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1 INTRODUCTION

1.1 BACKGROUND

WRM Water and Environment was engaged by Gujarat NRE Coking Coal Limited to assist in assessment of the potential surface water impacts of the proposed NRE No.1 Colliery project.

This study describes the existing surface water hydrology of the potentially affected streams, and the hydrological modelling undertaken to quantify the potential impacts. The modelling has been undertaken to address components of the Director General's Requirements (DGRs) for the project relating to the potential impacts on flows in the potentially affected watercourses and the associated reliability of water supplies from Cataract Dam.

The study draws on estimates of the extent of mine subsidence and the potential for cracking of the ground surface along watercourses. This report focuses on surface water hydrology, whilst the potential impacts on other features of the streams and upland swamps are covered by associated studies.

1.2 PROJECT DESCRIPTION

The proposed workings are contained within the NRE No. 1 Colliery in Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575), which are located approximately 13km northwest of Wollongong.

The proposed mining is subdivided into Wonga East (Area 1 and Area 2) and Wonga West (Area 3 and Area 4). These areas are shown in Figure 1.1.

Coal will be extracted from the Wongawilli Seam by longwall extraction from eleven panels in the Wonga East area and seven panels in the Wonga West area.

1.3 STUDY AREA

The Study Area includes the catchments of potentially affected streams in the vicinity of the project. As shown in Figure 1.1, the Study Area extends approximately 20km west from the Illawarra Escarpment and comprises the catchments of Lake Cataract, and the north-flowing tributaries which join the Cataract River downstream of Cataract Dam (Lizard Creek and Wallandoola Creek).

Lake Cataract is a component of the Upper Nepean water supply scheme, and is managed by the Sydney Catchment Authority (SCA).

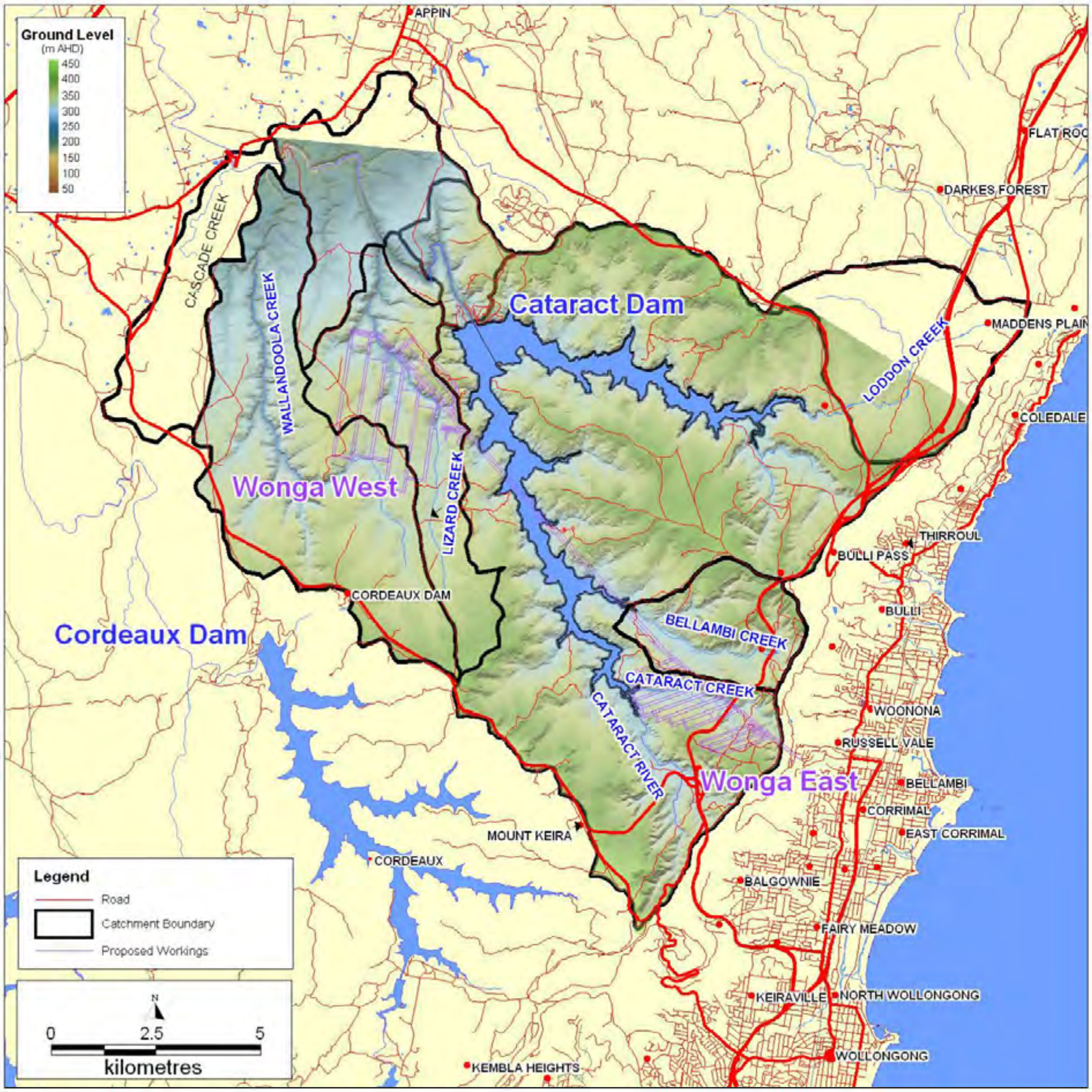

Figure 1.1 Study Area

1.4 SCOPE OF WORK

The following tasks were completed under the scope of this study:

- Delineate drainage catchments over the mine subsidence area,
- Produce longitudinal profiles over the proposed workings,
- Assess streams in terms of gradient, length, and order,
- Assess rainfall residuals for the nearest long-term rainfall gauge,
- Obtain streamflow from nearby streamflow gauges if relevant to the site catchments,
- Obtain hydrological data pertaining to Lake Cataract:
  - spill volumes,
  - stored volume,
  - water extractions, and
  - surface evaporation.
- Prepare and calibrate a rainfall-runoff model of the Lake Cataract catchment to generate a daily time series of inflows to the dam,
- Assess the contribution of the mine subsidence areas to the total runoff to Lake Cataract over a range of flow conditions,
- Assess the impact of the potential loss of flow due to subsidence-induced cracking on streamflow in the creeks crossing the proposed subsidence area.

2 CATCHMENT CHARACTERISTICS

2.1 LAKE CATARACT CATCHMENT

Ground surface elevations in the Lake Cataract catchment vary from 485m AHD near Mount Keira on the eastern escarpment to 150m AHD at the confluence of Wallandoola Creek and the Cataract River, at the downstream (western) end of the Study Area. The underlying geology predominantly comprises Hawkesbury Sandstone, however the Bald Hill Claystone and Bulgo Sandstone are exposed in the valley floor of Cataract Creek in the Wonga East Area. Steep rocky outcrops and cliffs are present in some areas, while some headwater streams drain upland valley fill and headwater swamps on the higher eastern plateau via ephemeral gullies incised into the sandstone.

Cataract Dam has significantly altered streamflow from the Cataract River since its construction in 1907. The dam has a capacity of 94,300ML and controls a catchment area of 130km^2. Flows downstream of the dam are further regulated by Broughton's Pass weir, which diverts water supplies to the Macarthur Water Treatment Plant via Cataract Tunnel.

There has been a long history of coal mining under the Upper Nepean water supply catchments. Mining activities by previous owners of NRE No.1 Colliery and the decommissioned BHP Billiton Cordeaux Colliery longwall as well as other old bord and pillar workings have caused adverse subsidence impacts in the Study Area. Longwall mining in the Appin, Westcliff and Northcliff workings approximately 2.5km to the north of the Gujarat Lease Area have also resulted in adverse impacts on surface water quality and quantity (Short, 2007).

Surface infrastructure associated with mining affects relatively small portions of the catchment, and as the SCA's Metropolitan Special Area is a restricted access area, the Study Area is otherwise largely undeveloped and in a natural condition.

2.2 WONGA WEST CATCHMENTS

As shown in Figure 2.1, the Wonga West area contains mine surface infrastructure and access roads associated with the existing Gujarat NRE No. 1, No. 4 and No. 5 shafts. It is drained by Wallandoola and Lizard Creeks, which flow north to join the Cataract River between Cataract Dam and Broughton's Pass Weir. The headwaters overlie the previously mined BHP Cordeaux Colliery to the south of the Gujarat lease. Valley infill and headwater upland swamps are also present predominantly in the southern portion of the Wonga West, and to a lesser degree, Wonga East areas.

Wallandoola Creek does not directly overly the proposed longwall workings, but as shown in Figure 2.2, a total reach of 1.3km at Wallandoola Creek, and a 4.5km reach of Lizard Creek are contained within the 20mm subsidence zone. Lake Cataract will not be undermined by the Wonga West workings.

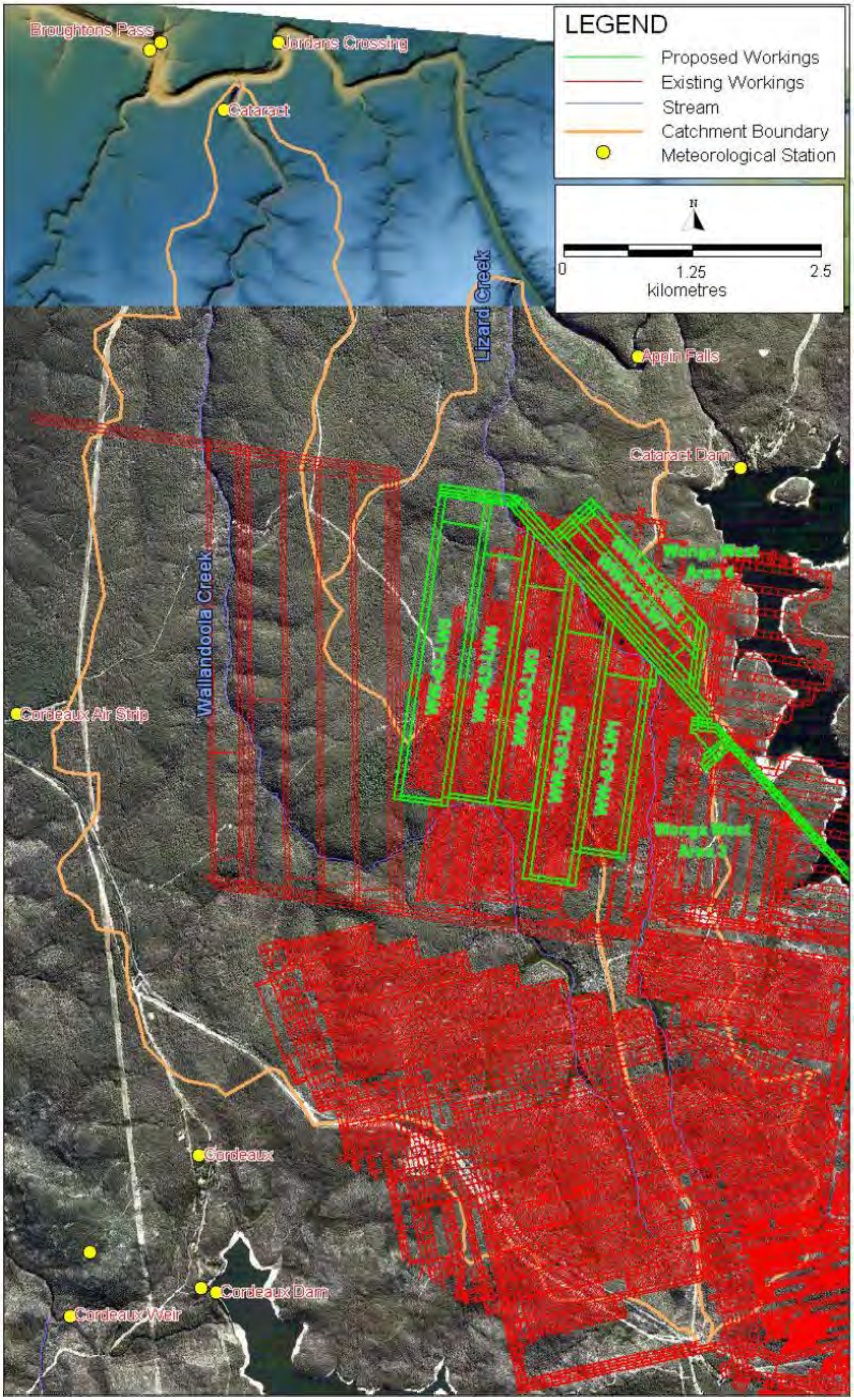

Figure 2.1 Lizard and Wallandoola Creek Catchment Areas

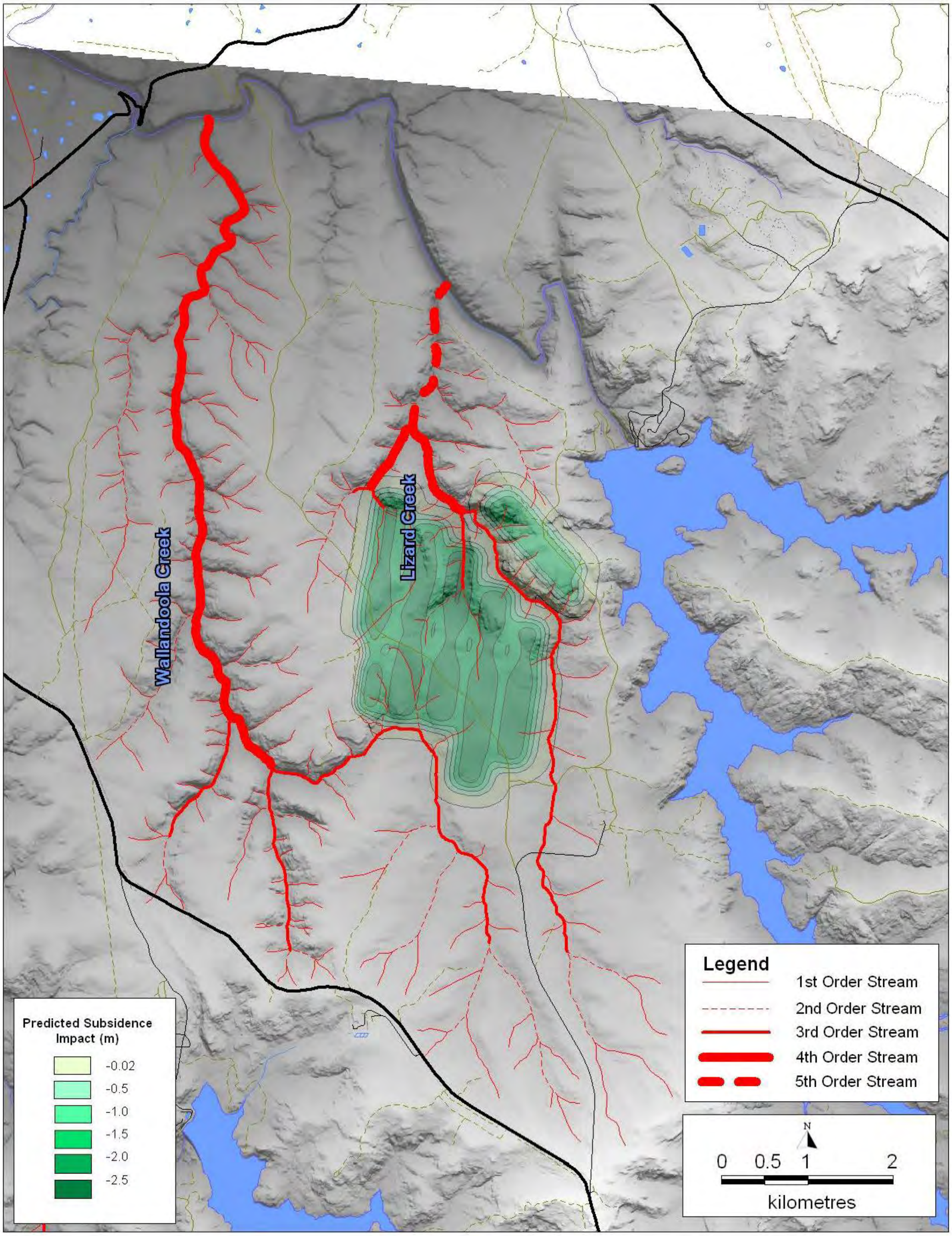

Figure 2.2 Stream Order – Wallandoola Creek and Lizard Creek

2.3 WONGA EAST CATCHMENTS

The Wonga East area is predominantly drained by Cataract Creek, and to a much lesser degree, Bellambi Creek and Cataract River. Cataract Creek joins the Cataract River within the impoundment of Lake Cataract.

As shown in Figure 2.3, parts of the upper catchments have been cleared for powerlines and access tracks. The Southern Freeway also crosses the eastern portion of these catchments. One upland swamp is present within Wonga East in the Cataract River catchment.

Longwall mining of the Balgownie Seam as well as bord and pillar extraction of the Bulli Seam has previously been conducted under Cataract Creek with no observed adverse impacts on the creek bed or banks (Geoterra, 2011).

As shown in Figure 2.3, the proposed Wonga East workings underlie Cataract Creek, but not the Cataract River. Figure 2.4 shows the western end of Panel 10 and the associated predicted 20mm subsidence zone could potentially undermine the eastern bank of the high water extent of the Lake Cataract backwater.

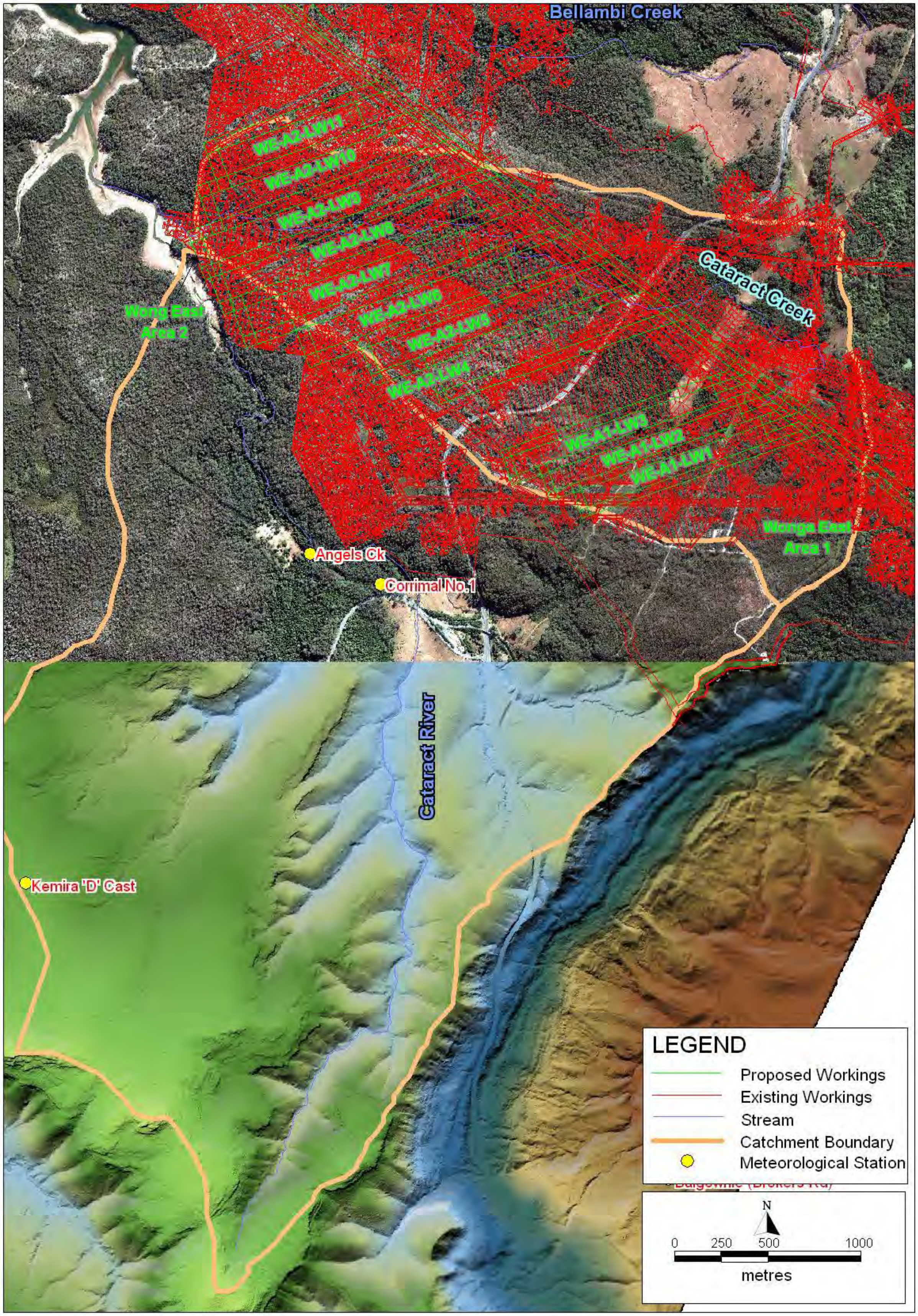

Figure 2.3 Cataract River and Cataract Creek Catchment Areas

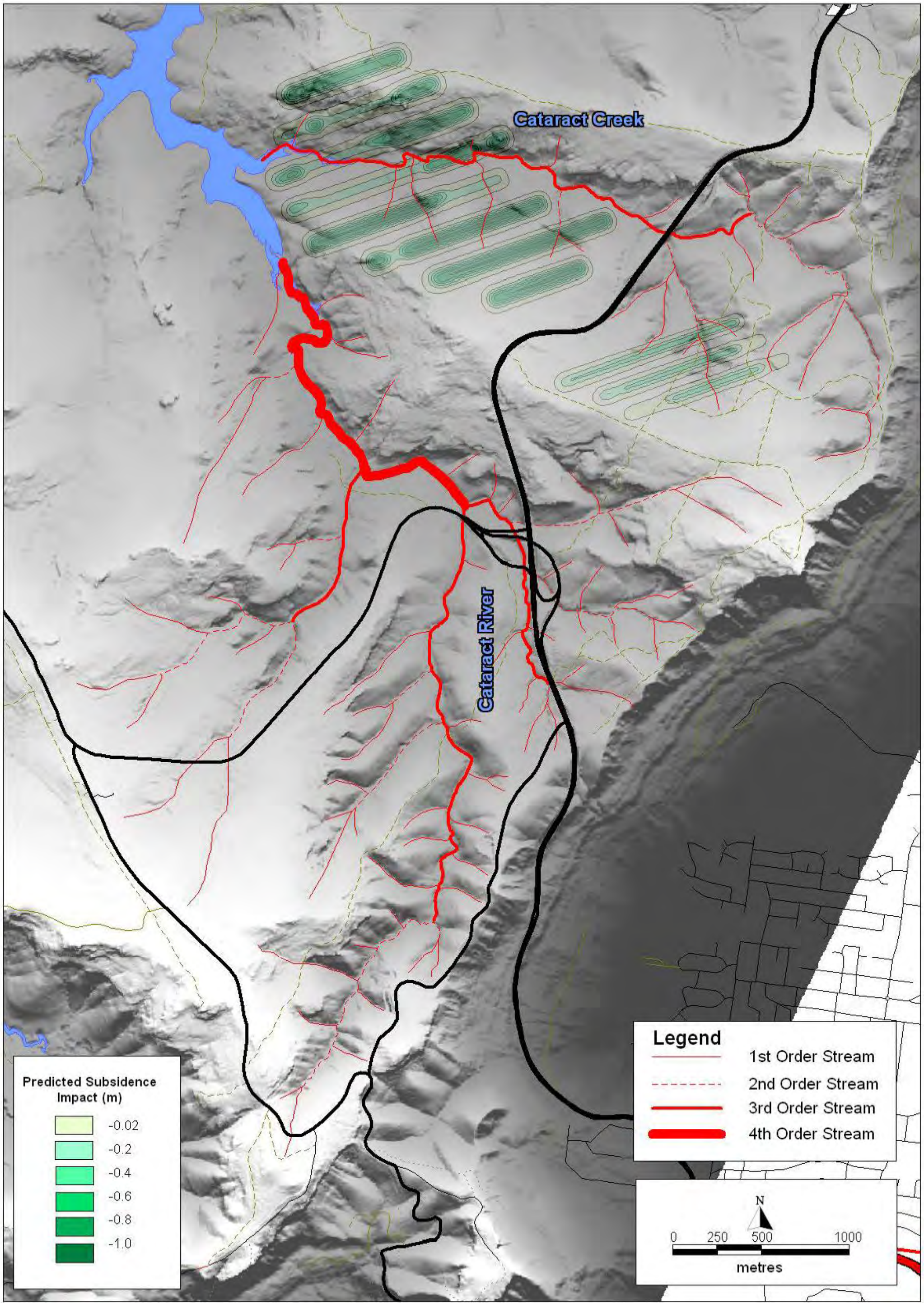

Figure 2.4 Stream Order – Cataract River and Cataract Creek

3 STREAM GEOMETRY

3.1 GENERAL

Longitudinal profiles of each of the potentially affected watercourses were produced from a digital terrain model derived using airborne laser scanning survey acquired over the Study Area on 20th October 2009. The accuracy of well defined points in the survey data is quoted as better than 100mm, based on comparison with ground survey in cleared areas (AAM Hatch, 2009).

3.2 WONGA WEST

3.2.1 Lizard Creek

As shown in Figure 2.2, Lizard Creek is a 3rd and 4th order stream that lies within the predicted 20mm subsidence zone, with a 2km stretch downstream of the subsidence zone being a 5th order stream.

A longitudinal profile of Lizard Creek is shown in Figure 3.1 (its alignment is shown in Figure 3.3). Lizard Creek is just over 10km long from its headwaters to its confluence with the Cataract River. Channel invert elevations fall from approximately 360m AHD to 200m AHD, including an almost 30m high waterfall located approximately half way along its length. A 20m waterfall just upstream of the Cataract River confluence is located downstream, and outside of, the 20mm subsidence zone. The channel gradient varies from around 0.4%, near the 5,500m chainage mark, and is steepest near the downstream end (around 3%).

The proposed Wonga West workings are located between Chainage 5,300m and Chainage 7,800m. . Approximately 3.6km of the stream reach is located upstream, 3.5km within and 3.2km downstream of the 20mm subsidence zone

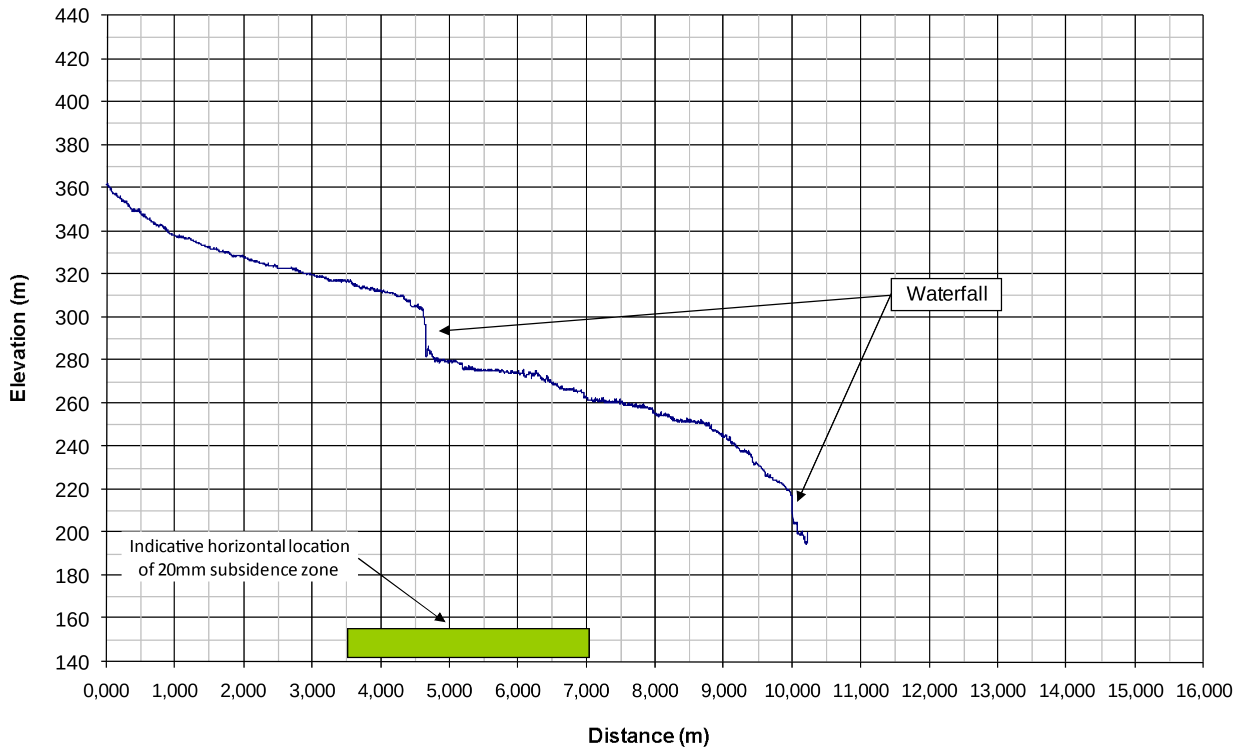

Figure 3.1 Longitudinal Profile of Lizard Creek

Channel cross-sections at three locations along Lizard Creek are shown in Figure 3.2.

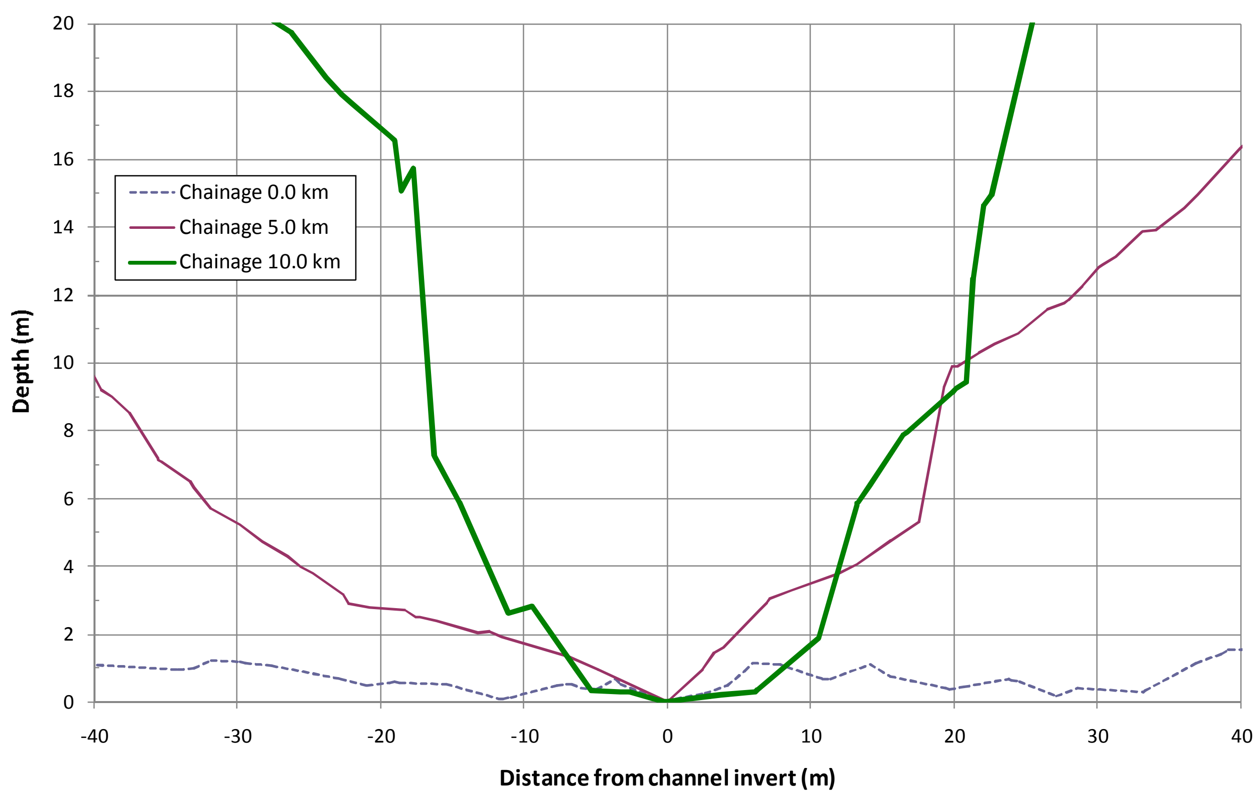

Figure 3.2 Cross-sections of Lizard Creek

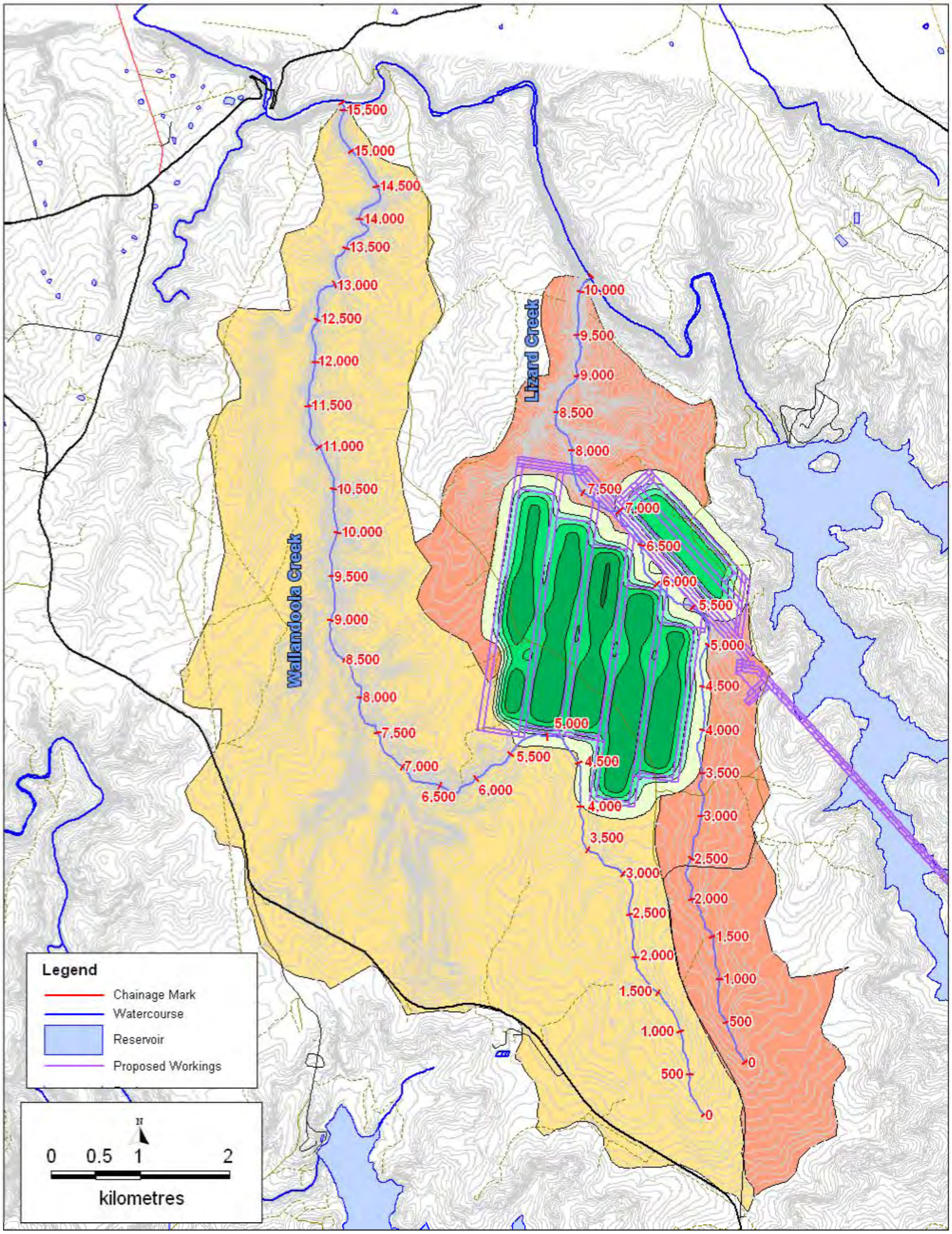

Figure 3.3 Alignments of Longitudinal Profiles of Wallandoola Creek and Lizard Creek

3.2.2 Wallandoola Creek

As shown in Figure 2.2 , Wallandoola Creek is a 4th order stream for most of its length.

A longitudinal profile of Wallandoola Creek is shown in Figure 3.4 (its alignment is shown in Figure 3.3). Wallandoola Creek is approximately 15.5km long from its headwaters to the confluence with the Cataract River. Channel invert elevations fall from approximately 370m AHD to 140m AHD, including series of stepped waterfalls totalling over 50m along a 2.5km reach approximately half way along its length. The channel gradient varies from 0.4%, near chainage 7,000m, and is steepest at the downstream end, at around 4%.

The proposed Wonga West workings are located adjacent to the channel between Chainage 3,500m and Chainage 6,000m. Approximately 4.0km of the stream reach is located upstream, 1.4km within and 10.2km downstream of the 20mm subsidence zone.

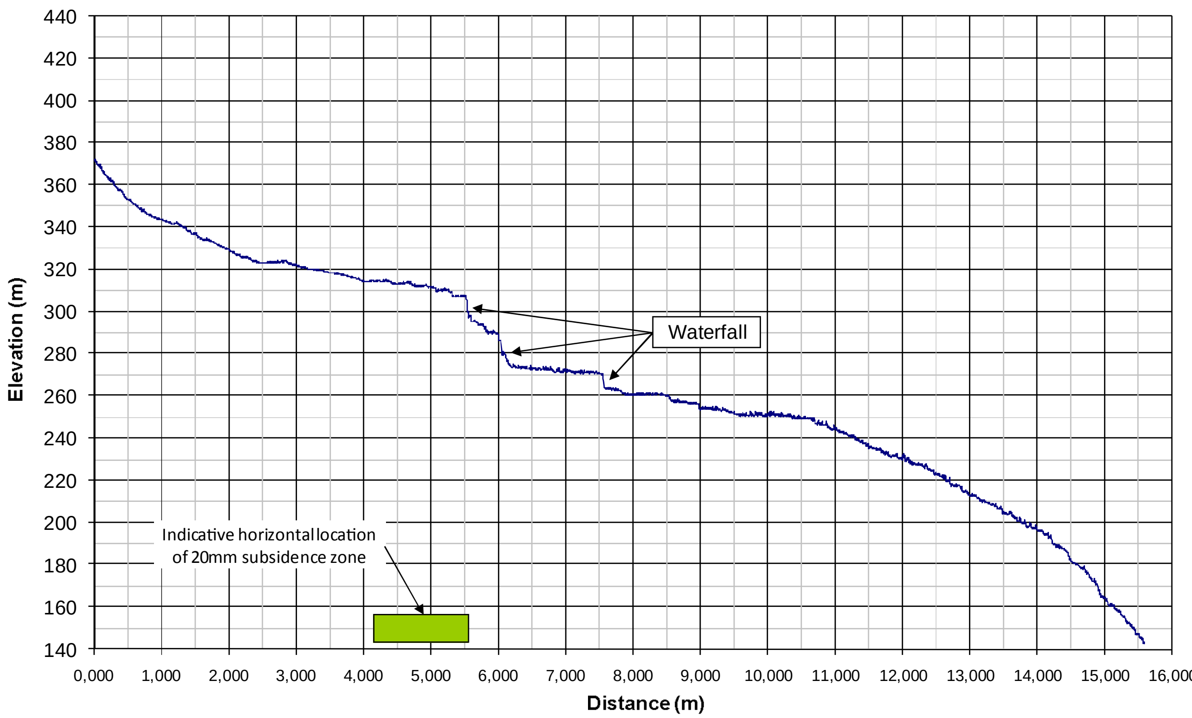

Figure 3.4 Longitudinal Profile Wallandoola Creek

Channel cross-sections at three locations along Wallandoola Creek are shown in Figure 3.5.

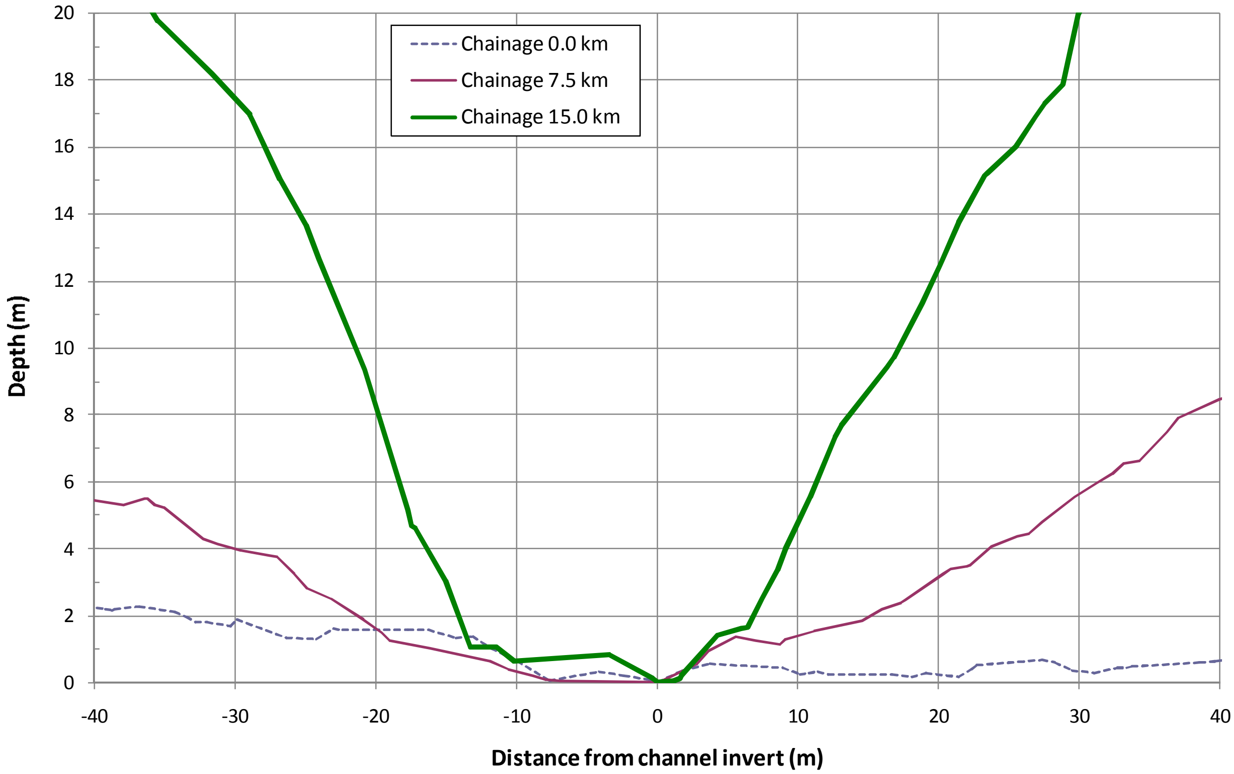

Figure 3.5 Cross-sections of Wallandoola Creek

3.3 WONGA EAST

3.3.1 Cataract Creek

As shown in Figure 2.4, Cataract Creek is a 4th order stream for most of its length.

A longitudinal profile of Cataract Creek is shown in Figure 3.6 (its alignment is shown in Figure 3.8). Cataract Creek is approximately 5.5km long from its headwaters to the upstream reaches of the Lake Cataract storage. Channel invert elevations fall from approximately 340m AHD to 285m AHD. The channel is relatively gently sloping at a gradient of 0.9%, for most of its length - the exception being the steep upstream 0.5km reach, which slopes at 4.2%

The proposed Wonga East workings are located between Chainage 3,100m and Chainage 4,200m. Approximately 3.7km of the stream reach is located upstream, 0.5km within and 0.7km downstream of the 20mm subsidence zone

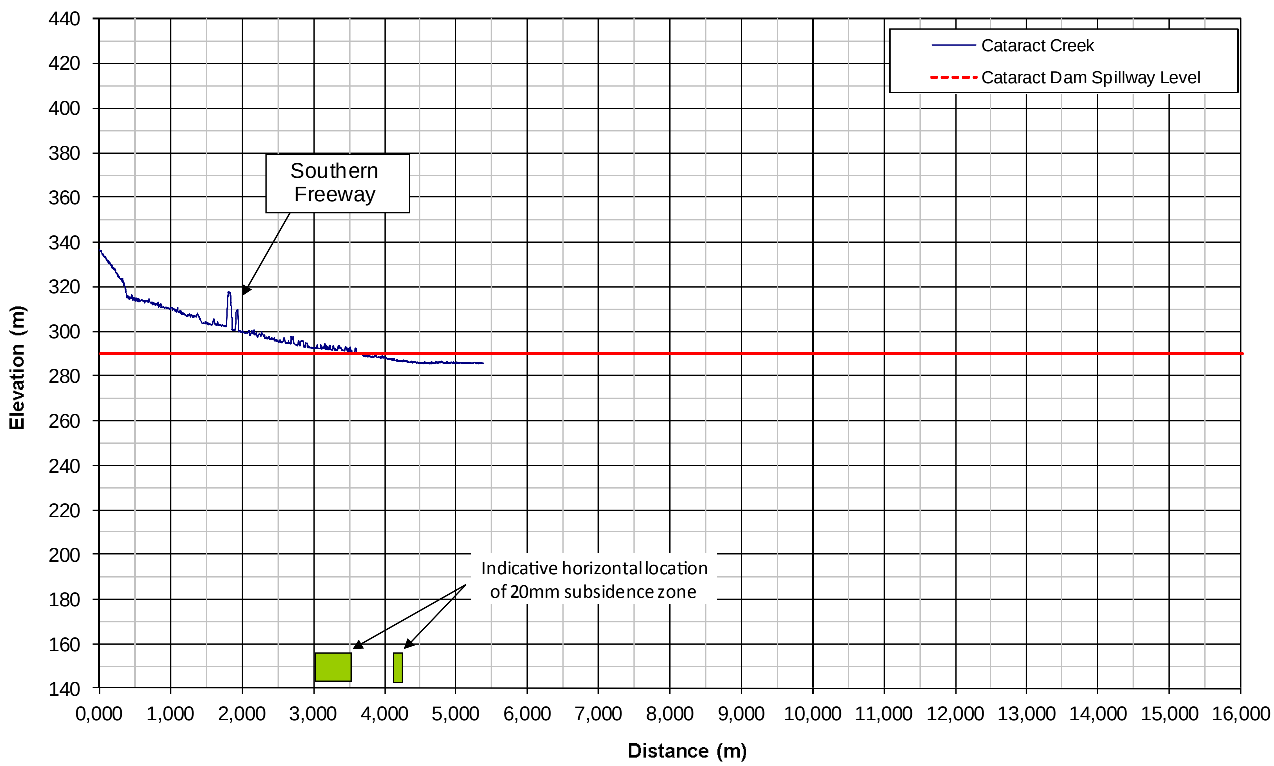

Figure 3.6 Longitudinal Profile Cataract Creek

Channel cross-sections at three locations along Cataract Creek are shown in Figure 3.7.

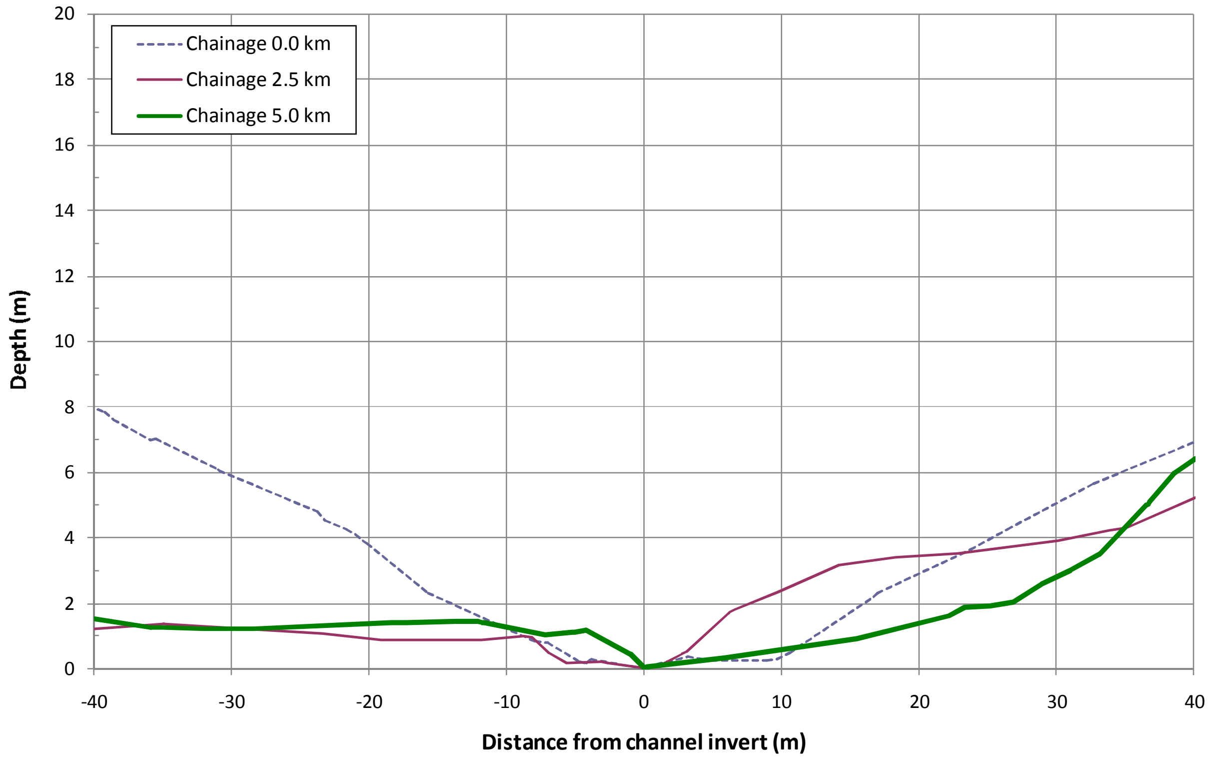

Figure 3.7 Cross-sections of Cataract Creek

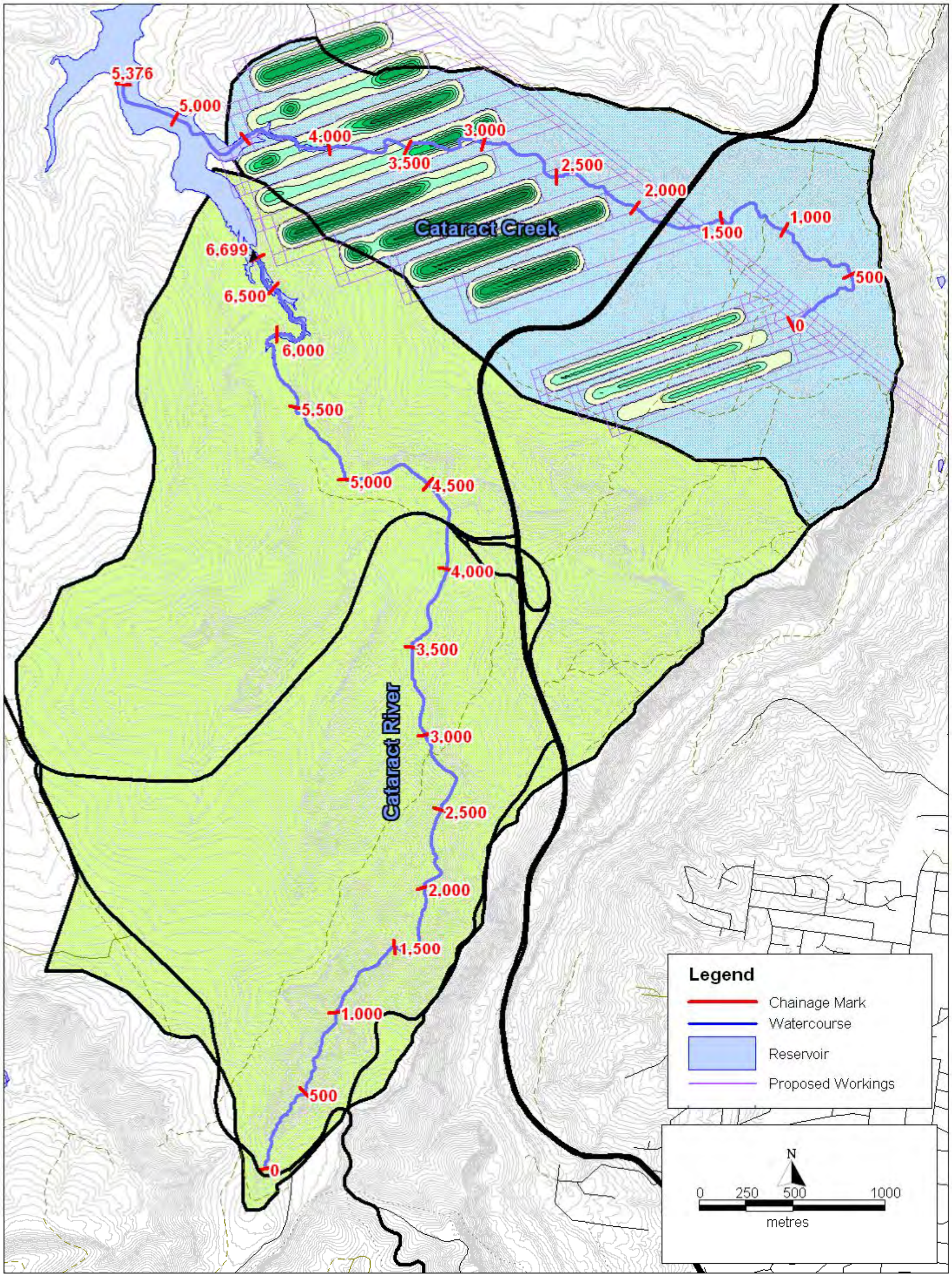

Figure 3.8 Alignments of Longitudinal Profiles of Cataract River and Cataract Creek

3.3.2 Cataract River

As shown in Figure 2.4, Cataract River is a 3rd order stream upstream of the Link Road crossing, and 4th order from the confluence near the crossing to the Lake Cataract backwater.

Cataract River is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage. Channel invert elevations fall from approximately 430m AHD to 285m AHD. The channel is relatively gently sloping at a gradient of 0.5%, for much of its length - the exception being the steep upstream 0.5km reach, which slopes at around 17%.

The proposed Wonga East workings do not underlie the Cataract River, however the predicted 20mm subsidence zone runs adjacent to the Lake Cataract backwater for a distance of about 600m.

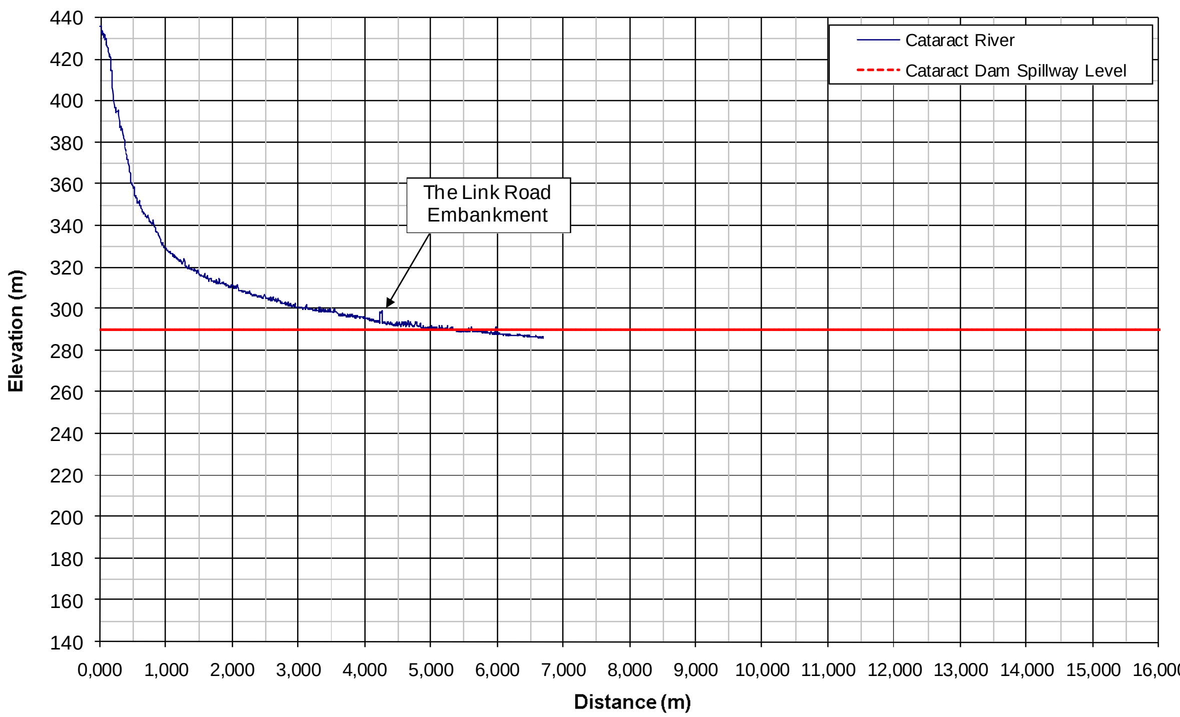

Figure 3.9 Longitudinal Profile Cataract River

Channel cross-sections at three locations along Cataract River are shown in Figure 3.10.

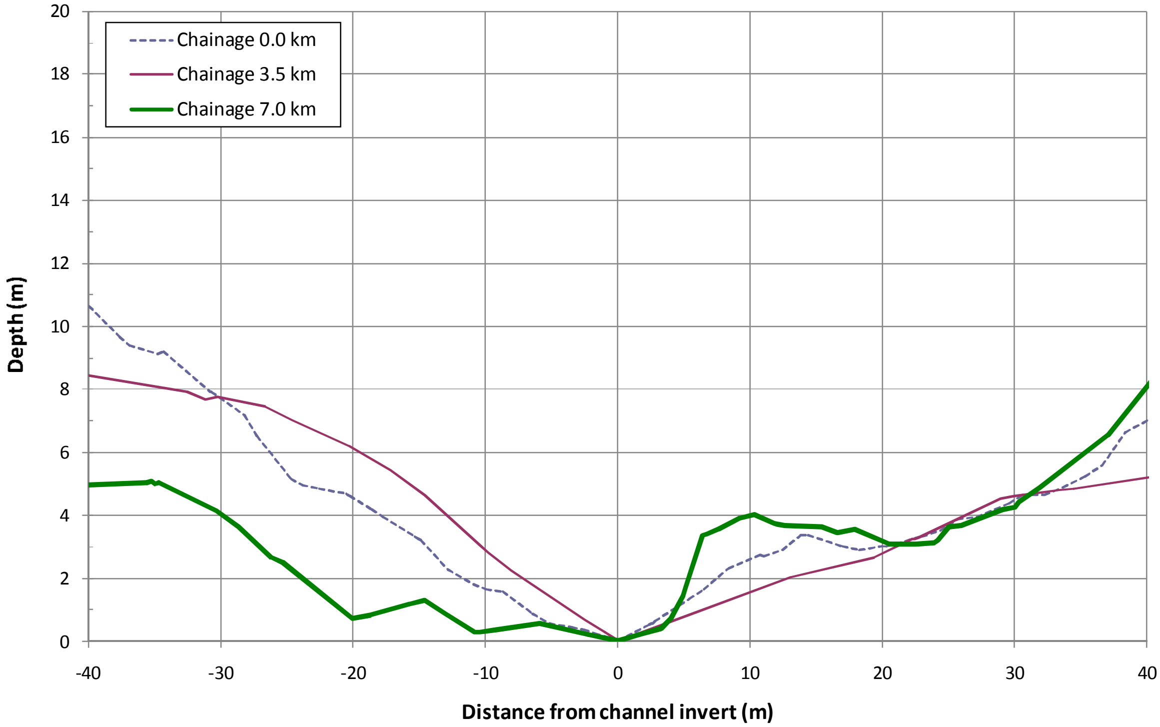

Figure 3.10 Cross-sections of Cataract River

4 CLIMATE CHARACTERISTICS

4.1 RAINFALL

4.1.1 Available Data

Daily rainfall has been recorded by the Bureau of Meteorology (BOM) and the SCA and its predecessors. The nearby rainfall stations with the longest records are located at Cataract and Cataract Dam. These stations have good quality records extending from 1883 to 1966 and 1904 to 2010 respectively.

The BOM's SILO data service has prepared Patched Point Datasets (PPDs) from the Cataract and Cataract Dam records. Gaps in the records are infilled with data interpolated from other nearby stations to provide continuous records between 1889 and the present day (Jeffrey et al., 2001).

4.1.2 Temporal Variability

As shown in Figure 4.1, annual rainfall at Cataract Dam for the period 1889 to 2011 has varied from 480mm in 1944, to 2,293 mm in 1950. Mean annual rainfall over this period was 1,080 mm/a.

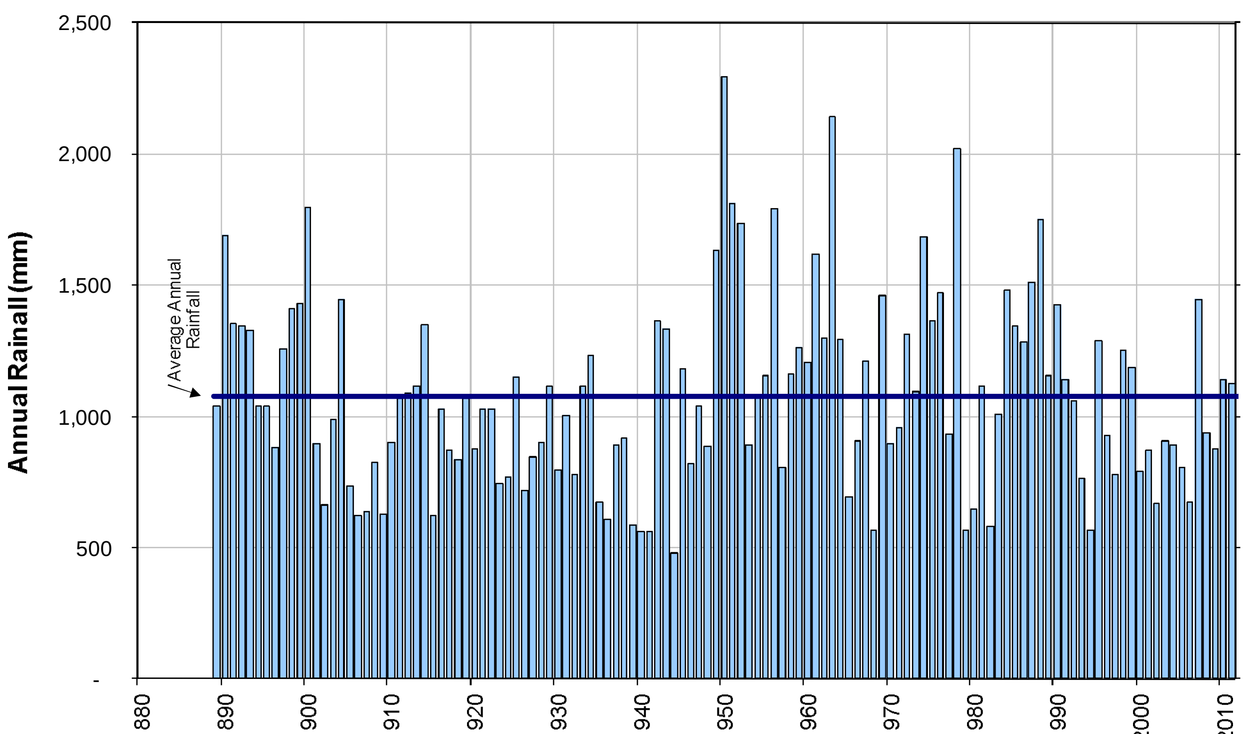

Figure 4.1 Annual Rainfall at Cataract Dam (Patched Point Dataset)

Cataract Dam rainfall is relatively consistent throughout the year. Rainfall is highest between January and June and lowest between July and December. This is illustrated in Figure 4.2, which shows mean monthly rainfall.

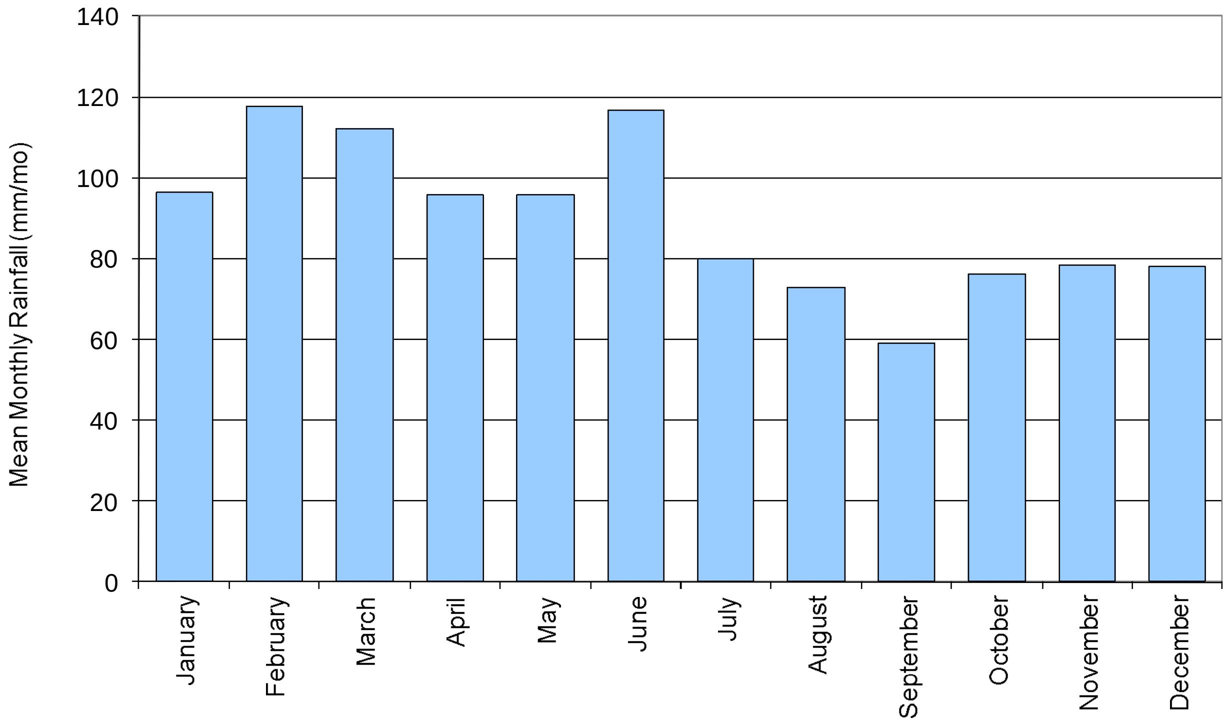

Figure 4.2 Variation in Mean Monthly Rainfall at Cataract Dam

Figure 4.3 shows a plot of rainfall residual at Cataract Dam for the period 1889 to 2010 (prepared using the PPD). The raw data for the station is overlaid on this line for comparison over the available period of record.

The rainfall residual shows departures from the long-term average (i.e. it has not been seasonally adjusted). Upward sloping lines indicate relatively wet periods, and downward sloping lines indicate relatively dry periods.

The figure shows that the period between 1905 and 1942, and the period since 1992 were relatively dry. The period from 1890 to 1900 and between 1950 and 1992 was generally relatively wet (with the exception of the late 1960s and the early 1980s). A plot of the SOI residual has been overlaid on the rainfall residual for comparison.

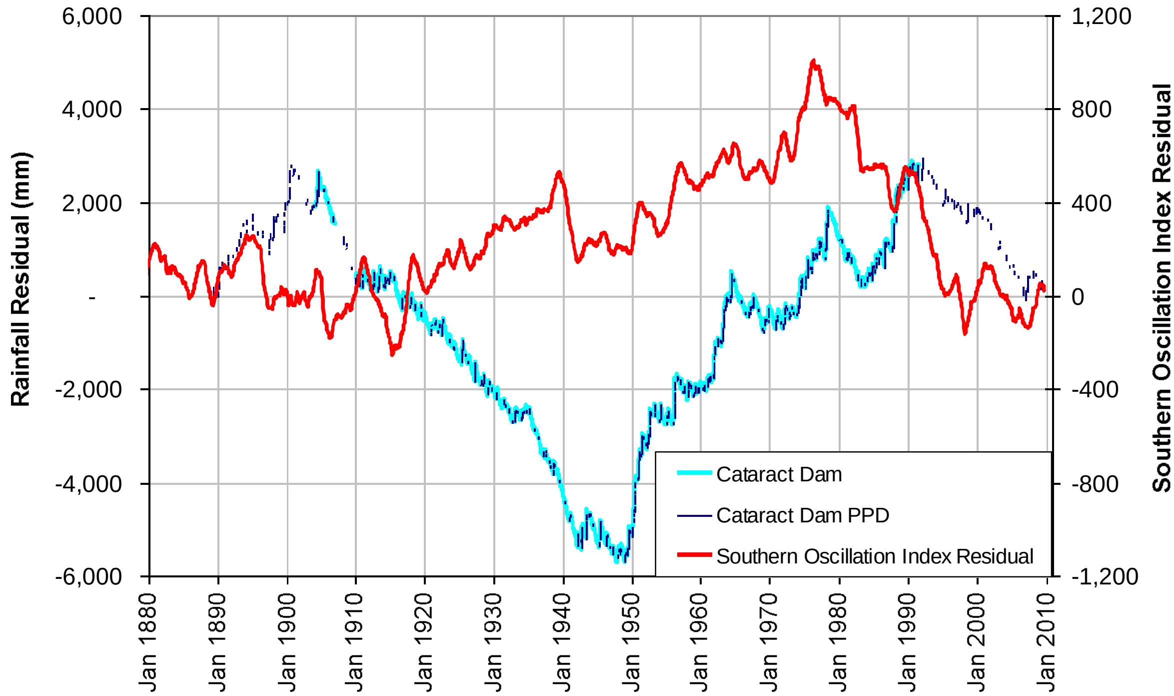

Figure 4.3 Rainfall Residual at Cataract Dam 1889-2009

4.1.3 Spatial Variability

The locations of rainfall stations of interest are shown in Figure 4.4. Few stations have operated in the immediate vicinity of the proposed workings, and most are located near the Study Area boundary. Table 4.1 shows the period over which data was available from each of the gauges.

Table 4.1 Daily Rainfall Recording Stations in the Vicinity of the Study Area

Station Number	Station Name	Period of Record	
		Start	Finish
568004	Cordeaux Airstrip	08-Feb-1964	-
68020	Cordeaux Quarters	01-Jul-1945	-
68017	Cataract	30-Mar-1883	29-Dec-1966
68016	Cataract Dam	01-Jan-1904	-
568065	Letterbox Tower	06-Dec-1964	-
568067	Beth Salem	30-Aug-1966	-
68086	Mount Keira Scout Camp	30-Jan-1944	29-Jul-1992

The length and quality of records from these seven stations is variable. Continuous data from an overlapping data period is only available for the period 1984 to 1991. Figure 4.5 and Figure 4.6 compare average annual and average monthly rainfall at the gauges over this common period.

The figures show rainfall increases significantly across the study area from west to east. The eastern stations exhibit relatively high rainfall in February, March, April and June compared to the rest of the Study Area. This spatial variability of rainfall is also illustrated in Figure 4.4, which shows isohyets derived from gridded interpolated rainfall data over the Study Area prepared by BOM for the period 1969 to 1990.

(Source: BOM gridded data 1969-1990)

Figure 4.4 Mean Annual Rainfall Isohyets

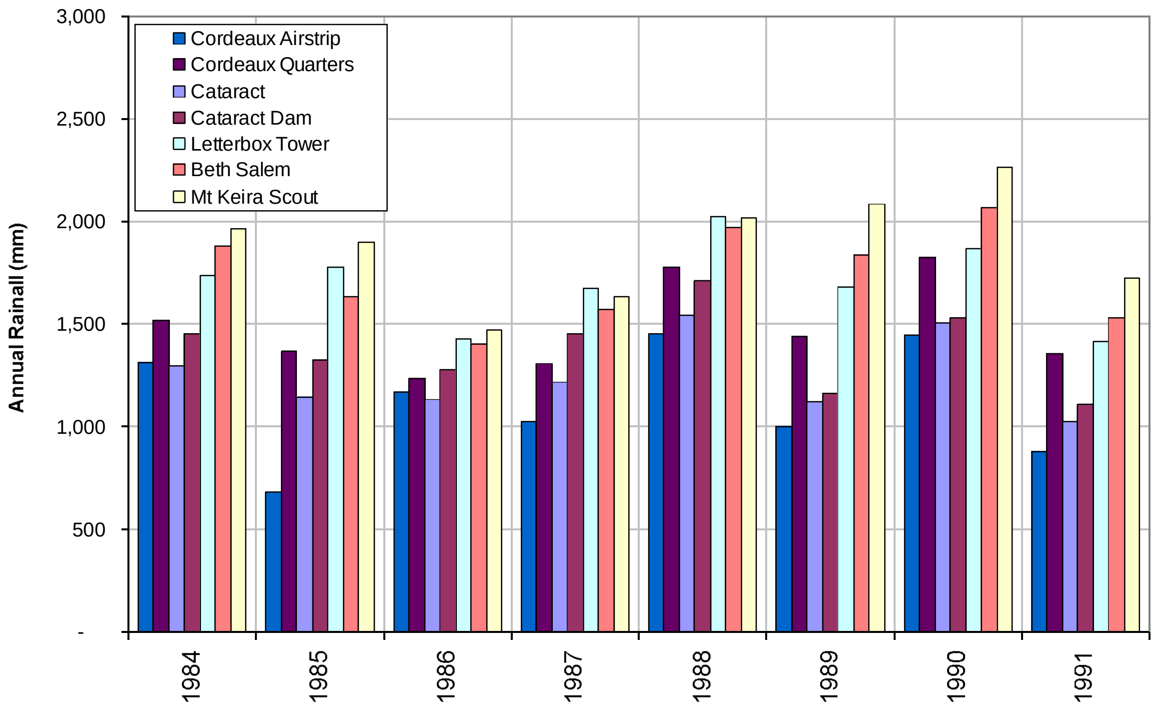

Figure 4.5 Variation in Mean Annual Rainfall across the Catchment (raw data 1984-1991)

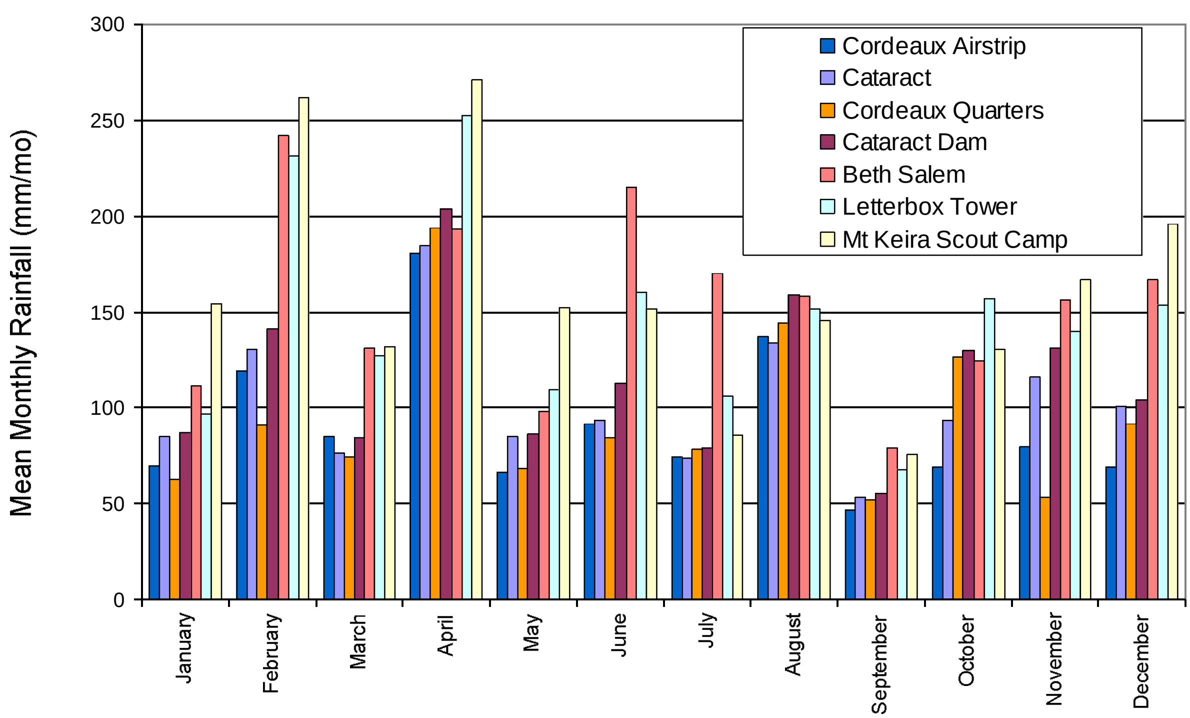

Figure 4.6 Variation in Mean Monthly Rainfall across the Catchment (raw data 1984-1991)

4.2 EVAPORATION

Daily Pan Evaporation has been recorded at the sites shown in Table 4.2 and Figure 4.7.

Table 4.2 Daily Evaporation Recording Stations in the Vicinity of the Study Area

Station	Location	Start	Finish
68017	Cataract		
668048	Cataract Dam	1908	
668049	Cordeaux Quarters	1-Jul-45	
668068	Upper Cordeaux	1973	31-Jul-96

Evaporation is relatively consistent across these gauges. Mean annual pan evaporation at Cataract Dam is approximately 1420 mm/a.

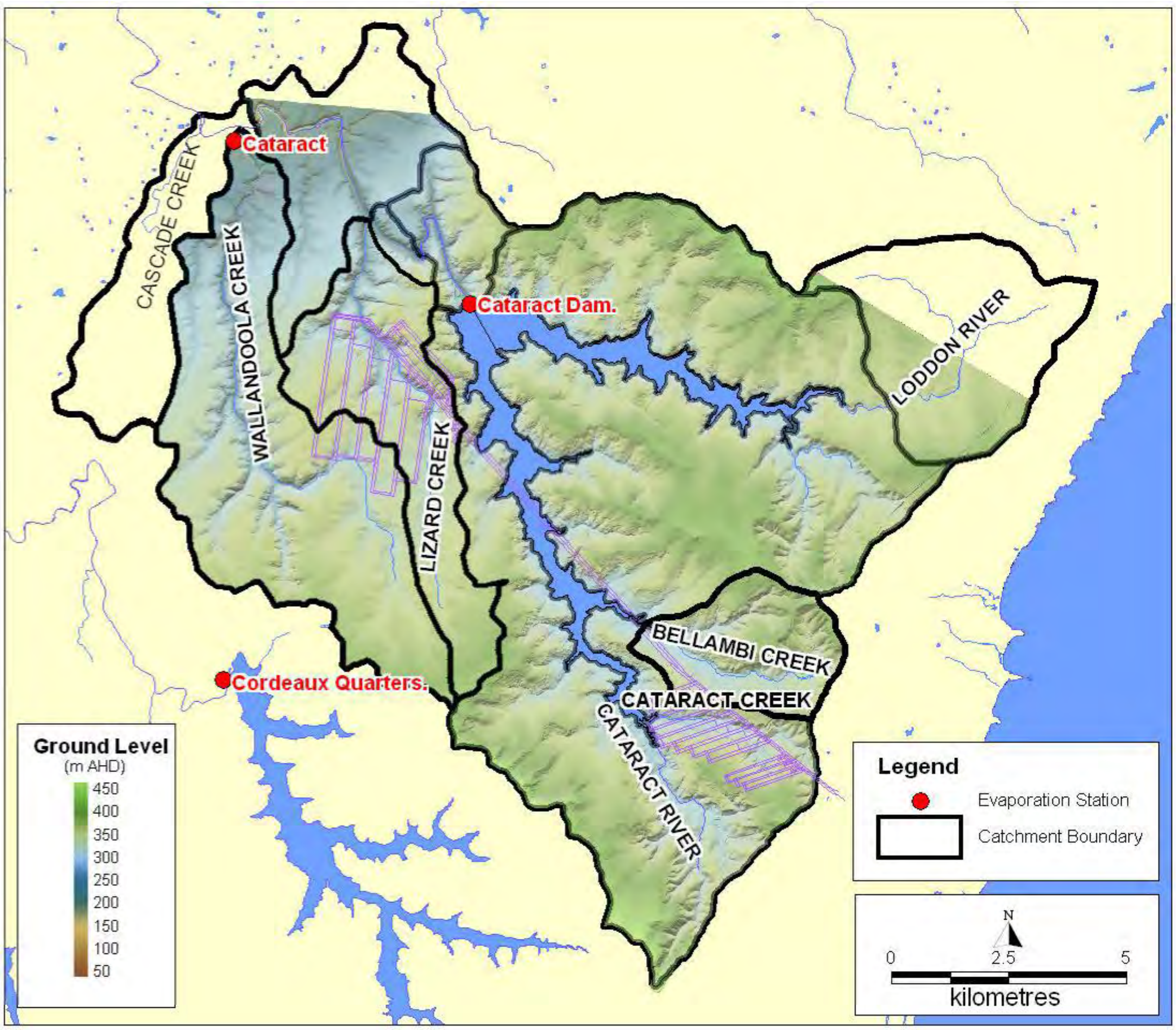

Figure 4.7 Daily Pan Evaporation Recording Stations

The monthly variation in pan evaporation at Cataract Dam is illustrated in Figure 4.8. Evaporation is highest in the summer months.

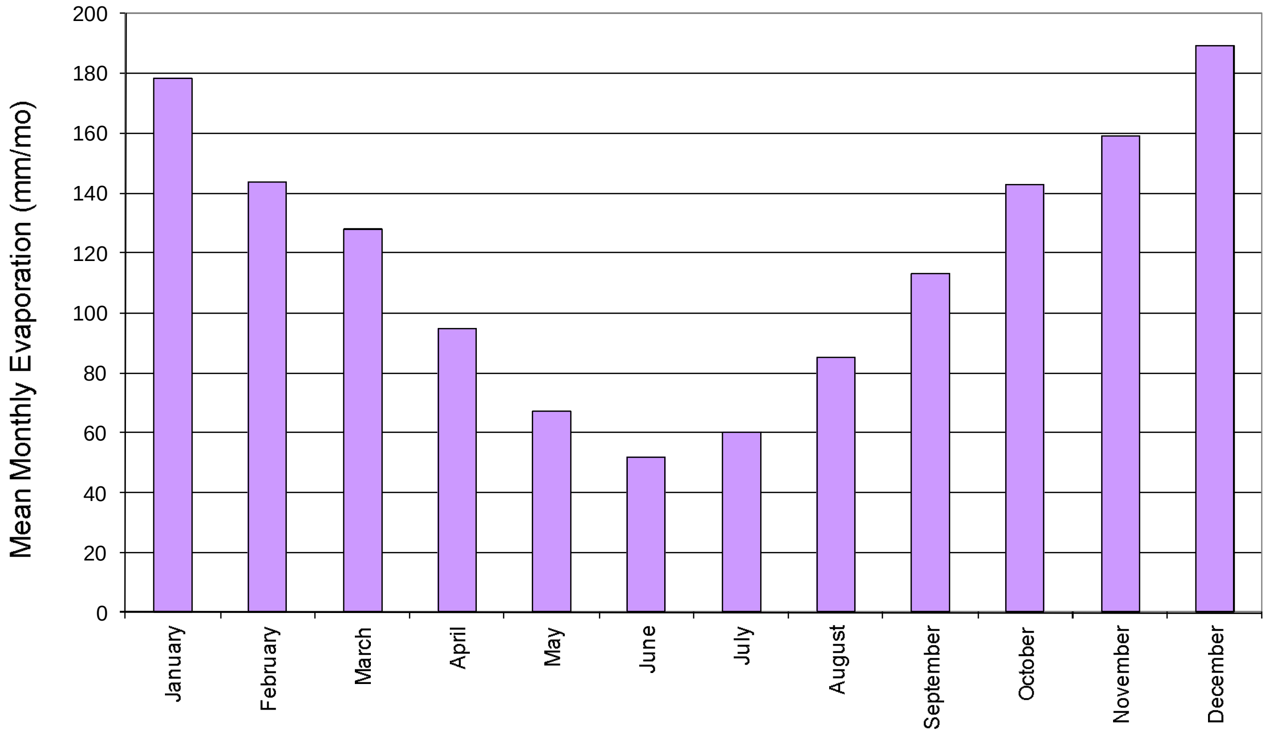

Figure 4.8 Monthly Pan Evaporation at Cataract Dam (PPD)

5 RUNOFF CHARACTERISTCS

5.1 STREAMFLOW DATA

Long term streamflow has been recorded in the Study Area at the gauges shown in Figure 5.1. Gauges in the immediate vicinity of the proposed workings used for this study are listed in Table 5.1. Both are in headwater streams flowing into Lake Cataract, and are not directly impacted by the predicted subsidence from the proposed workings.

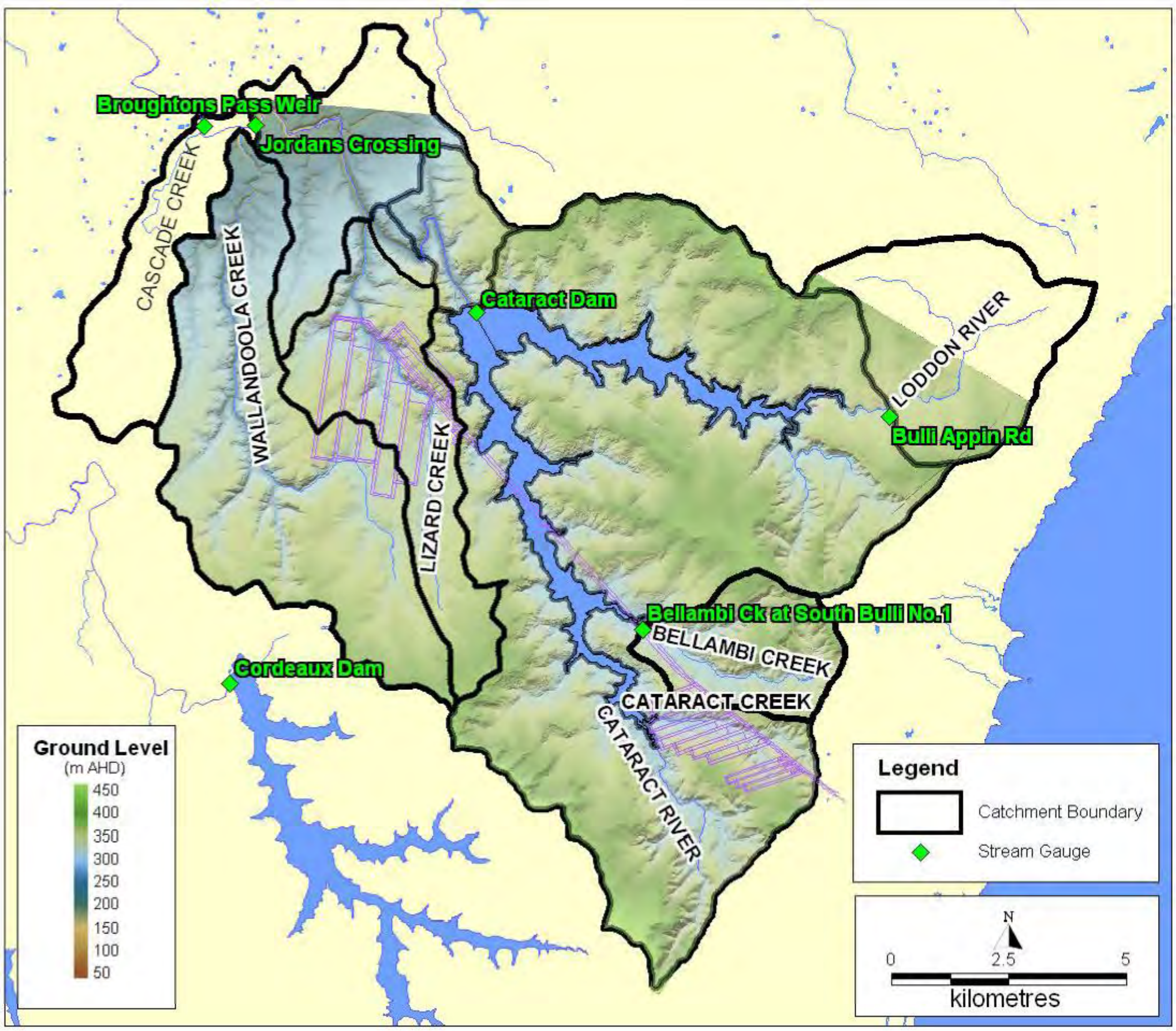

Figure 5.1 Streamflow Recording Stations in the Study Area

Table 5.1 Streamflow Recording Stations in the Study Area

Station Number	Station Name	Catchment Area (km²)	Mean Flow (ML/a)	Median Flow (ML/a)	Period of Record
2122321	Bellambi Creek at South Bulli No 1	9.3	2,608	1,194	01/01/1991-03/09/1995
2122322	Loddon River at Bulli Appin Rd	17.6	12,810	1,920	01/01/1991-08/11/2009

Streamflow is shown in Figure 5.2 for the overlapping period between 1991 and September 1995. The figure shows the catchments respond similarly, although much higher flows are generated from the Loddon River. Baseflow persists for extended periods after rainfall – and is similar in both streams, even though the Bellambi Creek catchment is much smaller. The flow frequency curves in Figure 5.3 show that flow occurs more than 90% of the time, and flows exceeding 3ML/d occur 50% of the time.

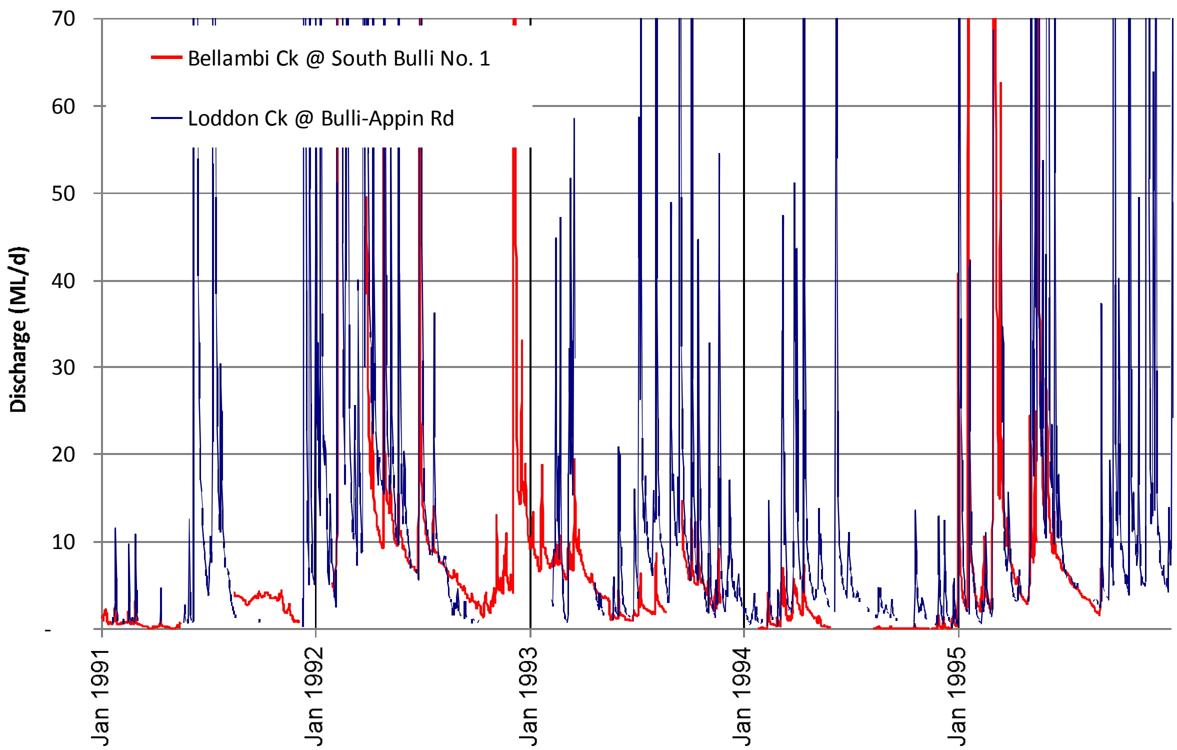

Figure 5.2 Sample Streamflow Record Bellambi Creek and Loddon River (1991-1995)

While persistent baseflow is a notable feature of the streamflow, it contributes a relatively small portion of total streamflow volume. The curves in Figure 5.4 show that over 90% of the total streamflow volume came from the largest 40% of daily flows. Flows of less than 3ML/d made up only 5% of total flow volume from both catchments.

There are however some periods when the flows are dissimilar – due probably to spatially variable rainfall. The Loddon River catchment exhibits a significantly higher runoff to rainfall ratio, as demonstrated in the table below, which compares total runoff (considering days when flow was recorded at both gauges only).

Table 5.2 Runoff Characteristics Loddon River and Bellambi Ck 1991-1995

Station Name	Mean Annual Flow (ML/a)	Runoff Depth (mm/a)
Bellambi Creek at South Bulli No 1	2,608	280
Loddon River at Bulli Appin Rd	9,239	525

Very low flows less than 1 ML/d occur less frequently in Bellambi Creek. This may be partially a result of the effect of Charlesworth Dam which is located in the upstream catchment, as shown in Figure 6.1.

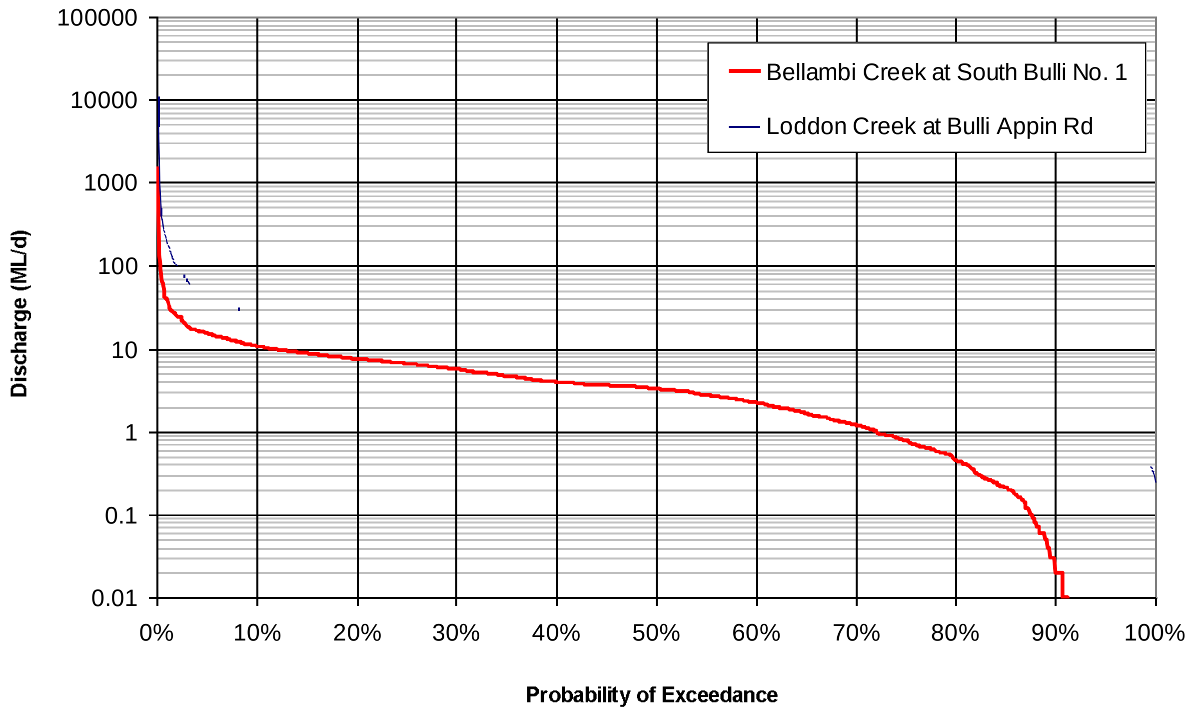

Figure 5.3 Flow Frequency Curves Bellambi Creek and Loddon River (1991-1995)

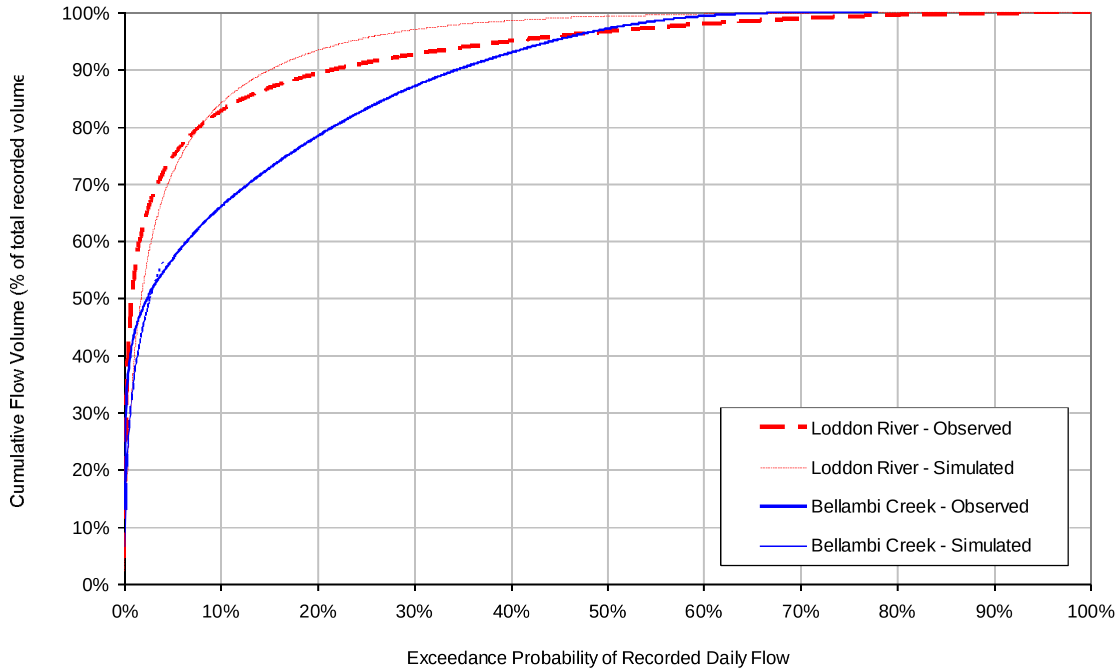

Figure 5.4 Cumulative Flow Volume Bellambi Creek and Loddon River

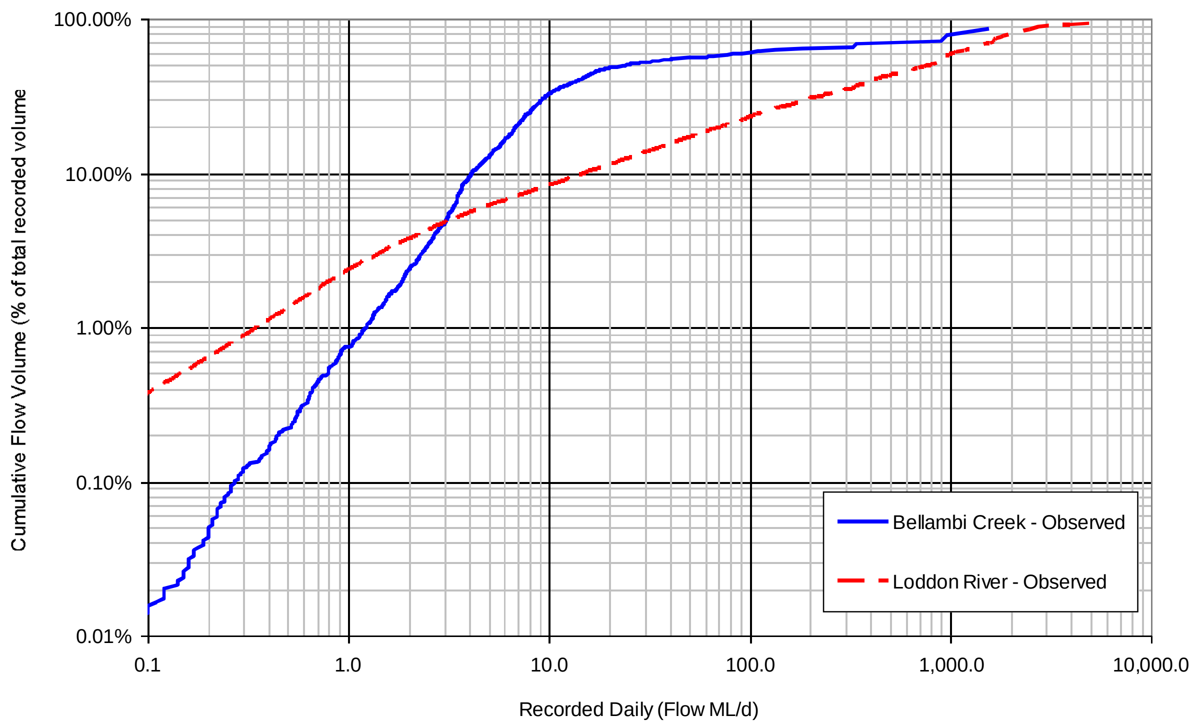

Figure 5.5 Cumulative Flow Volume Bellambi Creek and Loddon River

5.2 POOL LEVEL AND STREAM FLOW MONITORING

Pool water levels have been monitored in the study area since September 2009. Six sites are located on Lizard Creek, two on tributaries of Lizard Creek, three on Wallandoola Creek, three on Cataract Creek and two on the Cataract River as shown in Figure 5.6 and Figure 5.7 below (Geoterra, 2011). Figure 5.8 to Figure 5.12 show the recorded pool water levels in Wallandoola, Lizard and Cataract Creeks as well as the Cataract River.

Note that the logger at CC3 was found wet during the period 3/9/2011 to 2/12/2011 and therefore did not record any usable data over this period.

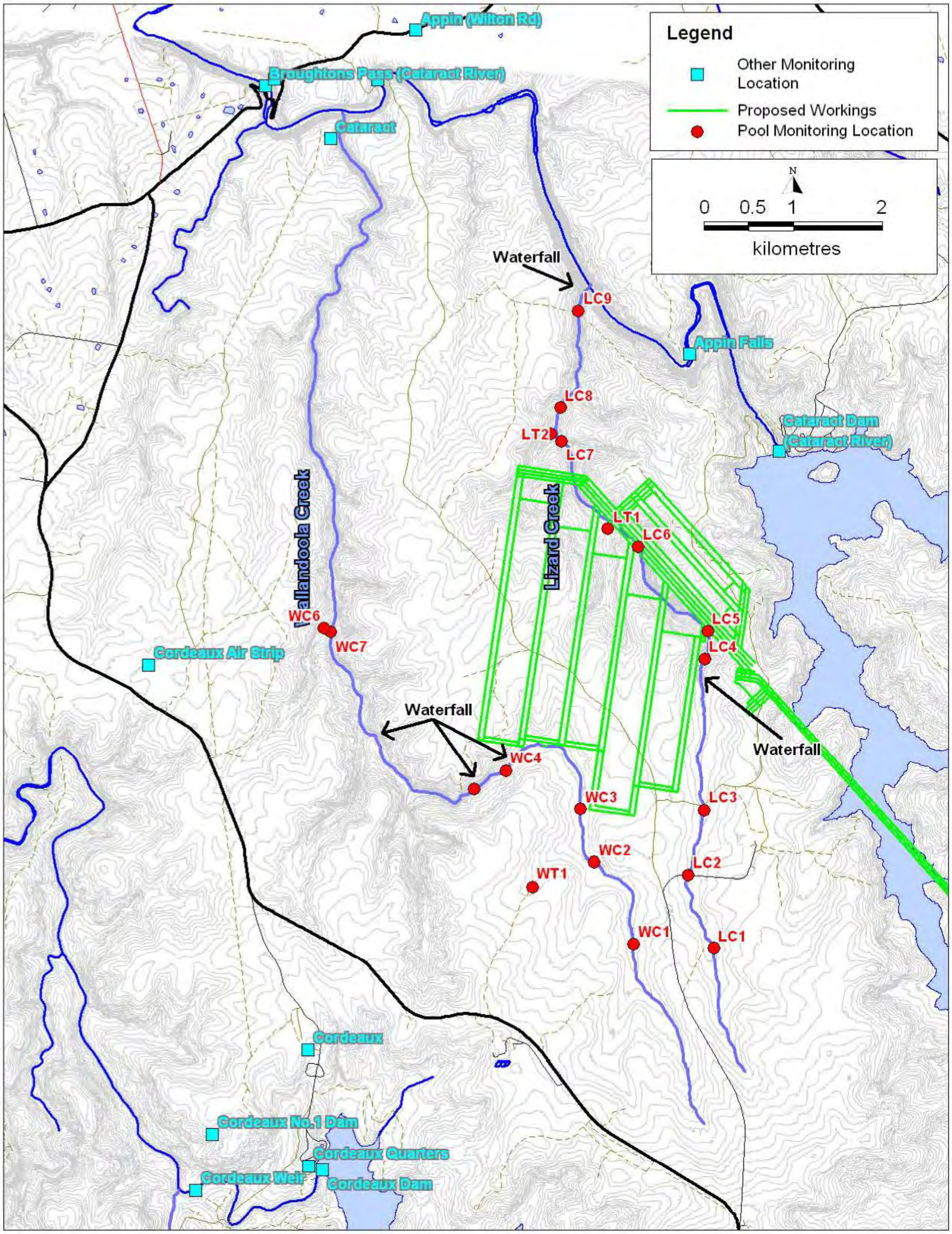

Figure 5.6 Pool Monitoring Locations, Wonga West

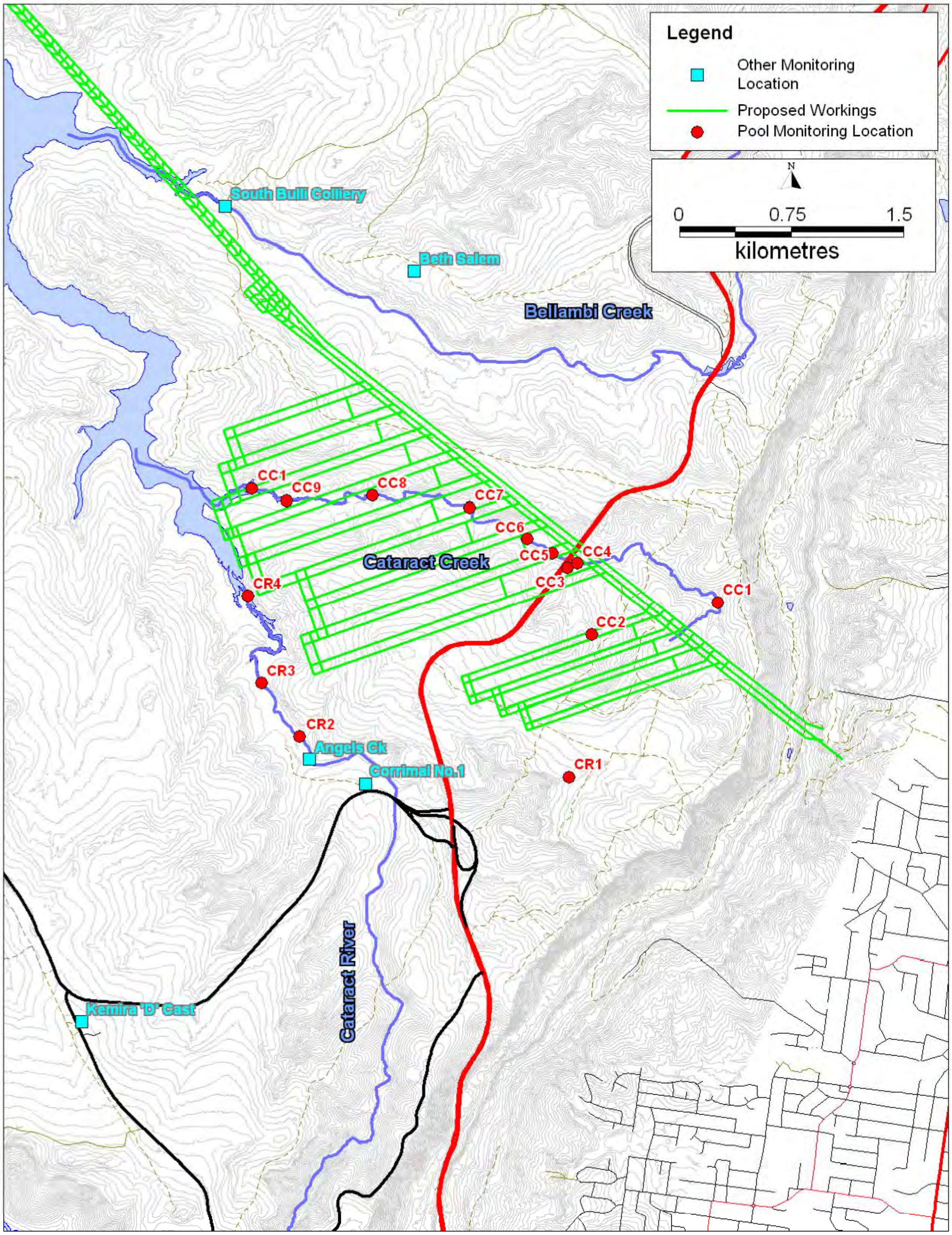

Figure 5.7 Pool Monitoring Locations, Wonga East

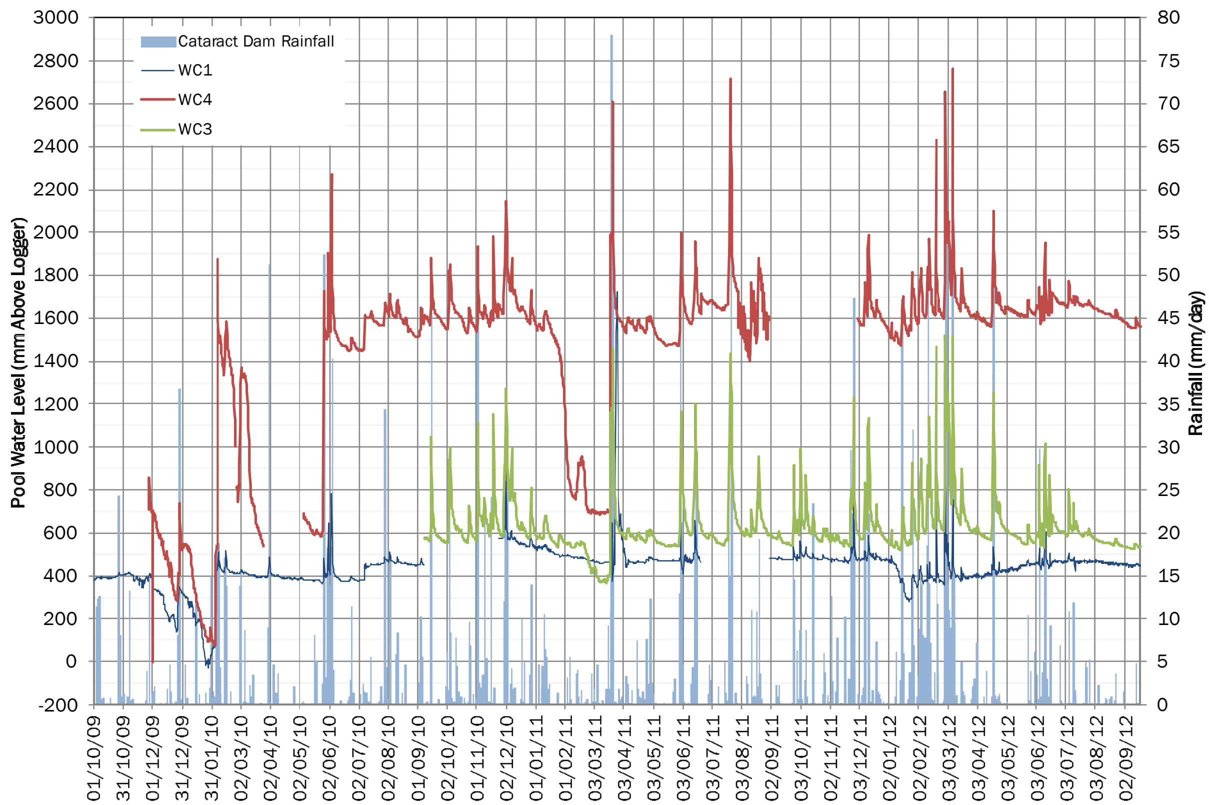

Figure 5.8 Wallandoola Creek Pool Monitoring Data

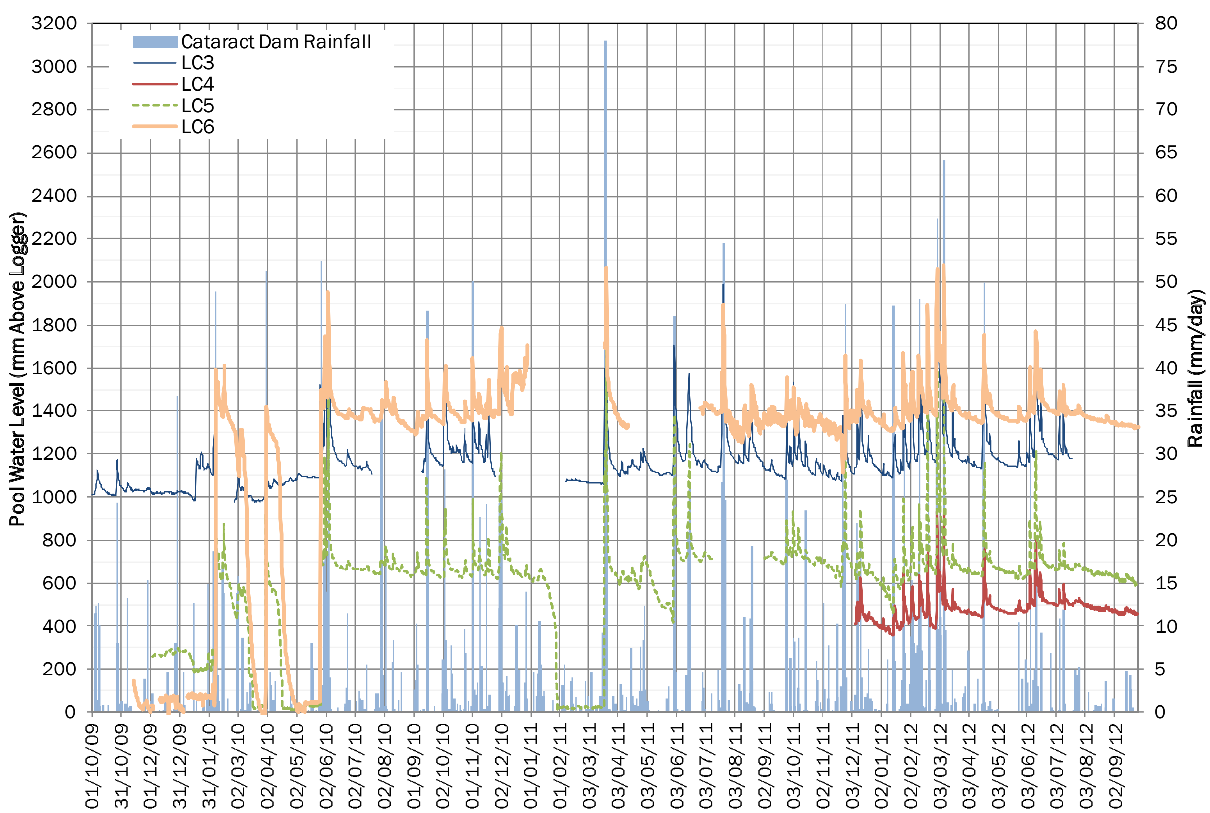

Figure 5.9 Lizard Creek Pool Monitoring Data, Sites LC3, LC4, LC5 and LC6

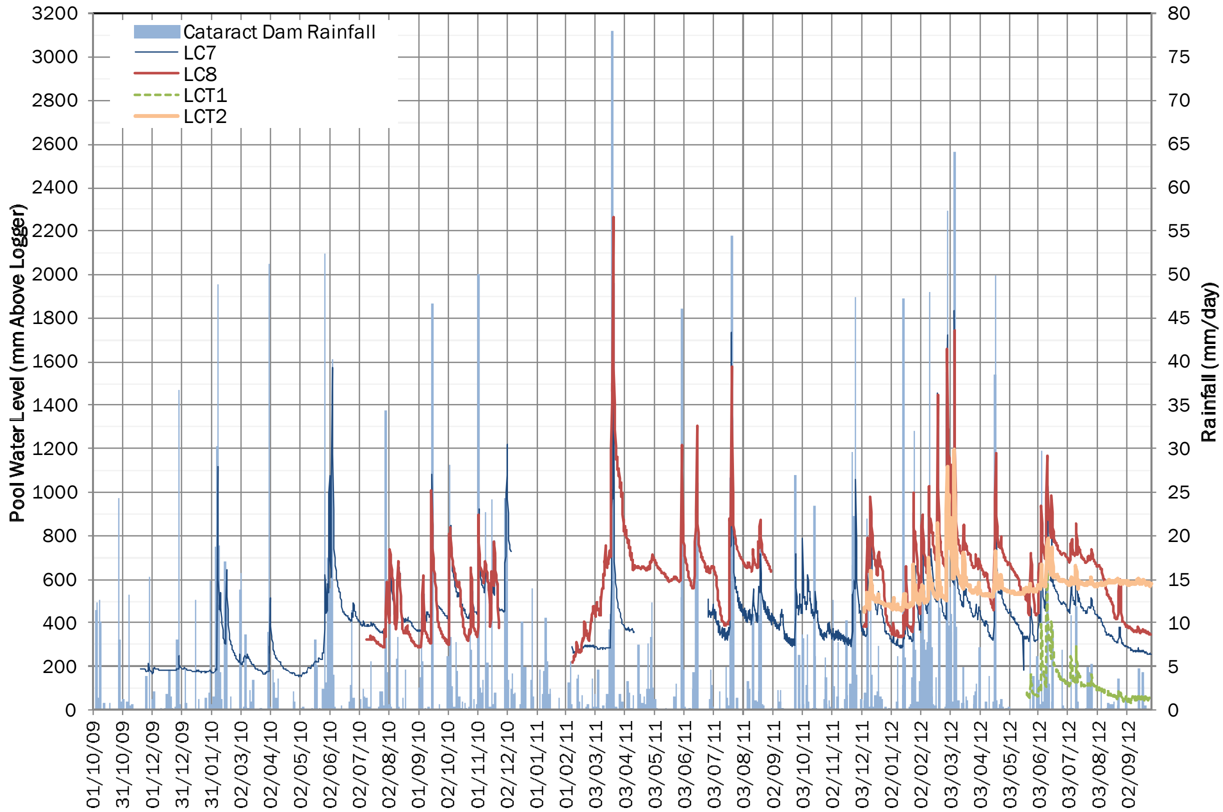

Figure 5.10 Lizard Creek Pool Monitoring Data, Sites LC7, LC8, LCT1 and LCT2

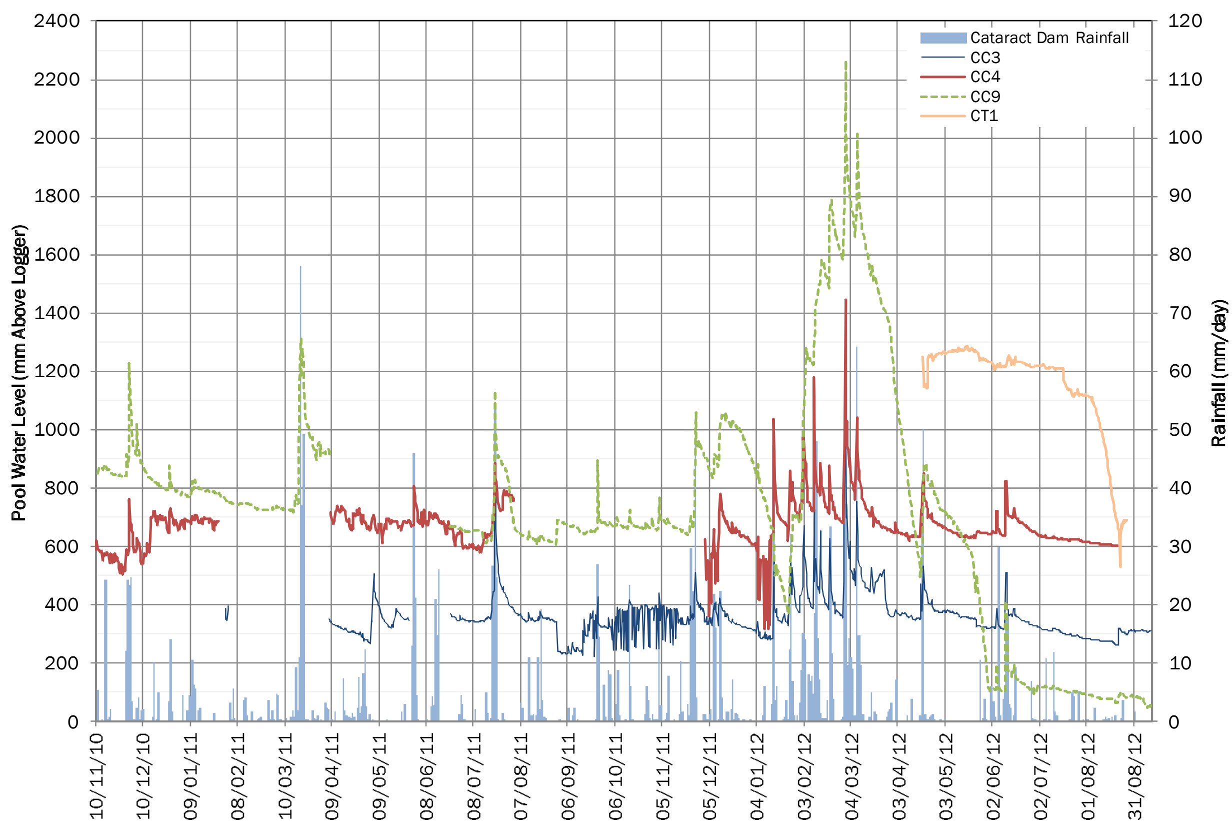

Figure 5.11 Cataract Creek Pool Monitoring Data

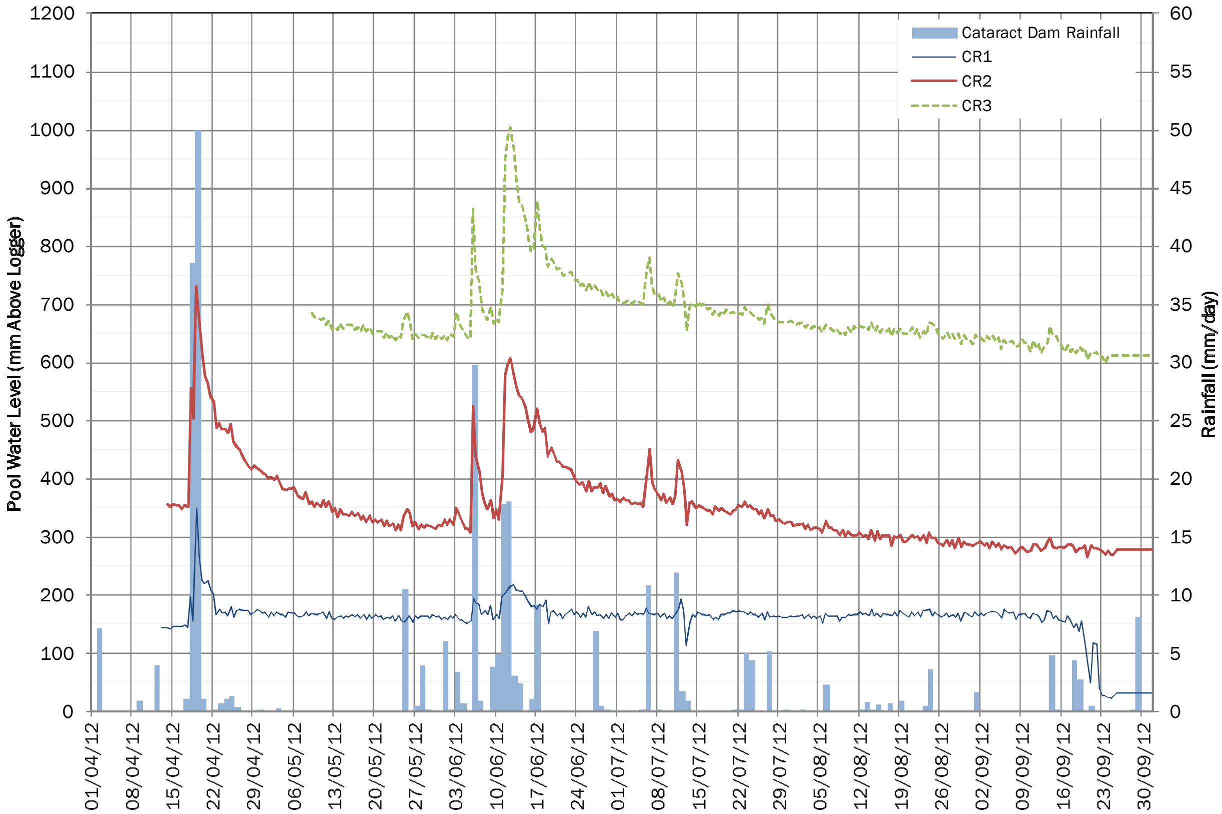

Figure 5.12 Cataract River Pool Monitoring Data

5.2.1 Lizard Creek

Volumetric stream flow monitoring has also been conducted in Lizard Creek since mid September 2009 at LC3 (see Figure 5.6). The monitoring data collected to date is shown in Figure 5.13.

Volumetric flow monitoring has not been conducted in Lizard Creek between LC3 and LC6 due to the presence of two zones of subsidence cracking in the creek bed resulting in disconnected stream flow during low flow periods due to mining subsidence over the Bulli Seam workings dating back to the 1970s.

The upstream zone extends from downstream of LC3 to approximately 200m upstream of the waterfall between LC3 and LC4. The downstream zone of cracking in Lizard Creek extends between LC5 and LC6.

The isolated cracked areas enable transfer of overland stream flow to the shallow groundwater system under the creek bed. This means that not all of the total catchment flow in this reach is present as overland flow, and therefore a surface flow based monitoring system would under report the actual volume of water flowing down the catchment and into Cataract River.

Stream flow resurfaces immediately downstream of LC6. No subsidence cracking or adverse stream flow effects are observed in Lizard Creek between LC6 and the confluence with Cataract River.

Volumetric flow monitoring was initially conducted at Site LC7 until it was observed that a variable proportion (possibly up to 30%) of the overland flow was draining through a natural bedding plane discontinuity which had been washed out. It should be noted that this diversion is natural and is not due to subsidence cracking.

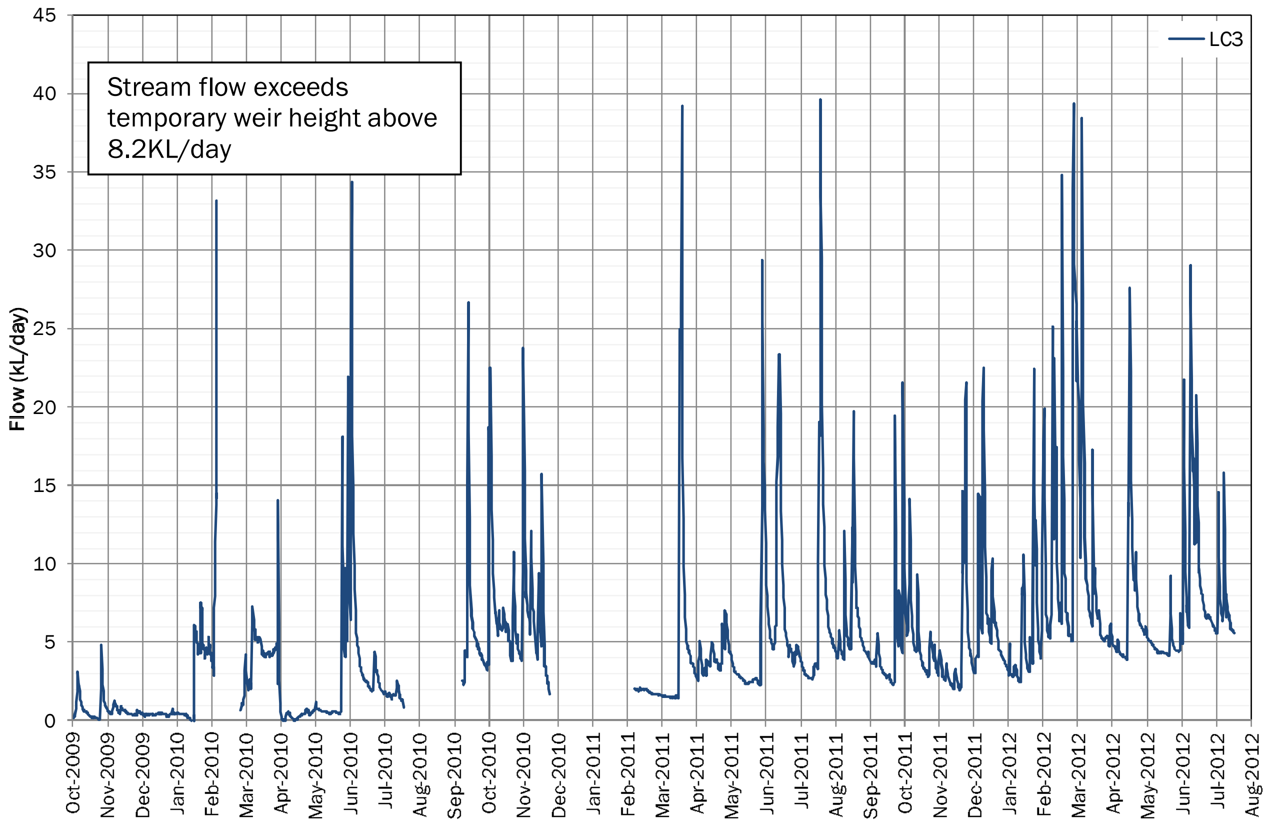

Figure 5.13 Recorded Flows in Lizard Creek at LC3

5.2.2 Wallandoola Creek

As a result of the lack of suitable sites between WC1 and WC4, no volumetric flow monitoring has been conducted to date in Wallandoola Creek. However, suitable sites are currently being searched for and installed. The limited availability of flow monitoring sites is due to the:

- valley fill swamp with no suitably defined / constrained channel between WC1 and downstream of WC2;
- elongated standing water pools between WC2 and WC4 with limited or unsuitable flow constriction points at the outflow of the pool.

In addition, no suitable overland flow monitoring sites are present in the stepped waterfall section between WC4 and WC5 due to previous subsidence cracking dating back to the 1970-80s which has caused subterranean diversion of the overland flow in that reach.

5.2.3 Cataract Creek

Volumetric stream flow monitoring has not yet been conducted in Cataract Creek, however 3 sites are being investigated for their suitability, taking into account the potential effects of:

- the presence of zones of subsidence cracking in the creek bed resulting in disconnected stream flow during low flow periods due to mining subsidence over the Bulli Seam and Balgownie Seam workings dating back to the 1970s. The isolated cracked areas can enable transfer of overland stream flow to the shallow groundwater system under the creek bed. This means that not all of the total catchment flow in this reach is present as overland flow, and therefore a surface flow based monitoring system could under-report the actual volume of water flowing down the catchment and into Cataract Reservoir;

- overland flow diversions through natural bedding plane discontinuities which are washed out. It should be noted that this diversion is natural and is not due to subsidence cracking.

5.2.4 Cataract River

Volumetric stream flow monitoring has not yet been conducted in Cataract River, however 2 sites are being investigated for their suitability, taking into account the potential effects of:

- the presence of zones of subsidence cracking in the creek bed resulting in disconnected stream flow during low flow periods due to mining subsidence over the BHP Cordeaux workings dating back to the 1970s. The isolated cracked areas can enable transfer of overland stream flow to the shallow groundwater system under the creek bed. This means that not all of the total catchment flow in this reach is present as overland flow, and therefore a surface flow based monitoring system could under-report the actual volume of water flowing down the catchment and into Cataract Reservoir.
- overland flow diversions through natural bedding plane discontinuities which are washed out. It should be noted that this diversion is natural and is not due to subsidence cracking.

6 CATCHMENT MODELLING

6.1 MODELLING APPROACH

Rainfall-runoff models were created for the two gauged headwater catchments in the Study Area; Loddon River and Bellambi Creek. The models were calibrated to the daily streamflow records and used to extend those records to the length of available climate record.

The AWBM was selected for catchment modelling, as it has been successfully used in neighbouring catchments for similar studies. It uses a group of connected conceptual storages (three surface water storages and one ground water storage) to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation. Simulated surface runoff occurs when the storages fill and overflow. The model parameters define the storage depths, the proportion of the catchment draining to each of the storages, and the rate of flux between them (Boughton, 2003).

Daily runoff from other catchments in the Study Area was estimated using the AWBM, with model parameters transposed from the adjacent calibrated catchments. Climate data specific to each sub-catchment of interest was used to account for the spatial variability described in the previous sections.

The catchment models were validated by directing the modelled runoff to a daily water balance model of the Lake Cataract system. Modelled stored water levels were then compared to historical records provided by the SCA.

6.2 INPUT CLIMATE DATA

Key climate data inputs for the AWBM are daily rainfall and daily evapotranspiration (this is different to most rainfall-runoff models, which use potential evapotranspiration) (Podger, 2004).

Rainfall data for the gauged catchments was obtained from nearby recording stations. The locations of these stations are shown in Figure 6.1 and Figure 6.2 respectively.

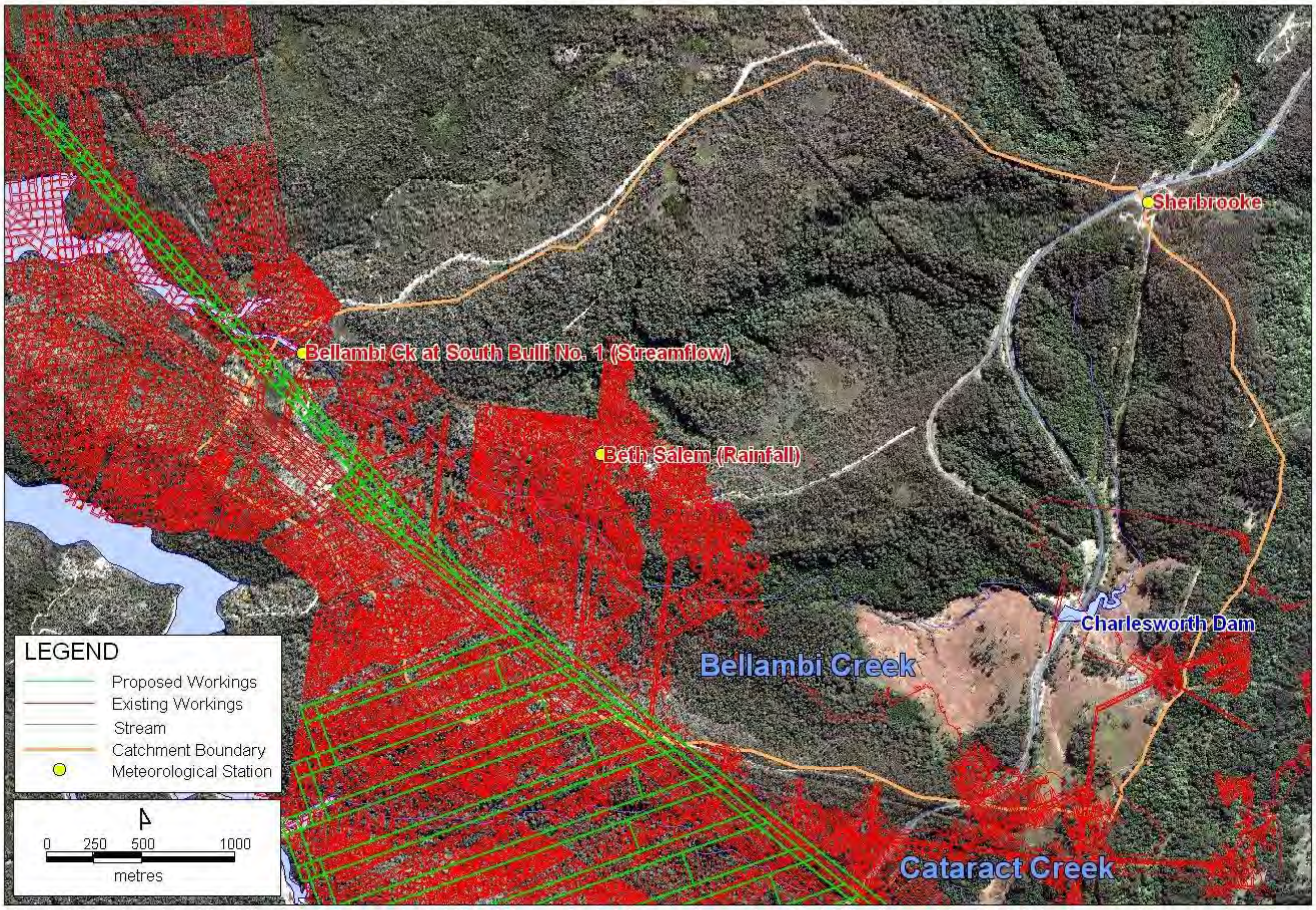

Figure 6.1 Bellambi Creek Catchment

Figure 6.2 Loddon River Catchment

As pan evaporation has not been recorded in the immediate vicinity of the streamflow gauges, the BOM's SILO Data Drill service was used to derive inputs for catchment modelling. The Data Drill *"accesses grids of data derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia"* (Bureau of Meteorology, 2006).

Data Drill data was used to infill and extend the datasets from the nearby recording stations where required. Details of the data used are summarised in Table 6.1. Daily rainfall derived using the Datadrill are compared to rainfall observations in Appendix A for nearby rainfall gauges.

While the Datadrill data is a synthetic dataset, and therefore needs to be used with caution, it can be useful for catchment studies where insufficient site-specific data is available.

Table 6.1 Input Data Sources for Catchment Modelling

Stream Gauge	Rainfall Data Source	Evapotranspiration Data Source
Bellambi Creek at South Bulli No.1	Beth Salem (Raw Data from SCA extend and with gaps in-filled using Data Drill at Beth Salem)	Data Drill at Beth Salem
Loddon River at Bulli-Appin Rd	Letterbox Tower (Raw Data from SCA extend and with gaps in-filled using Data Drill at Beth Salem)	Data Drill at Letterbox Tower

The recorded datasets are shown in the following four figures, which also show the duration and timing of rainfall data gaps that were infilled prior to calibration and the SCA quality codes assigned to the streamflow records. Descriptions of the corresponding quality codes are given in Table 6.2.

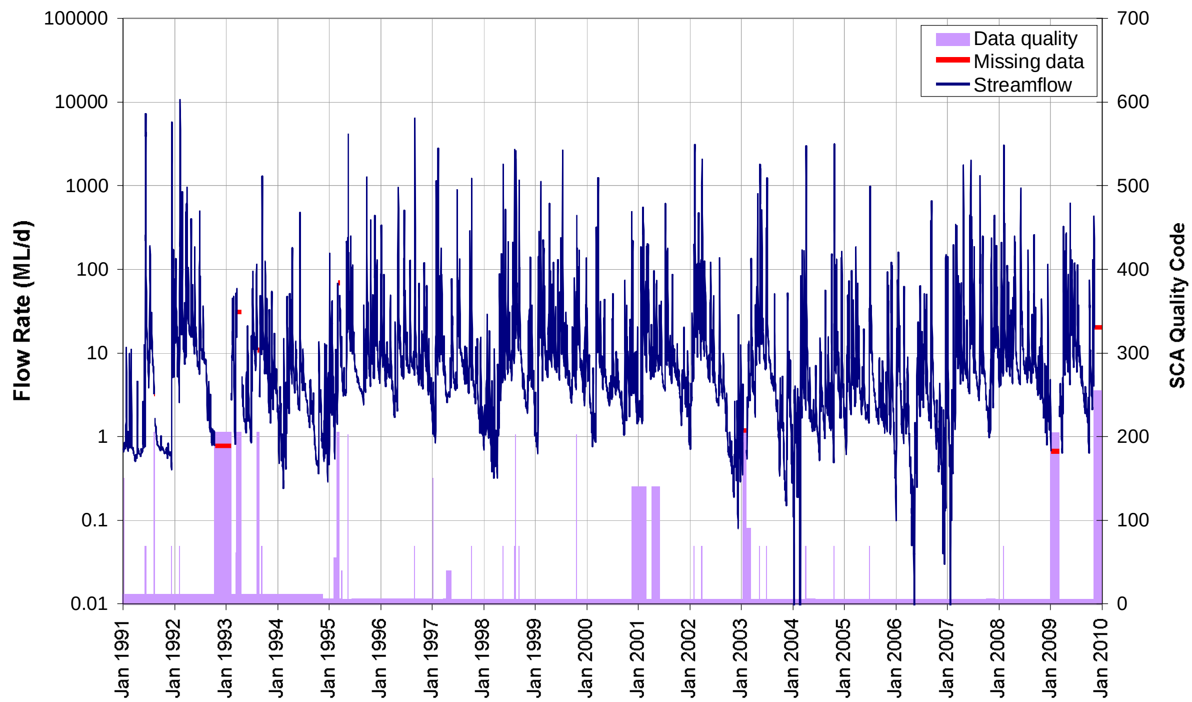

Figure 6.3 Streamflow Measured at Loddon River at Bulli Appin Road

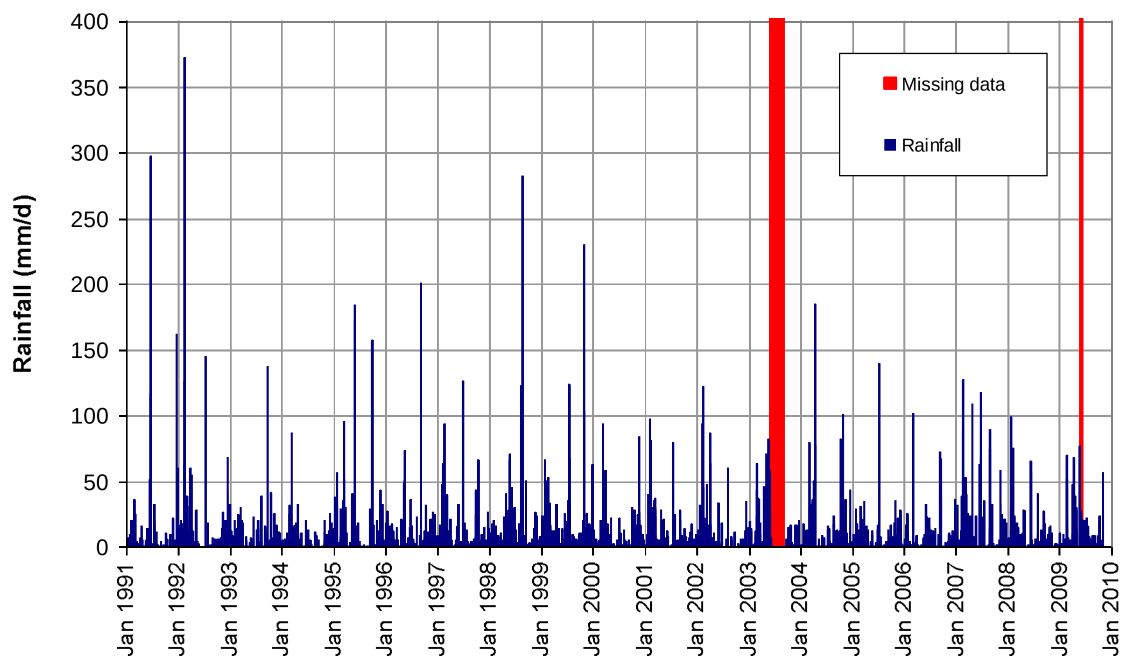

Figure 6.4 Rainfall Measured at Letterbox Tower over Loddon River Gauge Period

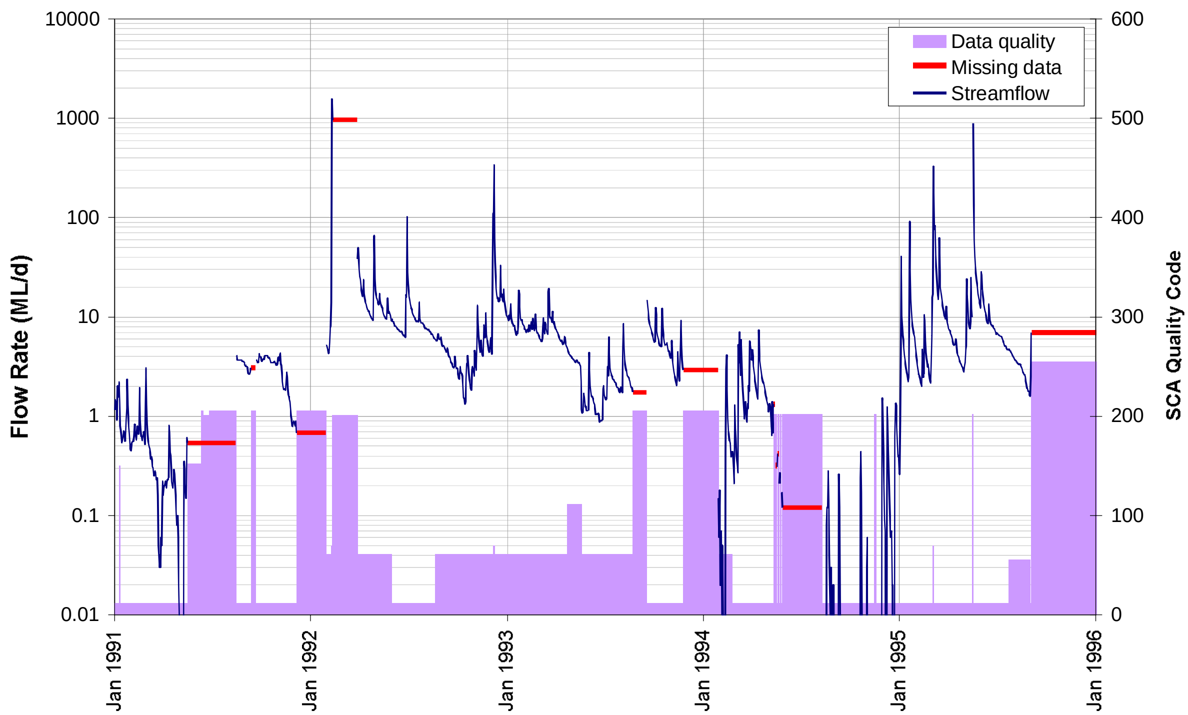

Figure 6.5 Streamflow Measured at Bellambi Creek at South Bulli No. 1

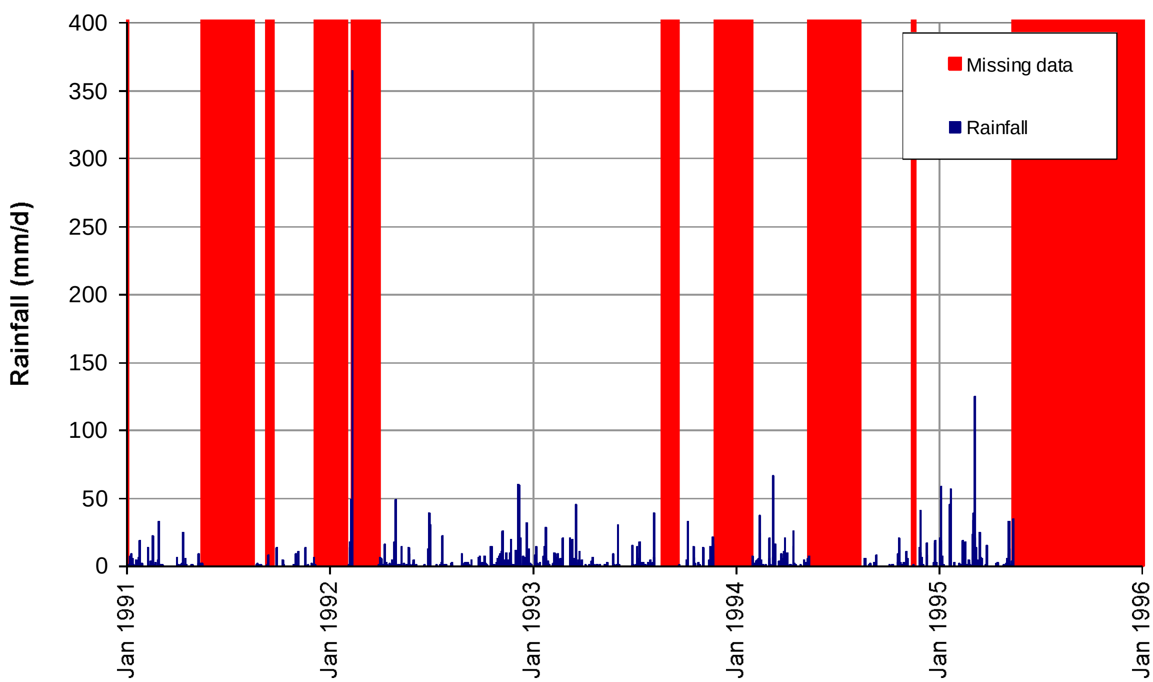

Figure 6.6 Rainfall Measured at Beth Salem Over Bellambi Creek Gauge Period

Table 6.2 SCA Quality Code Descriptions

Quality Code	Description
5	Good quality edited data
6	Reasonably good quality edited data
11	Good quality record processed pre 1995 and coded either 5 or 6
40	Good quality estimate (correlation or other reliable method)
55	Fair quality edited data
57	Fair quality contractor supplied data
61	Fair quality record processed pre 1995 and quality coded 55
69	Fair quality rating extrapolation
90	Fair quality estimation (correlation or other method)
105	Poor quality edited data
111	Poor quality records processed pre 1995 and quality coded 105
119	Poor quality rating extrapolation
140	Estimate that reasonably reflects the actual event with edit comments inserted to explain method of estimation
149	Contractors data supplied without quality codes
150	Data not yet quality coded
151	Backwater affected
152	Data for which quality
162	SENSOR OUT OF WATER WITH NO FLOW
201	Data not recorded - logger/sensor not installed
202	Data not available for release (e.g requires extensive editing)
204	Data lost due to vandalism
205	Data lost
255	Hydsys default - no data

6.3 CALIBRATION OF BELLAMBI CREEK CATCHMENT MODEL

The Bellambi Creek AWBM Model was calibrated over the period between the 1st of January 1991 and the 1st of September 1995.The adopted AWBM parameters are summarised in Table 6.3 below.

Table 6.3 Adopted AWBM Parameters – Bellambi Ck Catchment

Parameter	Value
A1	0.134
A2	0.433
BFI	0.317
C1	6
C2	94
C3	240
K_{base}	0.976
K_{surf}	0.632

It was not possible to perfectly replicate all streamflow features of interest (e.g. annual flow, flow frequency, monthly flow, daily flow, hydrograph shape, and baseflow) at all temporal scales. The calibration parameters were selected to achieve a compromise between matching the above characteristics.

Observed and simulated streamflow time series are compared in Figure 6.7. During the period from mid-1992 to mid-1993 the model underestimates baseflow, and during mid-1995 it overestimates baseflow. This is probably due to rainfall variability, with the earlier discrepancy due to differences between the rainfall recorded at Beth Salem compared to the rest of the catchment, and the latter due to the limitations of using Data Drill rainfall in areas of high rainfall gradient. The presence of Charlesworth Dam in the upper catchment will also tend to reduce flows during dry periods, and possibly slightly delay flow down the catchment.

The streamflow frequency curves in Figure 6.8 show a reasonable match, but flows between 10ML/d and 100ML/d tend to be overestimated by the model, and flows between 1ML/d and 10ML/d are underestimated.

Simulated mean annual runoff is 3,644 ML/a, compared to the observed mean annual runoff 3,279ML/a over the same period.

Objective functions for the calibration reported by the Rainfall Runoff Library Application (Podger, 2004) are:

- Nash Sutcliffe Criterion – Calculated vs Observed (Daily) - 0.81
- Nash Sutcliffe Criterion – Calculated vs Observed (Monthly) - 0.84

The Nash–Sutcliffe model efficiency coefficient E is defined by:

$$E = 1 - \text{residual variance/data variance}$$

Where:
residual variance is the sum of squares of differences between modelled and observed flow on each day, and data variance is the sum of squares of differences between observed flow on each day and observed mean flow.

A Nash–Sutcliffe model efficiency coefficient of 1 would indicate the model exactly replicated observed flow.

The model fit is reasonable given the limitations of the available data.

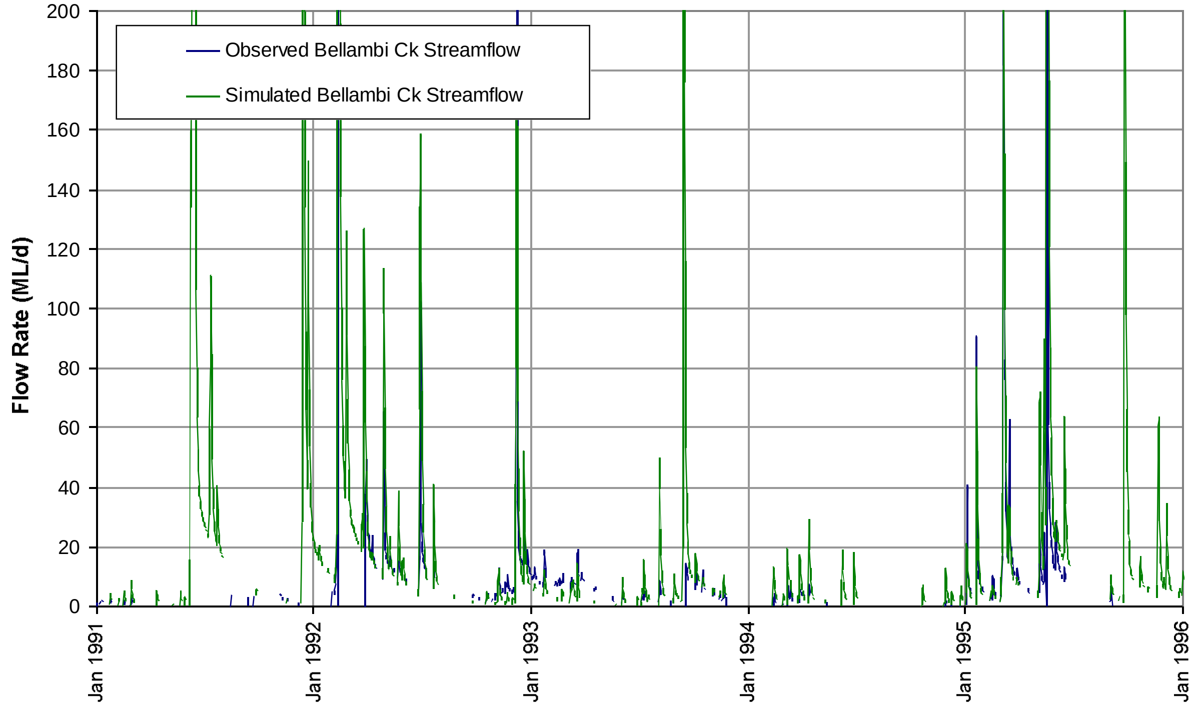

Figure 6.7 Observed and Simulated Streamflow – Bellambi Ck at South Bulli No. 1

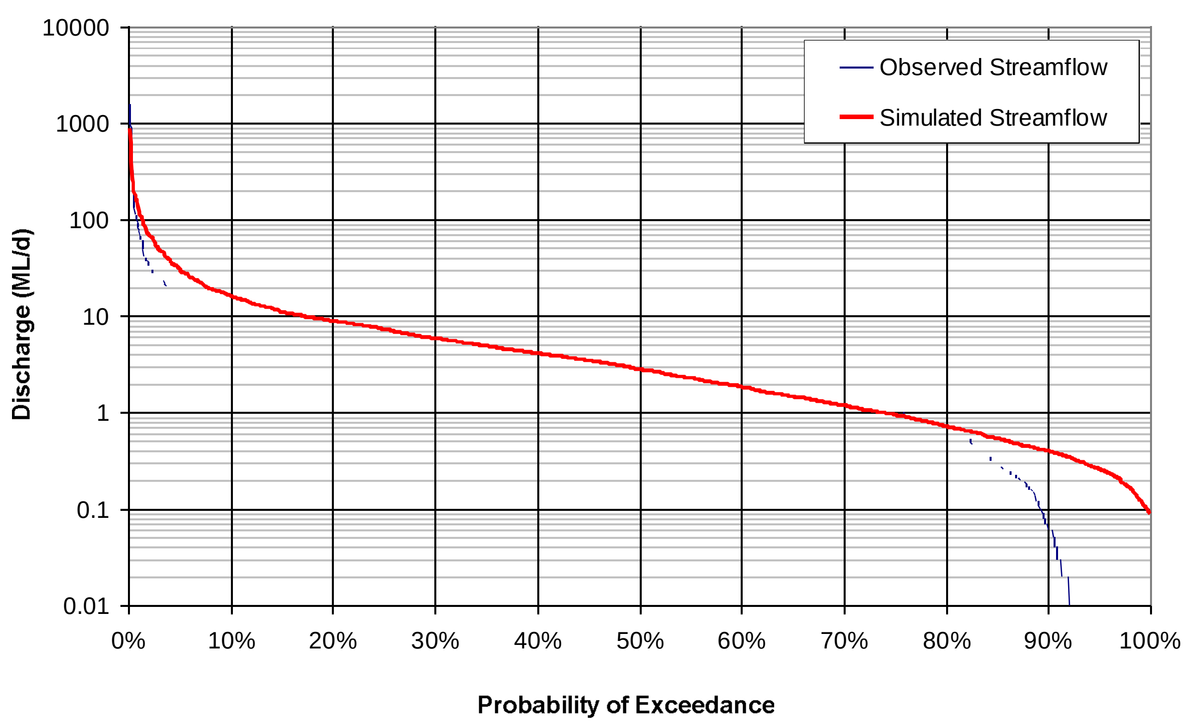

Figure 6.8 Observed and Simulated Streamflow Frequency Curves - Bellambi Ck at South Bulli No.1

6.4 CALIBRATION OF LODDON RIVER CATCHMENT MODEL

The Loddon River AWBM Model was calibrated over the period between the 1st of January 1991 and the 8th of November 2009.The adopted AWBM parameters are summarised in Table 6.4 below.

It was not possible to perfectly replicate all streamflow features of interest (e.g. annual flow, flow frequency, monthly flow, daily flow, hydrograph shape, and baseflow) at all temporal scales. The calibration parameters were selected to achieve a compromise. The calibration parameters were selected to achieve a compromise between matching the above characteristics.

Table 6.4 Adopted AWBM Parameters – Loddon River catchment

Parameter	Value
A1	0.214
A2	0.433
BFI	0.310
C1	3
C2	70
C3	182
K_{base}	0.81
K_{surf}	0

Observed and simulated streamflow time series are compared in Figure 6.9 below.

The model generally underestimates baseflow, which is highlighted in the streamflow frequency curves in Figure 6.10, which show a reasonable match to flows above 10ML/d, but significant discrepancies at lower flows. However, as discussed in section 5.1, flows less than 10ML/d contribute less than 10% of the total runoff volume from the catchment, and flows less than 5 ML/d make up less than 6% of the total Loddon River catchment runoff..

Simulated mean annual runoff is 11,585 ML/a, compared to the observed mean annual runoff of 12,810 ML/a over the same period.

Objective functions for the calibration reported by the Rainfall Runoff Library Application (Podger, 2004) are:

- Nash Sutcliffe Criterion – Calculated vs Observed (Daily) - 0.66
- Nash Sutcliffe Criterion – Calculated vs Observed (Monthly) - 0.79

The model fit is reasonable given the limitations of the available data, however, its applicability is limited when assessing very low flows.

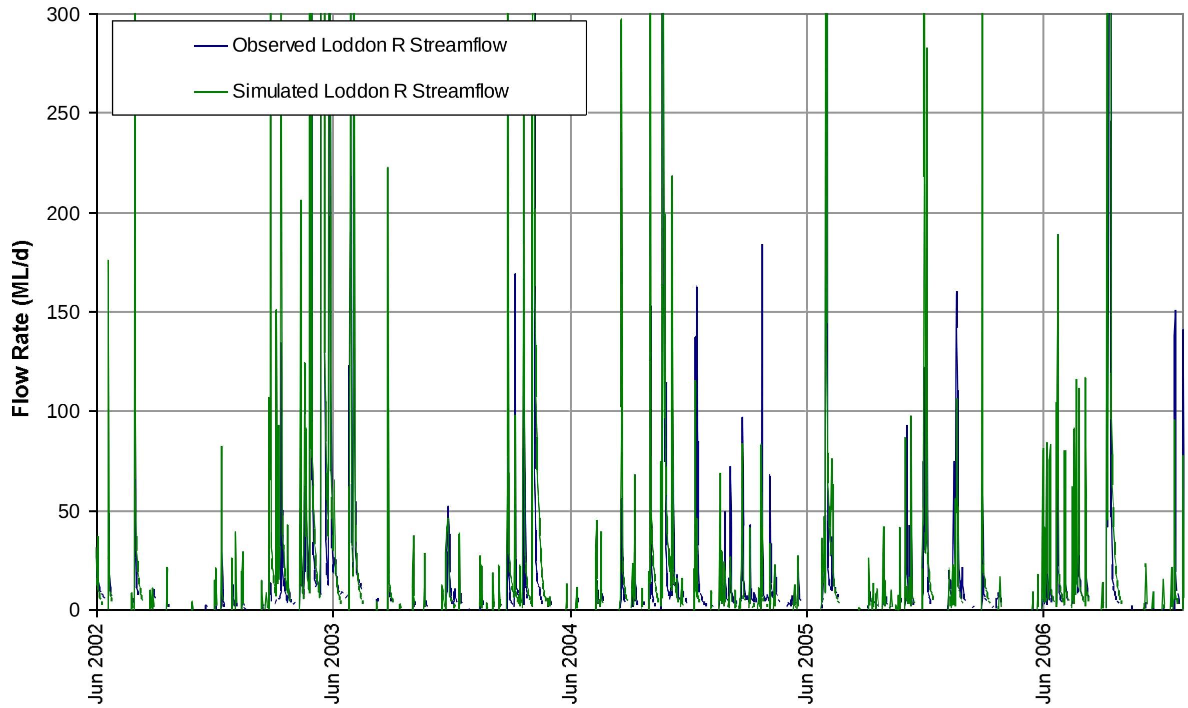

Figure 6.9 Observed and Simulated Streamflow – Loddon River at Bulli Appin Road – Sample of Record from June 2002 to December 2006

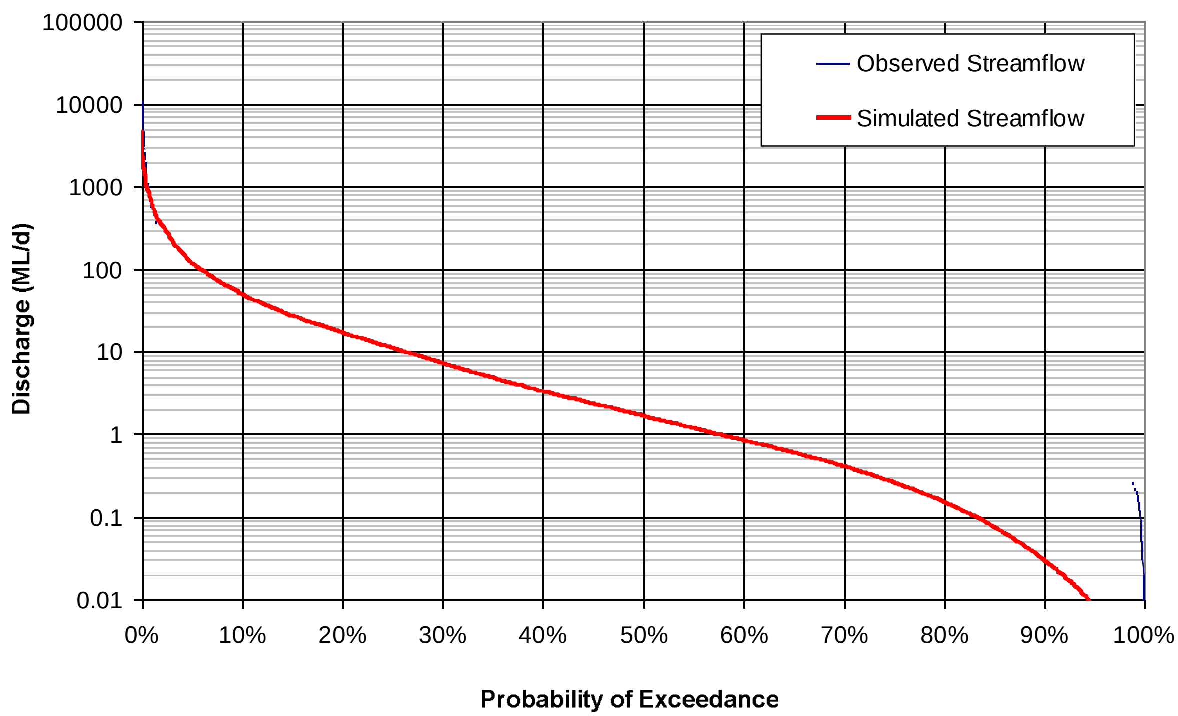

Figure 6.10 Streamflow Frequency Curves for Loddon River at Bulli Appin Road

6.5 VALIDATION OF LAKE CATARACT CATCHMENT MODEL AGAINST LAKE CATARACT BEHAVIOUR

6.5.1 Model Schematisation

The behaviour of Lake Cataract was simulated using a daily time step spreadsheet model comprising the following major components (shown schematically in Figure 6.11):

- Catchment runoff – estimated using recorded streamflow in contributing tributaries where available, and the AWBM rainfall/runoff model where it was not. The highly variable rainfall of the area necessitated subdividing the catchment into four subareas with different combinations of AWBM catchment parameters and input daily climate datasets (as summarised in Figure 6.11).

- Direct rainfall to the lake surface - a daily time series of rainfall depths was obtained from the SILO Patched Point Dataset for Cataract Dam. The rainfall depth was applied to the lake surface area estimated at each time step from the storage curve shown in Section 6.5.2.

- Evaporation from the lake surface – a time series of lake evaporation rates was obtained from the SILO Patched Point Dataset for Cataract Dam (Morton evaporation over shallow lakes). The lake evaporation rate was applied to the lake surface area estimated at each time step from the storage curve shown in section 6.5.2. No further evaporation adjustment factors were applied.

- Releases from the dam – the daily time series of recorded releases provided by SCA were extracted from the storage.

- Spills from the dam – inflows exceeding the remaining water storage were treated as spills.

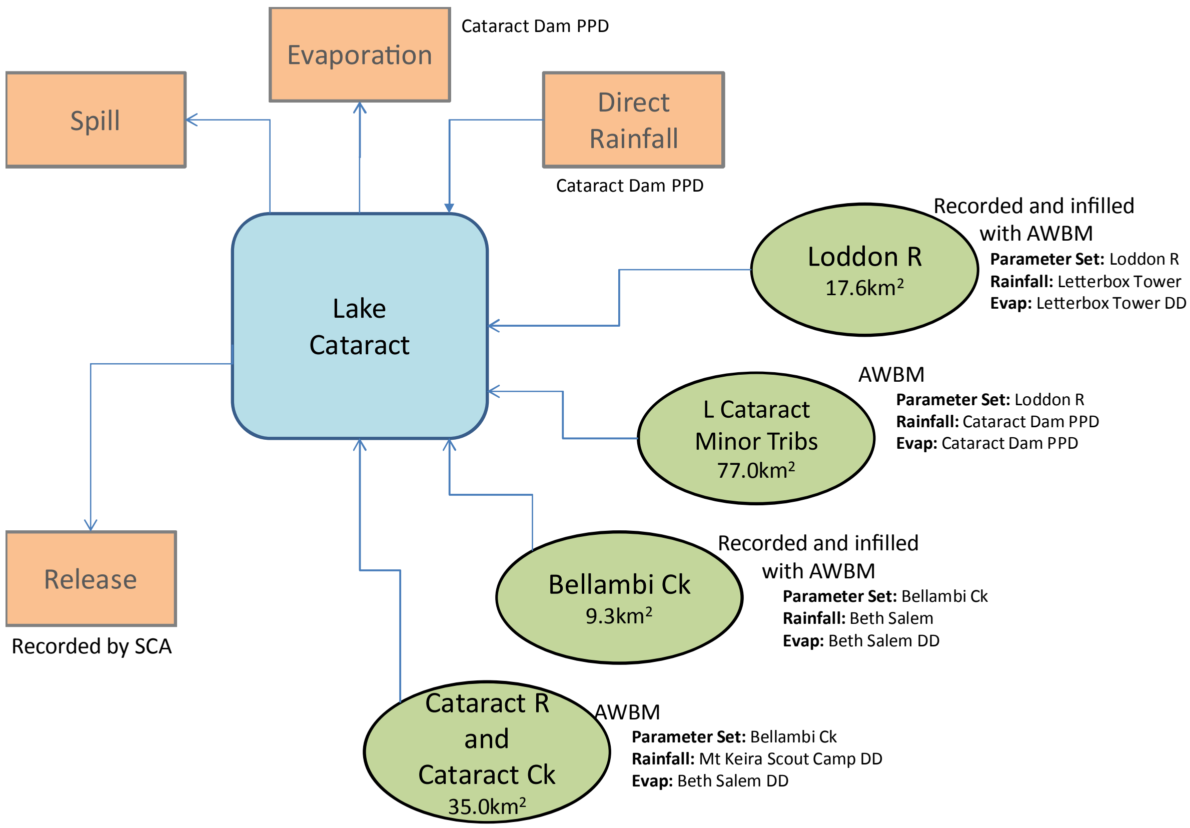

Figure 6.11 Lake Cataract Hydrological Model

6.5.2 Operational Data Supplied by SCA

The SCA provided data pertaining to the operation of Lake Cataract. The daily stored volume, controlled release and spillway discharge information shown in Figure 6.12 was used in the model.

Releases are made from Cataract Dam for the purposes of meeting water supply requirements and providing environmental flows.

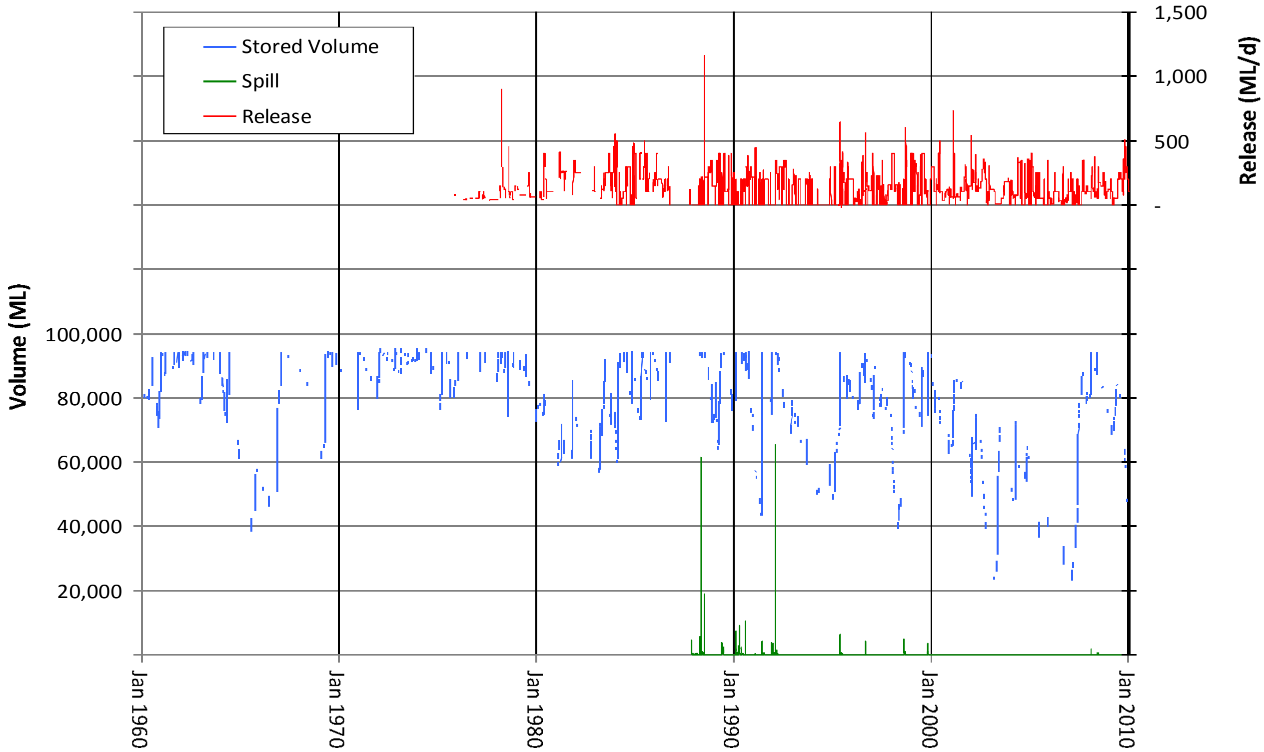

Figure 6.12 Lake Cataract Operational Data

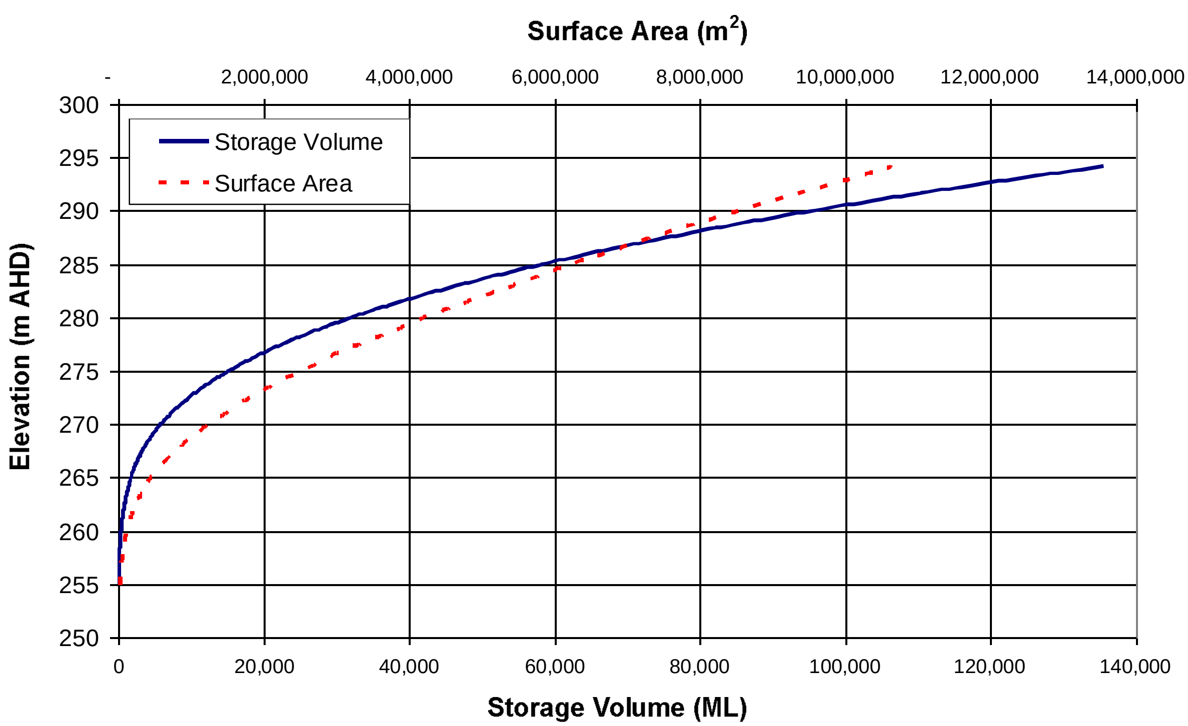

Figure 6.13 Lake Cataract Storage Curves

6.5.3 Model Validation

The results were validated against the recorded stored volume of Lake Cataract between 1976 and 2010, as shown in the following four figures. The modelled stored volume is a good representation of the observed behaviour. However, differences between modelled and observed inflows cause some discrepancies. These differences occur mostly during the larger inflow events, and are probably due to non-uniform rainfall over the catchment.

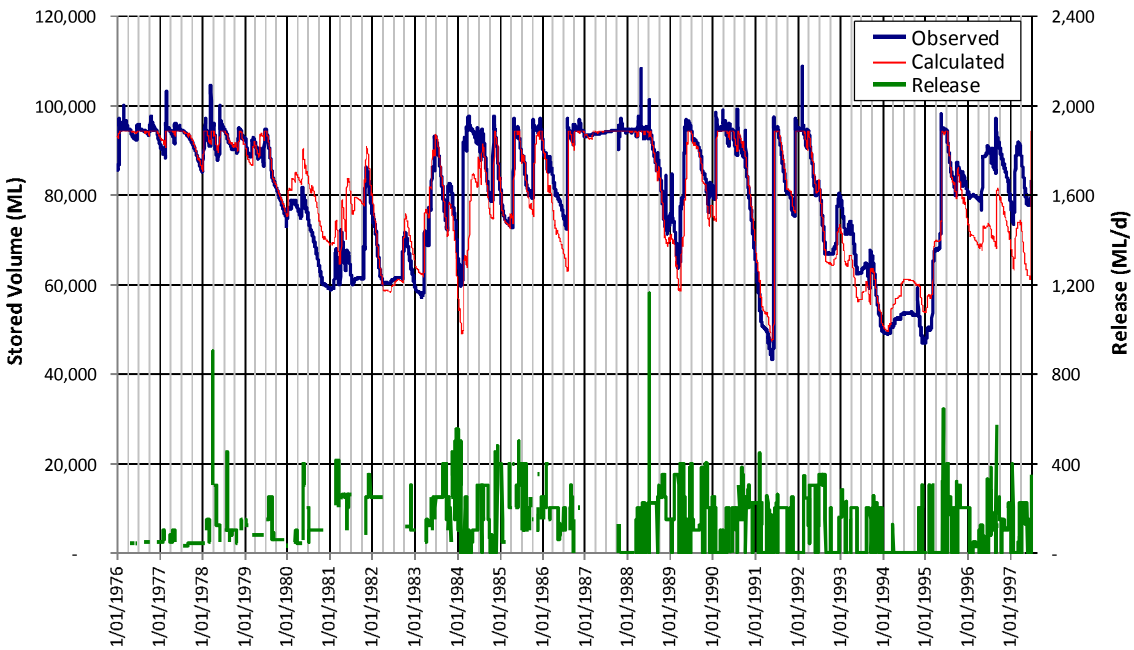

Figure 6.14 Observed and Modelled Storage Behaviour at Lake Cataract 1976 to 1997

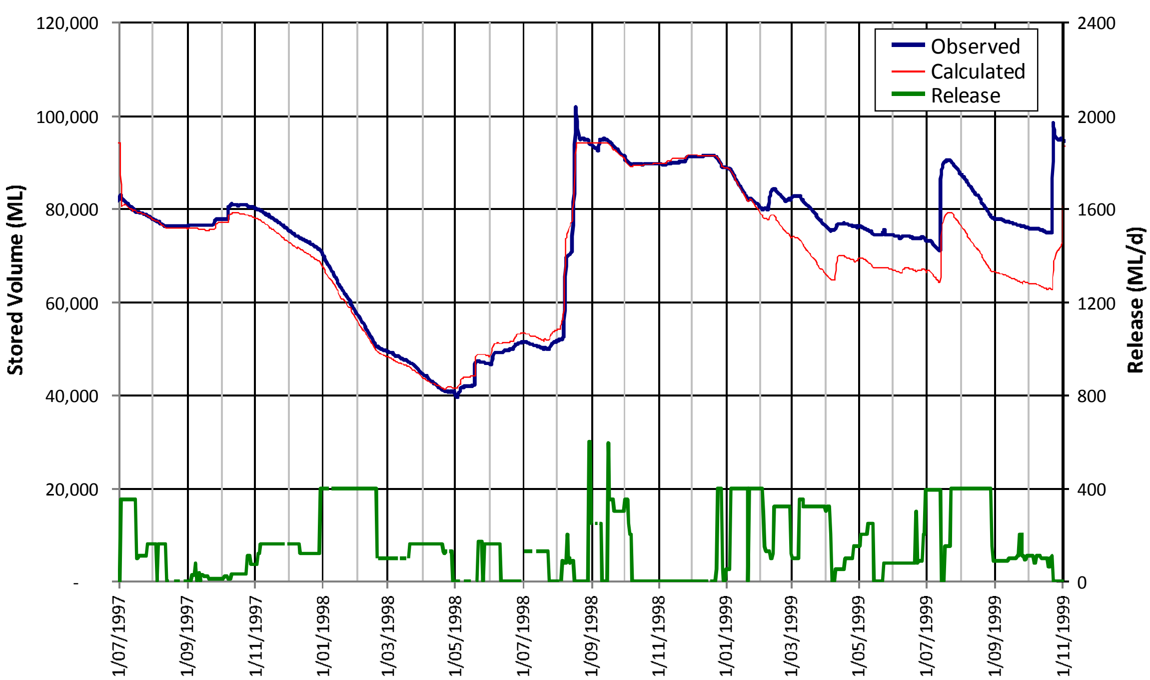

Figure 6.15 Observed and Modelled Storage Behaviour at Lake Cataract 1997 to 1999

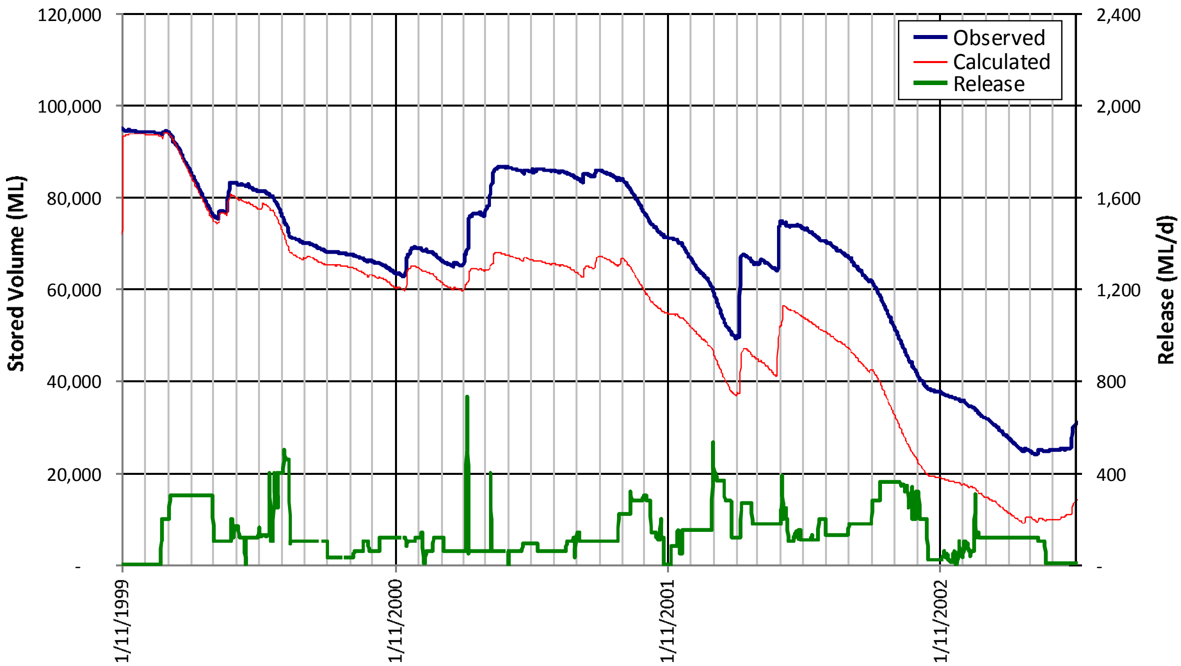

Figure 6.16 Observed and Modelled Storage Behaviour at Lake Cataract 1999 to 2003

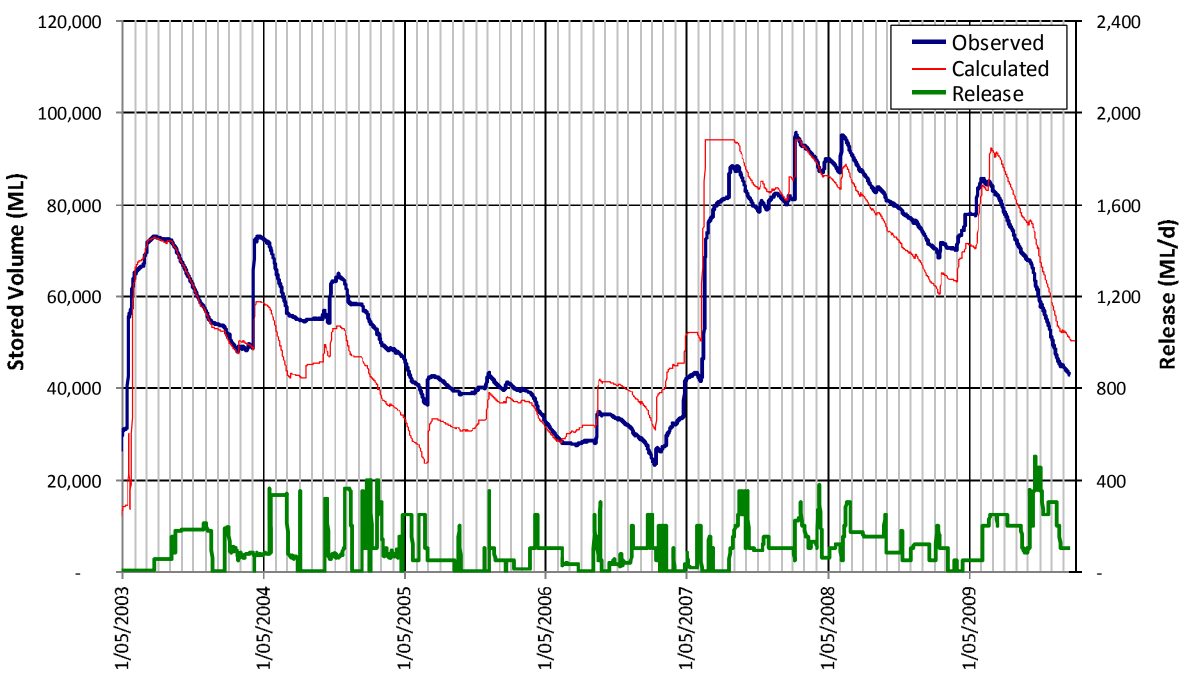

Figure 6.17 Observed and Modelled Storage Behaviour at Lake Cataract 2003 to 2010

6.6 VALIDATION OF WALLANDOOLA AND LIZARD CREEK RUNOFF MODEL AGAINST BROUGHTON'S PASS STREAMFLOW

The behaviour of the Cataract River catchment to Broughton's Pass Weir was simulated using a daily time step spreadsheet model comprising the following major components (shown schematically in Figure 6.18):

- Catchment runoff – estimated using the AWBM rainfall/runoff model. The catchment to Broughton's Pass Weir was subdivided as shown in Figure 6.18. The daily unit runoff time series derived for the Lake Cataract minor tributaries subcatchment was adopted (derived using daily rainfall and evapotranspiration data recorded at Cataract Dam and AWBM parameters transposed from the calibrated Loddon River model).

- Releases from the dam and weir – the daily time series of recorded releases provided by SCA were input to the top of the modelled reach. Diversions to Macarthur Water Treatment Plant (WTP), Upper Canal and environmental releases were also extracted upstream of Broughton's Pass Weir.

- Spills from the dam – the daily time series of recorded spillway discharges provided by SCA were input to the top of the modelled reach.

Releases are frequently made from Cataract Dam, and the effects of instream losses, and gauge errors make it difficult to assess the contribution of catchment runoff to flows at Broughton's Pass Weir.

For the purpose of validating the simulated runoff, the focus was periods of no release from Cataract Dam. Under these conditions, streamflow at Broughton's Pass Weir is largely due to flow from Wallandoola and Lizard Creeks. However, there will also be contributions from Cascade Creek and the residual catchment between Cataract Dam and the Wallandoola Creek confluence. As shown in Figure 6.19 (and the charts in Appendix B), despite these simplifications, the model appears to be reasonably representative of catchment runoff during these times.

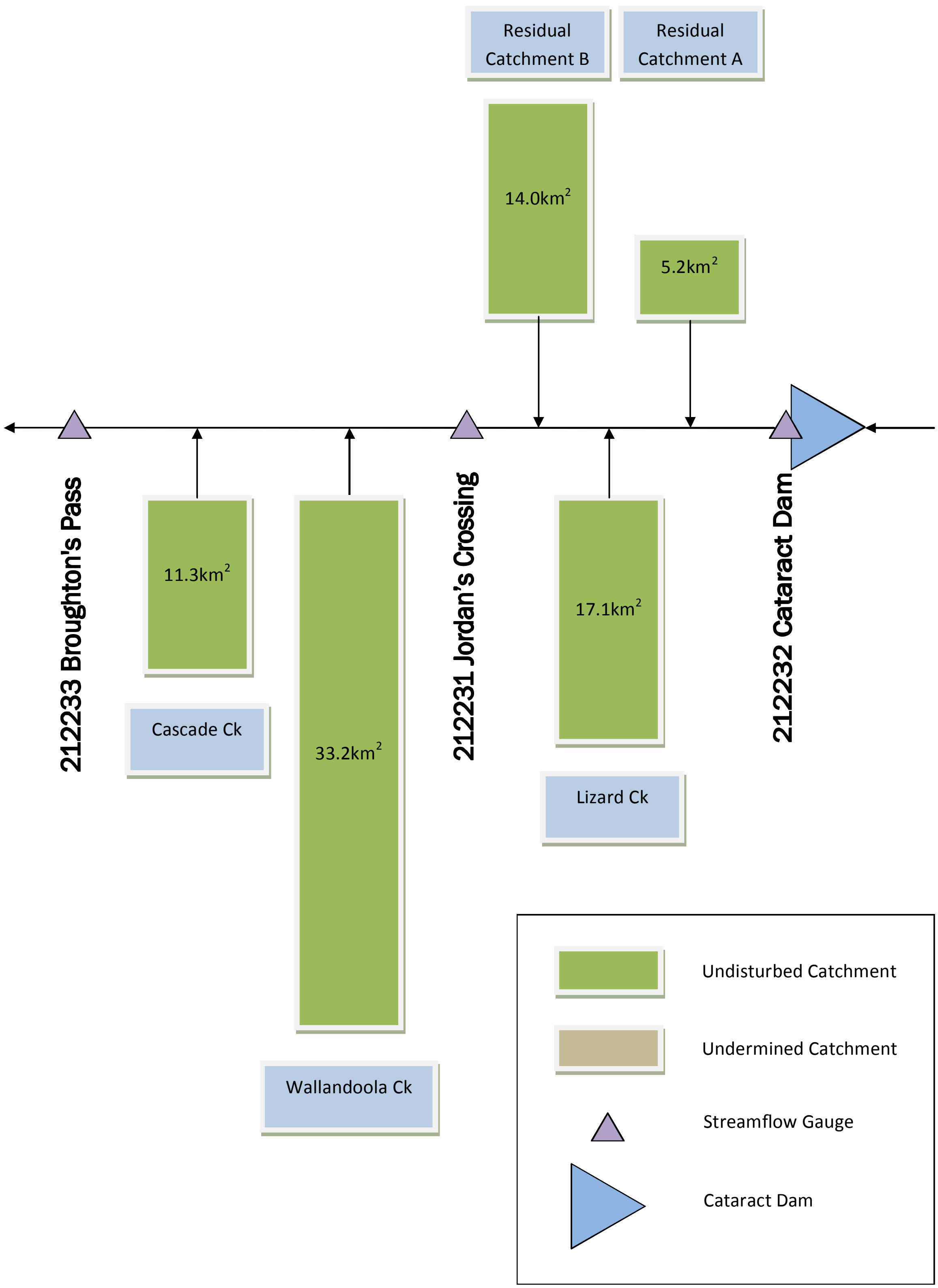

Figure 6.18 Model for validation of adopted Wallandoola and Lizard Ck rainfall-runoff relationships

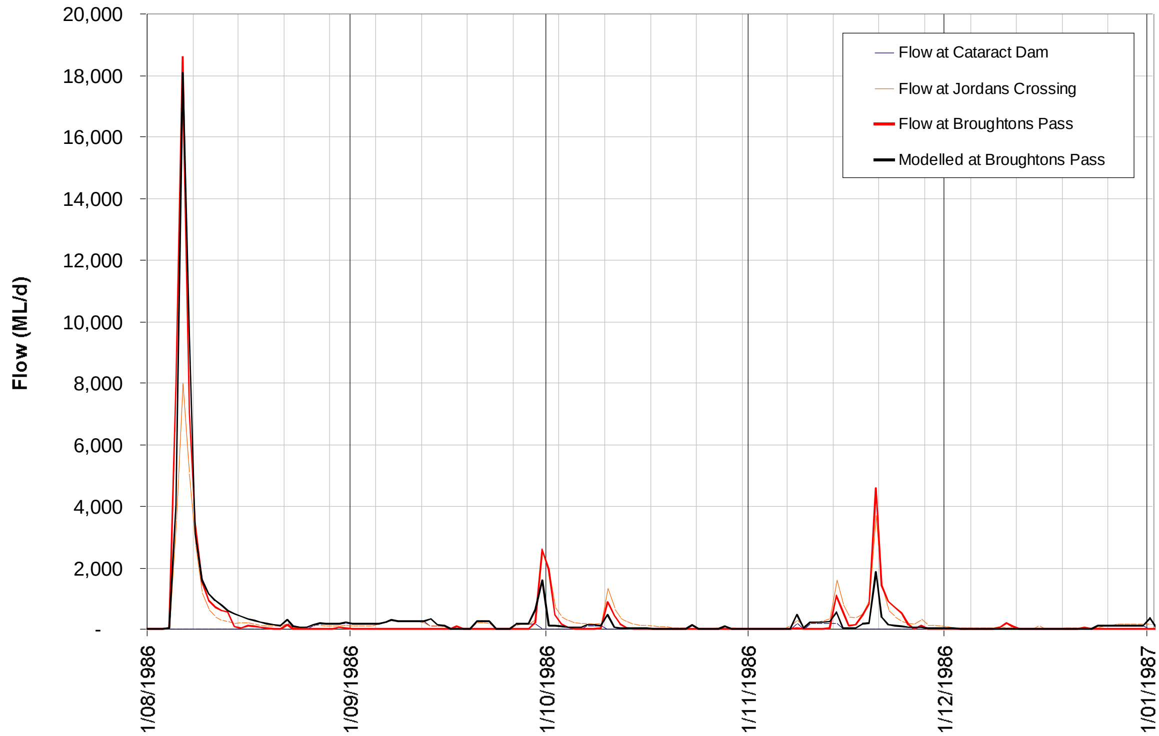

Figure 6.19 Observed and Modelled flow at Broughton's Pass Weir

7 CONTRIBUTION OF CATCHMENTS POTENTIALLY AFFECTED BY SUBSIDENCE

7.1 POTENTIAL MECHANISMS FOR HYDROLOGICAL IMPACTS

The following potential hydrological risks have been raised as stakeholder concerns:

- **Reservoir yield** - the possibility that quantity of water reaching Lake Cataract and Broughtons Pass Weir could be reduced,

- **Stream health** – the possibility that cracking of the stream beds draining into Cataract Dam and Broughtons Pass Weir may induce loss of overland stream flow and adversely affect stream water quality or stream health.

In its review of the Metropolitan Coal Project Environmental Assessment, the Planning Assessment Commission (PAC) Panel cited the following potential mechanisms whereby this may occur (NSW PAC, 2009):

1. Rainfall on the broader catchment, which previously found its way to watercourses by surface or subsurface flow infiltrates through fractures and is permanently lost to the surface water system.
2. Water in streams that are subject to fracturing is lost from the surface water system to the groundwater system and does not reappear.

The above potential risks are addressed in the following sections.

In its submission on the DGR's the Department of Water and Energy required this EA report *demonstrate the project is consistent with the spirit and principle of the NSW State Rivers and Estuaries Policy, Wetland Management Policy, including :*

1. *General description of channel form, river style or other descriptive category of any affected channel, including identification of key geomorphological indicators and conditions within the zone of influence for the proposal.*

2. *Hydrologic and geomorphic character of the riverine system, stream energy and stream power relationships, energy relationships at bankfull stage and at peak flow, and assessment of stream power and critical tractive stress for existing and any modified conditions for any rivers affected by the proposal, which provides details of:*
   - *long profile and cross sectional survey along the channel, and identification of at least the closest upstream and downstream controls on the channel*
   - *assessment of bed and bank material, identification of critical entrainment and destabilisation thresholds*
   - *assessment of the constriction and resultant change in afflux through, past or over the structure, and resultant changes in energy profiles involving the structure*

- *nature of bedload transport, and mechanism(s) to permit bedload transport through the structure*

3. *Procedures to develop stream relocation and reconstruction criteria which utilise best practice management, which must include the principles which underpin any embargoes currently in force under the Water Act, 1912, or operational rules of any Water Sharing Plan in force under the Water Management Act 2000 over the site*

4. *Methodologies by which proposed relocation or reinstatement of watercourses will be undertaken, and whether any proposed ecological offset provisions will provide adequate protection to any instream or groundwater dependent ecosystems which exist on the site*

5. *Mechanism to maintain long profile grade through the structure, or to provide energy dissipation through the structure at the re-entry point design volumes/velocity downstream*

6. *Nature of existing controls along all watercourses on the site, and proposed use of engineered and vegetation to provide long term control to the channel*

7. *Final configuration of any relocation, modification or other impact upon rivers and watercourses on or surrounding the site, including geomorphic character mimicking conditions of undisturbed rivers or watercourses adjacent to the proposal area*

The streams overlying the project area are not being relocated or reinstated, and no instream structures are proposed. The predicted subsidence impacts are expected to result in only small changes to the stream bed profile. As a result, localised reductions in bed gradients are not likely to cause significant additional ponding. Any localised increase in bed gradient is likely to be within the range of those occurring naturally, and as the stream bed material comprises competent rock, the resultant localised increases in stream power and tractive force are unlikely to cause bed scour. As a result, we have not undertaken a detailed assessment of bedload transport mechanisms or afflux.

The proposed workings will potentially disturb the following portions of the catchments in the Study Area (Seedsman, 2010).

Table 7.1 Potential Subsidence Areas Compared to Total Catchment Area

Stream	Catchment Area (km^2)						
	Total Catchment to D/S Confluence	Subsided by More Than 20mm	Percentage Subsided	U/S of Disturbance Envelope	% U/S	D/S of Disturbance Envelope	% D/S
Lizard Creek	17.1	6.3	36.8%	7.5	44.0%	3.3	19.2%
Wallandoola Creek	33.2	2.0	6.0%	8.7	26.2%	22.5	67.7%
Lake Cataract*	127.8	2.3	1.8%	4.0	3.1%	121.5	95.1%
Cataract Creek	5.2	1.4	27.5%	3.7	71.5%	0.05	1.0%
Cataract River	11.6	0.4	3.4%	0.0	0.0%	11.2	96.6%
Belambi Creek	9.3	0.2	1.9%	0.0	0.0%	9.1	98.1%

*Lake Cataract disturbance includes disturbance area in Cataract Creek, Cataract River and Bellambi Creek.

7.2 ASSESSMENT METHODOLOGY

The PAC has previously noted that without special techniques and extensive quality control and checking, the normal accuracy of stream gauging measurements combined with staged measurements and the derivation of rating curves, precludes reliable detection of small absolute changes in stream flows from one location to the next (NSW PAC, 2009). This is further affected by the likelihood that in Hawkesbury Sandstone based waterways such as those within the study area with natural (and potentially induced) bedding plane as well as jointing washouts and fractures, subsurface flow is present that can not be accurately measured, especially during low flow regimes.

In its review of the Metropolitan Coal Project Environmental Assessment, the PAC was of the view that because fracturing is likely to only occur in the surficial groundwater system, and that any increase in initial rainfall runoff losses would be temporary, any surface water losses would therefore be undetectable unless the surficial groundwater system intercepted a permeable subsurface stratum that bypassed the reservoir (NSW PAC, 2009).

Due to the low total predicted subsidence in Wonga East (<200mm), as well as the mine plan that avoids undermining the main channel of Lizard Creek and Wallandoola Creek at Wonga West, the potential for additional fracturing of the creek beds has been minimised.

The Southern Coalfield Inquiry was also of the view that there was no evidence that *"subsidence impacts have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra Region." (DECC, 2007)*

However, the PAC did make the case that the issue was not beyond doubt and recommended further investigation of catchment yield impacts.

The rate of water loss from pools affected by subsidence induced cracking has been measured in waterways overlying other projects in the Southern Coalfield (Gilbert, 2008). However, due to the lack and distribution of suitable overland stream flow monitoring sites within the Study Area, it is not possible to accurately determine the loss, if any of stream flow reporting into Cataract Dam or Broughtons Pass Weir.

In addition, mining subsidence effects, if any, in the Cataract River downstream of the Gujarat lease area may, or may not, also be causing stream flow losses in the streams system that reports to Broughtons Pass Weir

Given these limitations, it is not currently feasible to definitively quantify any overland stream flow losses that may, or may not, result from the potential loss mechanisms.

However, the catchment models developed for the study area have been used to describe how a range of modelled loss rates could impact on streamflow downstream of potentially affected subsidence areas.

7.2.1 <u>Potential Impact on Reservoir Yield</u>

The Lake Cataract model presented in Section 6.5 was used to investigate the impact that various loss rates from the upstream catchment would have on reservoir yield.

The modelling focussed on the dry periods from 1996 to 1998 and 2001 to 2007 when stored water volumes dropped below 40,000 ML. During higher flow events, where there was a large discrepancy between the modelled and observed inflow, the modelled inflow was modified to achieve an improved fit to observed volumes.

The results of this adjustment are shown in Figure 7.1 which shows a very close correlation between observed and modelled behaviour.

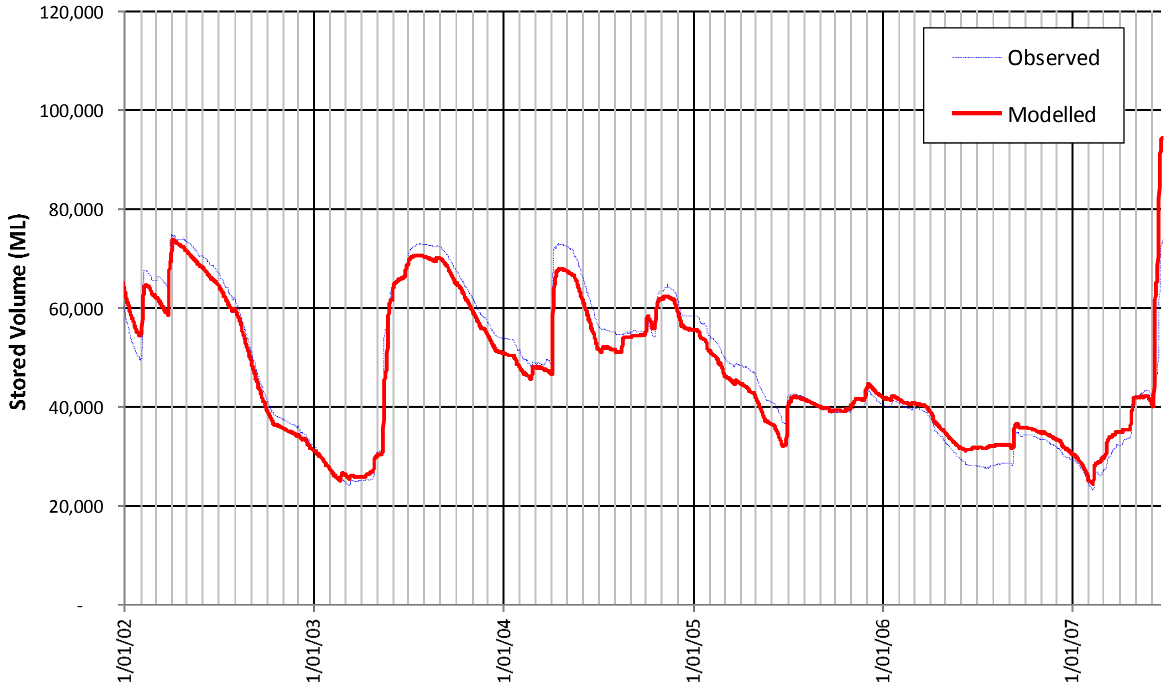

Figure 7.1 Observed and Modelled Dry Period Volume at Cataract Dam after Inflow Adjustment

Catchment and in-stream losses were applied by reducing the Cataract Creek/Cataract River inflow rate by a daily loss rate in ML/d (up to the daily flow rate).

7.2.2 Potential Impact on Streamflow

The Wallandoola and Lizard Creek catchment models described in Section 6 were used to investigate how a range of modelled loss rates would impact key features of streamflow downstream of the affected areas.

Daily flow rates at the reporting locations shown in Figure 7.2 were reduced by 1ML/d, 5 ML/d and 10ML/d to indicate the effect on the hydrograph shape and the flow frequency curves.

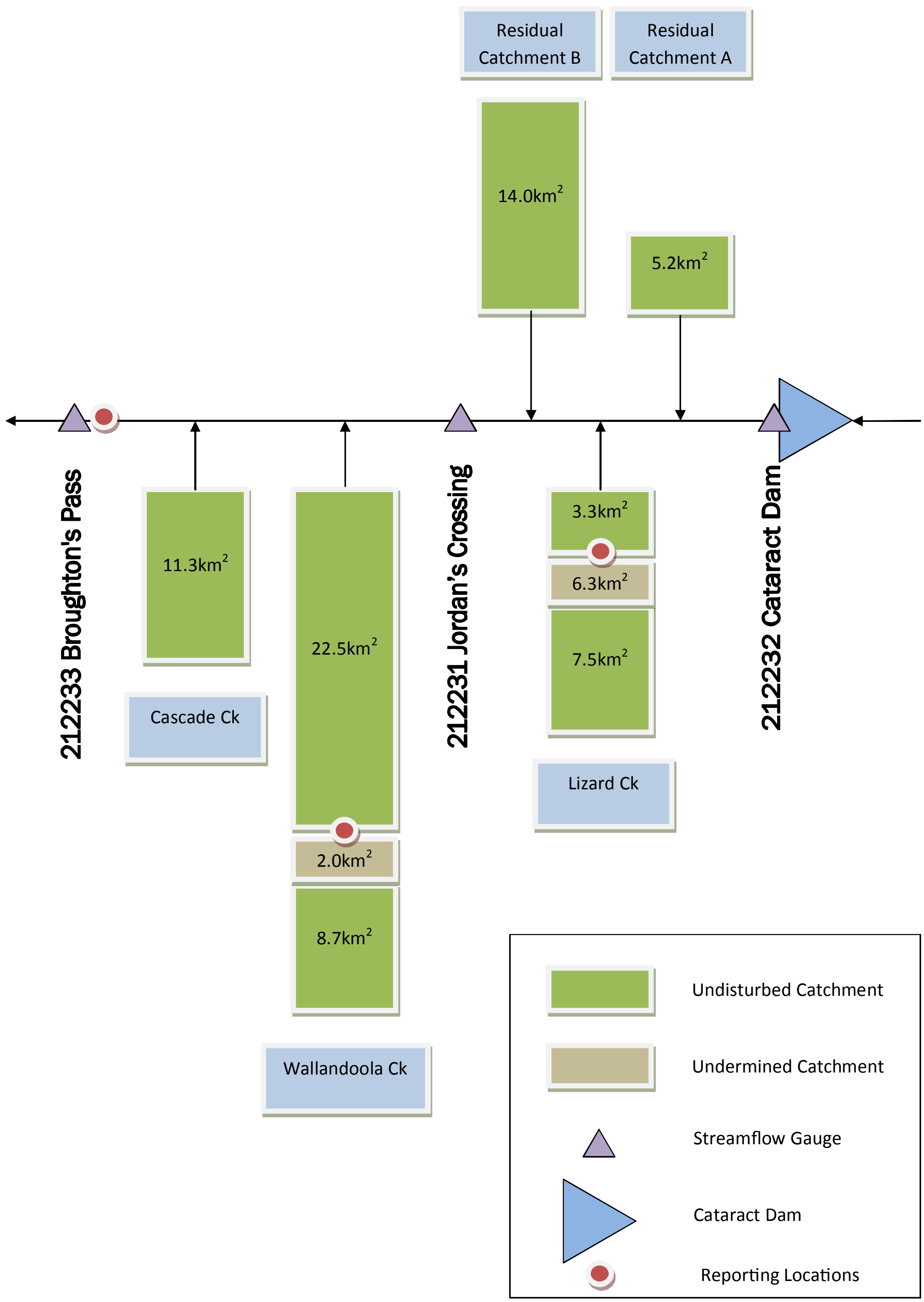

Figure 7.2 Model for illustrating potential impacts of subsidence induced losses on downstream flow

7.3 MODEL RESULTS

7.3.1 Potential Impact on Reservoir Yield

Figure 7.3 below compares the simulated stored water volume with no subsidence losses to those simulated with catchment losses of increasing magnitude.

Based on pool water level reduction rates, overland stream flow loss in the order of 0.5 ML/d have been estimated at other similar projects in the Southern Coalfields (Gilbert, 2008)

The overland stream flow loss rates were applied to the total Cataract River (including Cataract Creek) inflow. The results show that under historical water use and climate conditions recorded since 1976, losses of 1ML/d would have had very little impact on Lake Cataract water levels.

The maximum reduction in stored volume occurs in mid-2007 and ranges from 940ML for a loss of 0.5ML/d to 1,385ML for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such loss rates are very large, and based on previous experience and observations at similar coal mines in the Southern Coalfields (Gilbert, 2008) they are unlikely to eventuate given the anticipated and observed response of the Hawkesbury Sandstone based stream bed to the predicted subsidence along with the proposed panel layout.

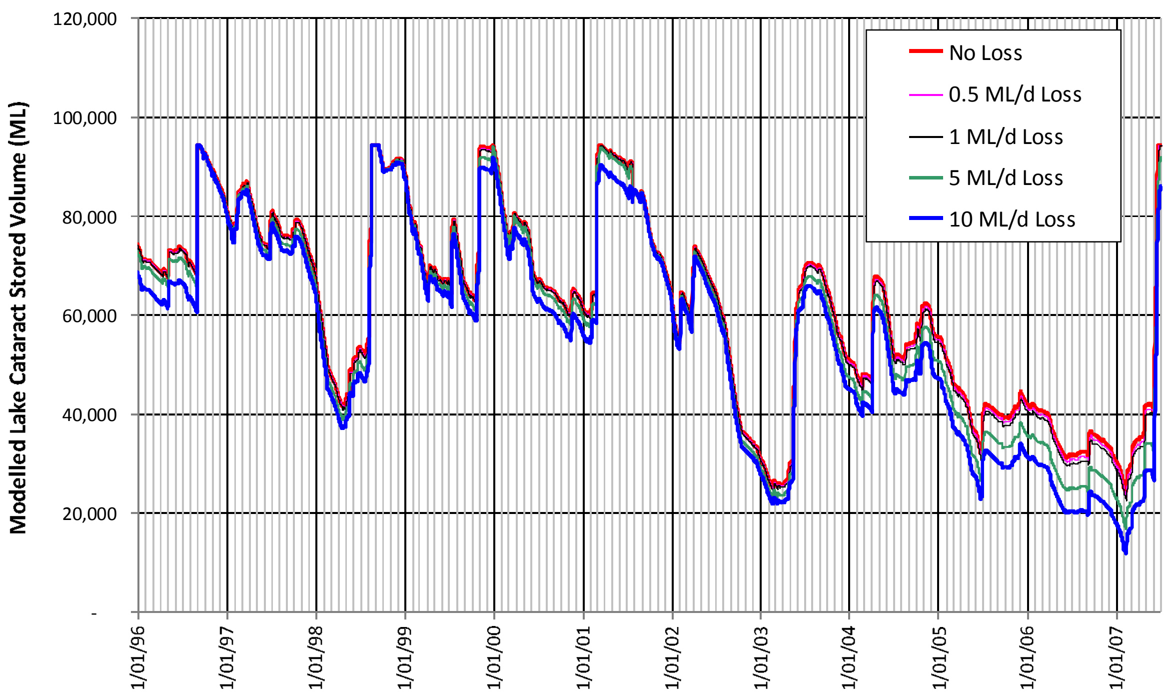

Figure 7.3 Impact of catchment loss on Lake Cataract dry period stored water volume

7.3.2 Potential Impact on Streamflow

The results of the analysis are illustrated in Figure 7.4 and Figure 7.5, which show modelled flow rates at the Reporting locations in Figure 7.2. It should be emphasised that the modelled low flows have not been fully validated against measured low flows due to the physical limitation and difficulty in obtaining sufficient overland stream flow monitoring sites to enable "total" measurement of stream flow as described in Section 5.2

The effect of losses of the magnitude considered would have a proportionally smaller impact on large flows. However, they could constitute a higher portion of baseflow under low flow conditions at the localised affected areas.

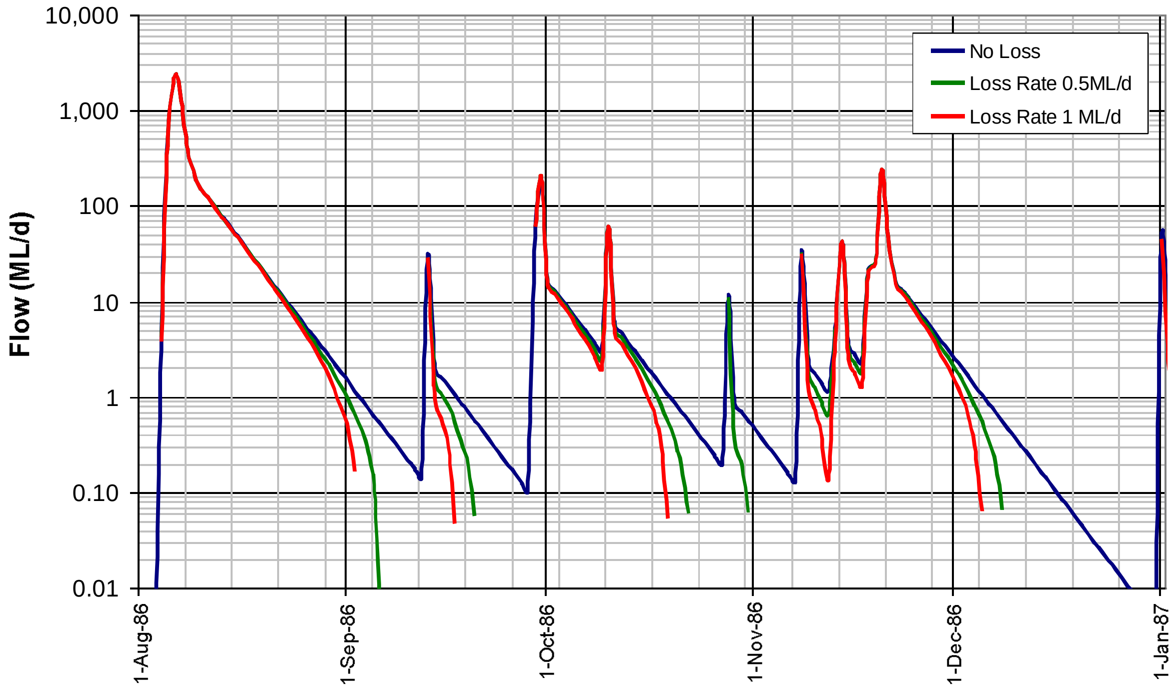

Figure 7.4 Example impact of flow loss on hydrograph shape Lizard Creek – Late 1986

The impact of the losses over the modelled period between 1983 and 2009 is illustrated more completely in Figure 7.5. The following observations can be drawn from these results:

- A loss of 0.5ML/d would reduce the frequency of flows greater than 1.0ML/d from around 38% to 32%. A loss of 1.0 ML/d would reduce the frequency of 1.0ML/d flows to 28%.

- A loss of 0.5ML/d would reduce the frequency of flows greater than 0.1ML/d from around 70% to 46%. A loss of 1.0 ML/d would reduce the frequency of 0.1ML/d flows to 37%.

Flows in Lizard Creek and Wallandoola Creek at the reporting locations just downstream of the proposed impact zone, are similar.

It should be noted that if flow losses occurred from a reach of the affected streams, it is thought that the flow would return to the channel further downstream. The impacts described above are therefore likely to affect only limited portions of the affected streams.

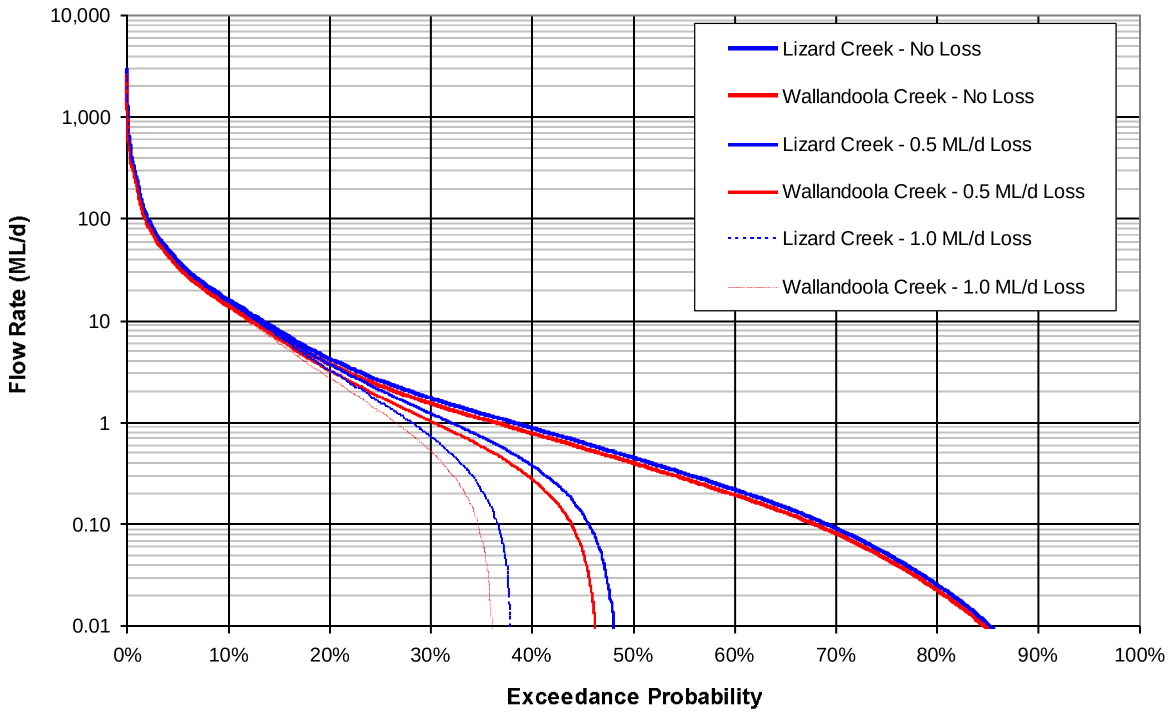

Figure 7.5 Impact of losses on flow frequency curve – Lizard Creek and Wallandoola Creek

8 CONCLUSIONS

The proposed mine panel layout has been designed to minimise adverse effects on the catchment and channels of Lizard and Wallandoola Creeks that could be affected by subsidence associated with the proposed Wonga West workings.

The catchment of Cataract Creek, Bellambi Creek and Cataract River are not anticipated to be adversely affected by the less than 200mm of predicted subsidence over the Wonga East workings.

Details are summarised below, for subsidence exceeding 20mm:

1. Lizard Creek. The predicted Wonga West 20mm subsidence zone underlies a 4.5km stretch of the creek. Of the total Lizard Creek catchment area of 17.1km^2, 7.4km^2 has been identified as potentially subsided by the proposed workings.

2. Wallandoola Creek. The predicted Wonga West 20mm subsidence zone underlies a 1.5km length of the upper reaches of the stream. Of the total Wallandoola Creek catchment area of 33.2km^2, 3.2km^2 has been identified as potentially subsided by the proposed workings.

3. Cataract Creek. The proposed Wonga East workings are located between Chainage 3,100m and Chainage 4,200m. Of the total Cataract Creek catchment area of 5.2km^2, 1.4km^2 has been identified as potentially subsided by the proposed workings.

4. Cataract River. The proposed Wonga East workings do not underlie the Cataract River. The predicted 20mm subsidence zone runs adjacent to the Lake Cataract backwater for a distance of about 600m. Of the total Cataract River catchment area of 11.6km^2, 0.1km^2 has been identified as potentially subsided by the proposed workings. The western end of Panel 10 in the Wonga East workings extends under the high water extent of the northern bank of the Lake Cataract backwater in the Cataract River.

Subsidence induced cracking could potentially reduce overland streamflow in isolated reaches overlying the proposed workings. However, monitoring in similar mining areas within the Southern Coalfield concluded these impacts are restricted to short reaches where flow infiltrates into cracks in the bed then remerges further downstream with no measureable loss of total catchment flow into the creek reaches downstream of the affected area.

Based on a catchment yield model calibrated to historical records since 1976, overland flow losses of 1ML/d would have very little impact on Lake Cataract water levels. The maximum reduction in stored volume occurs in mid-2007 and ranges from 940ML for a loss of 0.5ML/d to 1,385ML for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such a loss rate is very large, and unlikely to eventuate given the underlying geology and proposed mining method.

In the absence of long-term streamflow records on Lizard and Wallandoola Creek, the impact of losses from the affected reaches on the persistence of baseflow has been estimated by extracting a constant daily loss rate from a simulated streamflow record. The model parameters were transposed from AWBM models calibrated to adjacent catchment runoff records and validated against portions of the streamflow record at Broughton's Pass Weir. Flows in Lizard Creek and Wallandoola Creek at the reporting locations just downstream of the proposed 20mm subsidence zone, are similar.

A loss of 0.5ML/d would reduce the frequency of flows greater than 1.0ML/d from around 38% to 32% of the time. The frequency of flows greater than 0.1ML/d would be reduced from around 70% of the time to 46% of the time. A greater loss of 1.0 ML/d would further reduce the frequency of 1.0ML/d flows to 28% of the time. The frequency of flows greater than 0.1ML/d would be reduced further to 37%.

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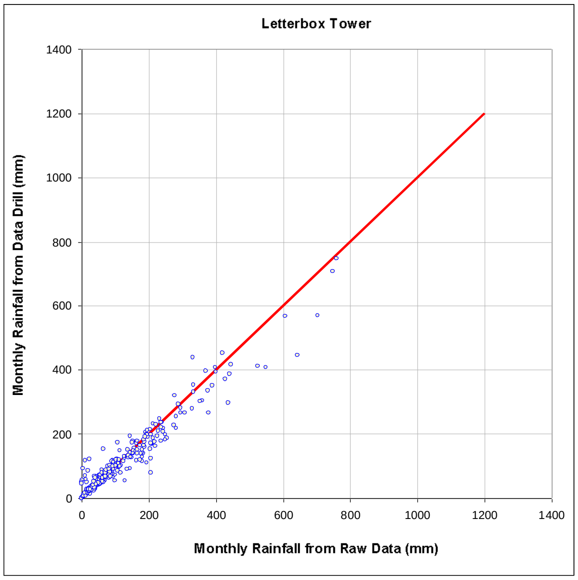
APPENDIX A

COMPARISON OF RAW RAINFALL DATA AND

SILO DATA DRILL RAINFALL DATA


Letterbox Tower
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)
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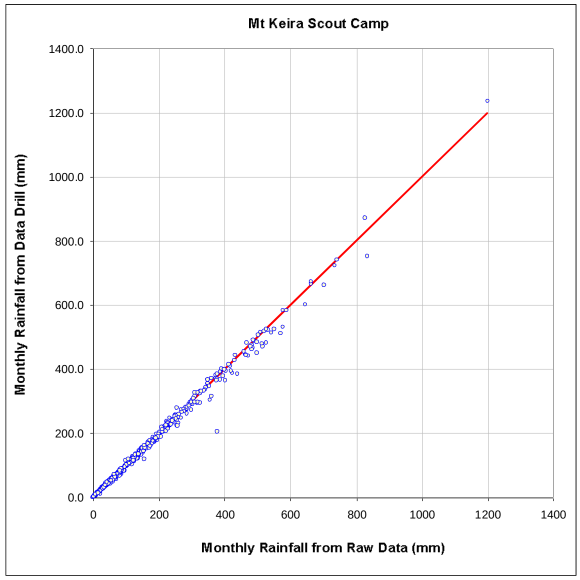
200
400
600
800
1000
1200
1400


Mt Keira Scout Camp
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)
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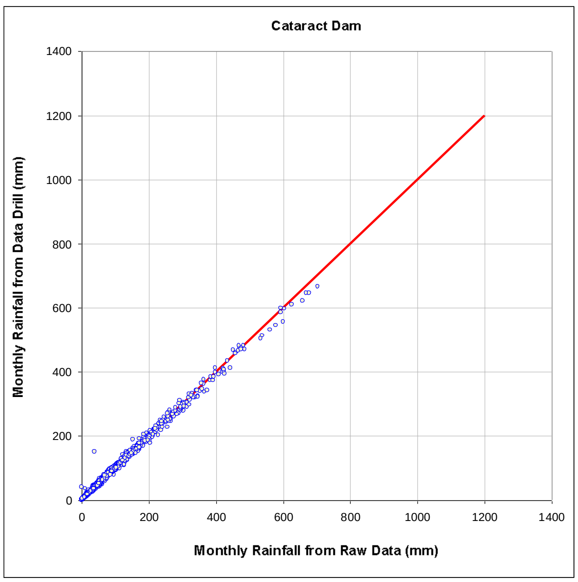
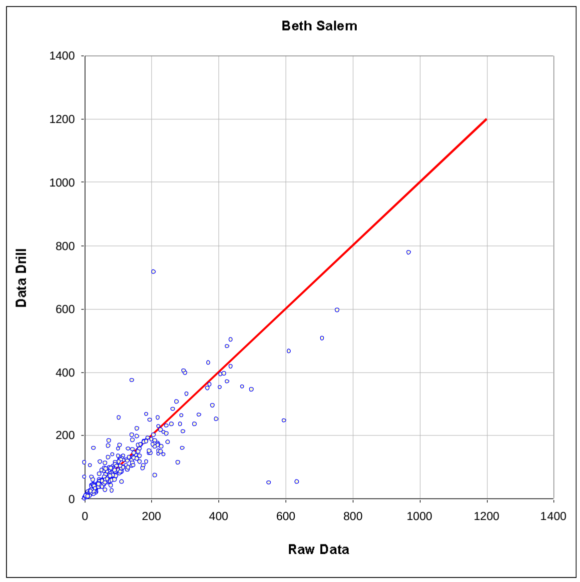
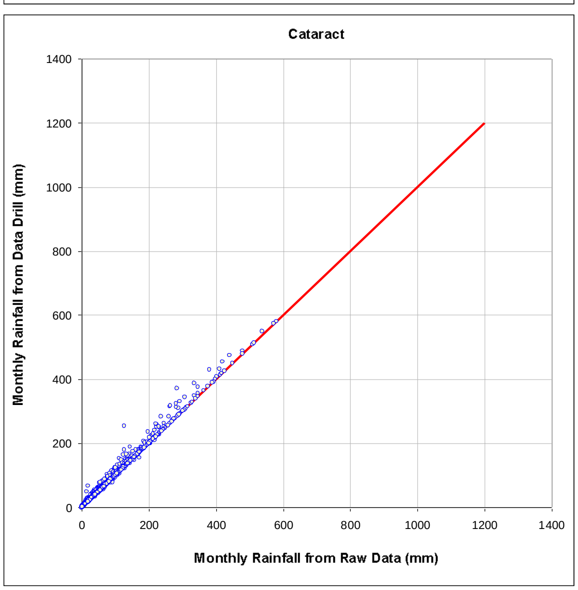
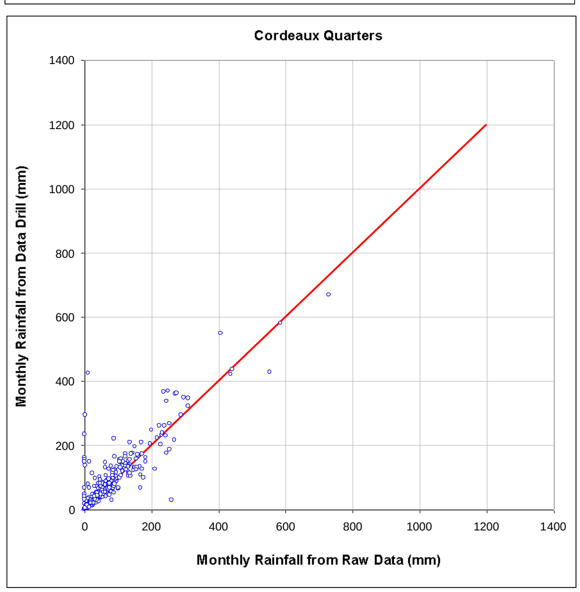
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0


Cataract Dam
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)

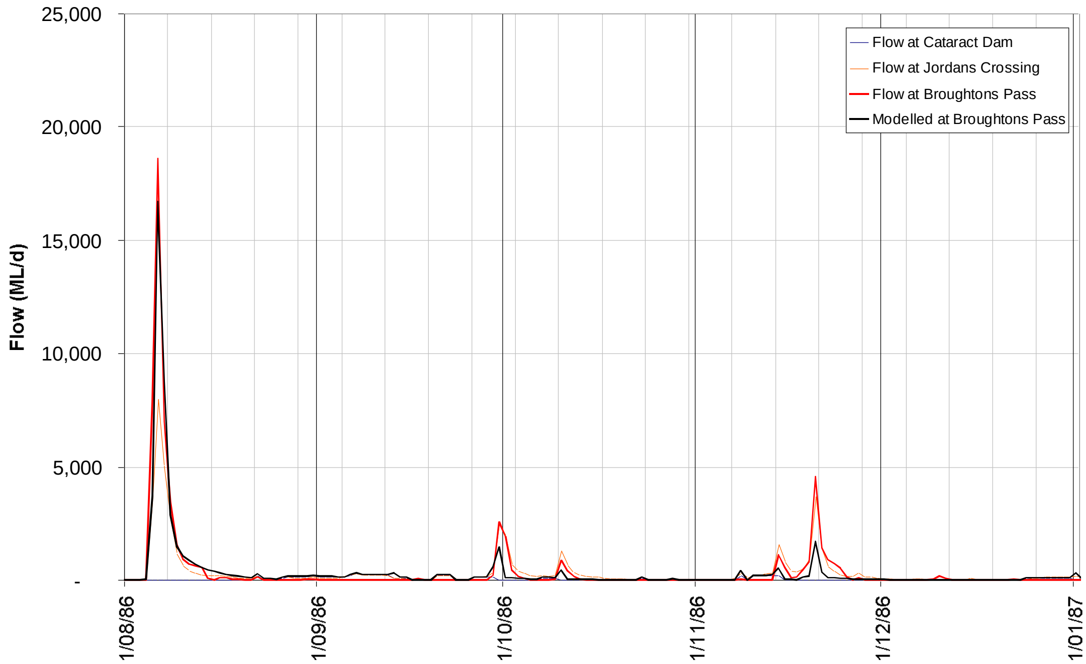

Beth Salem
Data Drill
Raw Data

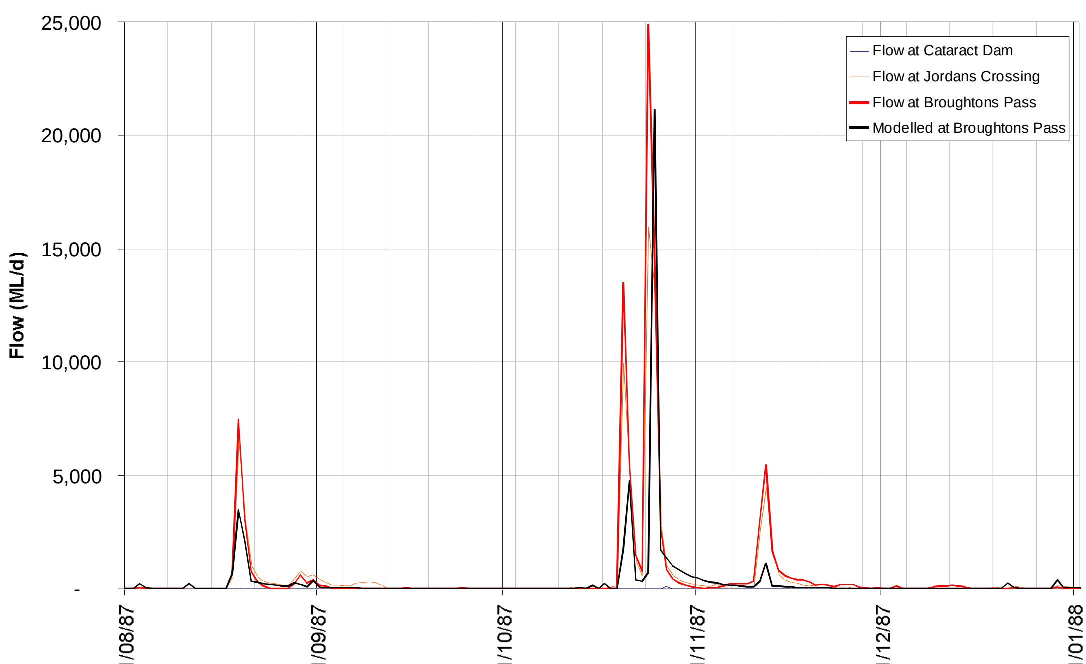

Cataract
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)


Cordeaux Quarters
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)

APPENDIX B

MODELLED AND OBSERVED STREAMFLOW DOWNSTREAM OF CATARACT DAM DURING PERIODS OF NO RELEASE


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
25,000
20,000
15,000
10,000
5,000
-
1/08/86
1/09/86
1/10/86
1/11/86
1/12/86
1/01/87


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
25,000
20,000
15,000
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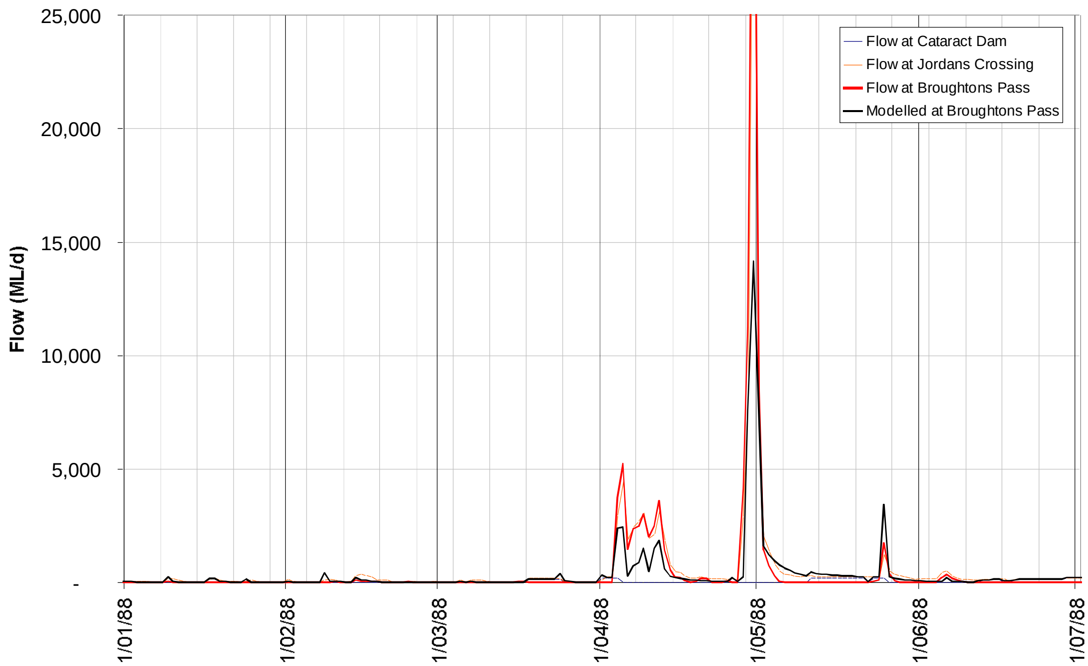
1/12/87
1/01/88


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
25,000
20,000
15,000
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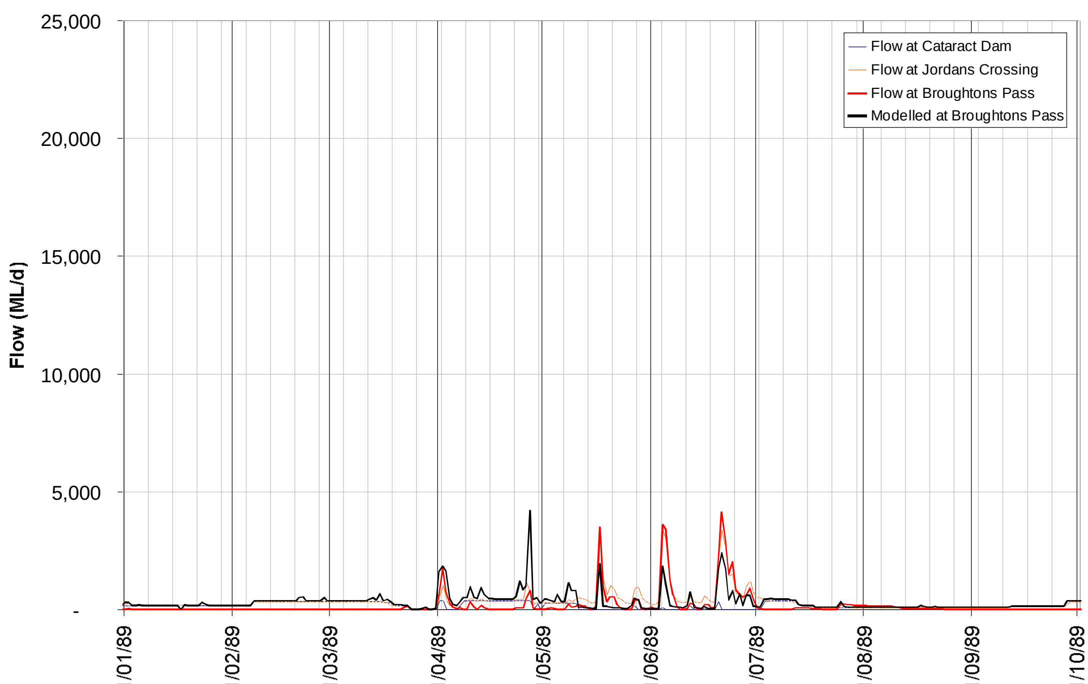
1/06/88
1/07/88


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
25,000
20,000
15,000
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5,000
-
1/01/89
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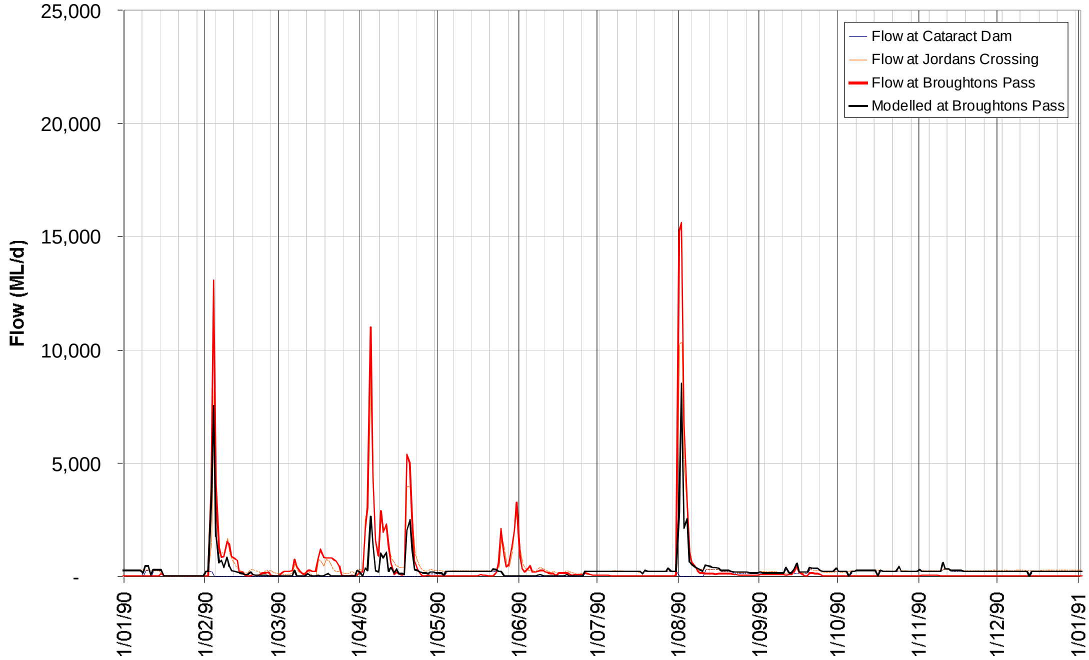
1/10/89


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
25,000
20,000
15,000
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5,000
-
1/01/90
1/02/90
1/03/90
1/04/90
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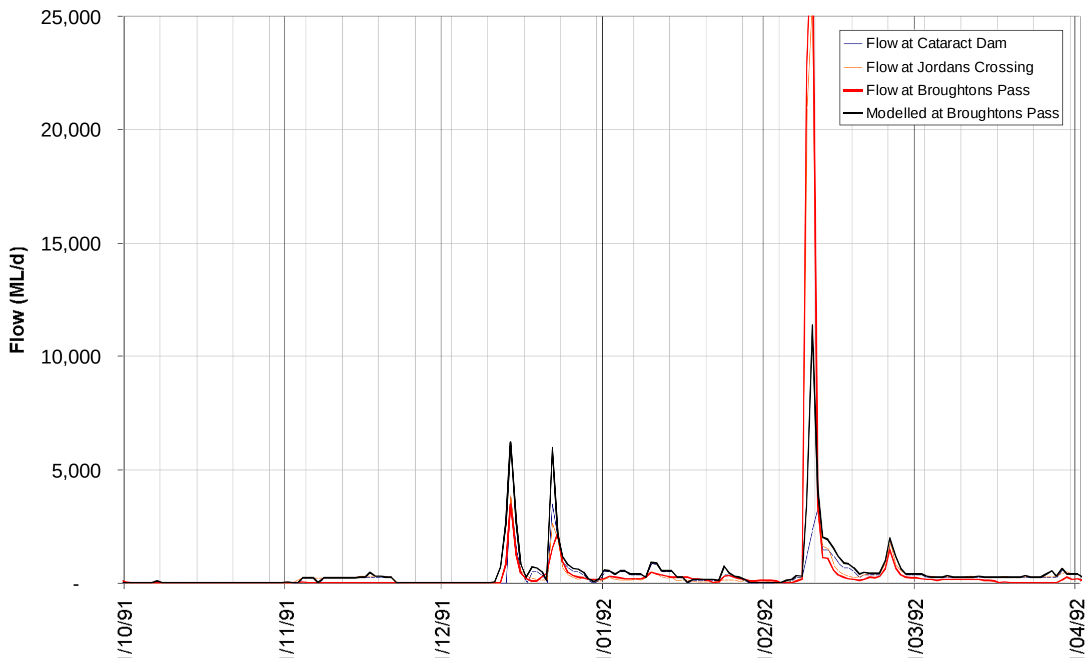
1/01/91


Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass
Flow (ML/d)
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20,000
15,000
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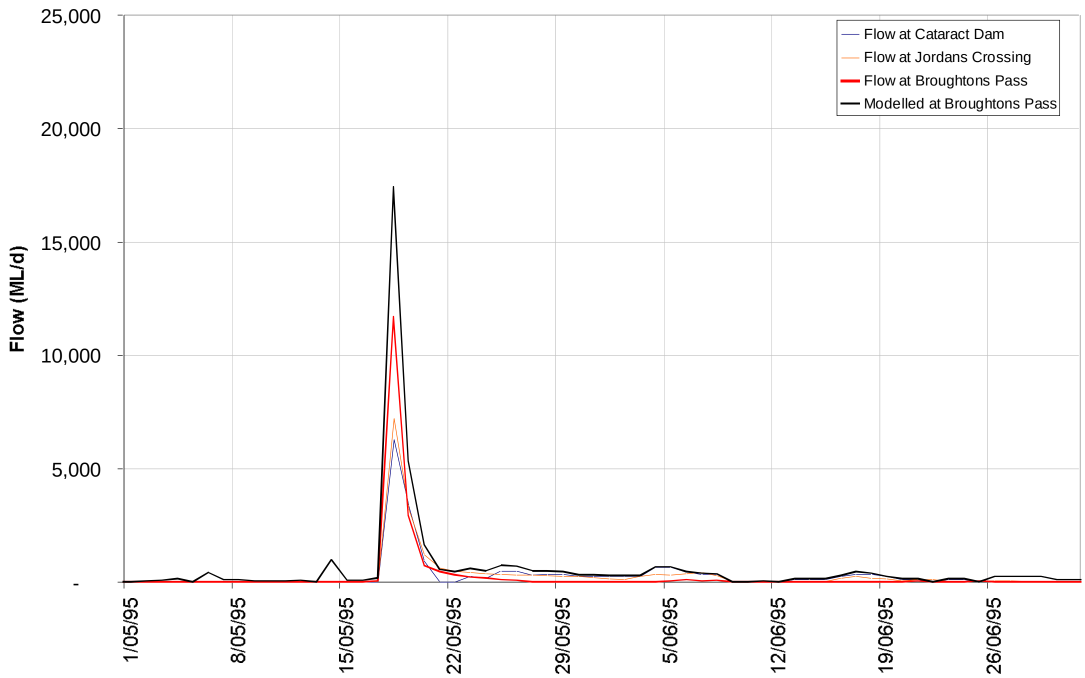
1/03/92
1/04/92


25,000
20,000
15,000
10,000
5,000
-
Flow (ML/d)
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8/05/95
15/05/95
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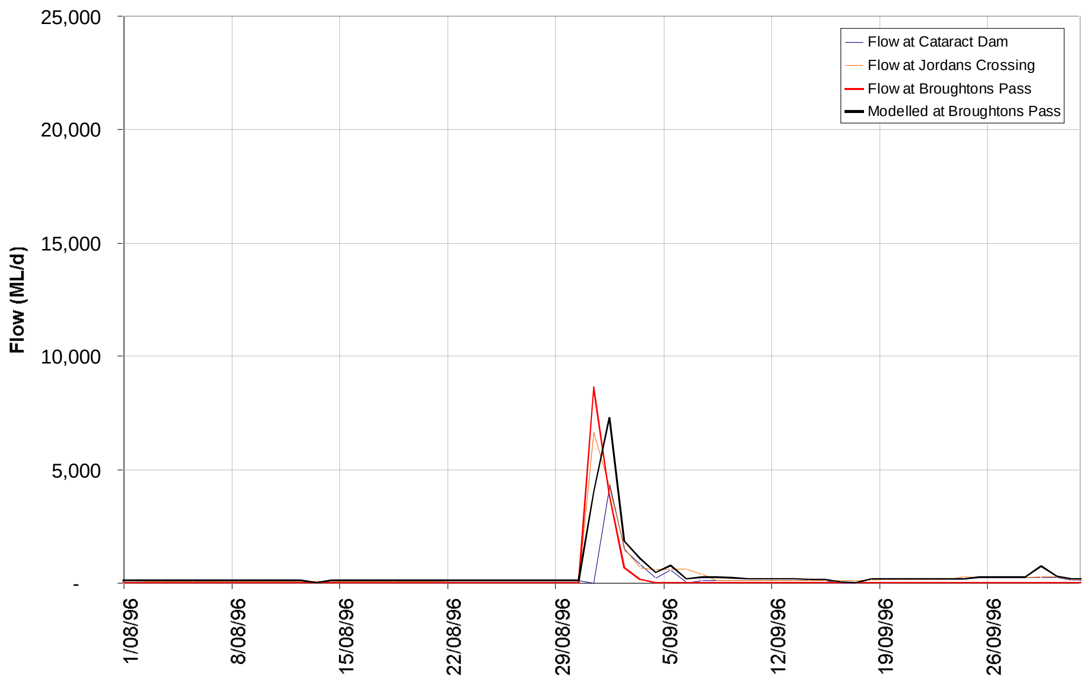
29/05/95
5/06/95
12/06/95
19/06/95
26/06/95
Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass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20,000
15,000
10,000
5,000
-
Flow (ML/d)
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8/08/96
15/08/96
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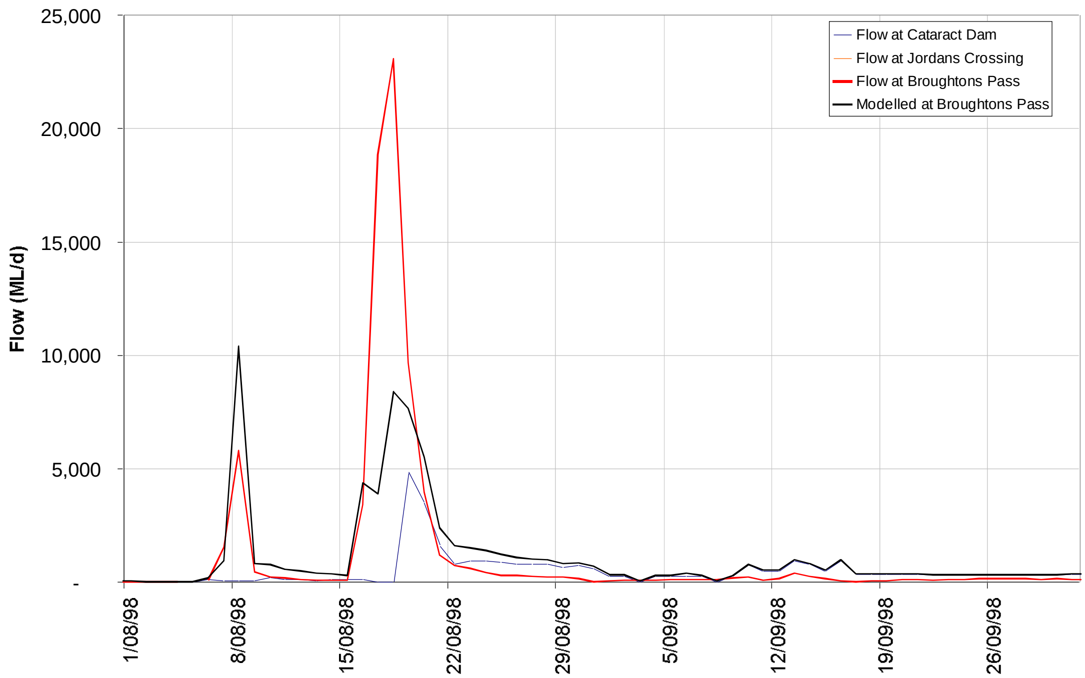
29/08/96
5/09/96
12/09/96
19/09/96
26/09/96
Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass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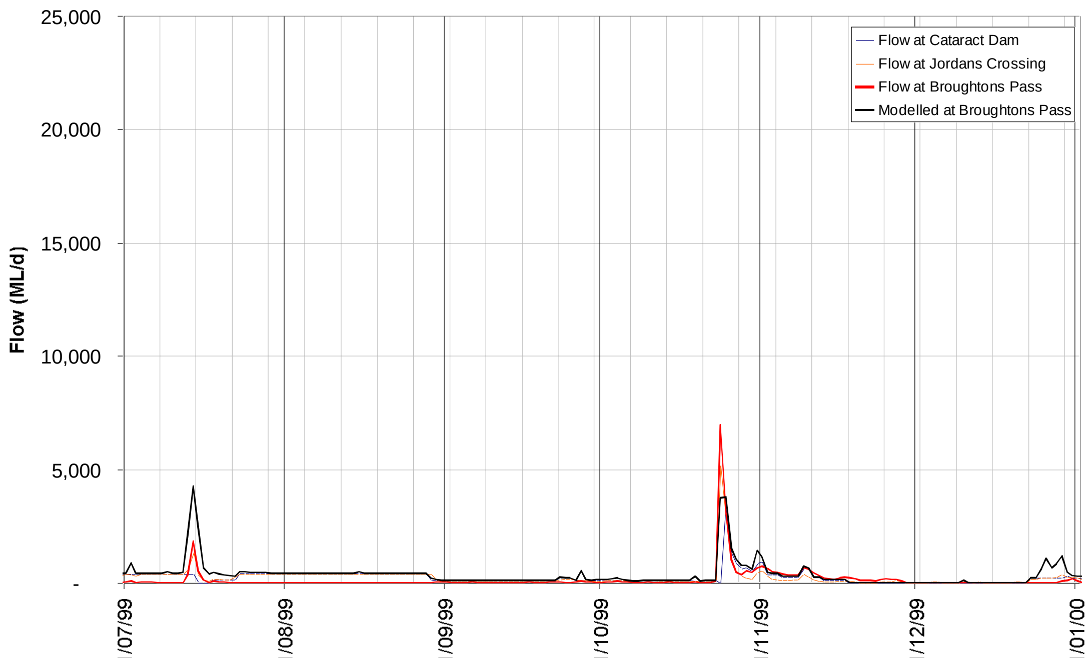
29/08/98
5/09/98
12/09/98
19/09/98
26/09/98
Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass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5,000
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Flow (ML/d)
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1/09/99
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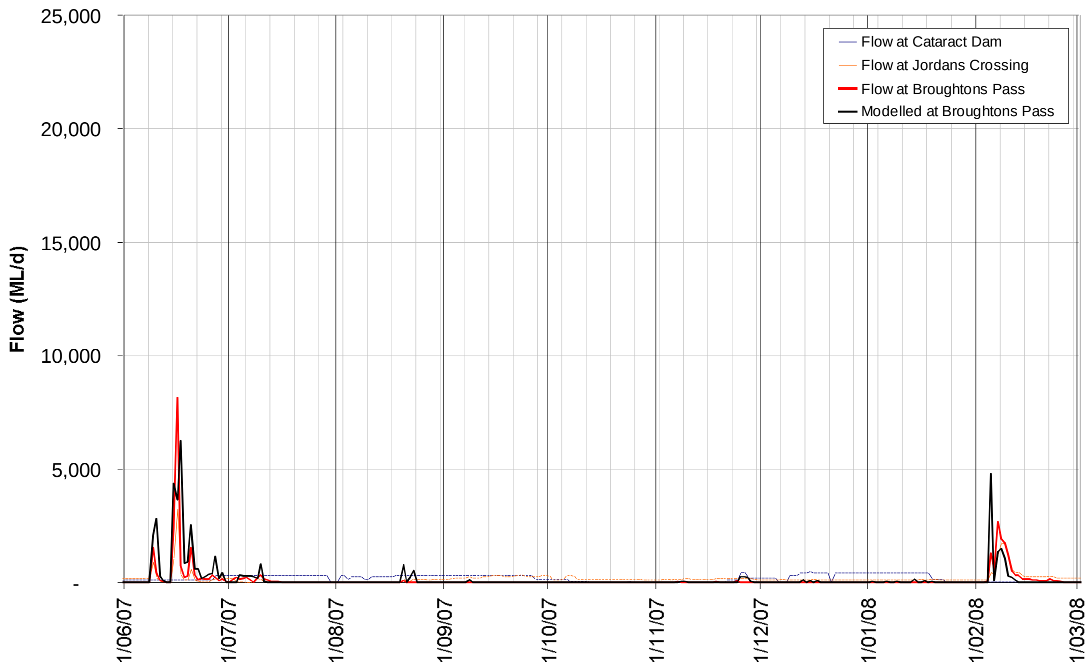
1/01/00
Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass


25,000
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15,000
10,000
5,000
-
Flow (ML/d)
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1/07/07
1/08/07
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1/10/07
1/11/07
1/12/07
1/01/08
1/02/08
1/03/08
Flow at Cataract Dam
Flow at Jordans Crossing
Flow at Broughtons Pass
Modelled at Broughtons Pass

APPENDIX B

STREAM SIGNIFICANCE ASSESSMENT

Stream Values	Stream Name	CC2 - CC3	CC1 - CC4	CC5 - CC6	CC6- CC7	CC7-CC8	CC8-CC9	CC9 - CC10	CT1	Above Cataract Ck
Scale	Total Catchment (km2)	6	6	6	6	6	6	6	6	29
	Sub - Catchment (km2)	1.6	1.8	0.5	0.7	0.8	0.5	0.2	0.4	13.1
	Maximum Stream Order	3rd	3rd	4th	4th	4th	4th	4th	2nd	4th
	Reach Rise (m)	10	14	5	7	9	5	3	20	20
	Reach Length (m)	560	1190	245	435	655	460	445	270	2750
	Av. Gradient	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.07	0.01
Hydrologic Value	Flow Regime	perm.	perm.	perm.	perm.	perm.	perm.	perm.	ephemeral	perm.
	% of Cataract Ck Catchment	25.8	29.2	9.0	12.3	13.0	8.8	3.5	6.7	45.2
	% of Cataract Dam Catchment	1.12	1.26	0.39	0.53	0.56	0.38	0.15	0.29	9.45
Environmental Quality	Reach Geomorphology / Geology	pool / rifle / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone / claystone	pool / sand	pool / sand / clay / exposed sandstone / claystone	pool / rifle / sand / clay / exposed sandstone and claystone
	Setting	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area
	Public Accessibility	limited	limited	nil	nil	nil	nil	nil	nil	nil
	Median pH	6.18 - 6.09	5.56 - 6.25	6.35 - 6.37	6.35 - 6.37	6.35 - 6.37	6.35 - 6.37	6.35 - 6.37	6.07	n/a
	Median EC (uS/cm)	145 - 130	134 - 132	125 - 135	125 - 135	125 - 135	125 - 135	125 - 135	81	n/a
	Reach previously undermined (km)	560m (Bulli pillar & Balgownie longwalls)	1190m (Bulli bord and pillar)	245m (Bulli bord pillar/ pillar extraction Balgownie LWs)	435m (Bulli bord pillar/ pillar extraction Balgownie LWs)	655m (Bulli bord pillar/ pillar extraction Balgownie LWs)	460m (Bulli bord pillar/ pillar extraction Balgownie LWs)	445m (Bulli bord pillar/ pillar extraction, Balgownie LWs)	270m (Bulli bord pillar/ pillar extraction, Balgownie LWs)	not undermined
	Distance from Closest Centreline to Proposed Nearest Panel (m)	over A1 LW2 and 3	310m to A2 LW2	over gateroad to A2 LW4	abutment pillar A2 LW5, over gateroad to A2 LW5	over gateroad to A2 LW6 and A2 LW7 and over A2 LW8	over A2 LW8 and A2 LW9	over A2 LW9;	over A2 LW5	closest workings are 100m to A2 LW8
Predicted Subsidence	Predicted Max. Subsidence (m)	0.16	<0.02	<0.02	<0.02	0.8	0.8	0.26	1.07	<0.02
	Predicted Max. Tensile Strain (mm/m)	<1	<1	<1	<1	5	5	1.3	5.6	<1
	Predicted Max. Compressive Strain (mm/m)	-2	<-1	<-1	<-1	-9.3	-9.3	<-1	-8	<-1
	Predicted Max. Tilt (mm/m)	3	<1	<1	2	6	<1	<1	9	<1
	Max. Equivalent Valley Height (m)	16	will not be undermined	15	20	23	18	19	16	will not be undermined
	Max. Predicted Upsidence (m)	60	will not be undermined	60	60	60	60	60	60	will not be undermined
	Max. Predicted Valley Closure (m)	100	will not be undermined	100	100	100	100	100	100	will not be undermined
Ecological Importance	Survey Effort	No direct aquatic or terrestrial fauna sampling.	Frog habitat survey	Aquatic survey (Site 5 and 6) Spring and Autumn 2008 - 2011. Macquarie Perch Survey Summer 2009/2010. Frog habitat survey. Bird point count.	Aquatic survey (Site 5 and 6) Spring and Autumn 2008 - 2011. Macquarie Perch Survey Summer 2009/2010. Frog habitat survey. Bird point count.	Aquatic survey (Site 5 and 6) Spring and Autumn 2008 - 2011. Macquarie Perch Survey Summer 2009/2010. Frog habitat survey. Bird point count.	Aquatic survey (Site 5 and 6) Spring and Autumn 2008 - 2011. Macquarie Perch Survey Summer 2009/2010. Frog habitat survey. Bird point count.	No direct aquatic sampling. Macquarie Perch Survey Summer 2009/2010. Frog habitat survey, bird point count	No direct aquatic sampling.	Aquatic survey (Sites 9 and 10) controls Spring and Autumn 2008 - 2011. No terrestrial fauna sampling
	Threatened Ecological Communities in Riparian Zone	None identified	None identified	None identified	None identified	None identified	None identified	None identified	None identified	None identified
	Threatened Species and Swamps Specialists Recorded	None identified	None identified	**Macquarie Perch** and **Silver Perch** identified CC6. *Maccullochella* sp identified may be Trout Cod or Murray Cod. Both species have been introduced into Cataract Dam	**Macquarie Perch** and **Silver Perch** identified CC6. *Maccullochella* sp identified may be Trout Cod or Murray Cod. Both species have been introduced into Cataract Dam	**Macquarie Perch** and **Silver Perch** identified CC6. *Maccullochella* sp identified may be Trout Cod or Murray Cod. Both species have been introduced into Cataract Dam	**Macquarie Perch** and **Silver Perch** identified CC6. *Maccullochella* sp identified may be Trout Cod or Murray Cod. Both species have been introduced into Cataract Dam	Macquarie Perch and Silver Perch identified. *Maccullochella* sp identified may be **Trout Cod or Murray Cod**. Both species have been introduced into Cataract Dam.	None identified	None identified
	Threatened Species Predicted	Potential habitat for Adams Emerald Dragonfly	Stuttering Barred Frog breeding habitat (good quality) identified.	Potential habitat for Adams Emerald Dragonfly. Stuttering Barred Frog breeding habitat (good quality) identified.	Potential habitat for Adams Emerald Dragonfly. Stuttering Barred Frog breeding habitat (good quality) identified.	Potential habitat for Adams Emerald Dragonfly. Stuttering Barred Frog breeding habitat (marginal quality grading to good) identified.	Potential habitat for Adams Emerald Dragonfly.	Potential habitat for Adams Emerald Dragonfly		Potential habitat for Adams Emerald Dragonfly and Sydney Hawk Dragonfly.
	Associated Upland Swamps	CCUS1, CCUS2, CCUS17, CCUS18, CCUS19, CCUS15 and CCUS14	-	CCUS7	CCUS7 and CCUS8.	CCUS3, CCUS23, CCUS9 and CCUS10	CCUS4, CCUS5, CCUS7, CCUS8, CCUS10 and CCUS11	CCUS12	CCUS6, CCUS20 and CCUS21	CRUS1, CRUS2, CRUS3, CRUS4 and CRUS5

Stream Values	Stream Name	Lizard Creek								
	Stream Attribute	**LC1 - LC2**	**LC2 - LC3**	**LC3 - Waterfall L1**	**Waterfall L1 - LC4**	**LC4 - LC5**	**LC5 - LC6**	**LC6 - LC7**	**LCT1**	**LCT2**
Scale	**Total Catchment (km2)**	17.1	_	_	_	_	_	_	_	_
	Sub - Catchment (km2)	5.7	0.8	1.6	0.3	0.4	1.1	1.4	1.7	3.7
	Maximum Stream Order	**3rd**	**3rd**	**3rd**	**3rd**	**3rd**	**3rd**	**4th**	**3rd**	**3rd**
	Reach Rise (m)	6	5	24	20	3	9	16	21	25
	Reach Length (m)	650	785	1320	315	390	1200	1670	940	820
	Av. Gradient	0.01	0.01	0.02	0.06	0.01	0.01	0.01	0.02	0.03
Hydrologic Value	**Flow Regime**	perm.	perm.	perm.	perm.	perm.	intermittent	perm.	intermittent	intermittent
	% of Catchment	33.3	4.6	9.3	2.1	2.3	6.4	8.1	9.9	21.6
Environmental Quality	**Reach Geomorphology / Geology**	valley fill swamp	valley fill swamp	pool / riffle / exposed sandstone / waterfall L1	pool / riffle / exposed sandstone	pool / riffle / sand / exposed sandstone	exposed sandstone / pool / riffle / sand	pool / riffle / exposed sandstone	exposed sandstone / pool / riffle	exposed sandstone / pool / riffle
	Setting	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area
	Public Accessibility	limited	limited	nil	nil	nil	nil	nil	nil	nil
	Median pH	4.5 - 5.5	5.44 - 5.93	5.93 - 6.44	5.93 - 6.44	6.44 - 6.30	6.30 - 6.11	6.11 - 6.25	4.54	5.4
	Median EC (uS/cm)	66 - 110	110 - 118	118 - 153	118 - 153	152 - 135	135 - 138	138 - 188	175	205
	Reach previously undermined (km)	680m (Cordeaux LW18, 19)	800m (Cordeaux LW20) / N S headings	1330m (N S & EW headings, LW202)	325m (EW headings LW303)	320m (LW303)	1270m (LW303 - 307)	720m (LW307 - 309)	1450m (LW307 - 309)	not undermined
	Distance from Closest Centreline to Proposed Nearest Panel (m)	920m to A2 LW3	390m to A2 LW3	125m to A3 LW1	125m to A3 LW1	170m to A3 LW1	165m to A3 LW3	130m to A4 LW7	over A3 LW3	120m to A3 LW5
Predicted Subsidence	**Predicted Max. Subsidence (m)**	<0.02	<0.02	0.2	0.2	<0.02	0.25	0.25	2.5	<0.02
	Predicted Max. Tensile Strain (mm/m)	<1	<1	2	<1	2	5	3	7	<1
	Predicted Max. Compressive Strain (mm/m)	<-1	<-1	<-1	<-1	<-1	<-1	<-1	-7	<-1
	Predicted Max. Tilt (mm/m)	<1	<1	3	<1	<1	3	<1.0	13	<1
	Max. Equivalent Valley Height (m)	will not be undermined	will not be undermined	8	15	38	46	22	31	36
	Max. Predicted Upsidence (m)	will not be undermined	will not be undermined	120	120	120	120	120	120	120
	Max. Predicted Valley Closure (m)	will not be undermined	will not be undermined	200	200	200	200	200	200	200
Ecological Importance	**Survey Effort**	Bird Area Survey, Floristic Survey	Bird Area Survey, Floristic Survey	Floristic Survey, Bird Area Search, Frog Habitat Survey, Spotlighting, Call Broadcasting, Anabat Survey, Hair Funnels	Bird Area Search	No direct aquatic or terrestrial fauna sampling.	Bird Count Point, Aquatic Survey (Site 3 and 17) Spring and Autumn 2008 - 2011	Bird Count Point, Aquatic Survey (Site 4) Spring and Autumn 2008 - 2011	Frog habitat survey, Spotlighting, Call broadcast, Hair funnels, Florisitic Survey.	Floristic Survey
	Threatened Ecological Communities in Riparian Zone	**Coastal Upland Swamps EEC (State)**	**Coastal Upland Swamps EEC (State)**	**Coastal Upland Swamps EEC (State)**	-	-	-	-	**Coastal Upland Swamp EEC (State)**	**Coastal Upland Swamp EEC (State)**
	Threatened Species and Swamps Specialists Recorded	Southern Emu Wren (regional significance)	*Monotoca ledifolia* (RoTAP). Red-crowned Toadlet (regional significance). Southern Emu Wren (regional significance).	Eastern Bentwing Bat, Eastern Falsistrelle	-	-	**Giant Burrowing Frog (national significance)**. Red-crowned Toadlet (regional significance). Beautiful Firetail (regional significance).	-	Powerful Owl, **Giant Burrowing Frog (national)**	**Giant Burrowing Frog (national)**
	Threatened Species Predicted	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly
	Associated Upland Swamps	LCUS1	LCUS1	LCUS2, LCUS3, LCUS4, LCUS5, LCUS6, LCUS7, LCUS8, LCUS10, LCUS11, LCUS12, LCUS13, LCUS14, LCUS15, LCUS16 and LCUS13	LCUS17, LCUS33, LCUS13, LCUS14, LCUS15 and LCUS16	-	-	LCUS22, LCUS23 and LCUS24	LCUS18, LCUS20, LCUS21 and LCUS19	LCUS25 and LCUS26

Stream Values	Stream Name	Wallandoola Ck				
	Stream Attribute	**WC1 - WC2**	**WC2 - WC3**	**WC3 - WC4**	**WC4 - Waterfall W1**	**Waterfall W1 - WC5**
Scale	**Total Catchment (km2)**	33.2	_	_	_	_
	Sub - Catchment (km2)	6.1	0.9	2.4	0.1	0.6
	Maximum Stream Order	**3rd**	3rd	3rd	3rd	3rd
	Reach Rise (m)	6	5	7	3	32
	Reach Length (m)	1120	580	1310	120	340
	Av. Gradient	0.01	0.01	0.01	0.03	0.09
Hydrologic Value	**Flow Regime**	perm.	perm.	perm.	intermittent	perm.
	% of Catchment	18.5	2.7	7.3	0.3	1.8
Environmental Quality	**Reach Geomorphology / Geology**	valley fill swamp	pool / riffle / exposed sandstone	pool / exposed sandstone	pool / exposed sandstone / Waterfall W1	exposed sandstone / pool
	Setting	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area	SCA Metropolitan Special Area
	Public Accessibility	limited	limited	nil	nil	nil
	Median pH	5.65 - 6.02	6.02 - 5.49	5.49 - 6.19	6.19 - 6.1	6.19 - 6.1
	Median EC (uS/cm)	112 - 124	124 - 114	114 - 142	142 - 138	142 - 138
	Reach previously undermined (km)	285m (Cordeaux LW22)	475m (LW P and LW208)	1310m (LW208 - 11)	on the W 20mm subsidence edge of LW211	on the W 20mm subsidence edge of LW211
	Distance from Closest Centreline to Proposed Nearest Panel (m)	565m to A3 LW2	170m to A3 LW2	65m to A3 LW4	220m to A3 LW5	305m to A3 LW5
Predicted Subsidence	**Predicted Max. Subsidence (m)**	<0.02	0.02	0.5	<0.02	<0.02
	Predicted Max. Tensile Strain (mm/m)	<1	2	6	<1	<1
	Predicted Max. Compressive Strain (mm/m)	<-1	<-1	<-1	<-1	<-1
	Predicted Max. Tilt (mm/m)	<1	<1	3	<1	<1
	Max. Equivalent Valley Height (m)	will not be undermined	will not be undermined	12	21	will not be undermined
	Max. Predicted Upsidence (m)	will not be undermined	will not be undermined	120	120	will not be undermined
	Max. Predicted Valley Closure (m)	will not be undermined	will not be undermined	200	200	will not be undermined
Ecological Importance	**Survey Effort**	Bird Area Search, Anabat Survey, Hair Funnels.	No direct aquatic or terrestrial fauna sampling.	Frog Habitat Survey, Bird Count Point, Floristic Survey.	No direct aquatic or terrestrial fauna sampling.	Bird Count Point.
	Threatened Ecological Communities in Riparian Zone	**Coastal Upland Swamp EEC (State)**	**Coastal Upland Swamp EEC (State)**	**Coastal Upland Swamp EEC (State)**	-	-
	Threatened Species and Swamps Specialists Recorded	Eastern Bentwing-bat, East Coast Freetail Bat	-	-	-	-
	Threatened Species Predicted	Potential habitat for Adam's Emerald Dragonfly	Potential habitat for Adam's Emerald Dragonfly, Heath Frog	Potential habitat for Adam's Emerald Dragonfly, Giant Burrowing Frog and Heath Frog	Potential habitat for Adam's Emerald Dragonfly, Giant Burrowing Frog	Potential habitat for Adam's Emerald Dragonfly, Giant Burrowing Frog
	Associated Upland Swamps	WCUS1 and WCUS2	WCUS1	WCUS3, WCUS4, WCUS5, WCUS6, WCUS7, WCUS8, WCUS9, WCUS11 and WCUS12	WCUS10	-

APPENDIX C

LIZARD CREEK AND WALLANDOOLA CREEK STREAM REACH AERIAL PHOTOGRAPHS (courtesy Photomaps by NearMap)

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-3

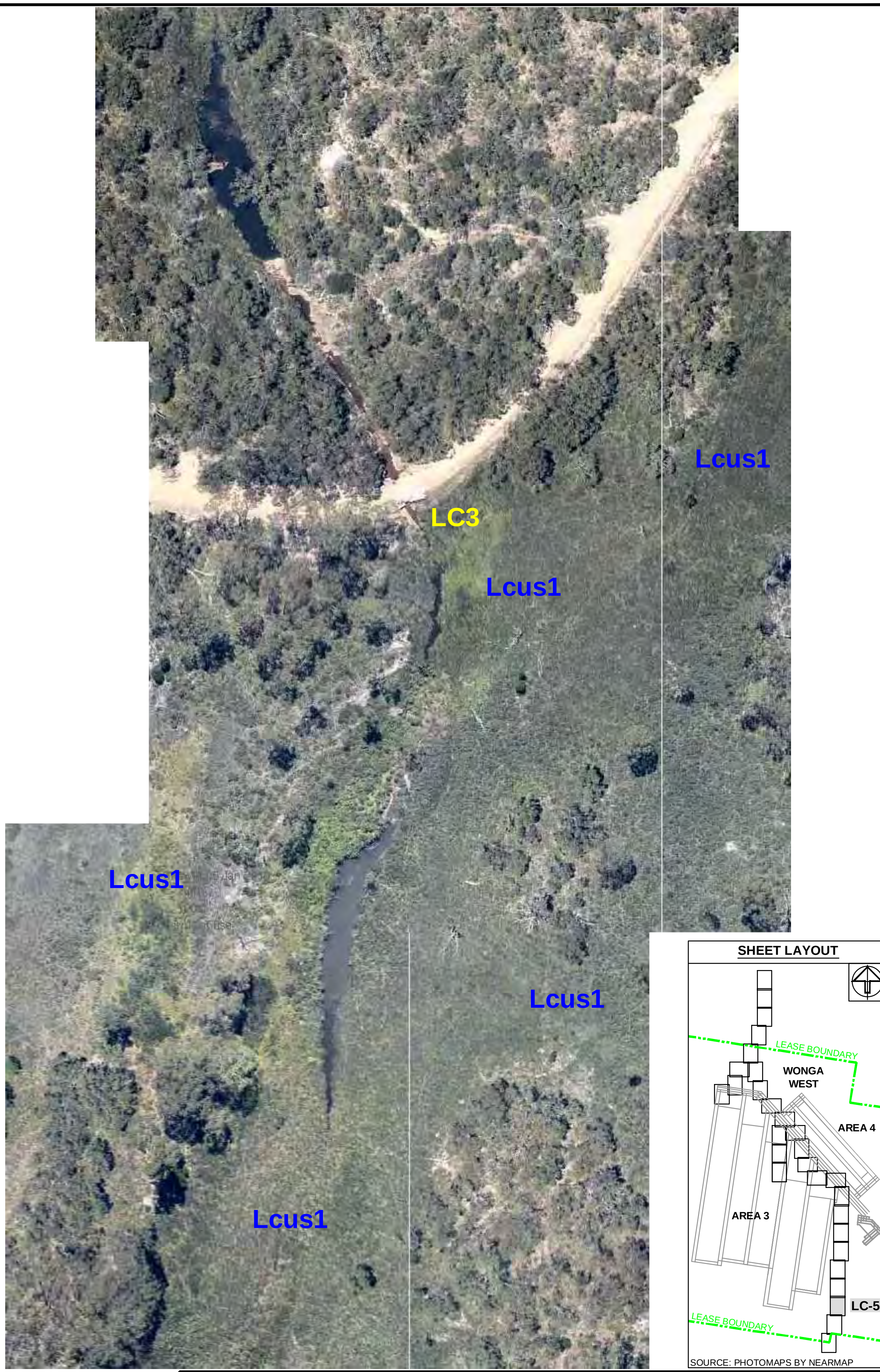
PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-4



PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

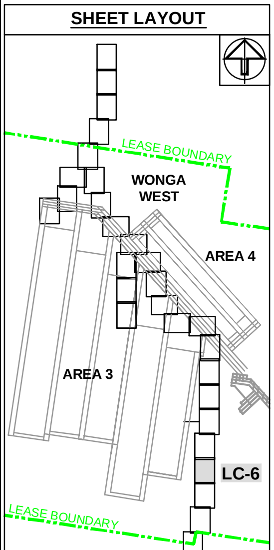
GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

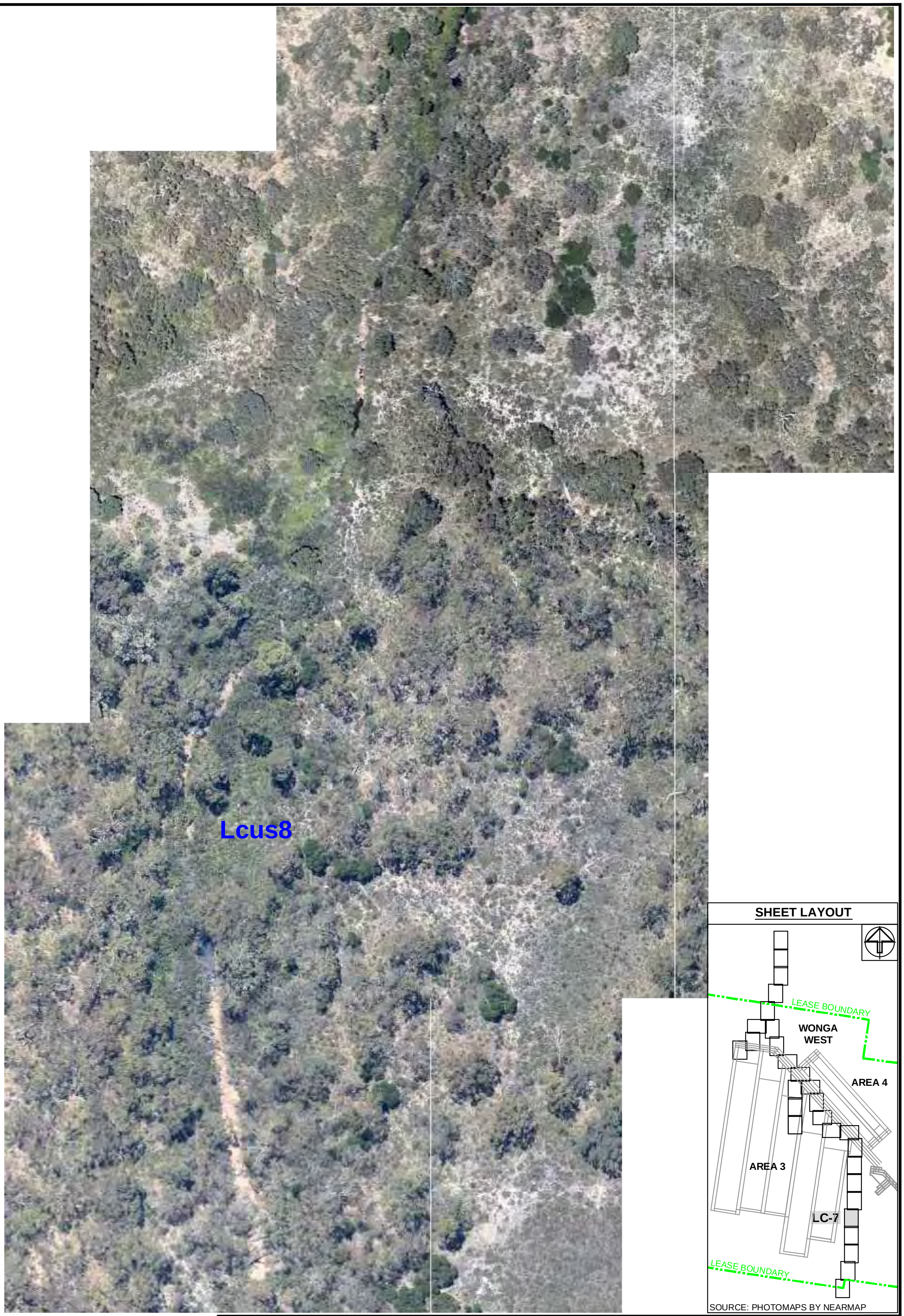
FIGURE LC-5

SHEET LAYOUT



SOURCE: PHOTOMAPS BY NEARMAP

PROJECT:	GUJ1 R1	GUJARAT NRE COKING COAL PTY LTD MAJOR EXPANSION PROJECT BELLAMBI, NSW	GeoTerra
DRAWN:	A. DAWKINS		
DATE:	23 Nov 2012		FIGURE LC-6
SCALE:	1:1000	LIZARD CREEK MAPPING	

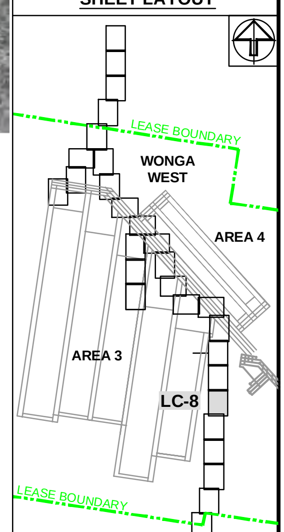


PROJECT:	GUJ1 R1	GUJARAT NRE COKING COAL PTY LTD MAJOR EXPANSION PROJECT BELLAMBI, NSW
DRAWN:	A. DAWKINS	
DATE:	23 Nov 2012	
SCALE:	1:1000	LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-7

SHEET LAYOUT



SOURCE: PHOTOMAPS BY NEARMAP

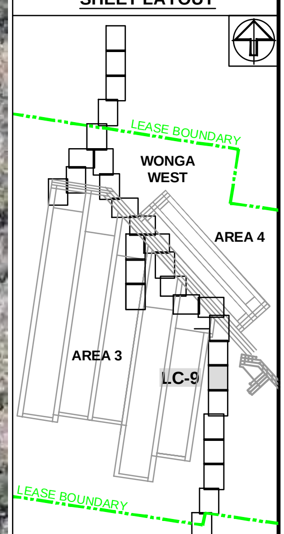
PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-8



SOURCE: PHOTOMAPS BY NEARMAP

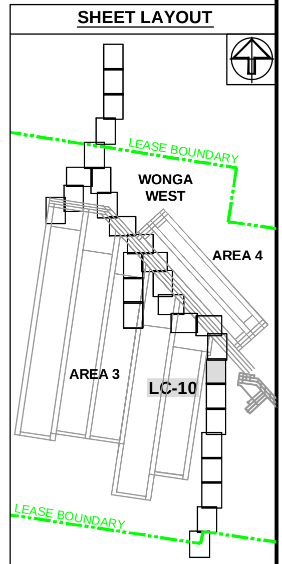
PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-9



PROJECT:	GUJ1 R1	
DRAWN:	A. DAWKINS	
DATE:	23 Nov 2012	
SCALE:	1:1000	

GUJARAT NRE COKING COAL PTY LTD
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-10

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	13 Sept 2010
SCALE:	1:1000

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MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-11

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	13 Sept 2010
SCALE:	1:1000

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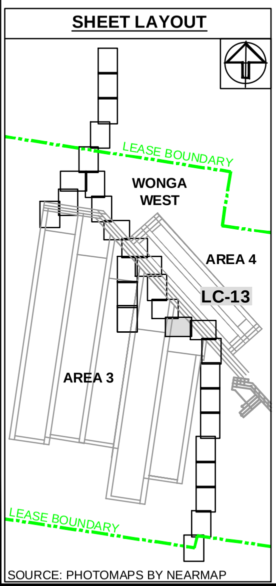
MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-12



PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
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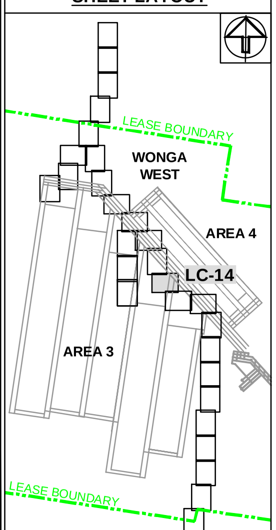
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-13

SHEET LAYOUT



SOURCE: PHOTOMAPS BY NEARMAP

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

GUJARAT NRE COKING COAL PTY LTD
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BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-14

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

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LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-15

PROJECT:	GUJ1 R1
DRAWN:	A. DAWKINS
DATE:	23 Nov 2012
SCALE:	1:1000

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MAJOR EXPANSION PROJECT
BELLAMBI, NSW

LIZARD CREEK MAPPING

GeoTerra

FIGURE LC-16