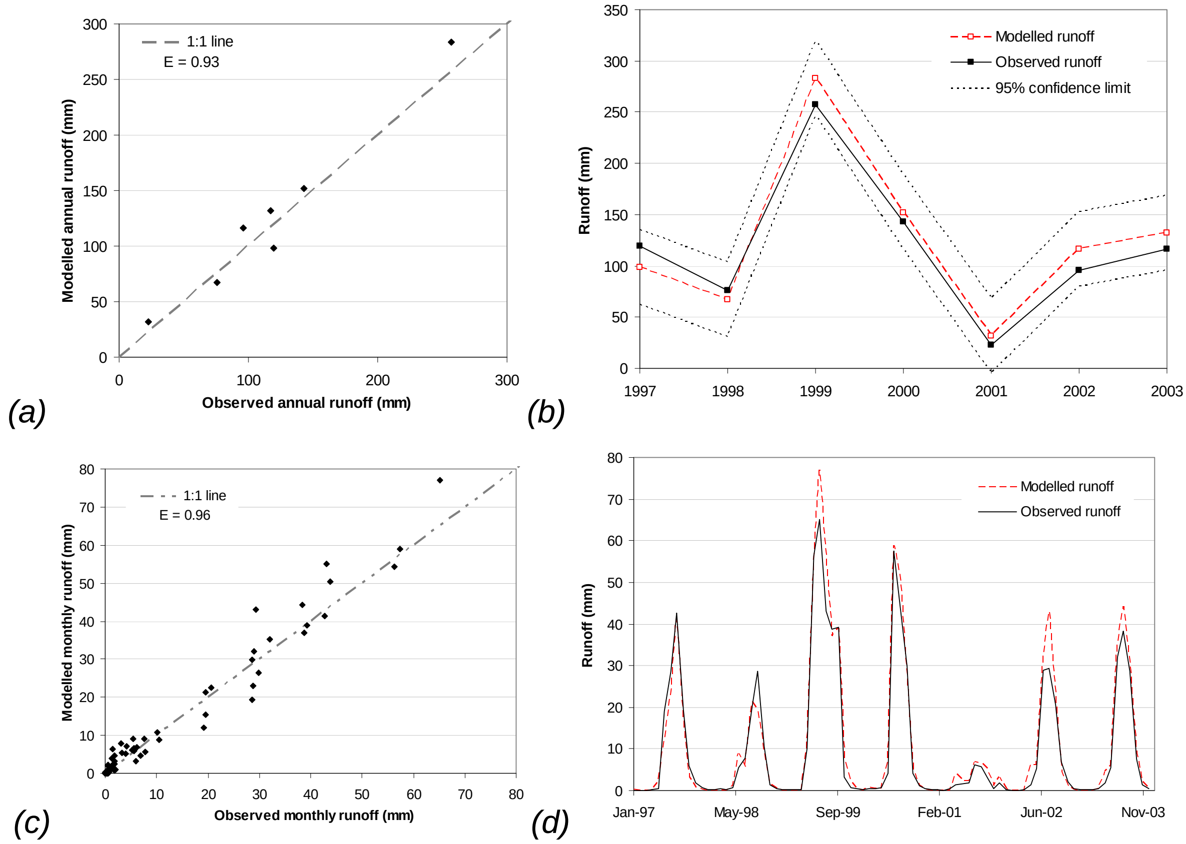

Figure 6 *Observed versus modelled runoff at Yates Bridge, results for (a,b) annual timescale and (c,d) monthly timescale*

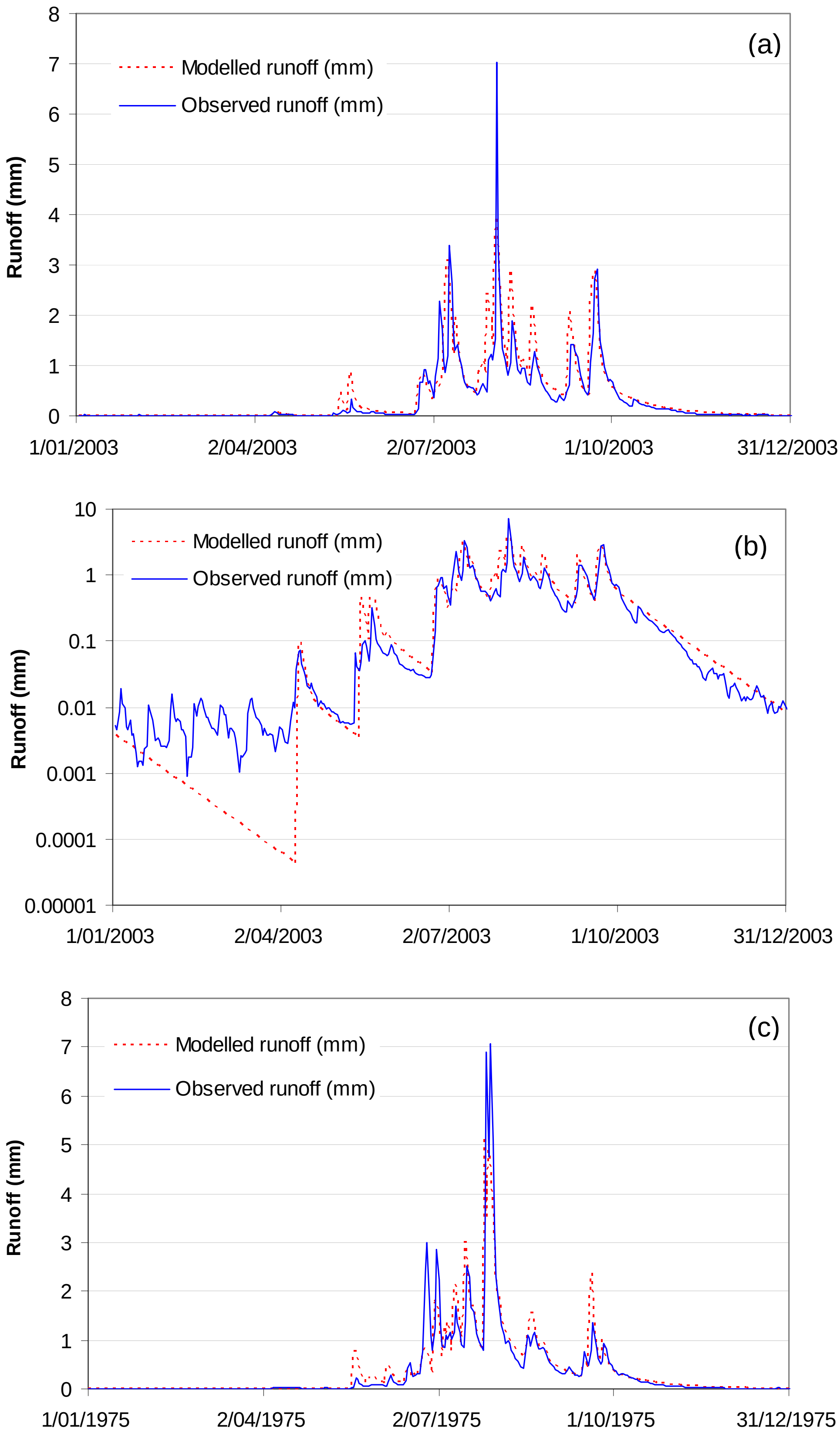

Figure 7 Comparison of observed and modelled daily flows for a calibration year (2003) – normal scale (a) and log-scale y axis (b) – and a verification year (1975) (c)

On average, the annual flow estimates obtained from the modelling are within 5 per cent of the observed annual flows at the Yates Bridge gauging station. The greatest error (28 per cent) occurs in 2001, which was a very low flow year. The daily hydrograph plotted on a log scale (Figure 7) shows that the modelled data is a poor fit to the observed summer low flows, with the rainfall runoff modelling linearly depleting the baseflow stores. For example, the average catchment runoff for the months January to March is 0.006 mm, but the modelled flow recedes to effectively zero (a large percentage error). A catchment runoff of 0.006 mm equates to approximately 2 ML/day.

The calibrated model parameters were then applied to the longer period (1975 to 2003) of daily rainfall and evaporation data to obtain estimates of streamflow for the extended period. Statistics were calculated for the flows using the extended period.

5.1.1 Annual streamflow

The mean annual flow for the eight observed whole years of record is 46.1 GL with a coefficient of variation of 0.53. The maximum recorded annual flow of 87.8 GL was recorded in 1974. The minimum recorded annual flow of 6.66 GL was recorded in 2001 and is less than a sixth of the average flow.

The combined observed and modelled annual streamflow (1975 to 2003) has an estimated mean annual flow of 39.9 GL and a coefficient of variation of 0.49 (Figure 8). The maximum and minimum recorded annual flows are 81.8 GL and 6.66 GL respectively. The flow in the Capel River at Yates Bridge is highly variable.

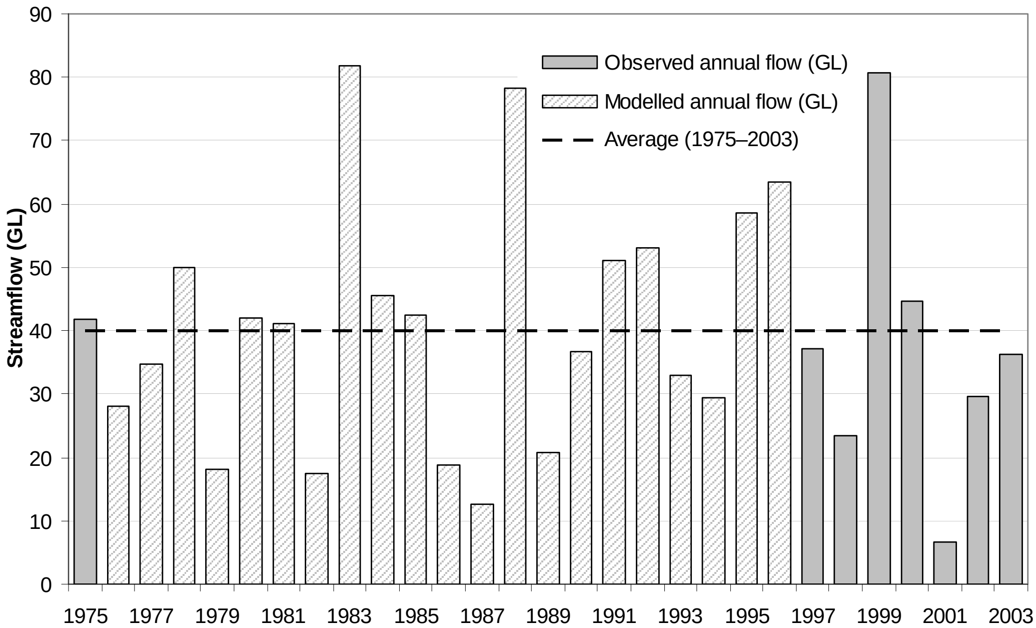

Figure 8 Modelled and observed annual streamflow record for Capel River at Yates Bridge (610219)

The mean annual runoff for the period 1975 to 2003 is 130 mm and the mean annual rainfall at Kirup rainfall station (009714) is 955 mm. The annual runoff coefficient for the upper Capel catchment is 13 per cent. The average annual baseflow index was modelled at 0.55.

5.1.2 Floodflows

A flood-frequency curve for the Yates Bridge gauging station was developed using the program AFAP. The curve was constructed using nine years of recorded data (1997 to 2005) and a Log Pearson Type III distribution was fitted to the data (Figure 9).

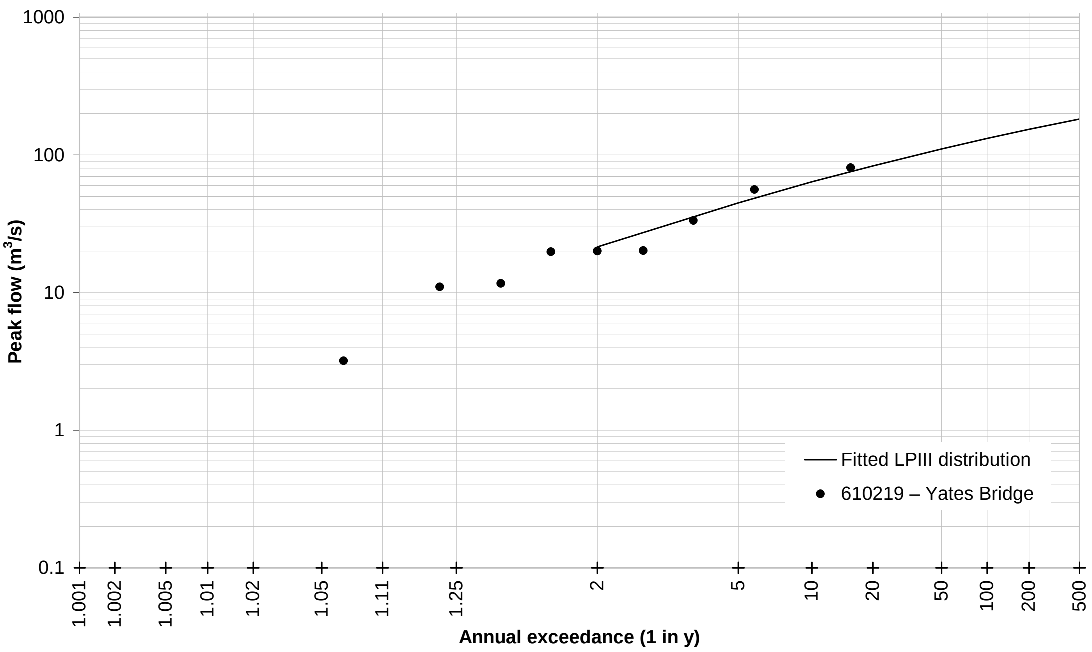

Figure 9 Flood-frequency plot for Capel River at Yates Bridge (610219)

The results were consistently lower than those produced by the flood-frequency analysis undertaken for the Capel River as part of the Busselton Regional Flood Study Review (JDA 1998, Table 1). The peak annual flow series was a combination of FLIKE analysis and results of runoff routing modelling (RORB). The flows since 1998 (i.e. those not included in the JDA study) have all been less than a 1 in 10 year ARI.

Table 1 Annual series flood-frequency data for Capel River at Yates Bridge (610219) (JDA 1998)

Average recurrence interval (1:year)	Annual exceedance probability (%)	Peak annual flow (m^3/s)	Growth factor (F_x/F_2)*
1:1.1	90.9	14	–
1:2	50	40	–
1:5	25	68	1.70
1:10	10	88	2.20
1:25	4	119	2.98
1:50	2	133	3.33
1:100	1	173	4.33

*Growth factor is calculated by dividing the X-year ARI peak annual flow by the 2-year ARI peak annual flow

5.1.3 Monthly streamflow

As with rainfall, the streamflow in the Capel River at Yates Bridge is highly seasonal, with 95 per cent of the flow occurring from June to October (Figure 10). August is the peak-flow month, with a mean flow of 12.1 GL. There is a lag between the peak-rainfall month (July for the upper Capel) and the peak-flow month. This is generally characteristic of catchments with large soil-storage capacities, but in this case may be a response to the filling of a large surface storage in the upper catchment.

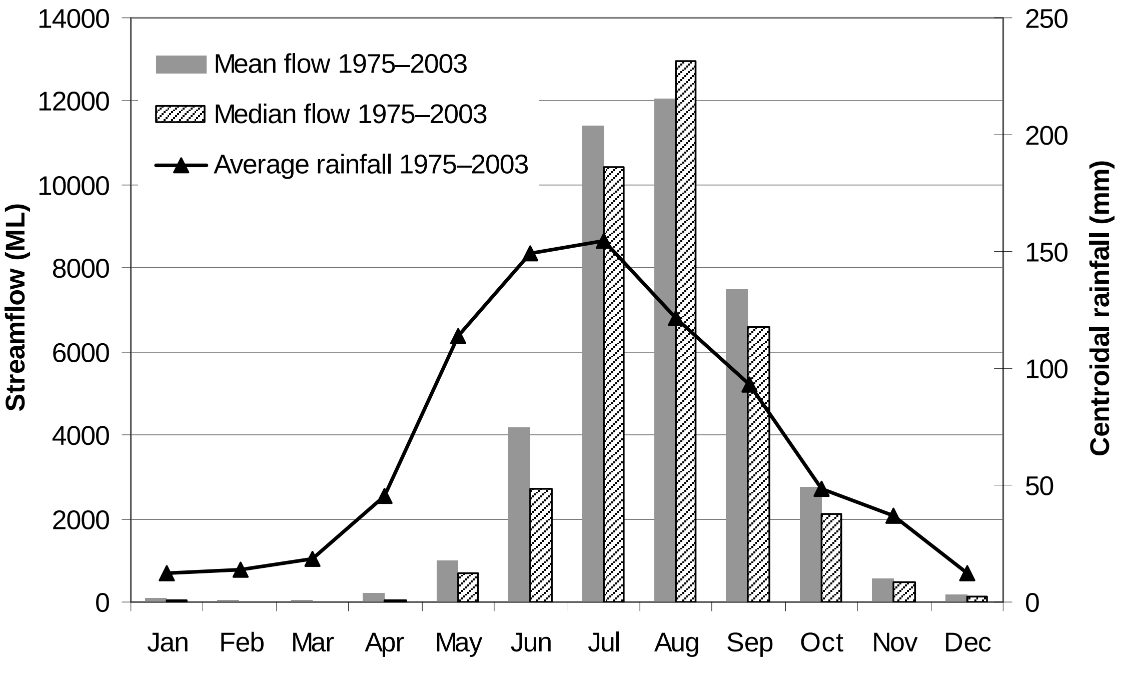

Figure 10 Average and median monthly streamflow for Capel River at Yates Bridge and average centroidal rainfall

5.1.4 Daily streamflow

Annual and monthly flow-duration curves were calculated using daily flows for each year. The thick black line is the total flow-duration curve for the period 1975 to 2003, the thin dashed blue lines are the observed yearly flow duration curves and the thin grey lines are the modelled yearly flow-duration curves (Figure 11). The flow-duration analysis can be used to describe the flow regime, and it is important in the development of environmental flows.

Based on observed and modelled data at Yates Bridge, the median daily flow is 12 ML, and flows greater than 0.01 ML are exceeded 97 per cent of the time. The individual yearly flow-duration curves provide an indication of the variability in the flow regime, with daily flows exceeding 0.01 ML between 87 per cent and 100 per cent of days in each year. There is also variability on a vertical scale, with median daily flows ranging from 3 ML to 42 ML.

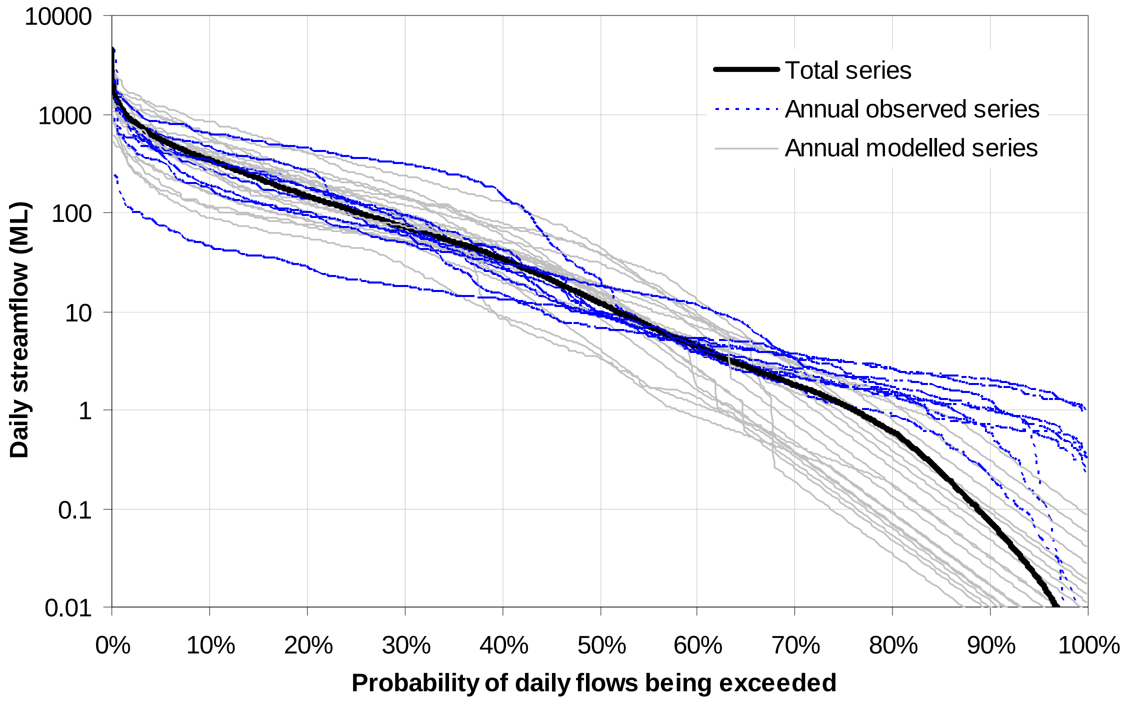

Figure 11 Observed and modelled daily flow-duration curves categorised by year for Capel River at Yates Bridge (610219)

The low flows (typically less than 1 ML/day) for the modelled years are not within the range of natural variability due to the linear depletion of the baseflow stores (Figure 11). This discrepancy was not reflected in the AWBM calibration statistics due to the low flows being such a small component of the overall flow. It was, however, evident in the daily hydrographs plotted on a log scale (Figure 7).

There are three years (1975, 1976 and 1997) where the observed flow-duration curves show a short period of zero flow each year. Monthly observed flow-duration curves show these periods occur in the months of November to March (Figure 12). In the latter years (1998 to 2003) the yearly curves are very flat at the low end, with flows always greater than 0.1 ML/day (no zero flows). This constant flow typically highlights the presence of groundwater contributions in the summer months. In this instance, however, it is primarily due to the additional summer flow releases from a large on-stream dam in the upper catchment to meet the needs of downstream water users. If the discharge from the upstream dam was monitored, this could be more accurately reflected in the modelled flow record.

Anecdotal evidence indicates that the upper reaches of the river were ephemeral before these releases started (Capel River Local Water User Group pers. comm.). This is confirmed by looking at the observed continuous-flow period (Figure 13). This indicates that the upper reaches of the Capel River did cease to flow during the summer months, but in recent times the daily flow has been continuous for most years.

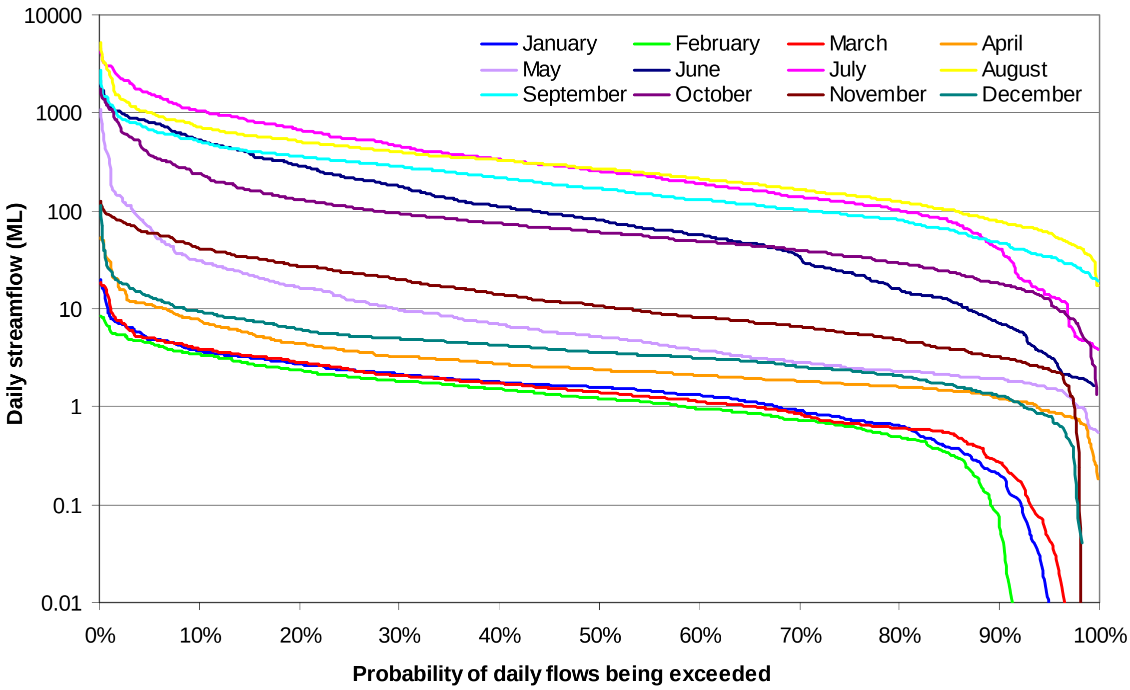

Figure 12 Observed daily flow-duration curves categorised by month for Capel River at Yates Bridge (610219)

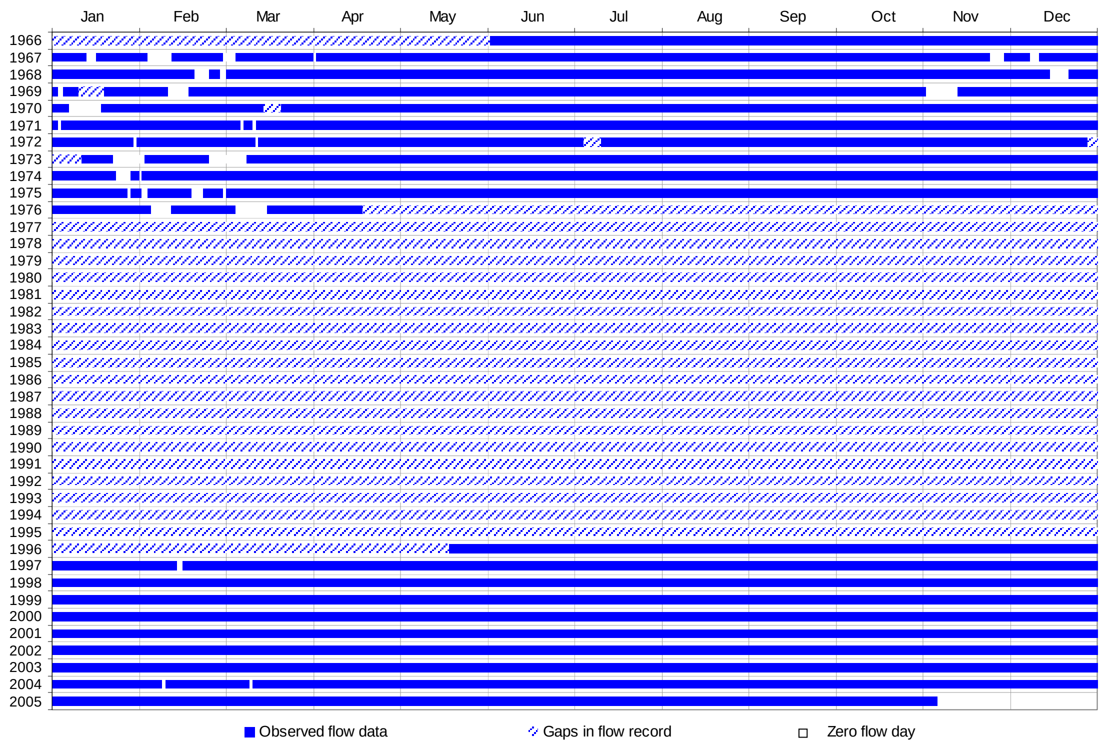

Figure 13 Observed streamflow duration at Yates Bridge (610219)

An assessment of the monthly flow-duration curves is very important, as the inter-annual variation of the curves (particularly low flow) over the period of record gives an indication of the types of flow the river is adapted to. Its ability to adapt to different flow regimes has implications for determining future ecological flow requirements, on an environmental, social and economic scale, as recognised by Beckwith (2006).

Flow-duration curves were also calculated for each month using the observed and modelled data (Figure 14). The months of April and May in particular exhibited unusual results, with the modelled flows significantly lower than observed, particularly for flows less than 1 ML/day. For most years, these months correspond with the beginning of winter flows. As the modelled data excludes summer-flow releases from the upstream storage and has a linear recession of the baseflow stores, there is an apparent vertical jump in the streamflow record in order to produce the runoff response required from the initial rainfall. As a result, the parameters chosen to model this initial condition are likely to be misrepresented. Overall the flow-duration curves were not consistent with those produced using observed data only (Figure 12).

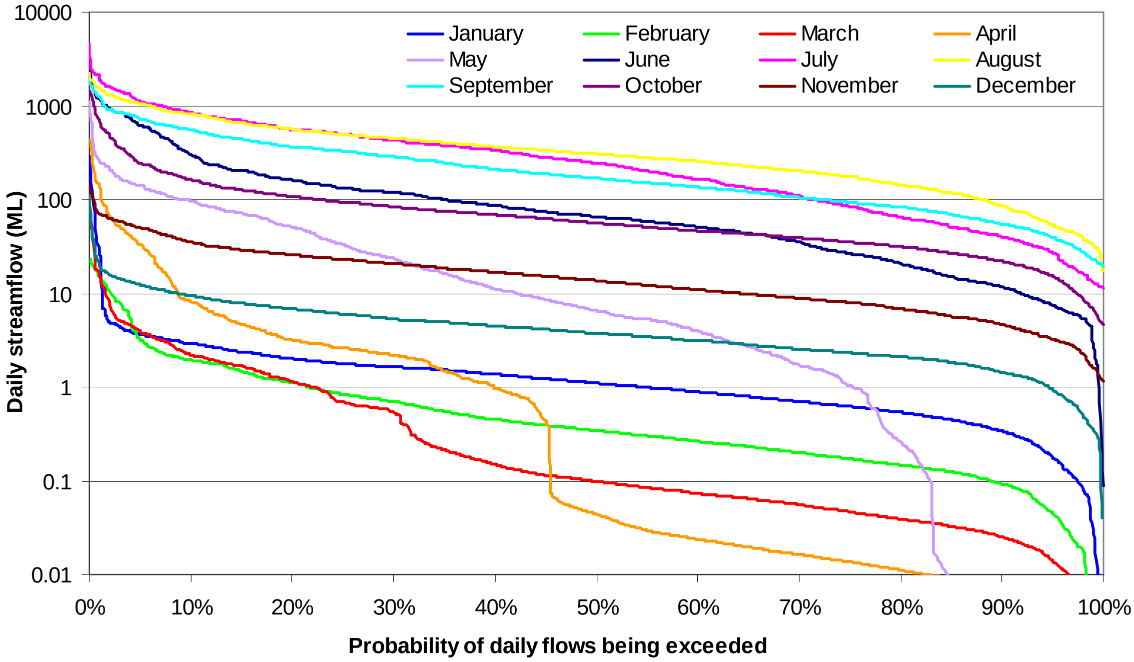

Figure 14 Observed and modelled daily flow-duration curves categorised by month for Capel River at Yates Bridge (610219)

5.2 Capel Railway Bridge (610010)

For Capel Railway Bridge (610010) the AWBM daily rainfall runoff model was prepared and calibrated from 1995 to 2003 and verified for the years 1994 and 2004. The centroidal rainfall derived using the Thiessen weighted polygon method was used as the catchment rainfall series, as was the evaporation record at the Capel Post Office.

The calibration produced a reasonable statistical fit to the observed data, although not as good as for Yates Bridge. Monthly and annual model efficiencies (E) for the calibration period were calculated at greater than 0.8 (Figure 15). At a daily timestep the model did not perform as well, with an efficiency of 0.75. Hydrographs for the calibration and verification periods further illustrate the fit to the observed data (Figure 16).

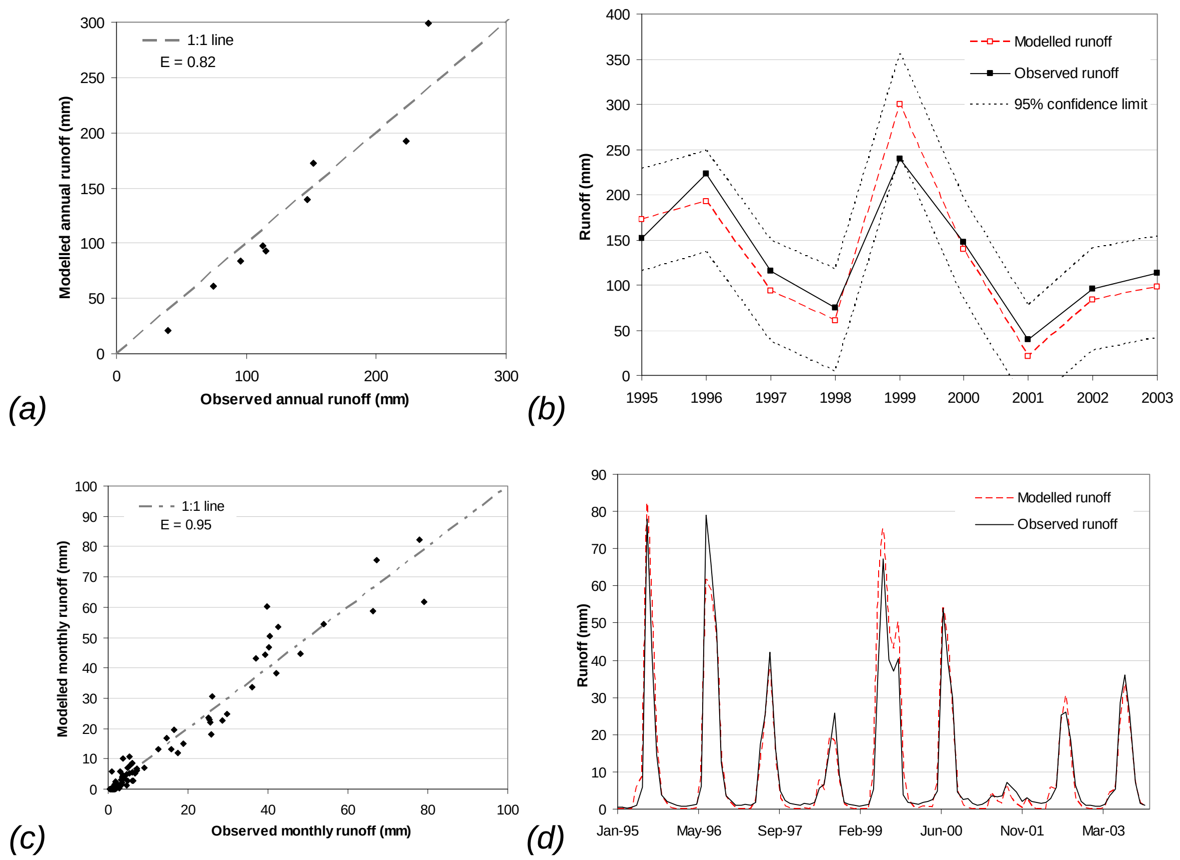

Figure 15 Observed versus modelled runoff at Capel Railway Bridge: results for (a,b) annual timescale and (c,d) monthly timescale

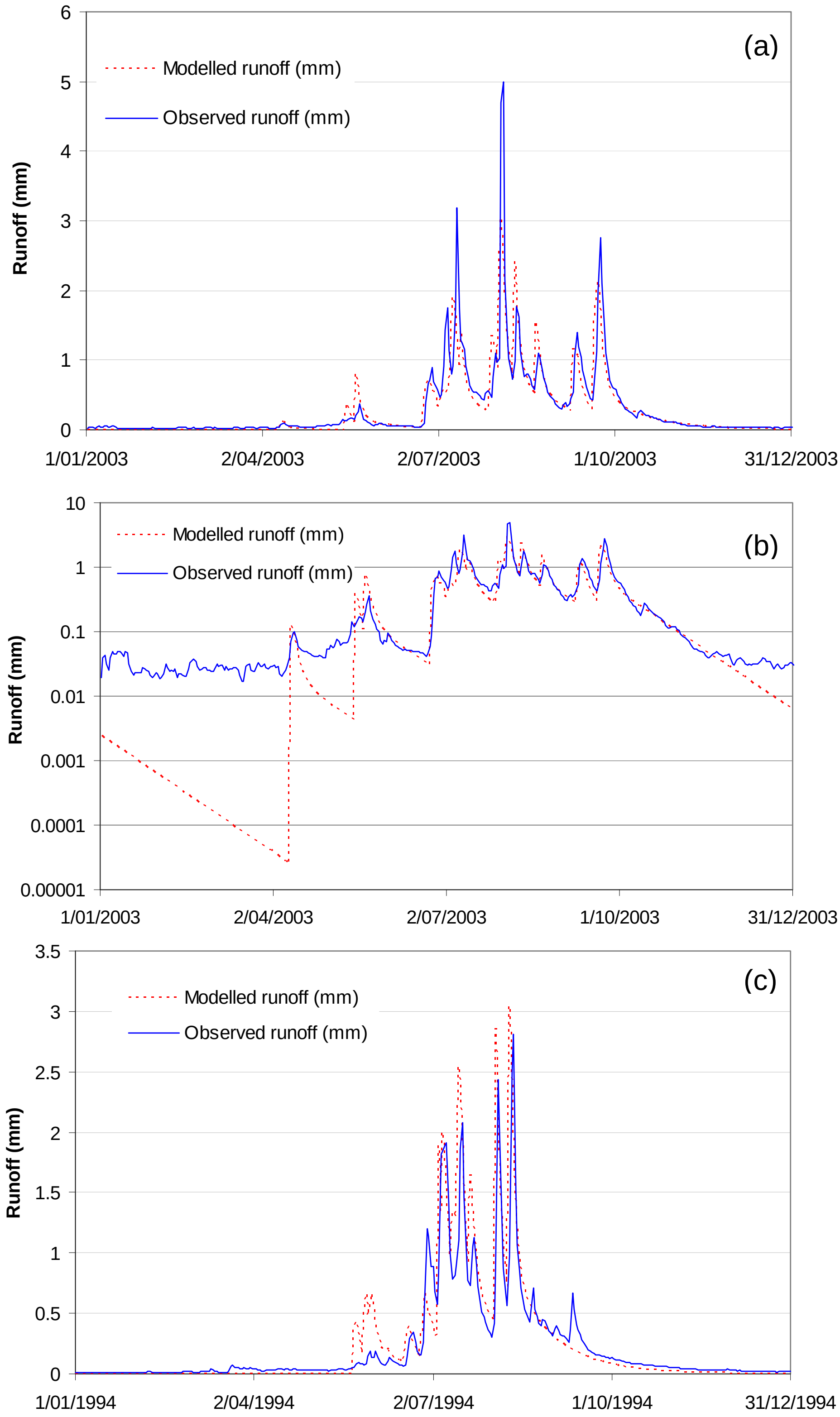

Figure 16 Comparison of observed and modelled daily flows for a calibration year (2003) – normal scale (a) and log-scale y axis (b) – and a verification year (1994) (c)

If the daily hydrographs are assessed using a log flow scale, it can be seen that the calibration produces a reasonable fit to the observed winter months but does not match well to the summer low flows (Figure 16). This is due to AWBM being a conceptual model rather than a process-based model, which does not account for continual baseflow contributions from stores. Instead, runoff is produced only in response to rainfall and the baseflow stores are linearly depleted.

The low flows were investigated further in order to simulate the baseflow contribution at the Capel Railway Bridge gauge. The minimum daily flow for the observed period of record, from May 1993 to October 2006, was 3.3 ML. This value was added as a constant yearly baseflow to all the modelled data from January 1975 to May 1993. As an example of how this impacts the daily hydrograph, the minimum daily flow was added to the modelled data for a calibration year (2003) (Figure 17). The impact is negligible for the winter period and flattens out the summer low-flow period, rather than linearly receding the baseflow stores.

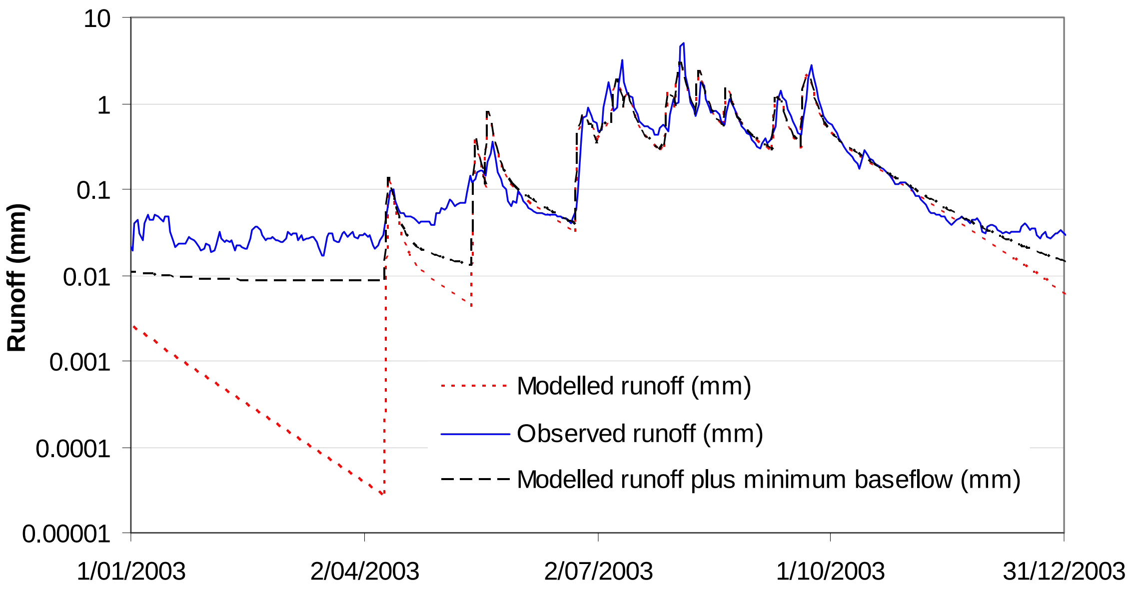

Figure 17 Comparison of observed, AWBM-modelled and modelled plus minimum daily flow for a calibration year (2003) (log-scale y axis)

5.2.1 Annual streamflow

The mean annual flow for the observed whole years of record is 50.0 GL with a coefficient of variation of 0.47. The maximum recorded annual flow of 94.6 GL was recorded in 1999. The minimum recorded annual flow of 15.7 GL was recorded in 2001 and is less than a third of the average flow. The minimum flow at Yates Bridge also occurred in 2001, and was less than one-sixth of the average flow. The less significant result at the Capel Railway Bridge indicates the influence of an increasing baseflow contribution between the gauges.

For the period 1975 to 2003, the combined observed and modelled annual streamflow at the Capel Railway bridge, with the low-flow correction applied, has an estimated mean annual flow of 44.8 GL and a coefficient of variation of 0.53 (Figure 18). The maximum and minimum recorded annual flows were 96.3 and 11.5 GL respectively.

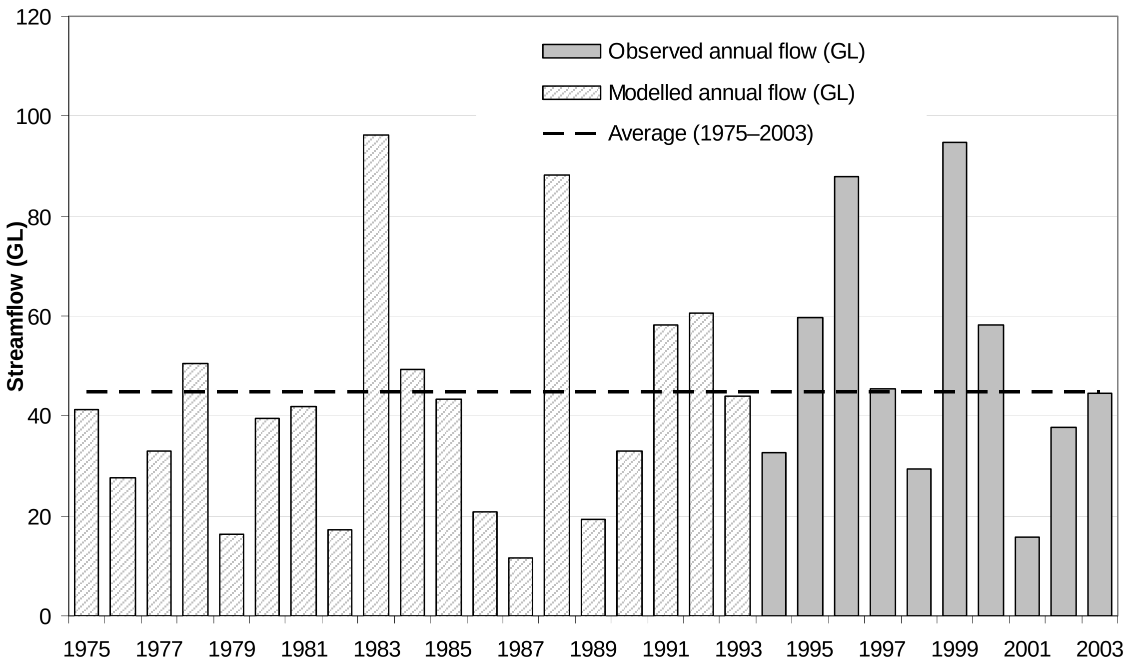

Figure 18 Modelled and observed annual streamflow record for Capel River at Capel Railway Bridge (610010)

The mean annual runoff for the period 1975 to 2003 is 113 mm, while the mean annual rainfall for the Capel Post Office rainfall station (009516) is 735 mm. The annual runoff coefficient is 15 per cent. The modelled average annual baseflow index is 0.55, or 55 per cent, which is a significant proportion of the total streamflow.

5.2.2 Floodflows

A flood-frequency curve for the Yates Bridge gauging station was developed using the program FLIKE. The curve was constructed using 12 years of recorded data (1994 to 2005) and a GEV distribution was fitted to the data (Figure 19).

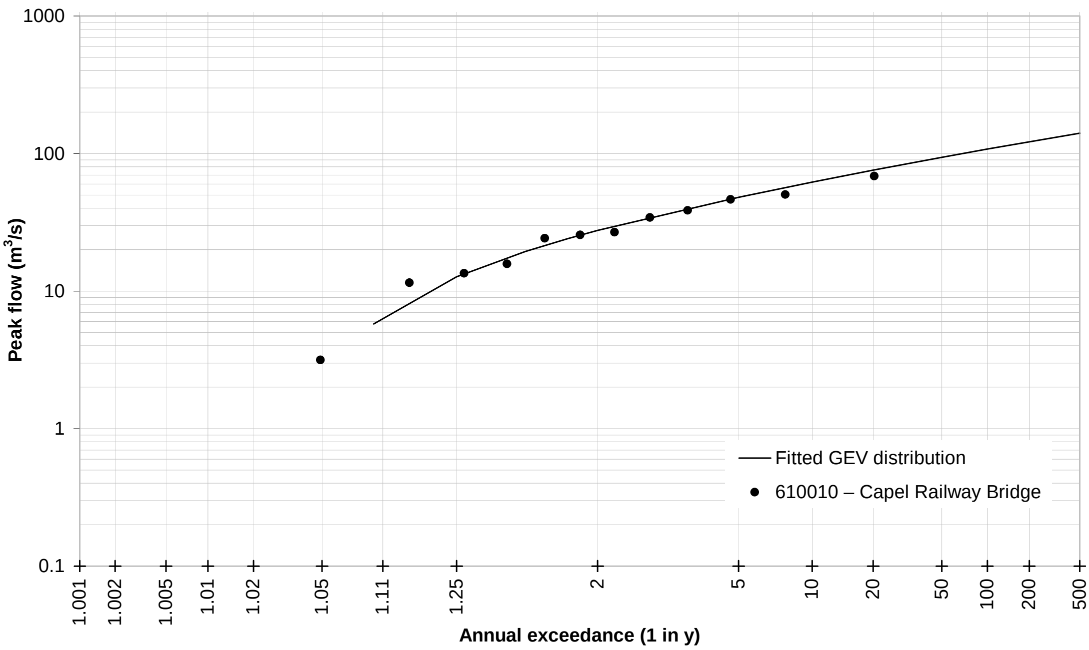

Figure 19 Flood-frequency plot for Capel River at Capel Railway Bridge (610010)

The results were consistently lower than those produced by the flood-frequency analysis undertaken for the Capel River as part of the Busselton Regional Flood Study Review (JDA 1998, Table 1). The peak annual flow series was a combination of FLIKE analysis and results of runoff routing modelling (RORB) (Table 2). The flows since 1998 (i.e. not included in the JDA study) have all been less than a 1-in-10-year ARI.

Table 2 Annual series flood-frequency data for Capel River at Capel Railway Bridge (610010) (JDA 1998)

Average recurrence interval (1:year)	Annual exceedance probability (%)	Peak annual flow (m^3s^{-1})	Growth factor (F_x/F_2)*
1:1.1	90.9	12	–
1:2	50	31	–
1:5	25	56	1.81
1:10	10	79	2.55
1:25	4	103	3.32
1:50	2	121	3.90
1:100	1	157	5.06

5.2.3 Monthly streamflow

As with rainfall, the streamflow in the Capel River at the Capel Railway Bridge is highly seasonal, with 90 per cent of the flow occurring from June to October (Figure 20). August is the peak-flow month, with a mean flow of 12.9 GL. The impact of the large soil-storage capacity is evident in the lag between the peak-rainfall month and the peak-flow month.

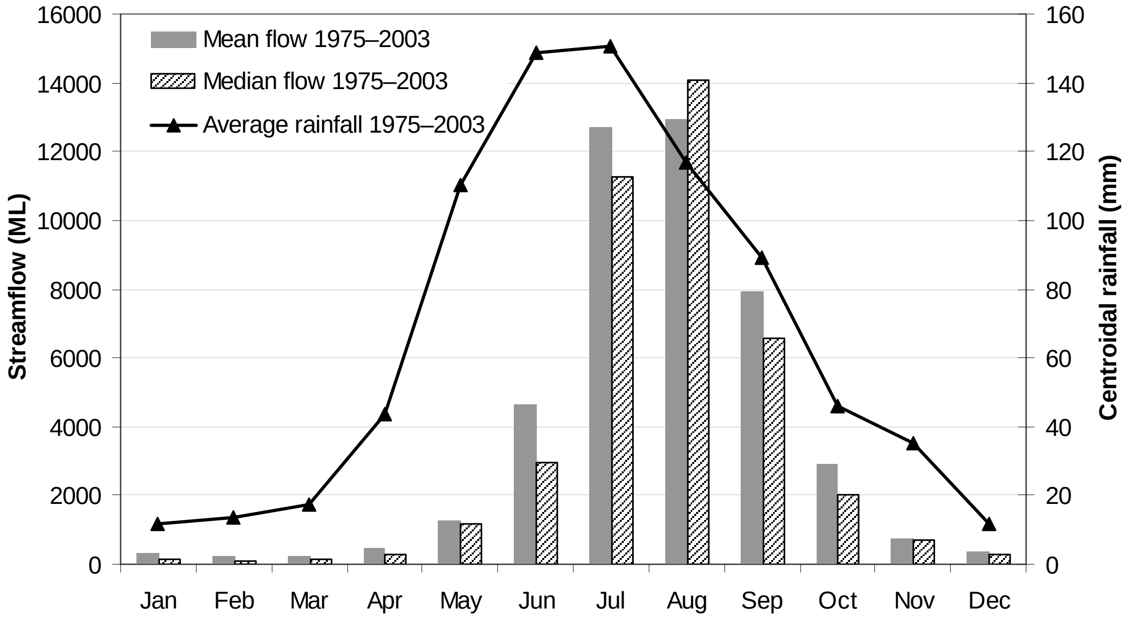

Figure 20 Average and median monthly streamflow for Capel River at Capel Railway Bridge and average centroidal rainfall

5.2.4 Daily streamflow

Annual and monthly flow-duration curves were calculated using daily flows for each year. The thick black line is the total flow-duration curve for the period 1975 to 2003, the thin dashed blue lines are the observed yearly flow-duration curves and the thin grey lines are the modelled yearly flow-duration curves (Figure 21).

At Capel Railway Bridge (Figure 21) the median daily flow is 24 ML, and flows greater than 3 ML are exceeded 100 per cent of the time. The curve is a gradual decline to the low-flow end, suggesting large groundwater contributions to a steady perennial river. The groundwater contribution, from the Leederville Aquifer, in the summer months can be seen by the very similar monthly flow-duration curves for January to March (Figure 22), indicating groundwater is the dominant source of flow. In addition there is large surface storage (e.g. Capel Sands dams).

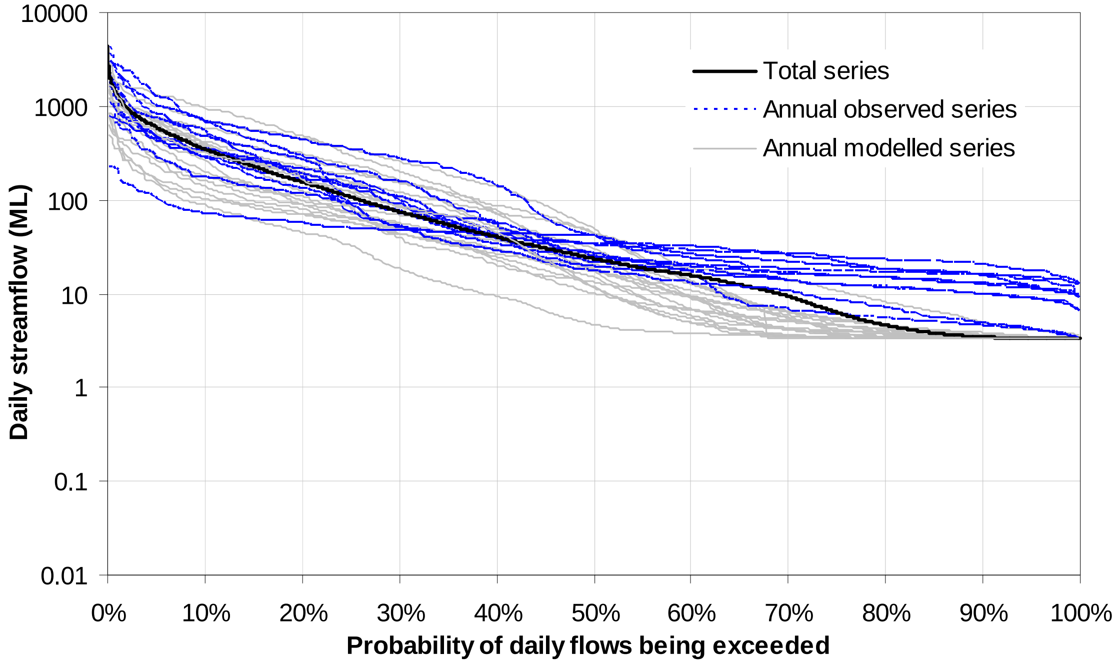

Figure 21 Observed and modelled daily flow-duration curves categorised by year for Capel River at Capel Railway Bridge (610010)

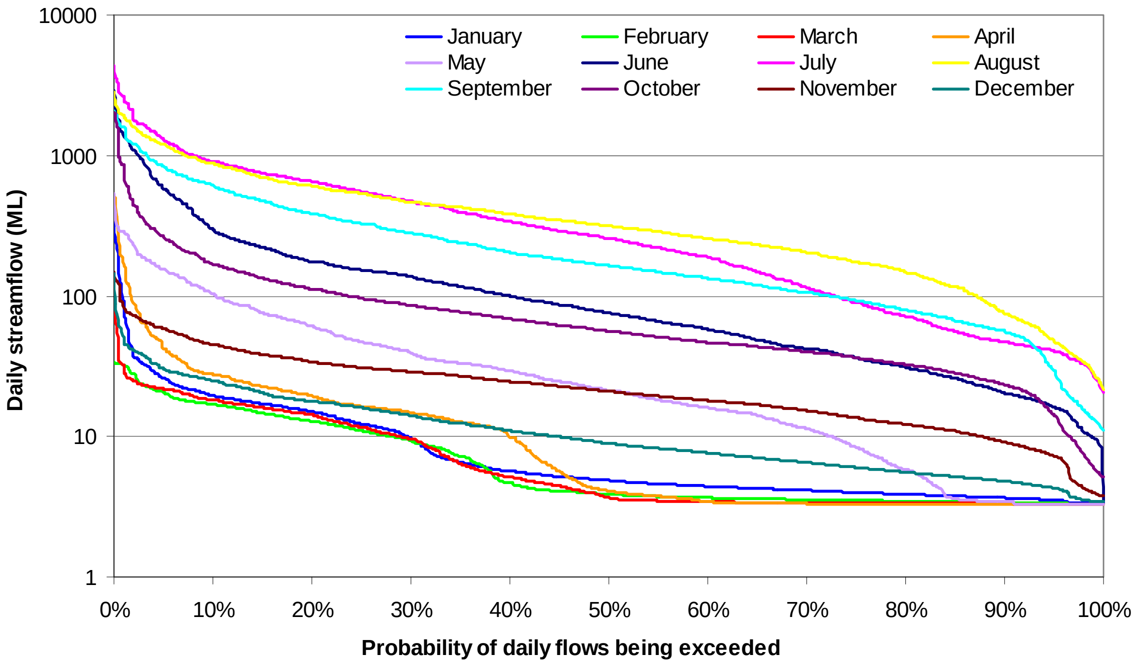

Figure 22 Observed and modelled daily flow-duration curves categorised by month for Capel River at Capel Railway Bridge (610010)

The monthly flow-duration curves for the combined modelled and observed data (Figure 22) compare well to the observed monthly flow-duration curves (Figure 23) with the exception of the summer months (January to May). Based on the slope of the curves and the maximum and minimum daily streamflow, the observed monthly flow-duration curves suggest that baseflow is a key component in these summer months, corresponding to the lowest rainfall months. This suggests that the adjusted modelled data do not fully account for the baseflow contribution.

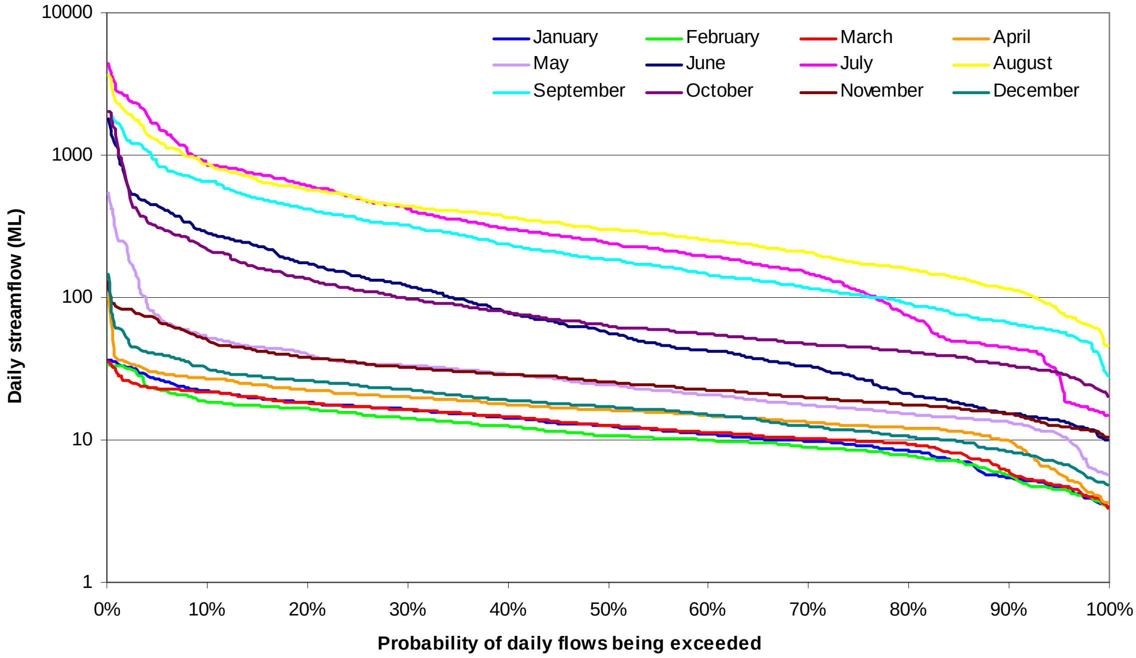

Figure 23 Observed daily flow-duration curves categorised by month for Capel River at Capel Railway Bridge (610010)

6 Conclusion

Located in the south-west corner of Western Australia, the Capel River flows to Geographe Bay. The catchment is 635 km^2, of which approximately 60 per cent is cleared. Streamflow gauging stations at Yates Bridge (610219) and Capel Railway Bridge (610010) are currently in operation and their recordings were analysed further to assist with the development of ecological water requirements for the Capel River.

The Capel River catchment has experienced a decline in annual rainfall since the 1970s, consistent with the trend in many locations in the south-west of WA. Over 75 per cent of average annual rainfall occurs between the months of May and September.

Rainfall runoff modelling was undertaken to develop a time series for the period 1975 to 2003. The mean annual flow at Yates Bridge was 39.9 GL, with 95 per cent of the streamflow occurring between the months of June and October. The annual runoff coefficient for the upper Capel catchment was 13 per cent and the average annual baseflow index was 55 per cent. Flow-duration analysis shows that the upper reaches of the river were once ephemeral, but the flow record now shows a perennial river due to summer flow releases from a large on-stream dam in the upper catchment.

The mean annual flow at Capel Railway Bridge was 44.8 GL, with 90 per cent of the streamflow occurring between the months of June and October. The annual runoff coefficient for the upper Capel catchment was 15 per cent, while the average annual baseflow index was 55 per cent. Flow-duration analysis suggests large groundwater contributions to a steady perennial river.

To obtain a more accurate flow representation it would be necessary to run a process-based model that explicitly models the surface water / groundwater interaction in the Capel River system. As environmental flow studies assess low-flow characteristics, it may not be practical to base the ecological water requirement study on the baseflow adjusted modelled series. Instead it is recommended that the study should be based on the observed record only (i.e. 1996 onwards for Yates Bridge and 1993 onwards for Capel Railway Bridge).

Appendix

Table A Final RRL–AWBM parameter set for Capel River at Yates Bridge (610219)

Parameter	Value
Capacity C1 – mm	32
Capacity C2 – mm	230
Capacity C3 – mm	720
Area A1 0<=A1<=1	0.1
Area A2 0<=A2<=1	0.42
Area A3 A3 = 1 – (A1+A2)	0.48
Baseflow index (BFI) 0<=BFI<=1	0.55
Baseflow recession constant Kbase 0<=KBase<=1	0.955
Surface runoff recession constant Ksurf 0<=Ksurf<=1	0.6

Table B Final RRL–AWBM parameter set for Capel River at Capel Railway Bridge (610010)

Parameter	Value
Capacity C1 – mm	25
Capacity C2 – mm	210
Capacity C3 – mm	600
Area A1 0<=A1<=1	0.1
Area A2 0<=A2<=1	0.42
Area A3 0<=A3<=1	0.48
Baseflow index (BFI) 0<=BFI<=1	0.55
Baseflow recession constant Kbase 0<=KBase<=1	0.955
Surface runoff recession constant Ksurf 0<=Ksurf<=1	0.65

Table C Statistics comparing the observed and modelled results of the RRL–AWBM calibration for Capel River at Yates Bridge (610219)

Statistic (1976–1995)	Observed	Modelled
Annual		
Average (mm)	119	126
Standard deviation (mm)	72	80
Mean absolute error (MAE) (mm)		5.8
Root mean square error (RMSE) (mm)		10.3
Coefficient of efficiency (E)		0.93
Monthly		
Average (mm)	9.9	10.5
Standard deviation (mm)	15.9	17.0
Mean absolute error (MAE) (mm)		0.62
Root mean square error (RMSE) (mm)		1.93
Coefficient of efficiency (E)		0.96
Daily		
Average (mm)	0.33	0.34
Standard deviation (mm)	0.70	0.68
Mean absolute error (MAE) (mm)		0.04
Root mean square error (RMSE) (mm)		0.22
Coefficient of efficiency (E)		0.71

Table D Statistics comparing the observed and simulated results of the RRL–AWBM calibration for Capel River at Capel Railway Bridge (610010)

Statistic (1976–1995)	Observed	Simulated
Annual		
Average (mm)	133	129
Standard deviation (mm)	65	83
Mean absolute error (MAE) (mm)		10.5
Root mean square error (RMSE) (mm)		18.2
Coefficient of efficiency (E)		0.82
Monthly		
Average (mm)	11.1	10.7
Standard deviation (mm)	17.6	18.4
Mean absolute error (MAE) (mm)		1.11
Root mean square error (RMSE) (mm)		2.67
Coefficient of efficiency (E)		0.95
Daily		
Average (mm)	0.36	0.35
Standard deviation (mm)	0.81	0.73
Mean absolute error (MAE) (mm)		0.07
Root mean square error (RMSE) (mm)		0.27
Coefficient of efficiency (E)		0.75

Where:

MAE is calculated as $\frac{1}{N}\sum\left|O_i - S_i\right|$ and has a range of 0 to infinity and a perfect score of 0

RMSE is calculated as $\sqrt{\frac{1}{N}\sum\left(O_i - S_i\right)^2}$ and has a range of 0 to infinity and a perfect score of 0

and E is calculated as $1-\frac{\sum\left(O_i - S_i\right)^2}{\sum\left(O_i - \overline{O}\right)^2}$ and has a range of negative infinity to 1 and a perfect score of 1

and where O represents the observed data point, S the modelled data point and N the total number of observations.

References

Beard, JS 1990, *Plant life of Western Australia*, Kangaroo Press, Sydney.

Beckwith Environmental Planning 2006, *Capel River – surface water management issue scoping report*, Beckwith Environmental Planning Pty Ltd, Perth.

Bureau of Meteorology 2006, *Australian climates*, Bureau of Meteorology, Canberra, viewed February 2007, <http://www.bom.gov.au/climate/map/climate_classifications/IDCJCM0000_climate_classification.shtml>.

CRLWUG (Capel River Local Water User Group) n.d., 'Submission in response to the draft blueprint for water reform in Western Australia', Capel River Local Water User Group, viewed January 2007, <http://dows.lincdigital.com.au/Submissions.asp>.

Department of Water, n.d., *Hydrogeological atlas of WA*, Department of Water, Perth, viewed February 2007, <http://portal.water.wa.gov.au/portal/page/portal/MapsDataAtlases/HydrogeologicalAtlas>.

JDA 1998, *Busselton regional flood study review*, vol. 2, *Appendices*, JDA Consultant Hydrologists, Perth.

Nash, JE & Sutcliffe, JV 1970, 'River flow forecasting through conceptual models, I, A discussion of principles', *Journal of Hydrology*, vol. 10, pp. 282–90.

Pen, LJ 1999, *Managing our rivers: a guide to the nature and management of the streams of southwest Western Australia*, Water and Rivers Commission, Perth.

Water and Rivers Commission 2003, *Water quality and hydrology in the Capel River 1941–2001*, South West inflo series, Water and Rivers Commission, Perth.

White, K & Comer, S 1999, '*Capel River action plan*', prepared for the Geographe Catchment Council, Water and Rivers Commission, Perth.