Climate Change Impacts on the Water Resources of the Cooper Creek Catchment

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EXTENDED ABSTRACT

The likelihood of changes to stream flow and flooding was assessed for the upper reach of the Cooper Creek (at Currareva) by perturbing input data to the Sacramento (rainfall-runoff model) and Integrated Quality-Quantity Model (IQQM) models according to quantified ranges of climate change for 2030. These ranges incorporate the range of global warming (IPCC 2001) and regional changes in temperature, rainfall and potential evaporation encompassing the results from seven different climate models. The methods used were primarily designed to manage uncertainty and its impact on natural and productive processes.

The wettest, driest and average climate scenarios for the region were used in hydrological models to assess changes in water flow for the Thomson River. Resulting changes in flood inundation downstream of Currareva were assessed and potential changes in vegetation identified. Changes in climate and water flow were measured against a base period from 1961-1990.

The dry scenario for 2030 was associated with mean temperature increase of 1.7^{o}C, 4% lower annual rainfall and 9% higher evaporation. The wet scenario for 2030 was associated with mean temperature increase of 1.0^{o}C, 1% higher annual rainfall and 3% higher evaporation.

The driest and wettest extremes indicate a range of change in mean annual flow of -7.1% to +1.5% by 2030. The median and dry scenarios were associated with a reduced frequency of low daily flows (<1000 ML/d) compared to base. The impact is likely to be associated with reduced waterhole persistence and connectivity during droughts.

Climate change was associated with extended lengths of periods of no flow. The longest simulated period of no flow was 280 days for the base scenario and 361 days for the average scenario, an increase of nearly 30%. These estimates assume that there is no major abstraction from waterholes, and that pumping for stock, irrigation and domestic supply will further reduce persistence times. The mean number of days per year of no flow at Currareva was nearly 2 weeks longer for the average and dry scenarios compared to the base scenario. The longer periods of no flow associated with the average and dry scenarios may have an adverse impact on the natural and human systems downstream of Currareva.

The 100 percentile flow under the dry scenario was 11% lower than the base scenario. A reduction in maximum flows may also result in decreases in inundation on the borders of floodplains, which may result in decreases in biodiversity in these areas, shrinking the floodplain. Annual and short-lived grass species may also be replaced by perennial grass species from neighbouring communities. The average and dry scenarios were also associated with a small reduction (2-9%) in high daily flows (99, 95, 90 and 88 percentile) and the wet scenario a small increase (3-4%) in high daily flows (99, 95, 90 and 88 percentile) compared to the base scenario.

The relationship between recorded peak discharge at Currareva and recorded area of inundation shows beneficial flooding downstream started at a flow of 8370 ML/day equivalent to a height of 2.9 metres (9 feet 6 inches). The inundation area downstream from Currareva was very sensitive to small increases in flow volume and height around this level (equivalent to the 87 percentile of flow).

Within the range of small event floods (88-92 percentile flows) the wet scenario was associated with an increased inundation area of up to 32% and the dry scenario a decreased inundation area of down to 75%. This change in inundation area of small event floods may have an impact on the production of herbage, natural resources and biodiversity near the main channels. Less inundation of small flood events on the floodplains may also mean that pastures in the outer country are used more. The increased grazing pressure on the outside country may lead to the degeneration of perennial grasses due to the decrease in available recovery time.

1. INTRODUCTION

A review of literature and assessment of the likely impacts of climate change in Desert Channels Queensland (DCQ) has been completed (Park 2005). DCQ (Figure 1) is 509,900 square kilometres and makes up the Queensland section of the Lake Eyre Basin., which is the worlds largest internally draining basin covering around 1.3 million km^2 (15% of the Australian continent). The DCQ region comprises of seven biographic regions including the eucalypt woodlands of the Desert Uplands through the Mitchell Grasslands and the vast floodplains of the Channel Country to the Simpson Dunefields.

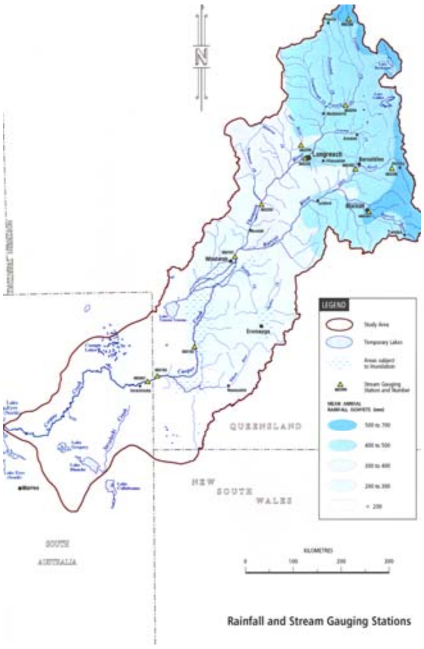

Figure 1. Lake Eyre Basin. The Queensland Section is known as Desert Channels Queensland.

Most of the area’s surface water is found in waterholes along the river systems. The channel country is an extensive natural flood irrigation system that often receives its floodwaters from rain that has fallen hundreds of kilometres away. The channel country refers to floodplains in the mid to lower reaches of three anastomosing river systems; Cooper Creek, Georgina River and Diamantina River. Beneficial flooding is recognised as making a significant contribution to floodplain ecosystem processes and to pastoral productivity. Although the floodplains have changed little since the first explorers, the public focus has been on preserving the extensive natural wetlands and the vast native flora and fauna that habitat these areas. A possible threat to preserving this biodiversity is a reduction in the volume, height and frequency of flood waters due to climate change.

This study modelled the water flows (seasonal, annual) in the Thomson River and compared them to those likely as a consequence of climate change. Water flows and stream height were used to compare the change (historical and climate change) in the inundation level in the reaches of the lower Thomson River of four floods (significant but different in terms of inundation level) that occurred between 1984 and 1991. These changes in flood inundation levels were assessed against the existing expert knowledge of responses of channel country pasture to temporal (seasonal, annual) and spatial flooding patterns.

2. METHOD

2.1. General Circulation Models

The overall approach was to perturb historical records of climate variables required to run various models using a series of climate change scenarios for 2030. The aim of this study was to represent the range of uncertainty displayed by a number of climate models rather than attempt to develop precise scenarios from individual models.

The projections of percent changes in regional climate variables were extracted from CSIRO’s OzClim database and from the CSIRO Consultancy Report on climate change in Queensland (Cai *et al.* 2003). The OzClim database includes different emission scenarios and global circulation models. The projections from a range of international General Circulation Models (GCM’s), and regional climate models (RCMs) were used (Table 1). This set of seven models

Table 1. Climate model simulations analysed in this report.

Centre	Model	Emissions Scenarios post-1990 (historical forcing prior to 1990)	Years	Horizontal resolution (km)
CSIRO, Aust	Mark2	IS92a	1881–2100*	~400
CSIRO, Aust	DAR125	IS92a	1961–2100	125
Canadian CC	CCCM1	IS92a	1961–2100	~400
DKRZ Germany	ECHAM4	IS92a	1990–2100	~300
Hadley Centre, UK	HadCM3	IS92a	1861–2099	~400
NCAR	NCAR	IS92a	1960-2099	~500
Hadley Centre, UK	HadCM3	SRES A1T	1950–2099	~400

includes some of the models that were used by CSIRO in its recent studies in the Burnett and Fitzroy region (Durack *et al.* 2005) and represent a broad range of climate change scenarios.

The multiple series of climate variables for 2030 climate were run through IQQM to produce output that was conditioned on 2030 climate.

2.2. Perturbing historical data

The locations of climate stations within the Cooper Creek Catchment of the Lake Eyre Basin (Figure 1) close to the Thomson and Barcoo Rivers were chosen for the extraction of climate change factors using OzClim. The stations that were chosen included Longreach, Muttaburra, Aramac, Prairie, Barcaldine, Blackall, Isisford, Jericho, Jundah, Tambo, Stonehenge and Windorah. These stations covered a large area of the basin and represented a range of climate change factors over the region. OzClim was used to obtain climate change maps for rainfall and evaporation, for each of the models and scenarios listed in Table 1, for all months. Each OzClim map was imported into ArcGIS (ESRI, 1999) and the points of the climate stations were overlayed. The climate change factors for rainfall and evaporation for each location and month were recorded and imported into a spreadsheet. This process was carried out for all the models and scenarios listed in Table 1.

The average monthly climate change factors for rainfall and evaporation across the upper Cooper catchment were calculated by taking the average across all stations for each month, for each climate model and scenario. These factors divided by the change in global warming were used for each model and scenario to help choose the three models that best represented the wet, average and dry scenarios of climate change.

The wet scenario was represented by the ECHAM4 model with IS92a emissions warming at high climate sensitivity and the dry scenario by the HADCM3 model with SRES A1T emissions warming at high climate sensitivity. The average scenario was represented by the average of the factors for all of the climate models and scenarios in Table 1. The average of the factors of all of the climate models produced climate change factors that were midway between the wet and dry scenarios in most cases.

2.3. Model set-up and calibration

The Sacramento rainfall-runoff model (United States National Weather Service and California Department of Water Resources, 1973) was previously configured and calibrated for the Cooper Creek Catchment by the Queensland Department of Natural Resources (Schreiber 1997). This calibration was based on records of historic streamflow, historic rainfall and Class-A pan evaporation for the period 1969-1995. From the calibrated model a daily streamflow model (IQQM Version 5.7) (Department of Land and Water Conservation, 1995) was developed for the period 01/01/1889 to 31/12/1995.

Two IQQM models were used to cover the study area 1) upstream of Longreach and 2) from Longreach to Currareva. Each model was run in turn with output from one used as input into the next. The two models were divided into a total of 40 sub-areas (14 upstream of Longreach, 26 between Longreach and Currareva). Forty historical rainfall files (one for each sub-area) and four historical evaporation files were perturbed by multiplying them with monthly climate change factors for the dry, average and wet scenarios using a macro in Microsoft Excel (Microsoft, 2003).

Sacramento models for each of the forty sub-areas were run using historical rainfall and evaporation then rerun using the modified rainfall and evaporation files to produce simulated historical runoff and runoff for each scenario. The Sacramento files were then used as input for IQQM, firstly for the upper Longreach region followed by the Longreach to Currareva region. Flows for the base and climate change scenarios were obtained at Longreach, at the junction of the Darr and Thomson Rivers, Isisford, and Currareva.

2.4. Inundation levels

Flooding in the Cooper Creek system is the key driver of beef production in the region as the floodwaters stimulate the growth of high quality ephemeral pastures, replenish waterholes necessary for stock-watering and redistribute the grazing pressure. The volume and height of flood waters are associated with the extent of inundation. The extent of beneficial flooding downstream of the junction of the Barcoo and Thomson Rivers was investigated by the Department of Natural Resources (1998). The area of inundation of four floods (1984, 1986, 1990 and 1991) ranging from a small event to a very large flood was determined using Landsat multi-spectral scanner satellite imagery. The recorded peak flood height, peak discharge and magnitude of the inundation area are shown in Table 2.

The relationship between recorded peak discharge

Table 2. Recorded peak flood height and peak discharge at Currareva and area of inundation in Queensland downstream of the junction of Thomson and Barcoo Rivers at Currareva

Date of flood peak at Currareva	**Peak height at Currareva (m)**	**Peak discharge (ML/day)**	**Area of inundation (km^2)**
December 1984	3.90	26100	3200
February 1986	6.32	178000	8700
February 1991	6.70	457000	11500
April 1990	7.95	1460000	14600

and area of inundation shows beneficial flooding downstream of Currareva starts at a flow of 8370 ML/d and a height of 2.9 metres. These relationships were applied to the modelled flows under climate change conditions and the change in area of inundation from this base level was determined.

2.5. Application of the climate change factors

Base data was comprised of 32 years of daily data from 1961 to 1992 for 40 rainfall and 4 evaporation stations across the catchment. Percentage changes derived from OzClim for precipitation and evaporation for each month of 2030, were multiplied with the base data.

3. RESULTS

The results show that based on the set of scenarios, either increases or decreases in stream flow are possible for the Cooper Creek Catchment. The change in mean annual flow for Currareva ranges from approximately -7.1% to +1.5% by 2030 (Table 3).

Changes in the frequency of daily flows for Currareva for each scenario are shown in Figure 2. There was little difference in the frequency of daily flows (high or low) between the base and wet scenarios. However the average and dry scenarios were associated with a reduced frequency of low flows (<1000 ML/d) compared to base. This pattern was similar to that at Longreach, Isisford and the junction of the Darr and Thomson Rivers. The impact is likely to be associated with reduced waterhole persistence and connectivity during periods of drought.

Table 3. Changes in mean annual stream flow for Currareva for dry, average and wet climate change scenarios for 2030

Scenario	**Dry**	**Average**	**Wet**
Global warming scenario	A1T	Average of All	IS92a
GCM	HadCM3	Average of All	ECHAM4
Global mean warming (°C)	1.24	Average of All	0.78
Change in annual rainfall (%)	-3.99	-0.98	1.16
Change in annual potential evaporation (%)	9.17	4.02	2.75
Change in streamflow @ Currareva (%)	-7.1	-4.4	+1.5

The 100 percentile flow under the dry scenario was 11% lower than the base scenario. This finding requires further investigation because these extreme flood events play an important role in delivering the water required to reach, and eventually fill the large downstream water storages such as the Coongie Lakes and Lake Eyre in South Australia. These water storages support important ecosystems and biodiversity through natural cycles of wet and dry and this role may be more important under dry climate change conditions. Other than the 100 percentile flow the average and dry scenarios were associated with a small reduction (5-9%) in high flows (99, 95, 90 and 88 percentile) and the wet scenario a small increase (2-4%) in high flows (99, 95, 90 and 88 percentile) compared to the base scenario.

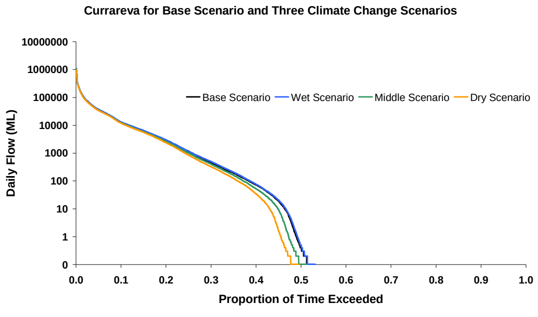

Figure 2. Daily flow exceedance curves for the base scenario and dry, average and wet climate change scenarios for Currareva in 2030.

The mean number of days per year of no flow at Currareva was higher ($P<0.01$, paired T test) for the average and dry scenarios compared to base. The base and wet scenarios were not different ($P>0.05$). The longest simulated duration of no flow at Currareva for the base scenario was 280 days (Table 4). The average scenario had a 361 day period of no flow which was associated with a lower climate change factor in February for rainfall, compared to the other scenarios, producing insufficient rain and a period of no flow at a time when the other scenarios had small flows (<540 ML/d for 1 month). This shows that climate change has the potential to dramatically increase the duration of no flows by reducing the frequency of low flows.

Under the dry scenario 20% of the no flow periods lasted longer than 175 days compared to 139 days for the base scenario, a difference of 36 days longer (Table 4). The difference for wet and average scenarios was 22 days longer. The climate change scenarios were associated with extended lengths of the long periods of no flow.

Table 4. Duration of no flows at Currareva for the base scenario and the wet, average and dry climate change scenarios

Probability of exceeding (%)	Duration of no flow (days)			
	Base	Wet	Average	Dry
0	280	280	361	286
0.2	139	161	161	175
0.4	87	79	88	100
0.6	47	43	34	42
0.8	13	12	14	13

The chance of long periods (150-200 days) of no flows was higher for the dry scenario than the base scenario (Table 5). Under dry climate change conditions their was a greater risk of long periods (150-200 days) of no flow being extended which will affect waterhole replenishment and may at times reduce the quantity and quality of water available for human, stock and wildlife use. The median duration of no flow was 65, 64, 75 and 79 days respectively for the base, wet, average and dry scenarios. These differences are unlikely to have any practical significance. There was no statistically significant difference between these medians ($P>0.05$) using the Kruskal-Wallis non-parametric test (Kruskal & Wallis, 1952).

Table 5. Chance of exceeding 150 and 200 day durations of no flows at Currareva for base scenarios and wet, average and dry climate change scenarios

Duration of no flows (days)	Chance of exceeding (%)			
	Base	Wet	Average	Dry
150	19	21	21	24
200	6	8	8	11

The volume and height of water at Currareva is associated with flood inundation areas however beneficial flooding occurs once certain flow thresholds are exceeded. The beneficial flood threshold (BFT) was the transition point where flows at Currareva began to produce beneficial flooding downstream. The inundation area increased rapidly when flows increased from the BFT (c. 87 percentile) to 90 percentile, which were represented by flows of 8195 and 12906 ML/d respectively for the base scenario.

The small difference in high flows between the base and climate change scenarios was associated with a large difference in inundation area for flows in the 88 to 92 percentile range. Within this range of small event floods the wet scenario was associated with an increased inundation area of up to 32% and the dry scenario a decreased inundation area of down to 75% (Table 6). This change in inundation area of small event floods may have an impact on the production of herbage, natural resources and biodiversity near the main channels.

Table 6. Inundation areas in Queensland downstream of Currareva for the base scenario and for dry, average and wet climate change scenarios for 2030. Percentage change in inundation from the base scenario is shown

	Inundation area (km^2)	Change in inundation area (%)		
Percentile	Base	Wet	Average	Dry
100	13859	0	-1	-2
99	8501	1	-1	-1
95	4169	2	-2	-4
92	2541	2	-4	-8
90	1212	7	-10	-15
88	359	32	-31	-75

The frequency of flows exceeding the BFT is important for over-bank flows and flooding beyond main water courses such as floodplains. Herbage growth on the floodplains and replenishment of waterholes are important for cattle production and native flora and fauna. The percentile flows at which BFT occurred were 87.2, 86.9, 87.5 and 87.8 for the base, wet, average and dry scenarios respectively.

4. DISCUSSION

The range of change from the driest and wettest extremes of regional climate change indicate a wide range of change in mean annual flow ranging from approximately -7.1% to +1.5% by 2030. This was driven by less early spring (Sep-Oct) and more summer (Nov-Feb) rainfall in the wet extreme and less late winter to early summer rainfall (Aug-Dec) in the dry extreme.

The average and dry scenarios were associated with a reduced frequency of low daily flows (<1000 ML/d) compared to base. The impact is likely to be associated with reduced waterhole persistence and connectivity during periods of drought. The reduction in persistence of waterholes may have consequences for the plant and animal life that rely on these water sources. Also increased salinity may result from the reduced replenishment of waterholes, which may result in the changing of vegetation in and around waterholes to that which is more tolerant of higher mineral concentrations. In addition, reduced connectivity of waterholes will mean less passage of aquatic biota between waterholes restricting them to one waterhole for extended periods. This may reduce biodiversity of aquatic biota in waterholes.

The 100 percentile flow under the dry scenario was 11% lower than the base scenario. This finding requires further investigation because these extreme flood events play an important role in delivering the water required to reach, and eventually fill the large downstream water storages such as the Coongie Lakes and Lake Eyre in South Australia. These water storages support important ecosystems and biodiversity through natural cycles of wet and dry and this role may be more important under dry climate change conditions. Reduction in maximum flows may also result in decreases in inundation on the borders of floodplains, which may result in decreases in biodiversity in these areas, shrinking the floodplain. Annual and short-lived grass species may also be replaced by perennial grass species from neighbouring communities.

The average and dry scenarios were also associated with a small reduction (2-9%) in high daily flows (99, 95, 90 and 88 percentile) and the wet scenario a small increase (3-4%) in high daily flows (99, 95, 90 and 88 percentile) compared to the base scenario. These differences are only small and are probably insignificant against the ‘noise’ associated with the modelling process.

Climate change was associated with extended lengths of long periods of no flow. The longest simulated period of no flow was 280 days for the base scenario and 361 days for the average scenario, an increase of nearly 30%. If we apply a 30% increase to the recorded (1939-1989) maximum no-flow period (21 months from 1951-1952), the extended period of no-flow due to climate change of 27 months could be associated with most waterholes drying to within 10% of their bankfull volumes (Hamilton *et al.* 2005). These estimates assume that there is no major abstraction from waterholes, and that pumping for stock, irrigation and domestic supply will further reduce persistence times.

The mean number of days per year of no flow at Currareva was statistically higher for the average and dry scenarios compared to base. Nearly 2 weeks per year more of no flows under the dry scenario may not have an adverse impact on the natural or human systems downstream of Currareva but further discussion with regional experts and natural resource scientists is needed. The base and wet scenarios were not different. An increase in no flows is likely to affect waterhole persistence and salinity, which may have consequences for animals and plants within and external to waterhole environments.

Climate change has the potential to dramatically increase the duration of no flows by reducing the frequency of low flows. Under dry climate change conditions their was a greater risk of long periods (150-200 days) of no flow being extended which will affect waterhole replenishment and may at times reduce the quantity and quality of water available for human, stock and wildlife use. Reduced replenishment of waterholes may also affect aquatic biota within waterholes by reducing water quality and the available space to move and hide. Reduced replenishment of waterholes may also mean decreased inundation of large floods due to waterholes needing to be filled first.

Within the range of small event floods the wet scenario was associated with an increased inundation area of up to 32% and the dry scenario a decreased inundation area of down to 75%. This change in inundation area of small event floods may have an impact on the production of herbage, natural resources and biodiversity near the main channels. Less inundation of small flood events on the floodplains may increase the utilisation of pastures in the outer country. This may threaten the survival of perennial grasses through reduced recovery time and higher grazing pressure.

5. CONCLUSION

In this study we have assessed the likelihood of changes to mean annual flow by perturbing input data to the Cooper Creek Catchment Integrated Quality Quantity Model according to quantified ranges of climate change for 2030. These ranges incorporate the range of global warming according to the IPCC Third Assessment Report (IPCC, 2001), regional changes in temperature, rainfall and potential evaporation encompassing the results from seven different climate models. The methods used are primarily designed to manage uncertainty and its impact on processes impacting on water supply. Identifying the likely impacts of climate change and implementing sustainable agricultural management practices will be important in adapting to climate change.

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